1. INTRODUCTION AND BACKGROUND

Used fuel from Canada's CANDU[1] reactors is currently safely stored at the nuclear generating station sites in Ontario, Quebec and New Brunswick. Most of this used fuel is produced by the 20 reactors at Ontario Hydro's Pickering, Bruce and Darlington nuclear power sites. Hydro Québec operates one reactor at its Gentilly site and New Brunswick Power operates one reactor at its Point Lepreau site. Future nuclear energy production scenarios are discussed in Chapter 9.

In 1978, the governments of Ontario and Canada agreed to co-operate in the development of technologies for the safe management and permanent disposal of nuclear fuel waste through the establishment of the Canadian Nuclear Fuel Waste Management Program (NFWMP) (Joint Statement 1978). Atomic Energy of Canada Limited (AECL) was given the responsibility for undertaking research and development on a specific used fuel disposal concept: "...disposal in a deep underground repository in intrusive igneous rock", while Ontario Hydro was given the responsibility for developing the storage and transportation components of the fuel waste management system. The objective of the Canadian Nuclear Fuel Waste Management Program was to provide the data necessary to assess the safety and feasibility of the disposal concept.

Public opinions expressed in forums established by the Hare Commission (Hare et al. 1977), the Royal Commission on Electrical Power Planning (1976, 1980) and the Select Committee on Ontario Hydro Affairs (1980) were considered in the development of the Nuclear Fuel Waste Management Program. A review of public views that affected the development of the program is included in Appendix A and R-Public (Greber et al. 1994).

In 1981, the governments of Ontario and Canada announced that "...no disposal site selection will be undertaken until after the concept has been accepted" (Joint Statement 1981). The disposal concept was first to be assessed, and public and regulatory acceptance sought, before proceeding further with the concept.

The objective of concept assessment was to evaluate the safety and feasibility of the disposal concept during the preclosure and postclosure phases. The division between the pre- and postclosure phases is taken to be the point at which the used fuel disposal vault and shafts have been sealed, the surface facilities removed, and the site returned to a state such that safety would not depend on institutional controls. The postclosure phase is the period extending after closure. AECL has the primary responsibility for the overall environmental and safety assessment of the concept. Ontario Hydro performed the environmental and safety assessment of the preclosure phase of the disposal concept. Two interim concept assessments were completed in 1981 and 1985 (Wuschke et al. 1981, 1985), each of which included a preclosure assessment (Johansen et al. 1981, 1985). This report, therefore, documents the third iteration of the preclosure assessment. It is a primary reference for the Environmental Impact Statement (EIS), which has been submitted by AECL to the Federal Environmental Assessment Panel. AECL's assessment of the postclosure phase is documented in another primary reference (Goodwin et al. 1994) (see preface for a list of all Primary References).

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[1] The CANDU reactor, a unique Canadian design, uses natural uranium fuel and is moderated and cooled by heavy water.

1.1 OBJECTIVES AND SCOPE

1.1.1 Objectives of the Nuclear Fuel Waste Management Program

The objectives of the Canadian Nuclear Fuel Waste Management Program at the concept assessment stage, in general terms, are:

i) to establish if disposal in stable plutonic rock formations (referred to as intrusive igneous rock in the 1978 Joint Statement) is a safe and acceptable means of isolating used nuclear fuel from the environment, by gaining acceptance of the concept from the federal government and the public through a public review process involving the provinces where used nuclear fuel is produced and stored or which have a stake in the nuclear industry: Ontario, Québec, New Brunswick, Manitoba and Saskatchewan; and

ii) to develop guidelines and methodologies for evaluating potential sites and disposal/transportation activities at a site-specific stage.

General Requirements for the Disposal Concept

The Nuclear Fuel Waste Management Program has focused on developing a disposal concept that meets the following general requirements:

- Human health and the natural environment must be protected;
- The burden placed on future generations must be minimized, social and economic factors being taken into account;
- There must be scope for meaningful public involvement during all stages of concept implementation; and
- The disposal concept must be appropriate for Canada.

Technical Objectives during Concept Development

During the development of a concept that would meet the general requirements, the Nuclear Fuel Waste Management Program has focused on meeting the following technical objectives regarding safety and feasibility:

- to develop and demonstrate the technology to site, construct, operate, decommission, and close a disposal facility in plutonic rock;
- to develop and demonstrate a methodology to evaluate the safety of a disposal facility against established safety standards; and
- to establish that technically suitable disposal sites are likely to exist in Canada.

The disposal technology was developed to meet the following specific requirements:

- The technology should not rely on long-term institutional controls as a necessary safety feature;
- The technology should be currently available or readily achievable;

- The technology should be adaptable to a wide range of physical conditions and to potential changes in regulatory standards and societal requirements;
- The technology should include monitoring; and
- The technology should include retrievability.

1.1.2 Objectives of the Preclosure Assessment

The preclosure environmental and safety assessment is a non site-specific analysis of the potential effects on the natural environment, the public, the workers and their community, associated with the following stages of the preclosure phase (see Chapter 2 for a detailed definition of each stage):

i) siting (divided into site screening and site evaluation);

ii) construction of a conceptual disposal facility (referred to as the Used Fuel Disposal Centre or UFDC);

iii) operation of the disposal facility, including transportation of used fuel to the disposal site; and

iv) decommissioning and closing of the facility.

The objectives of this assessment are:

i) to identify the potential environmental effects and safety implications of the preclosure phase activities associated with the conceptual disposal system;

ii) to identify practical measures that could be used to prevent, minimize and/or mitigate, and manage environmental effects and safety hazards;

iii) where it is possible in a non-site specific context, to assess the significance of residual effects and safety hazards (i.e. effects or hazards remaining after the application of impact management measures); and

iv) to suggest guidelines and analytical methods that could be used in the assessment of disposal and transportation activities at the site-specific stage.

1.1.3 Scope of the Preclosure Assessment

The scope of environment that is being assessed includes the following elements (Government of Ontario 1990b):

i) air, land or water;

ii) plant and animal life, including humans;

iii) the social, economic and cultural conditions that influence the human life or a community;

iv) any building, structure, machine or other device or thing made by humans;

v) any solid, liquid, gas, odour, heat, sound, vibration or radiation resulting directly or indirectly from human activities; or

vi) any part or combination of the foregoing and the interrelationships between any two or more of them.

This assessment assumes that the public would be involved in the decision-making process that takes place throughout the preclosure phase.

The preclosure assessment is largely a product of sixteen designated support documents (outlined in Figure 1-1), prepared for AECL by a multi-disciplinary team of Ontario Hydro staff. The relationship between the preclosure assessment and the other primary references for the EIS is illustrated in Figure 1-2.

The scope of the preclosure assessment (Table 1-1) includes the public and worker safety and environmental implications of siting, construction, operation, decommissioning and closing of a used fuel disposal facility, as well as transportation of used fuel to the disposal facility, under normal and accident conditions. This scope was developed based on the EIS guidelines prescribed by the Federal EA panel (1992) as well as the Atomic Energy Control Board (AECB) regulatory policy statement R-71 (AECB 1985), which states that the normal life-cycle of a waste management facility can be separated into a number of relatively distinct stages: siting, design, construction, operation, closure and postclosure. The design stage is not an explicit stage in the reference schedule for the disposal facility, as design activities are expected to take place during siting and even during construction where some of the design features would be adapted to the specific underground geology. AECB policy statement R-71 also requires that transportation be taken into account as part of the disposal system and considered in the Environmental Impact Statement (EIS). An assessment of three modes of transportation (road, rail, water or a combination thereof) is, therefore, included in the scope of this document. This transportation assessment is based on a separate assessment performed by Ontario Hydro (Grondin et al. 1993).

The assessment of effects from the siting, construction, operation, decommissioning and closing of a disposal centre is based on the conceptual UFDC design study prepared by AECL (Simmons and Baumgartner 1994; AECL CANDU et al. 1992). The reference design describes the technical feasibility, facilities, procedures, environmental protection and occupational safety provisions, costs, personnel requirement and schedule estimates. Where necessary, the reference design is supplemented by analysis assumptions based on experience in Ontario Hydro and other relevant industries. These assumptions are detailed in the appropriate chapters. The assessment of effects from used fuel transportation is based on transportation system designs developed by Ontario Hydro (Ulster 1993a) for road, rail and water transportation.

For purposes of this assessment, the location of the disposal facility is assumed to be in one of three regions within the Ontario portion of the Canadian Shield (Figure 1-3), since the majority of the used fuel in Canada is produced in Ontario. The transportation assessment is based on transportation of used fuel from the nuclear generating stations in Ontario to each of the three regions shown in Figure 1-3, but implications of used fuel transportation from Quebec and New Brunswick are also addressed.

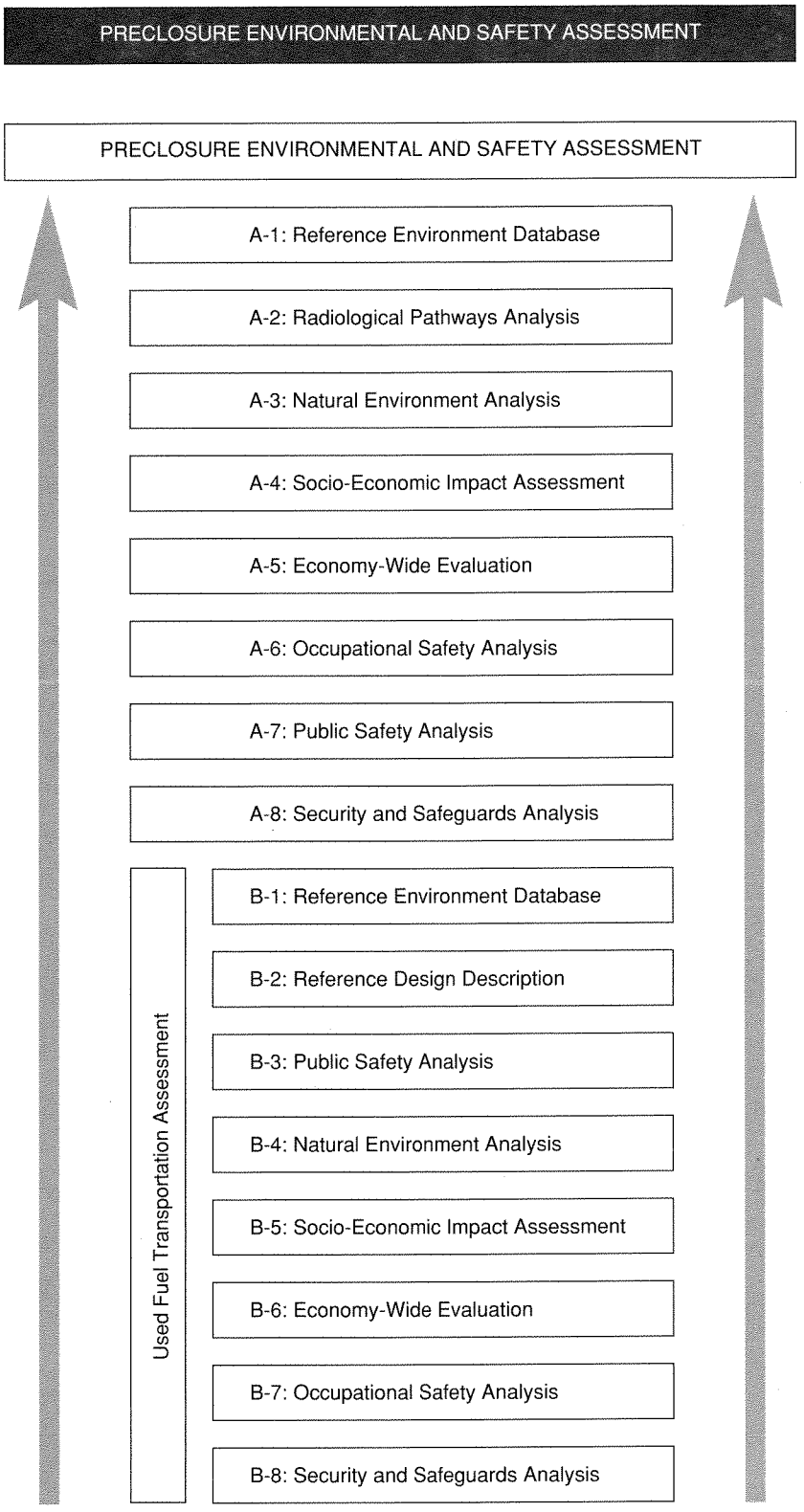
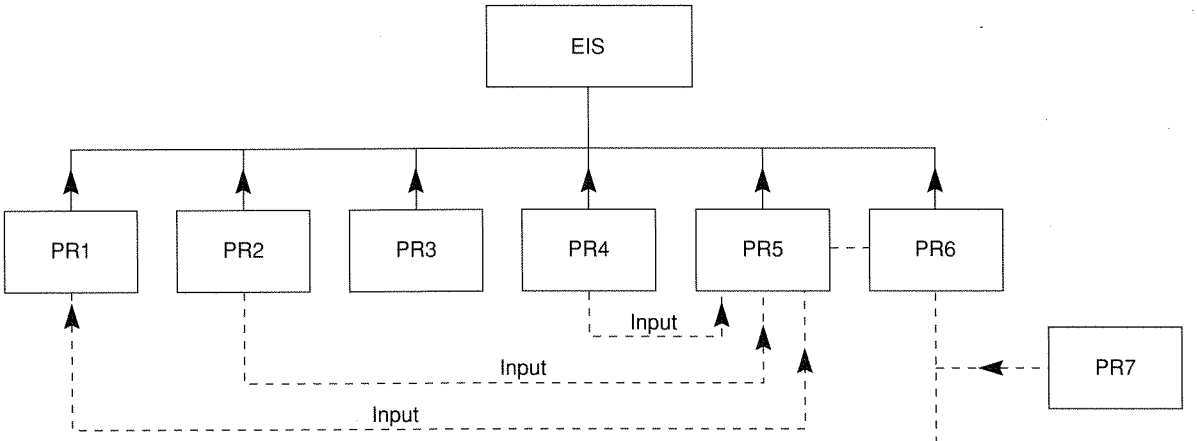


FIGURE 1-1: Preclosure Environmental and Safety Assessment Support Documents



LEGEND

PRI: The Disposal of Canada's Nuclear Fuel Waste: Public Involvement and Social Aspects.

PR2: The Disposal of Canada's Nuclear Fuel Waste: Site Screening and Evaluation Technology.

PR3: The Disposal of Canada's Nuclear Fuel Waste: Engineered Barriers Alternatives.

PR4: The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility.

PR5: The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System.

PR6: The Disposal of Canada's Nuclear Fuel Waste: Postclosure Assessment of a Reference System.

PR7: The Disposal of Canada's Nuclear Fuel Waste: The Vault Model for Postclosure Assessment.

PR8: The Disposal of Canada's Nuclear Fuel Waste: The Geosphere Model for Postclosure Assessment.

PR9: The Disposal of Canada's Nuclear Fuel Waste: The Biosphere Model, Biotrac, for Postclosure Assessment.

FIGURE 1-2: Relationships Between Primary References (PR) and the Environmental Impact Statement (EIS)

TABLE 1-1
Scope of the Preclosure Assessment

INTRODUCTION AND BACKGROUND FOR THE ASSESSMENT (Chapters 1, 2 and 3)		
	ANALYSIS CHAPTERS	
	Type of Effects Analyzed	Primary Models, Methods and Databases Used
SITING (Chapter 4)	• Socio-economic impacts on the community(es)	• review of case studies and social theory • input/output economic model[1]
	• Non-radiological safety effects on the public and workers	• review of case studies • database of accidents to workers[2]
	• Non-radiological effects on the natural environment	• interaction matrix • review of case studies
CONSTRUCTION (Chapter 5) (normal and accident conditions)	• Socio-economic impacts on the community(es)	• review of case studies and social theory • input/output economic model[1]
	• Radiological effects on the public and workers (radon from excavation)	• review of mining experience and natural radon emission data
	• Non-radiological safety effects on the public and workers	• databases of accidents to workers • reference route traffic database[3]
	• Non-radiological effects on the natural environment	• interaction matrix • review of case studies • U.S. Environmental Protection Agency Air Emission Factors (U.S. EPA 1978) • reference environment database, GIS model[4]
OPERATION (Chapter 6) (normal and accident conditions)	• Socio-economic impacts on the community(es)	• review of cases studies and social theory • input/output economic model[1]
	• Radiological effects on the public, workers and the environment	• PREAC[5] and PSAC[6] • hazard identification/quantification
	• Non-radiological safety effects on the public and workers	• databases of accidents to workers • reference routes traffic database[3]
	• Non-radiological effects on the natural environment	• CEMTOX[7] • interaction matrix • review of case studies • U.S. EPA Air Emission Factors (U.S. EPA 1978) • reference environment database, GIS model[4]
TRANSPORTATION (Chapter 7) (normal and accident conditions)	• Socio-economic impacts on the communities	• review of case studies and social theory • input/output economic model[1]
	• Radiological impacts on the public, the environment and workers	• INTERTRAN[8] and TADS[9]
	• Non-radiological safety effects on the public and workers	• reference routes accident database[3] • databases of accidents to workers
	• Non-radiological effects on the natural environment	• interaction matrix • U.S. EPA Air Emission Factors (U.S. EPA 1978) • Ontario Ministry of the Environment Traffic Noise Model • reference routes traffic database[3]

continued...

TABLE 1-1 (concluded)

	ANALYSIS CHAPTERS (continued)	
	Type of Effects Analyzed	Primary Models, Methods and Databases Used
DECOMMISSIONING AND CLOSING (Chapter 8) (normal and accident conditions)	• Socio-economic impacts on the community(es)	• review of case studies and social theory • input/output economic model[1]
	• Radiological safety effects on the public, the environment and workers	• case studies
	• Non-radiological safety effects on the public and workers	• databases of accidents to workers[2]
	• Non-radiological effects on the natural environment	• interaction matrix • review of case studies
SENSITIVITY ANALYSIS AND SCENARIO ANALYSIS (Chapter 9)		
FUTURE ASSESSMENT STRATEGY AND CUMULATIVE EFFECTS (Chapter 10)		
CONCLUSIONS (Chapter 11)		

[1] Input/output model used in the economy-wide evaluation and documented in Cheng (1993c).

[2] Ontario occupational work injury and fatality statistics documented in Myint (1989). It incorporates data from Ontario mines, construction industry, and forestry industry.

[3] Used Fuel Transportation Database documented in Grondin (1993a).

[4] UFDC Reference Environment Database documented in Grondin and Fearn-Duffy (1993a). Use of a GIS system is also documented in the same report.

[5] PREAC = Preclosure Radiological Environmental Assessment Code, a pathways analysis model developed by Ontario Hydro and used to calculate the individual and collective doses to the public from a UFDC in the reference environments in the northern, central and southern regions of the Canadian Shield of Ontario.

[6] PSAC = Public Safety Analysis Code, a model developed by Ontario Hydro and used to estimate the frequencies of postulated accidents and to calculate the individual and collective doses to the public from the postulated accidents at a UFDC.

[7] CEMTOX = ChEMically TOXic environmental assessment code, a model developed by Ontario Hydro and used to calculate the environmental concentrations of chemically toxic nuclides in the reference environments in the northern, central and northern regions of the Canadian Shield of Ontario.

[8] INTERTRAN = A model sponsored by the IAEA and used to calculate the collective doses to the public from normal used fuel transportation

[9] TADS = A model developed by Ontario Hydro and used to calculate the individual and collective doses from used fuel transportation accidents

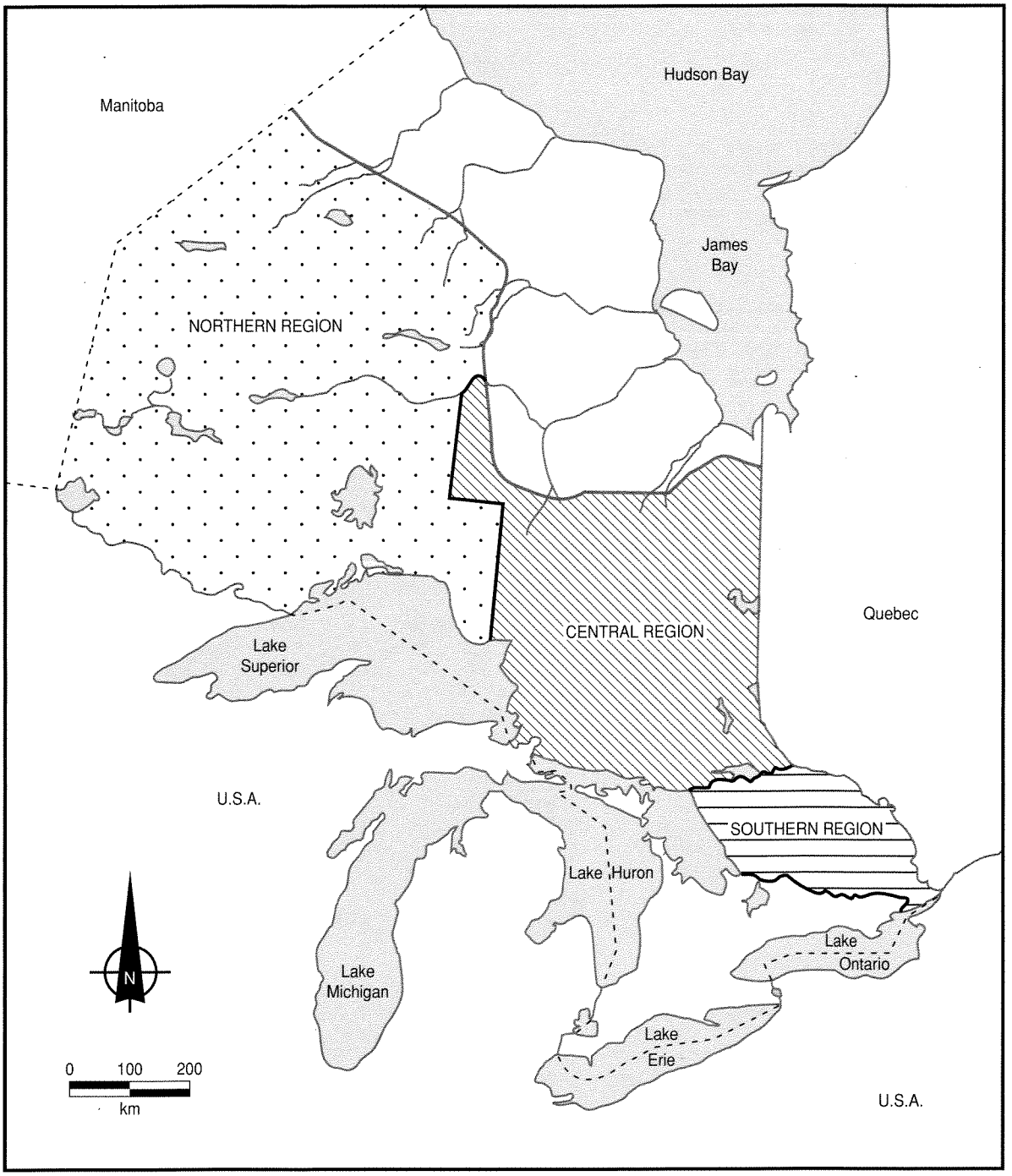


FIGURE 1-3: The Three Reference Regions in the Ontario Portion of the Canadian Shield

1.1.4 Organization and Terminology of This Document

(a) Organization

In overview, this document is organized largely along the lines of the preclosure stages in the disposal implementation sequence. This organization is reflected in Table 1-1.

Chapter 1 presents a brief introduction to the Nuclear Fuel Waste Management Program, objectives, assessment scope and how the preclosure assessment relates to the overall EIS and other primary references (Figure 1-2). Section 1.2 reviews present regulatory requirements at the provincial, federal and international levels which had a bearing on this assessment of the disposal concept and/or could have a bearing on the preclosure phase of disposal implementation. Sections 1.3-1.4 outline how public views have been considered in this generic assessment (1.3) and how they would be incorporated in site-specific assessments during concept implementation (1.4). Section 1.5 introduces a framework for assessing the significance of effects and risks for purposes of both this generic assessment and later site-specific assessments. Finally, Section 1.6 outlines the quality assurance program followed in carrying out this assessment, including validation of new computer models and peer reviews.

Chapter 2 describes the conceptual design of the disposal system used as a basis ("reference design") for this preclosure assessment, including a disposal facility (referred to as the Used Fuel Disposal Centre or UFDC) and a system for transporting used fuel from Canadian nuclear generating stations to the disposal facility.

Chapter 3 describes the general (not site-specific) environment baseline used as a basis ("reference environment") for the preclosure assessment, including population settlement and land use patterns as well as natural components of the environment. It should be noted that the socio-economic component of this assessment is based more on documented social science research and experience with other major projects (case studies) than on the combination of reference design and reference environment.

Chapters 4, 5, and 6 present the methodology for and results of analyses of effects which could be caused by disposal facility siting, construction and operation, respectively, based largely on the reference design and environment information summarized in Chapters 2 and 3. Both normal and potential accident conditions are considered. Table 1-1 outlines the main categories of effects analyzed as well as models, methods and databases used in the assessment.

Chapter 7 similarly presents the methodology for and results of analyses of effects which could be caused by transporting used fuel from storage at Canadian nuclear generating stations to the disposal facility, again largely based on the design and environment information in Chapters 2 and 3. The analysis results in Chapter 7 are primarily based on transportation of used fuel from existing Ontario Hydro nuclear stations to a disposal facility assumed to be located somewhere within the Ontario portion of the Canadian Shield (Figure 1-3). These results are extrapolated to take into account the incremental effects of used fuel transportation from nuclear stations in Quebec and New Brunswick.

Chapter 8 presents the results of analysis of disposal facility decommissioning, monitoring and closure of the underground vault. Completion of this stage defines the endpoint of the preclosure phase of disposal implementation and of the scope of this assessment.

Chapter 9 presents the results of an array of sensitivity analyses intended to identify how variations in disposal system design and implementation parameters and in environmental conditions, depending on final design and location of the facilities, would affect the results of the base-case analyses presented in Chapters 4-8. In addition, Section 9.11 discusses the implications of certain scenarios (natural and social environment and energy production scenarios) specified in the EIS guidelines. These sensitivity and scenario analyses serve to augment the assessment, in the absence of specific environmental data and public views associated with a specific site and a final disposal system design optimized for a specific site.

Chapter 10 outlines a strategy and site-specific methods which could be used for environmental and safety assessment during implementation stages. Both ecological and socio-economic perspectives, as well as an approach to cumulative effects assessment, are discussed.

Chapter 11 presents a summary and conclusions drawn from the analysis results in Chapters 4-9 with a view to the strategy outlined in Chapter 10.

(b) Terminology

In any multi-discipline assessment, such as this, it is inevitable that some differences in the use of terms will arise. The Glossary at the back of this document provides definitions of technical terms as well as common words which are used with a special meaning in the document.

Two terms which deserve special mention are "environmental effect" and "environmental impact". They are both commonly used in the environmental assessment field, often interchangeably, and there is no generally accepted rule for using one term or the other. In this document, an attempt has been made to use both terms in a specific and consistent manner.

In general, the term "environmental effect" is intended to mean a change in the environment (defined as including social and economic conditions as well as natural components) caused by implementation of the disposal system. In the context of social and economic (socio-economic) assessment, the term "impact" is intended to mean an "effect" which is considered to be important or significant by the community(s) affected. In other words, some natural or socio-economic environment effects may lead to socio-economic impacts, while some will not. The key to this distinction is that a socio-economic impact assessment is carried out in light of the goals and values of the community(s) affected, not just the views of assessment professionals. On the other hand, in the context of radiological assessment, the term "impact" generally refers to the direct result of radioactive emissions from a facility (i.e. radionuclide concentration in the environment, potential dose to exposed human or other living organisms), whereas "effect" generally refers to the potential health consequence to organisms which are exposed. In other words, some radiological impacts may lead to health effects, while others will not. In the context of natural environment assessment, no such distinction is generally made; the term "effect" is used throughout, regardless of significance.

1.2 RELEVANT REGULATORY REQUIREMENTS AND GUIDELINES

The main legislation (acts and regulations) and guidelines at the federal, provincial and international levels that might have a bearing on the preclosure phase of disposal implementation are listed in Table 1-2. These and others are described in Appendix B.

The listings in Table 1-2 and Appendix B are not meant to be exhaustive. Rather, they are intended to be illustrative. Municipalities, which receive their authority from provincial legislation, may also have relevant

TABLE 1-2
Major Legislation[1] Applicable or Potentially Applicable to the Preclosure Phase

FEDERAL LEGISLATION (alphabetical order)
• Atomic Energy Control Act
• Canada Labour Code
• Canada Shipping Act
• Canada Water Act
• Canada Wildlife Act
• Canadian Environmental Assessment Act[2]
• Canadian Environmental Protection Act
• Fisheries Act
• National Parks Act
• National Transportation Act
• Navigable Waters Protection Act
• Nuclear Liability Act
• Railway Act
• St. Lawrence Seaway Act
• Transportation of Dangerous Goods Act
ONTARIO LEGISLATION (alphabetical order)
• Conservation Authorities Act
• Dangerous Goods Transportation Act
• Emergency Plans Act
• Environmental Assessment Act[2]
• Endangered Species Act
• Environmental Protection Act
• Heritage Act
• Highway Traffic Act
• Labour Relations Act
• Lakes and Rivers Improvement Act
• Occupational Health and Safety Act
• Public Lands Act
• Water Resources Act
INTERNATIONAL REQUIREMENTS AND CODES
• International Atomic Energy Agency Safeguards Requirements
• International Atomic Energy Agency Radioactive Materials Transportation Regulations
• CFR 49 United States Code of Federal Regulations on the Transportation of Dangerous Goods
• United Nations Convention on Environmental Impact Assessment in a Transboundary Context
• International Maritime Dangerous Goods Code (IMDG) (United Nations)
• Draft Code for the Safe Carriage of Irradiated Nuclear Fuel in Flasks on Board Ships (United Nations)

[1] A brief description and a reference for these and other potentially applicable legislation are included in Appendix B.

[2] Applicable at the time of implementation. This concept review is under the federal Environmental Assessment and Review Process (EARP) Guidelines Order (Government of Canada 1984).

requirements. In addition, directives, policies, or procedures of the governments or government agencies might have to be considered. These could be found, for example, in regulatory documents issued by the AECB, in the Federal Nuclear Emergency Response Plan prepared by Health Canada, or in Guidelines for Preparing Environmental Assessments issued by the Ontario Ministry of Environment and Energy, the Ministry of Transportation and other Ontario Ministries.

At present, the Canadian disposal concept is not site-specific. It is expected that used fuel will remain safely stored at the reactor sites for several decades and, in the interim, safety and environmental protection legislation and guidelines will likely change. It is, therefore, difficult to anticipate all the requirements which will apply to concept implementation. It is assumed that an implementing organization would be established at the time of, or soon after, the federal government's decision on acceptability of the concept, if that decision is positive. It is further assumed that the organization would:

i) comply with all applicable legislation, or other regulatory requirements;

ii) develop appropriate standards where necessary; and

iii) mitigate effects (radiological and non-radiological) according to the ALARA (as low as reasonably achievable) principle, and reduce any other adverse effects to a minimum or acceptable level.

1.3 PUBLIC VIEWS

Public views on the management of radioactive materials and their potential effects on people, communities and the natural environment are considered in this generic assessment of the disposal concept. This assessment assumes that the implementing organization, when established, will seek public views and involve the public in the decision-making process for implementation of the concept.

Since 1978, AECL has been gathering information on public views, opinions and concerns regarding the nuclear fuel waste disposal concept and related topics. A list of issues identified in a formal public consultation program has been documented by AECL (Greber and Anderson 1989). AECL has summarized the results of program-specific consultation activities in a separate primary reference (Greber et al. 1994).

In addition, beginning prior to 1978, Ontario Hydro has identified and addressed public issues and concerns associated with radioactive materials in the context of electricity generation, used fuel storage, transportation and disposal. Components of this research on public views related to the Nuclear Fuel Waste Management Program have been compiled by Hardy Stevenson and Associates (1992a) for general use in the assessment.

Public opinion survey respondents, focus groups, interest groups and locally affected publics differ in their degree of knowledge, in their degree of control or involvement in the decision-making, in the degree to which they are affected by a particular issue, and in the motivation they have to express their concerns. These different publics have different and sometimes conflicting opinions and concerns. Until the locally affected publics are consulted, the degree of concern about an issue is not likely to be known. General public input, such as gathered in opinion surveys, focus groups, commissions, etc., is used as an indication of the potential issues involved in used fuel disposal. The issues that have led to important changes in the disposal concept have been highlighted in the text of this assessment.

The major issues related to the preclosure phase, identified during AECL and Ontario Hydro public consultation activities and considered in this assessment, are summarized in Appendix A.

1.4 ROLE OF THE PUBLIC IN THE DECISION-MAKING PROCESS

The preclosure assessment makes a number of assumptions on how the implementing organization for used fuel disposal would involve the public in the decision-making process at the implementation stage (see Sections 4.1 and 6.5). These are important because the relationship established between the implementing organization and the affected community or communities through the siting and environmental assessment process is a major factor influencing the occurrence and management of socio-economic impacts. This relationship would determine the type of interaction that the project would have with the affected communities (see Chapter 6 for a definition of community).

1.4.1 The Environmental Assessment Process and the Role of Communities

The siting process would be based on the principles of fairness, openness, voluntarism, shared decision-making, and commitment to safety and environmental protection, and would provide a framework for the siting activities (see Section 4.1 for details on the principles). It is assumed that more site-specific environmental screening and assessment (including suitable technology options) would be carried out for site selection decision-making purposes. Furthermore, it is assumed that even with public involvement in the siting process, formal environmental assessment reviews and government/regulatory approvals will be sought at appropriate times in the siting and development of any disposal facility. The environmental assessment process is a planning process which should ensure that the eventual decision to select a particular disposal facility design and a particular site has taken into account all aspects of the affected environment (natural, social, cultural and economic).

The environmental assessment process, whether it is a provincial or a joint federal-provincial process, would require public participation. The siting and concurrent environmental assessment activities would be integrated into a consensus building process that may involve joint planning with the community and governmental agencies. It is necessary to establish early in the siting stage, the role that the community would have in the identification, monitoring, mitigating and enhancement of impacts, and to specify the rights and responsibilities of all parties involved (e.g. implementing organization, public, government agencies). It is assumed that, before siting activities begin, the implementing organization would have a public involvement policy in place which would include the following commitments:

i) citizen participation in the decision-making process throughout the preclosure phase;

ii) the role of the community in each stage of the preclosure phase would be clearly defined in consultation with the community;

iii) the community would have a share of control in the planning and implementation of the facility; and

iv) the implementing organization would be flexible and willing to change the community involvement mechanisms to respond to community priorities, values and concerns.

1.4.1.1 Role of Communities in the Identification of Potential Environmental Effects

The environmental effects of the disposal facility and the used fuel transportation system would be determined based on the project interaction with, and response of, people and their communities and the natural environment. Potentially affected people and their communities will have to participate in the identification of potential environmental effects (including socio-economic impacts) and in the determination of the significance of the identified effects. In general, people base their decision on significance partly on factual information about a project, but ultimately this decision is a reflection of their values. The adoption of a "valued ecosystem components" approach in the environmental assessment (see Chapter 10) would ensure that the value that people in the community, technical experts, and other stakeholders attach to a given ecosystem component is factored into the assessment. The social impacts arising from changes in the environment would therefore be assessed together with the effects on the natural environment, and the impact management measures proposed would be directed at all effects of concern.

1.4.1.2 Role of Communities in the Establishment of an Impact Management Program

Impact management would involve the coordinated application of prevention, mitigation, compensation and enhancement, and the establishment of mechanisms for community involvement in monitoring and in decision-making. Its purpose would be to avoid, reduce the severity, redress and/or enhance the impacts associated with the disposal facility in a manner which is socially acceptable through joint planning with potentially affected communities. Affected or potentially affected communities must be full participants in the establishment of policies, the development of institutional arrangements, the implementation of community monitoring and a mechanism for on-going review and assessment, all of which could be components of community impact agreements between the implementing organization and the affected communities.

It is assumed that public participation in the establishment of an impact management program by the implementing organization would be based on the following principles:

i) the people and communities that would host a disposal facility, and those potentially affected by it, have a legitimate right to participate fully in the decision regarding the prevention, mitigation, compensation of negative impacts and enhancement of positive ones;

ii) effective and continuous communication would be established between the implementing organization the community and its diverse groups or stakeholders in order to facilitate joint problem solving;

iii) dispute and conflict resolution processes would be established to ensure that impact management goals are met and that community concerns are addressed; and

iv) monitoring of changes in the community resulting from disposal facility implementation activities, would be done; monitoring results would be used in periodic reviews of the program and in possible revisions to the program (as required).

The community impact agreements would be site-specific and agreed to between the proponent and the community. Some of the features that could be included in a community impact agreement are:

i) statements describing project characteristics, community characteristics and the full range of possible impacts or concerns;

ii) a description of the rights and duties of each party to the agreement;

iii) agreements to provide necessary project information such as construction schedules, employment levels and projections for the number of in-migrants;

iv) provisions for monitoring including the identification of variables to monitor, the participation and/or verification by the community of monitoring results;

v) provisions for the determination and evaluation of actual impacts and the selection of appropriate mitigation;

vi) provisions to implement community liaison measures;

vii) a financial agreement that may include compensation;

viii) a description of audit procedures;

ix) a process for dispute resolution; and

x) allowances for extensions to the agreement or future negotiation and settlement of impacts that may arise after the term of the original agreement.

A special set of guidelines or policies may also be required for particular aspects of the project or to address broader social policy issues in a more comprehensive manner. For example, specific guidelines and agreements will likely be required with any Aboriginal communities affected.

In addition to formal agreements, the establishment of effective liaison measures can provide the means for continued participation in decision-making regarding the project's development.

1.4.2 Role of Communities during the Disposal Facility Construction, Operation, Decommissioning and Closure

It is assumed that the implementing organization would involve the community in managing the disposal facility construction, operation, decommissioning and closure. Active participation of citizens in the management of the facility could be through representation on the board of directors and other management committees (e.g. committees responsible for emergency response, health and safety, environmental protection, etc.). The public involvement mechanisms would need to be negotiated with the community and these mechanisms should be flexible enough to respond to the priorities, values and concerns of the community as the facility progresses from one stage to the next. Effective liaison between the community at large and the implementing organization would provide the community with information about the activities being carried out at the disposal facility and the implementing organization with information on possible community concerns.

Further discussion of public involvement in implementation stage planning and assessment is given in Chapter 10.

1.5 FRAMEWORK FOR ASSESSING SIGNIFICANCE AND RISK

This section defines the concepts of significance, health and risk as they are used in this assessment.

1.5.1 Definition of Significance

Determining whether a project (concept in this case) is likely to cause significant adverse environmental effects is a key objective (explicit or implicit) of any environmental assessment process. It is a requirement of the EARP Guidelines Order (1984) which governs this assessment. In general, for a full site-specific environmental assessment, the determination of significance of identified adverse effects would be based on a number of factors, such as:

i) magnitude of effects, including cumulative effects, relative to some reference level(s) (e.g. regulatory criteria, guidelines, standards and practices, sustainability of natural resource use, natural background levels, etc.);

ii) geographical extent of effects (site-specific);

iii) duration and frequency of effects;

iv) degree of reversibility/irreversibility of effects;

v) ecological context (e.g. already affected by human/industrial development or fragile ecology with little resilience to additional stresses);

vi) case studies based on similar or relevant projects; and

vii) views and concerns of potentially affected public/community.

This approach is generally consistent with the approach outlined in the emerging "Guide to the Canadian Environmental Assessment Act". However, for a concept assessment such as this one (without site-specific baseline conditions), significance cannot be determined fully.

For purposes of this concept assessment, three types of factors were used as the main indicators of significance of identified effects on the public, workers and the environment (Appendix C contains a summary of the factors relevant to each stage of the preclosure phase; a more detailed summary can be found in Grondin and Fearn-Duffy (1993b)):

i) requirements of laws, statutes, regulations and governmental guidelines;

ii) industrial standards/targets; and

iii) case-studies and industrial practices.

It is important to emphasize that these factors were only used as indicators of significance for concept assessment purposes. For implementation purposes, the actual significance of a given effect would be determined in consultation with regulatory staff and the affected public, and with the knowledge of the site-specific baseline conditions and ecological context.

The preclosure assessment is both an environmental assessment and a safety assessment. It is, therefore, convenient to divide the discussion of significance into these two components.

1.5.1.1 Significance and Safety

The significance of the identified effects of the preclosure phase activities on the safety of the public and workers was evaluated in terms of:

i) regulatory criteria for radiological safety under normal and accident conditions as prescribed by the AECB;

ii) targets used at the Ontario Hydro nuclear generating stations; and

iii) natural concentration of radiological and non-radiological contaminants in the environment, and background radiation dose.

The indicators of significance are listed in Appendix C and used in the analysis chapters.

1.5.1.2 Significance and Environmental Effects

Given the definition of environment used in this assessment (see Section 1.1.3), the significance of effects on both the socio-economic and natural components of the environment was considered.

a) Significance of Impacts on the Socio-Economic Environment

The full significance of socio-economic impacts could not be determined without the participation of the affected people and their communities. Such determination of significance would be done during the environmental assessment process at the implementation stage. The manner in which public input would be incorporated in the assessment of socio-economic impacts is discussed in Section 1.4 and in Chapter 10 (describing the approach/methods that would be used in the site-specific environmental and safety assessment).

Nevertheless, the extent to which impacts have been experienced and managed in the past for comparable projects provided an indication of the potential significance of such impacts for this concept assessment. The case studies used in the socio-economic part of this assessment are listed in Appendix D.

b) Significance of Effects on the Natural Environment

Although some degree of significance can be derived in a non-site specific assessment based on most of the general factors listed under Section 1.5.1 above, full significance is difficult to determine without the proper ecological context. The factors used as indicators of significance in this natural environment analysis are listed in Appendix C for each stage of the preclosure phase consistent with the three types of factors or indicators, introduced under Section 1.5.1 also (i.e. (1) legislation, regulations and government guidelines, (2) industrial targets, (3) case studies and industrial practices).

Here again, input from regulatory staff, technical experts, the public and other stakeholders is required to determine what value should be attributed to a given ecosystem component, and ultimately to determine the full significance of potential effects on this component (see Chapter 10 for a description of the valued ecosystem component approach).

The determination of the significance of identified effects on the natural environment in this concept stage assessment was, therefore, not as conclusive as would be expected at the site-specific stage. Using case studies, however, measures that have been used elsewhere to mitigate similar types of impacts were identified.

1.5.2 Definition of Health

The guidelines for the preparation of the EIS require that the effects of the disposal concept on human health be assessed. It is, therefore, useful to define how the concept of health is used in this assessment.

The definition of health used in this assessment is taken from the World Health Organizations's Constitution: health is defined therein as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization 1967).

This definition closely parallels the aboriginal view that health is holistic - it is not only physical well-being, but also psychological, social, cultural and spiritual well-being (CEARC 1990).

1.5.3 Definition of Risk

In the context of this assessment, the term "risk" is broadly defined as "the existence of a threat to life and health" (Advisory Committee on Nuclear Safety 1986). If this definition is compared with the broad definition of "health" given in Section 1.5.2, it follows that the concept of risk goes beyond its technical definition of probability multiplied by consequences. Risk also needs to be placed in a social context.

This section will first describe how risk has been defined and estimated in terms of human deaths and injuries. Then, the social implications of risk will be discussed.

It will be important for the implementing organization to recognize that risks to the environment (natural and social) are viewed and evaluated by the public based on the core social values around which society is organized. This is particularly so for risks associated with new technologies, such as the disposal technology, since people make technological choices based in part on technical and scientific factors, but mostly on societal values (Otway and Thomas 1982; Rayner and Cantor 1987). Such moral and ethical issues are discussed in Section 6.5. General public views on risk are reviewed in Section 1.5.3.2.

In the end, a good understanding of the concept of risk and of its social implications will be necessary in order for the implementing organization to minimize effects of a proposed facility at a given site.

1.5.3.1 Technical Definition of Risk

In the preclosure assessment, the technical definition of risk includes both radiological and non-radiological considerations.

a) Radiological Risk

In order to assess compliance with established regulatory criteria, an estimate of the radiological dose (expressed in sievert or Sv) to workers and the public was included in the assessment. The radiological risk was obtained by multiplying a given radiological dose by: (1) the probability of occurrence of this dose and (2) the risk conversion factor recommended by the International Commission on Radiological Protection (ICRP 1991) expressed in terms of the number of fatal cancers per Sv of exposure.

For routine emissions, the probability of occurrence of the dose is 1 and for accident conditions, it is the product of the probability of occurrence of an accident and the probability that a dose results from that accident. The ICRP risk factor for the public is 5×10^{-2} fatal cancers per Sv of exposure and for workers 4×10^{-2} fatal cancers per Sv of exposure. The fact that the age of

the worker population normally lies between 20 and 65 years old, makes the workers a less vulnerable population than the general public, and accounts for the difference in the value of the risk factor.

A summary of human health effects from exposure to ionizing radiation in general is contained in Appendix E.

b) Non-radiological Risk

Non-radiological risks to workers are expressed in terms of fatalities and lost time injuries per unit of work-time. They are based on data from experience in relevant industries. Non-radiological risks to the public from the disposal facility life-cycle activities cannot be quantified at this non-site specific stage. They are analyzed qualitatively and practical mitigation measures are discussed in Chapters 4 through 8.

1.5.3.2 Social Context of Risk

It has been common in the past for risk researchers to describe risk as a concept in which experts and their "objective facts" are pitted against lay persons and their "subjective values". However, more recent risk research reflects the fact that even scientific assessments or evaluations cannot be performed independent of values and assumptions (Kasperson 1978). On the one hand, it has been recognized that values that stem from personal, cultural or philosophical context or methodological values are difficult, if not impossible, to avoid in science and risk assessment (Schrader-Frechette 1991). On the other hand, lay persons do not evaluate risks exclusively in terms of values, independent of experience and certain types and degrees of knowledge. The perceptions, observations and facts that individuals have of the world around them, and of risks in particular, are a result of both values and the action of the external world (physical and social) upon them. Community dynamics, moral and ethical values, political and economic values and distributions, education and availability of information on the level of risk all have a role to play in the lay persons' process of risk appraisal.

a) Factors Influencing Acceptability of Risk

There are certain patterns in the social context within which individuals become aware of and appraise technological risks (Slovic et al. 1978, 1982; Sandman 1985). Risks are generally considered less acceptable to individuals and communities if:

i) the individuals are unfamiliar with the activity;

ii) the risks are involuntary (the individuals do not choose to do or accept the activity);

iii) the individuals have no personal control over the risks or it is not clear who would control the risks;

iv) the risks can be associated with dramatic, memorable events;

v) uncertainty exists over the degree of risk;

vi) the individuals dread the potential consequences of an accident;

vii) consequences are difficult to detect;

viii) the risks are seen as unfair or inequitable (risk distribution skewed); and

ix) and the risks are difficult/impossible to protect against.

b) Risk Concerns as a Source of Social Impacts

Since risk in its basic definition is related to health, and using the World Health Organization (WHO) definition of health as including mental and social well-being, it follows that risk could be an important source of social impacts. In addition, stress related physical health effects could arise from the way risks are viewed and evaluated by members of the public.

High levels of concern over the health and safety of family, friends and community, and the concern that one's livelihood may be jeopardized by contamination of the environment, can all interfere in the normal day to day interactions of people. Therefore, risk has the potential to influence all aspects of community life: social, economic and political. Details on these risk related social impacts are given in Section 6.5.

c) Public Views on Risk

Public views, opinions and values need to be taken into account in a complete assessment of risk. However, this is a difficult task in this non-site specific assessment given that such views are likely to be influenced by geographical location, age composition of the population, past experience, time and many other factors. Public views on risk would need to be ascertained during the site-specific environmental assessment process. Some general public views on risk were nevertheless used to help define the risk context for this concept assessment. The manner in which these views influenced the design of the conceptual disposal facility and the assessment is described in the design (Chapter 2) and analysis chapters (Chapters 4 to 8) where appropriate.

Focus group research and public opinion surveys regarding used fuel management in Ontario confirmed that Ontario residents were concerned about nuclear materials and the disposal and transportation of used fuel (Greber et al. 1994; Pieroni 1984; Decima Research Ltd. 1985). Used nuclear fuel and a disposal facility have many of the features which could lead to a high degree of concern over risk. The hazardous nature of radiation, the fact that it is invisible and imperceptible to the human senses contribute to the view that its threat is "unfamiliar, insidious and even unfair" (Siting Process Task Force on Low Level Radioactive Waste Disposal 1987). Risk studies which attempted to rate risks of various natures showed that the public views risk of a nuclear nature as high (Lowrance 1976; Fischhoff 1978; Slovic et al. 1978).

The public views on the risk associated with a nuclear fuel waste disposal facility can also be indicated by the closest distance that residents would be willing to live from such a facility. For both low and high level radioactive waste facilities, the closest distance quoted was about 30 km (Decima Research Ltd. 1985).

The controllability of the risk was found to be the most emphasized factor in public views on risk (Decima Research Ltd. 1985). The type of community control preferred included: communities having the right to decide whether or not a high-level waste disposal facility should be located near them; and independent monitoring of effects by the community.

1.6 QUALITY ASSURANCE

1.6.1 Assessment Quality Assurance Objectives and Requirements

The preclosure assessment quality assurance program had two main objectives:

i) to establish a clear understanding of the quality requirements, the responsibilities of the Ontario Hydro Preclosure Assessment

Team and the management control activities that would be utilized to ensure the quality of the assessment; and

ii) to provide procedures to each team member for meeting the quality requirements of the preclosure assessment through individual task work plans, and to establish a system for review and approval of documents.

To assure the quality of studies and analyses contributing to the preclosure assessment, work was conducted under the following requirements:

i) models, calculations and analysis to be realistic where possible and conservative where necessary;

ii) parameter values and assumptions to be well documented;

iii) wherever possible, parameter values from widely recognized sources (e.g. CSA Standards) to be used;

iv) computer codes to be adequately translated from conceptual models and verified;

v) wherever possible, widely recognized codes and models available to the AECB and other agencies to be used;

vi) results and predictions from models to be systematically documented for ease of retrieval and review of assumptions;

vii) scientific peer review to be undertaken; and

viii) any significant deficiencies and limitations in the data and/or analysis to be identified, and their implications addressed in the assessment documents.

1.6.2 Planning and Controlling Work

To undertake and control work contributing to the preclosure assessment, a multi-disciplinary team was established by Ontario Hydro. Eight major sub-tasks were identified for assessment of the disposal facility and eight other sub-tasks were identified for assessment of used fuel transportation. Work scopes and schedules were developed and revised on a yearly basis, for each area of analysis. The work scope identified responsibilities and specified various work procedures and deliverables. Members of the team were selected from the appropriate areas of the Ontario Hydro organization responsible for the required types of work.

Team meetings were held regularly to keep track of progress, ensure consistency between the various analyses and provide internal working level review of the work. AECL coordination staff were present at many of these meetings. These meetings were documented and actions were assigned. Semi-annual status reports were submitted to AECL and published in the Nuclear Fuel Waste Management Program semi-annual status report.

The work under the 16 sub-tasks resulted in the 16 support documents outlined in Section 1.1.3 (Figure 1-1). The procedures for review of the support documents and their approval were defined and issued to the contributors. Draft versions of the support documents were issued, reviewed by Ontario Hydro and AECL, and peer reviewed. The final versions were reviewed and approved by Ontario Hydro according to pre-established review and approval procedures.

1.6.3 Quality Assurance of Computer Models

Several computer codes have been developed and used to assess the potential radiological and toxic chemical impacts on the environment from the operation of the disposal facility (the PREAC, PSAC and CEMTOX codes) and radiological impacts from transportation of used fuel to this facility (the TADS code) (see the analysis chapters for a full description of the use of these codes).

These computer codes were developed based on Ontario Hydro Quality Assurance procedure QEPS 2.34 for computer models (Ontario Hydro 1991c).

Each computer model had three levels of documentation:

i) a theory manual;

ii) a programmer's manual; and

iii) a verification report.

The computer code INTERTRAN used in the risk assessment of used fuel transportation is an IAEA sponsored code used internationally and was not subjected to internal quality assurance procedures. The input data was, however, subjected to the quality assurance requirements listed above.

1.6.3.1 The Theory Manual

The physical problem to be analyzed and the analysis scenario are outlined in the theory manual. The theory used to develop the computer code is detailed and the mathematical models described. Theory manuals have been prepared for PREAC, PSAC, CEMTOX, and TADS (Russell 1993c, 1993e, 1993f; Kempe 1993c).

1.6.3.2 The Programmer's Manual

The programmer's manual contains a general description of the code and the algorithm. A brief overview of the model is provided, followed by a global algorithm illustrating the translation of the scientific model into a structured plan for the calculations. A variable list and an index key (showing the meaning of the various indices) is included. The source code is listed in the detailed program description section and example input data files and output files are listed in appendices. Programmer's manuals have been prepared for PREAC, PSAC, CEMTOX and TADS (Russell 1993b, 1993d, 1993g; Kempe 1993b).

1.6.3.3 The Verification and Validation Report

This report documents the results of the following actions:

i) verify that the programming statements in the code are a reasonable representation of the theory under consideration;

ii) decompose the code into functional groups and examine the coding in detail; verify by hand calculations, or other software tests, that the coding is a correct translation of the mathematical models described in the theory manual; test the robustness of the code;

iii) perform and document a complete hand calculation using simplified but reasonable approximations to detailed or repetitive numerical calculations; compare these with the results from the computer program; and

iv) identify portions of the code that will allow validation against independent environmental data sets.

Verification reports have been prepared for PREAC, CEMTOX, PSAC and TADS (Wai 1993a, 1993b and 1993c; Kempe and Beck 1993).

1.6.4 Peer Reviews

The preclosure assessment and the component analyses have been extensively reviewed internally by Ontario Hydro and AECL staff, and externally by recognized experts in the various disciplines relevant to the assessment:

i) the pathways analysis was reviewed by staff at Health and Welfare Canada, and the PREAC code development was closely reviewed by T. Oren of the Technical Advisory Committee to AECL;

ii) the pre-guidelines version of the socio-economic impact assessment (SEIA) was reviewed by C. Cluett from Battelle and K. Storie from Memorial University;

iii) the occupational safety analysis was reviewed by D. Chambers of SENES, A. Marko, former Director of Physics and Health Sciences Division at AECL, and D. Bernhardt of Rogers and Associates Engineering Corporation;

iv) the security and safeguards components of the assessment were reviewed by staff from the Atomic Energy Control Board (AECB) and R. Smith, Safeguards Consultant;

v) the used fuel transportation database was reviewed by staff from the Institute for Risk Research (University of Waterloo), the Ontario Ministry of the Environment, the AECB, Hydro Quebec and New Brunswick Power;

vi) the reference transportation system design was reviewed in part by staff from the Canadian Coast Guard, the Canadian Railway Company, the Transportation of Dangerous Goods Directorate (part of Transport Canada), and marine consultants MacDonald and James;

vii) the radiological public safety analysis of used fuel transportation was reviewed by staff from the Institute for Risk Research;

viii) the occupational safety analysis of used fuel transportation was reviewed by staff from the AECB, the Ontario Ministry of the Environment, Hydro Quebec and New Brunswick Power;

ix) the used fuel transportation assessment was reviewed by British Nuclear Fuel Limited of the United Kingdom; and

x) the final draft of the preclosure assessment was reviewed by K. Davies of Ecosystem Consultants and D. Dixon, Environmental Consultant.

In addition, papers on the assessment components were presented at conferences, including:

i) The 2nd International Conference on Radioactive Waste Management, Canadian Nuclear Society, Winnipeg, Canada, 1986.

ii) The International Symposium on the Back End of the Fuel Cycle - Strategies and Options, International Atomic Energy Agency, Vienna, Austria, 1987.

iii) The 9th Symposium on the Packaging and Transportation of Radioactive Materials, Washington. D.C., U.S.A., 1989.

iv) The International Symposium on Hazardous Materials/Wastes: Social Aspects of Facility Planning and Management, Toronto, Canada, 1990.

v) The 12th Radiation Protection Conference and Symposium of the Canadian Radiological Protection Association (CRPA), Winnipeg, 1991.

vi) The International Consensus Conference on Risks of Transporting Dangerous Goods, Toronto, Canada, 1992.

vii) The International High Level Radioactive Waste Management Conference, Las Vegas, Nevada, U.S.A., 1992.

1.6.5 Primary Reference Production Quality Assurance Procedures

The preclosure assessment was prepared in a planned and controlled manner to ensure that it addresses the applicable requirements of the EIS Guidelines. The document was prepared in accordance with AECL's Quality Assurance process for primary references.

CHAPTER 2

2. CONCEPTUAL DESIGNS OF USED FUEL DISPOSAL CENTRE AND TRANSPORTATION SYSTEMS

This chapter presents the main features of the conceptual used fuel disposal centre and transportation system designs that were used as a basis for the assessment (these will be called "reference" in this chapter). Given that a conceptual design is only one of many potential alternative designs for the disposal facility and transportation system, foreseeable developments in these conceptual designs are discussed in Section 2.4.

2.1 REFERENCE DESIGN FOR A USED FUEL DISPOSAL CENTRE

The reference Used Fuel Disposal Centre (UFDC) design, developed by AECL, has been described in detail in AECL CANDU et al. (1992) and Simmons and Baumgartner (1994). The main design features are summarized in the following sections.

2.1.1 Overview

2.1.1.1 The Reference Disposal Technology

The basis of the concept is to dispose of nuclear fuel waste in an underground vault in the plutonic rock of the Canadian Shield. The reference vault would be located 1 000 m below the surface and the disposal area would occupy approximately 2 km x 2 km. In the reference design, waste isolation would be achieved by the following natural and engineered barriers to radionuclide release:

i) the used fuel waste form;

ii) the corrosion-resistant container;

iii) buffer material compacted around the container;

iv) backfill material compacted within the disposal rooms;

v) access tunnel, shaft and borehole seals; and

vi) the plutonic rock (granite).

These barriers are illustrated schematically in Figure 2-1. Details on how the barriers provide containment and isolation are contained in Johnson et al. (1994a).

Even though the first four barriers would be present in filled and sealed disposal rooms, the radiological analysis (contained in Chapter 6) only credited the used fuel waste form and the corrosion-resistant container as barriers during the preclosure phase for conservatism (Used fuel is in the form of ceramic pellets of uranium oxide encased in sealed sheaths made of a zirconium alloy. Both components resist corrosion, dissolution and radionuclide release. The walls of the titanium container would also act as a barrier to radionuclide movement).

In the conceptual design of the vault, containers filled with used fuel are placed in boreholes (this activity is referred to as 'fuel emplacement') drilled into the floor of individual disposal rooms. Compacted buffer material, a mixture of 50% by weight sodium bentonite clay and 50% by weight silica sand, surrounds each container in individual boreholes. Lower backfill material, a mixture of 25% by weight glacial lake clay and 75% by weight crushed granite from the vault excavation, is used to backfill the lower part of the disposal rooms. The upper portion of the room is filled by spray-compacting an upper backfill material similar in composition to the

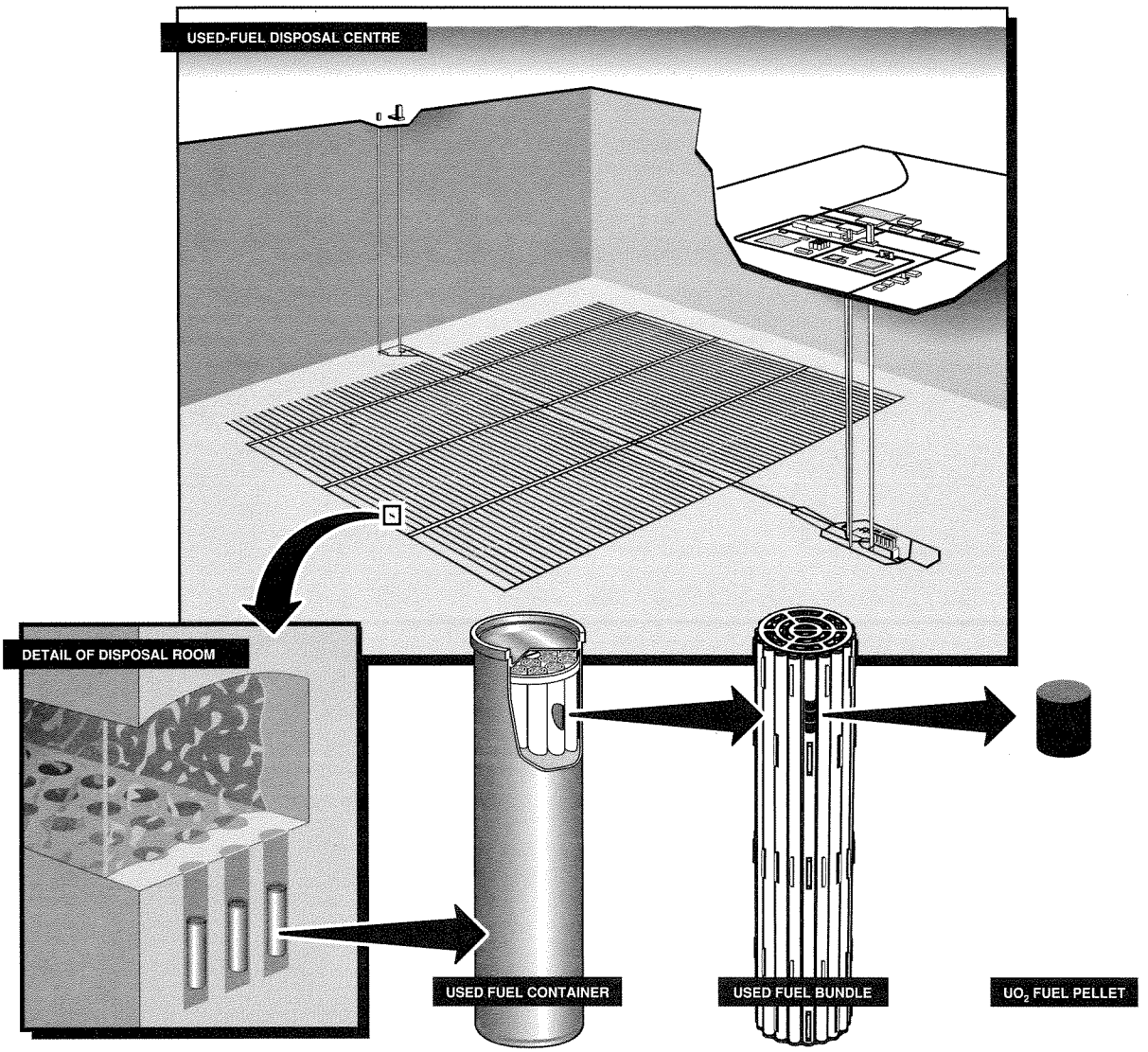


FIGURE 2-1: Schematic Illustration of Barriers to Radionuclide Contamination Provided by the Reference Design

buffer. The service areas and access tunnels are backfilled and sealed in a similar way. The shafts are sealed with concrete plugs and lower backfill material. Supply of the clay and other materials is discussed in Section 6.4.

2.1.1.2 The Reference Site

AECL's conceptual design (Simmons and Baumgartner 1994) specifies the UFDC as a self-contained complex. A general layout of the reference site and surface facilities within the site are shown in Figures 2-2 and 2-3, respectively. The reference site layout would include facilities such as the basket and container fabrication plant, used fuel packaging plant, underground vault and all the surface facilities associated with the underground operations (e.g. the access shafts, concrete batching plant, backfill preparation plant and rock-crushing plant). In addition, the reference UFDC would include the ancillary facilities required to provide the operational and personnel services such as the auxiliary building, administration building (including fire hall and security services), powerhouse, utilities, warehouse, waste management facilities for both radioactive and inactive wastes, and quality control laboratories. The UFDC would require an area of land measuring 5.2 km x 3 km, including a fenced area of 1.5 km around the used fuel packaging plant and the upcast shaft complex (this is called the protected area for security purposes).

The conceptual design assumes that the UFDC site would have the following characteristics:

i) relatively flat and undeveloped site;

ii) within 300 km of a populated centre (e.g. 15 000 inhabitants or more);

iii) within 25 km of a suitable railway line, highway and electrical power grid;

iv) adjacent to a suitable source of fresh surface water;

v) located on stable plutonic rock of the Canadian Shield;

vi) unpopulated within 500 m of the outer boundary; and

vii) located in a zone of low seismic risk.

It was also assumed that the site contains nothing that is of significant scenic, cultural or historic value that would preclude its development and that there is no obvious present or future alternative use for the site. As recommended in the AECB regulatory document R-71 (AECB 1985), it is also assumed that the site host rock would not contain commercial grade minerals to minimize the probability of human intrusion in the postclosure phase. Assumptions made in the present analysis with respect to site selection are discussed in Chapter 4.

2.1.1.3 Reference Vault Layout

As illustrated in Figure 2-4, the reference vault has five vertical shafts connecting the surface to the vault to provide for ventilation and for transportation of container casks, personnel, materials and equipment.

A network of underground tunnels would provide access to the disposal area made up of eight panels. Each panel would have 64 disposal rooms, with a possible 282 boreholes per room.

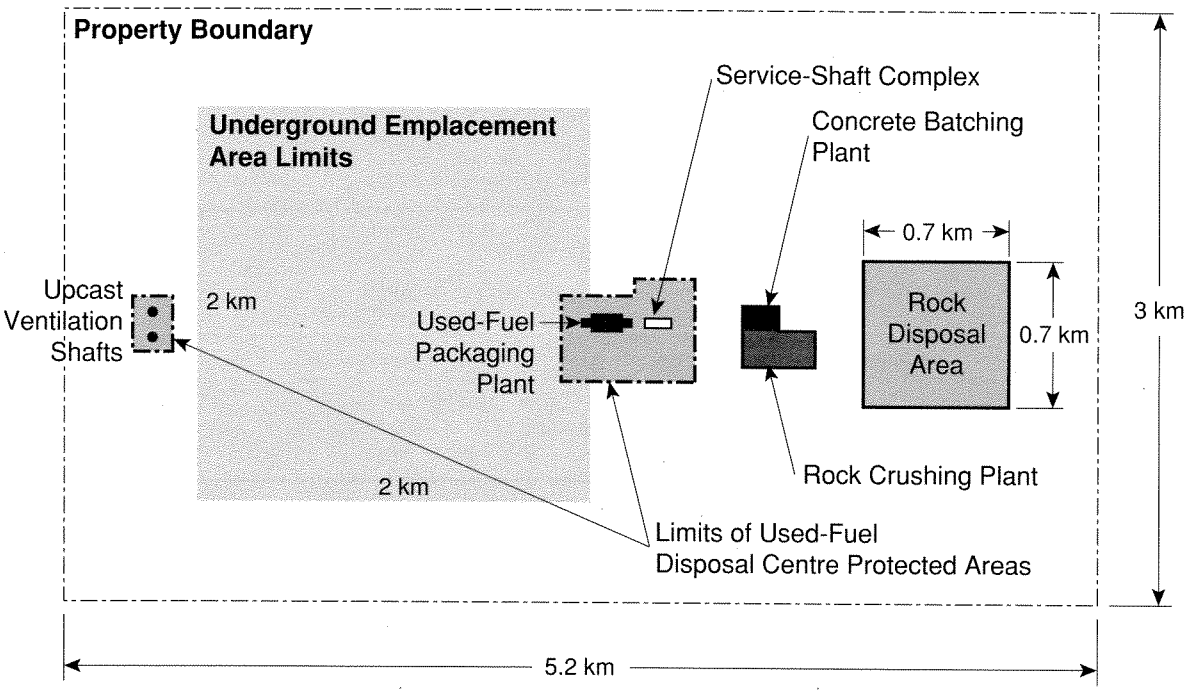
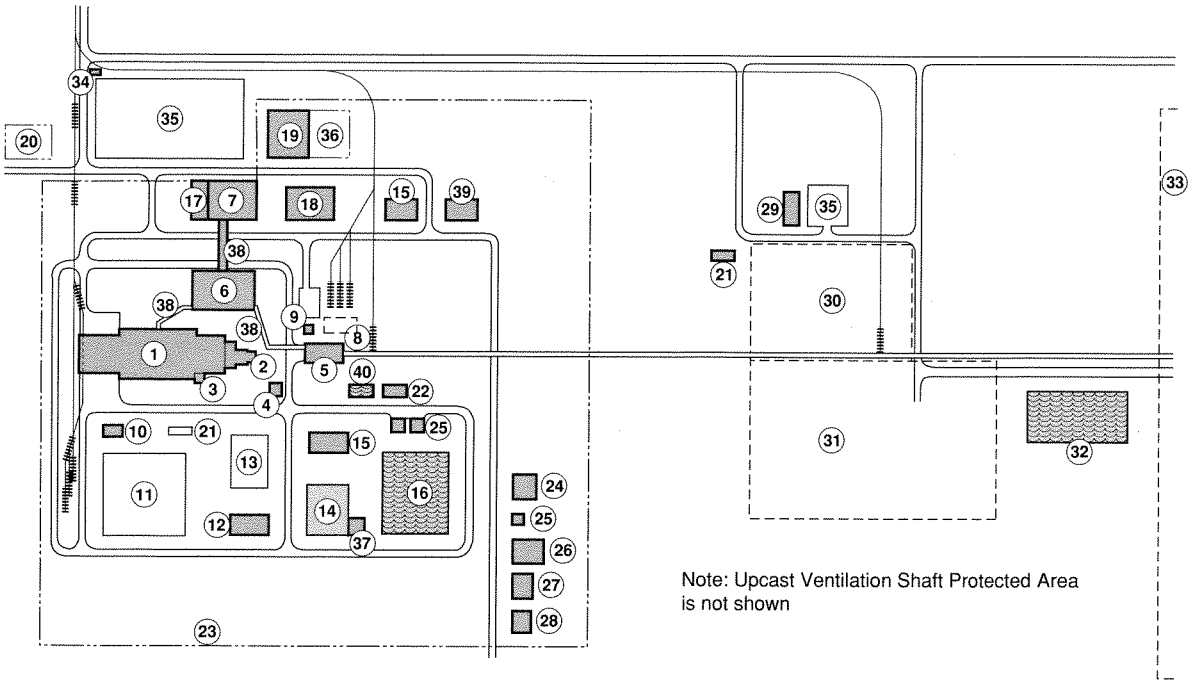


FIGURE 2-2: General Layout of the Reference Site



1. Used-Fuel Packaging Plant
2. Waste Shaft Headframe
3. Stack
4. Downcast Ventilation Shaft
5. Service Shaft Complex
6. Auxiliary Building
7. Admin. Building Including Firehall
8. Sealing Material Storage Bins
9. Dust Collection Bag House
10. Active Solid Waste Handling Bldg.
11. Waste Management Area
12. Active Liquid Waste Treatment Building
13. Low-Level Liquid Waste Storage Area
14. Sewage Holding Pond
15. Garage
16. Storm Runoff Holding Pond
17. Cafeteria
18. Basket and Container Fabrication Plant
19. Warehouse
20. Switchyard
21. Transformer Area
22. Air Compressors
23. Security Fence (Main Protected Area)
24. Powerhouse
25. Fuel Tanks
26. Water Storage Tanks
27. Water Treatment Plant
28. Pumphouse and Intake
29. Quality Control Offices and Laboratory
30. Concrete Batching Plant Area
31. Rock Crushing Plant Area
32. Process Water Settling Pond
33. Rock Disposal Area
34. Guard House
35. Parking Area
36. Storage Yard
37. Sewage Treatment Plant
38. Overhead Corridor
39. Hazardous Materials Storage Building
40. Service Shaft Complex Water Settling Pond

FIGURE 2-3: Layout of Main Surface Facilities Within the Reference Site (not to scale)

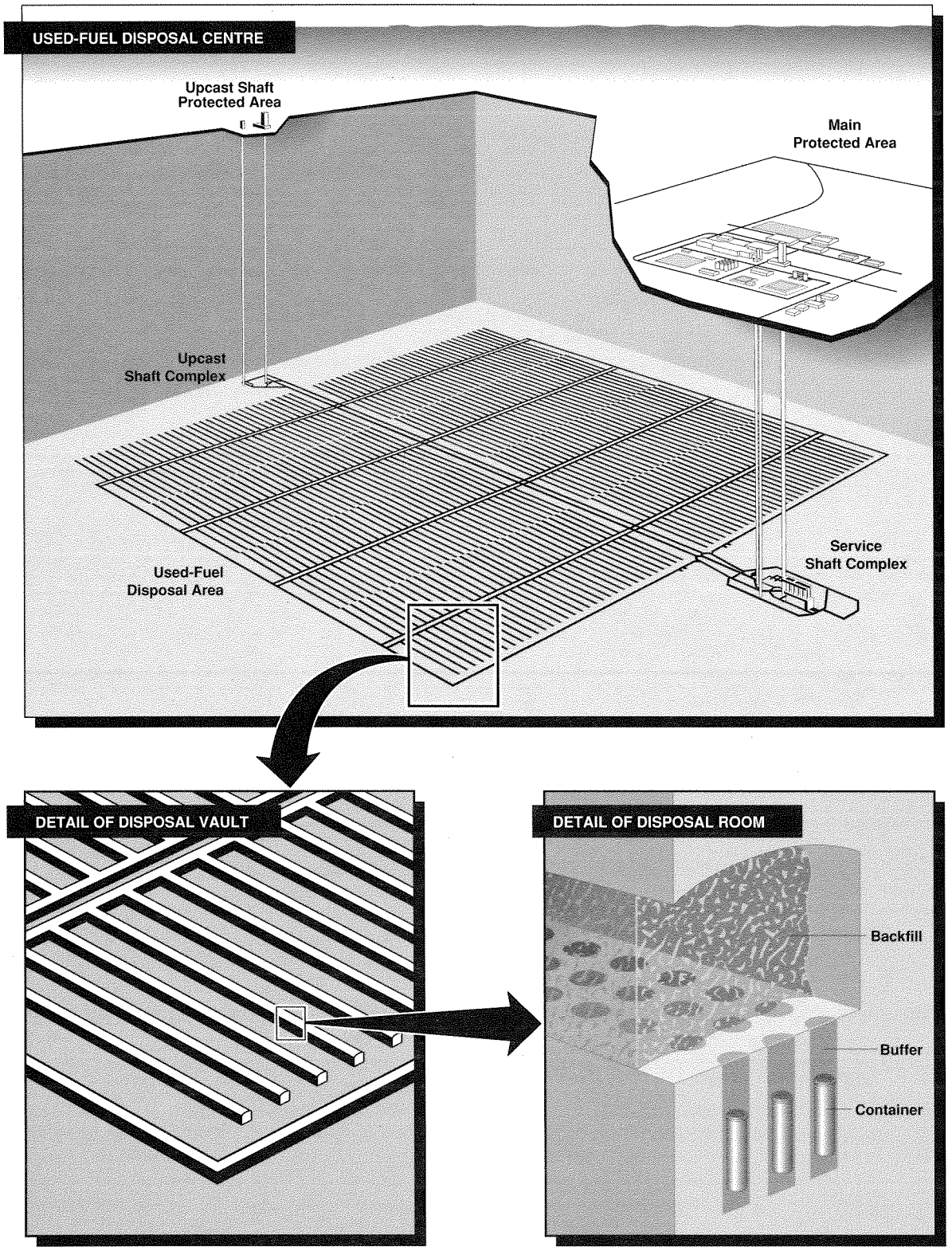


FIGURE 2-4: Reference Vault Layout

Access to the disposal area would be provided by a perimeter tunnel and two central tunnels dividing the area into two halves, four panels in each half.

The emplacement of containers would be carried out in one panel on one side of the twin central access tunnel, during the simultaneous excavation of disposal rooms in a panel on the other side. The twin central access tunnels would permit the segregation of container traffic from other traffic and provide for division of the ventilation systems into two separate parts, one for the mining operation and one for the used fuel emplacement operation.

2.1.1.4 Reference Used Fuel: Source and Volume

The reference used fuel is from the Bruce Nuclear Generating Station. It has an average burnup of 685 $GJ \cdot kg^{-1}U$. A burnup of 1 008 $GJ \cdot kg^{-1}U$, which is almost the peak burnup, was used for the design of the shielding. For this study, it is assumed that the used fuel would be stored at the reactor sites in water-filled storage bays for ten years before transportation to the UFDC (current used fuel storage practices in Canada are discussed in Frost (1993c) and summarized in the EIS). The bundle weights for all CANDU reactors are virtually the same. The peak burnup will vary according to the refuelling strategy for the particular reactor but the average burnup is fairly uniform.

The reference design study assumes a vault capacity of about 10 million used fuel bundles (which would have contained 191 133 Mg of uranium when initially fed into the reactor). This estimate of disposal need was based on a projected nuclear-generated electrical growth of 3% (including completion of Darlington NGS in Ontario and construction of another 600 MW reactor outside Ontario) up to, and including, the year 2035. It includes fuel from nuclear stations in Ontario, Quebec and New Brunswick also maintained in capacity to 2035 (see Section 2.3.3 for a general discussion of fuel transportation from Quebec and New Brunswick). A discussion of used fuel production scenarios can be found in Chapter 9, where projections of used fuel production are compared to actual used fuel production to date. The reference design study also assumed a disposal operation lasting about 41 years which results in a disposal rate of about 250 000 bundles per year. Using these assumptions, the used fuel inventory to the year 2035 would be disposed of by the end of the operational period.

As described in the reference disposal facility design (Simmons and Baumgartner 1994), the fuel would be packaged in disposal containers each with a capacity of 72 used fuel bundles (see Figure 2-5). Thus, we would require 3 471 containers per year, for a total of 140 256 containers over the operational lifetime of the vault (Simmons and Baumgartner 1994).

2.1.1.5 Project Stages, Schedule, Cost Estimate and Labour Requirements

The schedule for the UFDC project stages and major activities is shown in Figure 2-6. In addition to the well-defined siting, construction, operation, decommissioning and closure stages, extended monitoring stages of undefined durations are included as part of the preclosure phase.

1. Project Stages

The following project stages have been defined in the reference UFDC design:

i) Siting comprises the identification of potential disposal sites (site screening) and then a detailed investigation of one or more preferred sites (site evaluation) including underground exploration. All of these steps would be done in consultation with the public and within the framework provided by a siting process (see Chapter 4 for a discussion of the principles on which a siting process would be based);

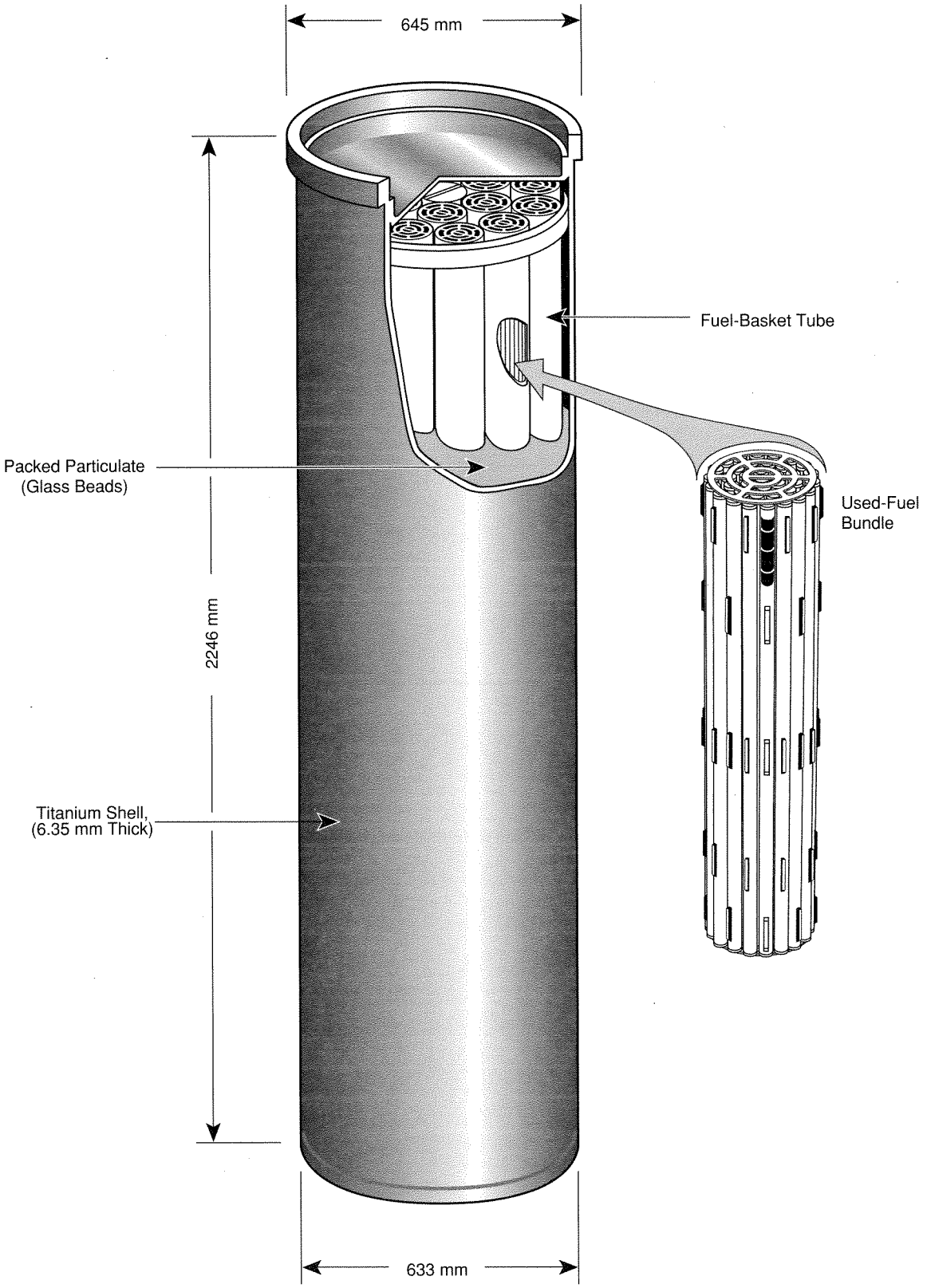


FIGURE 2-5: Reference Disposal Container

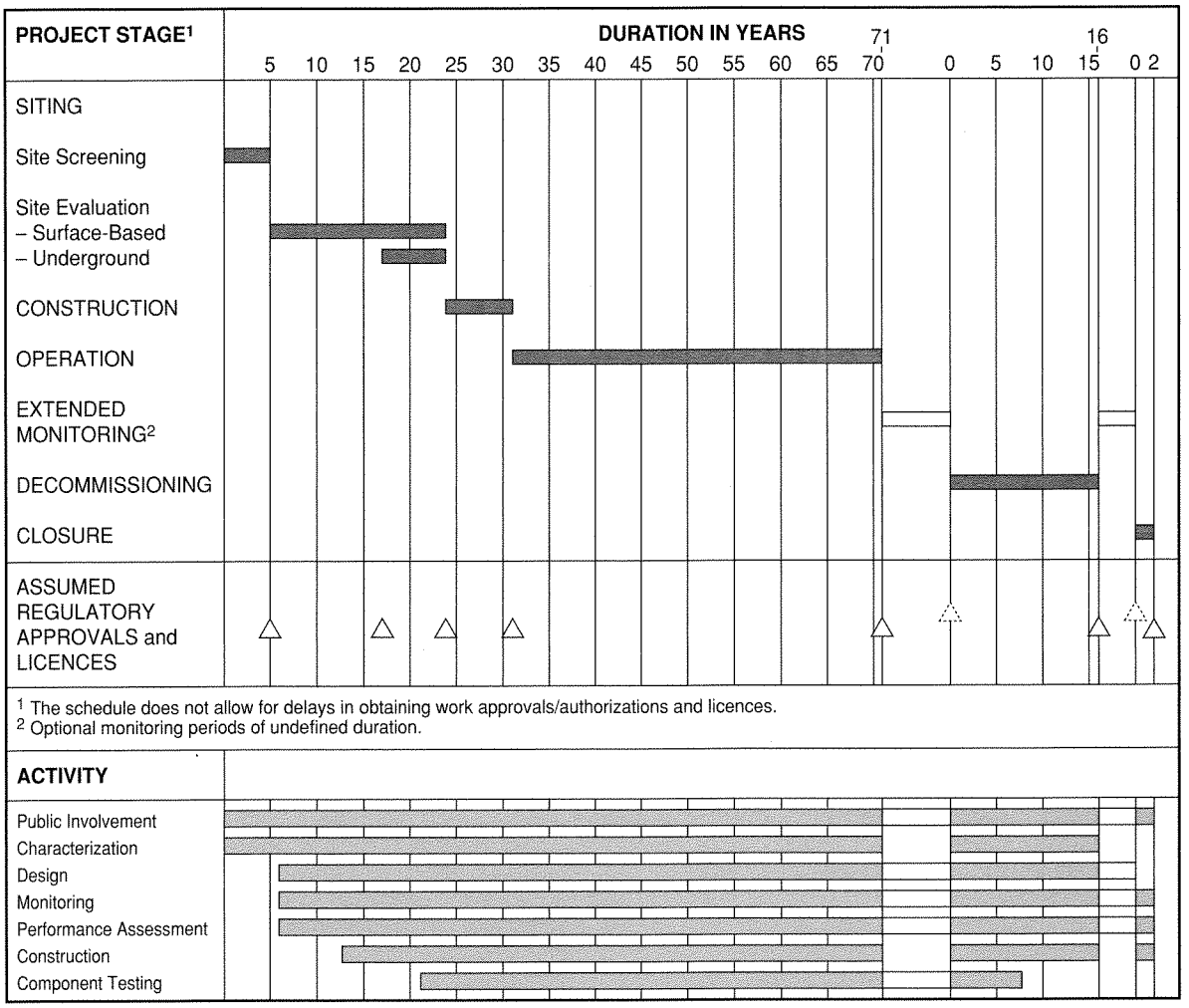


FIGURE 2-6: Schedule for UFDC Stages and Activities

ii) Construction comprises the development of the site and construction of facilities making up the UFDC, namely the transportation facilities and access routes, the used fuel packaging plant, the used fuel disposal vault, and the ancillary service facilities, utilities and infrastructure needed to operate the centre and excavation of the underground facilities and some of the disposal rooms;

iii) Operation involves receiving the used fuel that has been transported from the nuclear stations site, packaging it in the disposal containers and emplacing these containers in the underground vault, backfilling and sealing the disposal rooms that have been filled with used fuel containers, and excavating additional disposal rooms; (note that for purposes of the present study, used fuel transportation is assessed separately from operation);

iv) Extended Monitoring if required, would involve monitoring conditions in the vault, geosphere and surface environment following the operation stage. Extended monitoring may be required before decommissioning of the facility and/or after decommissioning but before final closure;

v) Decommissioning involves the decontamination, dismantling and removal of the surface and subsurface facilities, and the sealing of the tunnels, shafts, service areas, and exploratory and monitoring boreholes throughout the disposal vault; and

vi) Closure is the removal from the surface of instrumentation and equipment left in place for the extended monitoring of disposal vault performance that could open up a pathway for radionuclide migration. If there is no extended monitoring stage after decommissioning, this stage is combined with decommissioning

Note that the extended monitoring stage was not included in the original disposal centre design. It was added in response to the public views, expressed during the AECL public consultation program (Greber and Anderson 1989), that such a feature was desirable.

2. Project Activities

During the above stages, a number of activities would take place, which are described below:

i. Characterization is the surface and subsurface investigation of a site. Data is gathered to develop and refine the geotechnical models required for refining and finalizing the design and for conducting pre- and postclosure performance assessments to establish the suitability of the site. The scope of characterization is determined in consultation with the public, government agencies, scientific groups and other stakeholders. The data acquisition that starts during the siting stage continues throughout the construction and operation stages, and extends into the monitoring activities in the transition period between pre- and postclosure. Many of the systems installed during initial site characterization become elements of the monitoring activities. Site characterization at the site screening and site evaluation sub-stages is further discussed in Chapter 4;

ii. Design and Refinement is the development of an increasingly detailed facility, based on the evolving geotechnical model for the site developed using site characterization data;

iii. Monitoring is the continuous or intermittent measurements of conditions in the region that is influenced, or potentially influenced, by the disposal centre and transportation systems . The scope of monitoring is determined in consultation with the public, government agencies, scientific groups and other stakeholders. Baseline environmental monitoring is further discussed in Chapter 10;

iv. Performance Assessment is the frequent analysis of characterization and monitoring data to assess the short- and long-term performance of the disposal centre and disposal vault. Results of the performance assessments are used in the various project stages to obtain the approvals, permits and licences necessary to proceed to the next stage;

v. Construction is the excavation of rock, the development, fabrication and assembly of surface and underground installations, the development of disposal rooms in the operation stage and finally the disassembly and sealing in the decommissioning and closure stages; and

vi. Component Testing is the planning, testing, and analysis of test results to assess the specific performance of elements of the disposal system.

3. Project Cost and Labour Requirements

Estimating the cost and labour requirements of a disposal project such as this, based on only concept-level engineering studies three decades in advance of its assumed in-service date, is a challenge. Preliminary cost and labour estimates for the UFDC reference design were suggested by AECL in 1988 as part of the results of their Concept Assessment Engineering Study. These estimates have been refined since then, as the reference design and implementation plans have evolved. The latest update of the estimates is presented in AECL's UFDC engineering primary reference (Simmons and Baumgartner 1994). Because of the lead-time required to carry out the related analyses in this Preclosure Assessment (i.e. socio-economic impact and occupational safety analyses required cost and/or labour estimates), a 1992 version of the estimates was used for these analyses.

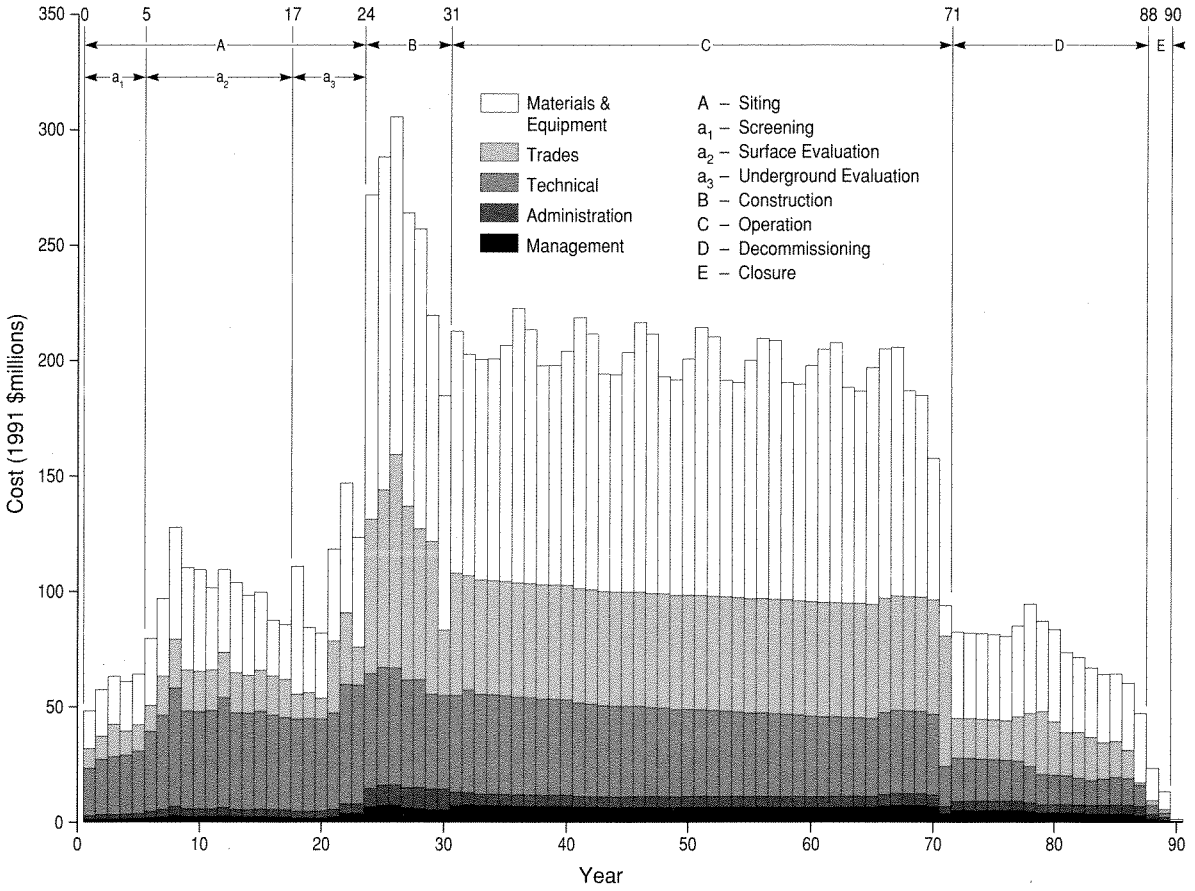
Both sets of estimates (i.e. the 1992 set used for Preclosure analyses and the latest 1993 update) are presented in Table 2-1. This table includes estimate totals and breakdowns for each UFDC implementation stage/ substage. Figure 2-7 shows the profile of annual costs over the lifespan of the UFDC, based on the latest estimates. Similarly, Figure 2-8 shows the profile of annual labour requirements over the same lifespan, including a breakdown into four labour categories (trades, technical, administration and management). As can be seen from Table 2-1, the estimate totals used for the analyses are virtually identical to the latest update totals. The differences between stage estimates are relatively minor, well within the accuracy range reported by AECL for these estimates (-15% to +40%). The effect of these minor differences on the conclusions of this Preclosure Assessment is considered to be negligible.

In summary, the total cost of the UFDC over a projected lifespan of about 89 years is estimated at approximately $13.3 billion (1991 $). The total direct labour requirement for the UFDC over that same lifespan is estimated at over 60 000 person-years. The maximum annual labour requirement is estimated at approximately 1 300 person-years during the peak of the 7-year construction stage, but the annual requirement remains relatively level at around 1 000 person-years throughout the 41-year operation stage.

TABLE 2-1
Estimated UFDC Life-Cycle Costs and Labour Requirements

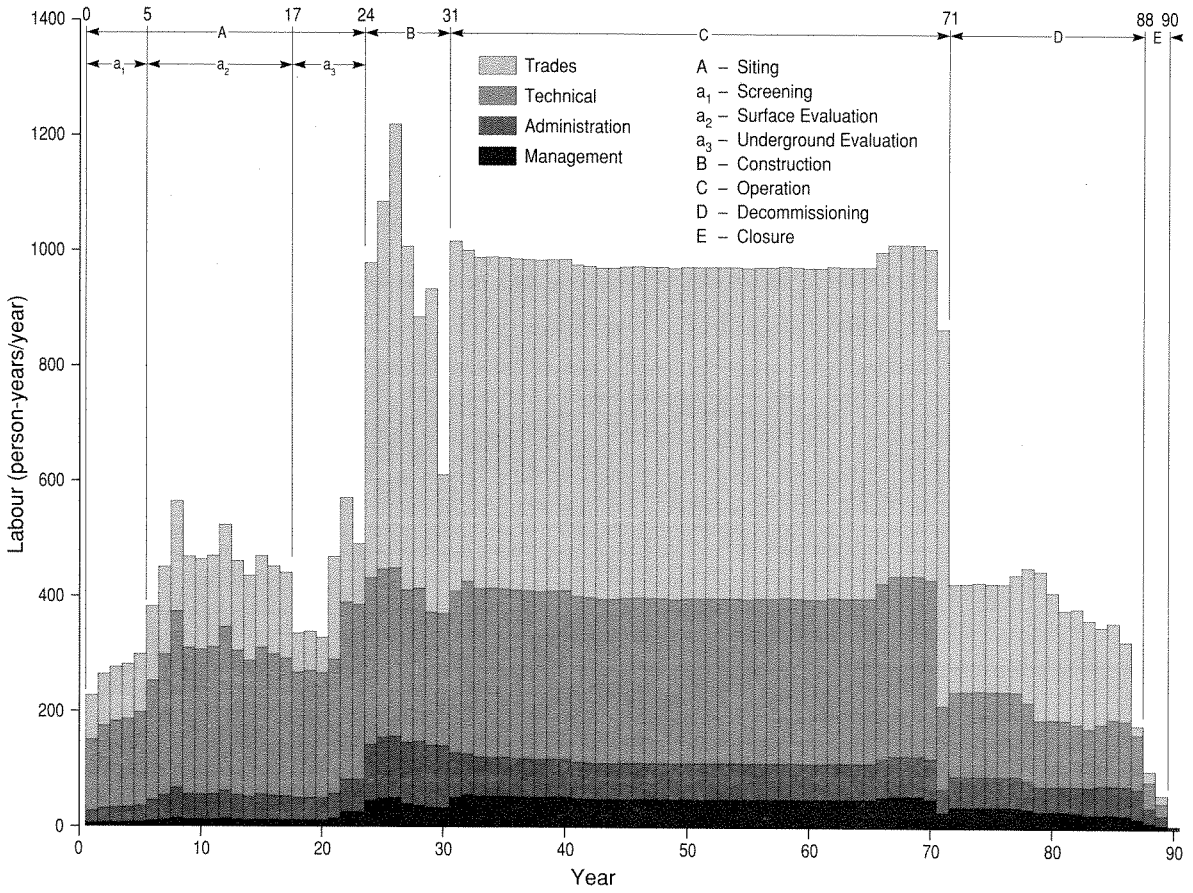
Stage/Substage	Duration (years)	Costs (1991 $millions)		Labour (person-years)	
		Analysis[1]	Update	Analysis[1]	Update
SITING					
Site Screening	5	277	289	1 639	735
Site Evaluation/Surface	12	1 152	1 210	6 667	4 537
Site Evaluation/Underground	6	681	680	3 130	2 824
Total Siting	23	2 110	2 179	11 430	8 095
CONSTRUCTION	7	1 810	1 808	7 040	7 342
OPERATION	41	8 080	8 056	37 700	39 854
DECOMMISSIONING	16	1 290	1 248	6 540	6 733
CLOSURE	2	30	30	140	145
TOTAL	89	13 320	13 320	62 850	62 170

[1] The numbers in the "Analysis" columns are based on a 1992 preliminary estimate, and were used in analyses for this Preclosure Assessment. The numbers in the "Update" columns are based on the final 1993 estimates. See text Section 2.1.1.5 part 3 for explanation of difference.



Notes: 1. The cost fluctuation every five years during Operations Stage reflects capital equipment replacements.
2. Research costs are included as Contracts under Materials and Equipment.

FIGURE 2-7: Estimated Annual UFDC Costs



Notes: 1. Research labour is not included since it is an off-site contract.
2. 1 person-year = 261 days

FIGURE 2-8: Estimated Annual UFDC Labour Requirements

The basis and assumptions for these cost and labour estimates are detailed in the UFDC engineering primary reference (Simmons and Baumgartner 1994). The cost estimate includes continuing research and development, long-term component testing, design, environmental assessment, licensing and performance monitoring. The siting and possible extended monitoring stages are not yet fully defined (pending consultation with regulators and public at the appropriate time during implementation), thus order-of-magnitude cost estimates have been included at this time. The overall UFDC cost estimate does not include the cost of used fuel transportation (presented separately in Section 7.6). It also does not include specific provisions for review and approval process costs or mitigation/compensation which would be negotiated with a host community. However, the overall UFDC cost estimate includes a 17% contingency factor. The accuracy of the overall estimates is considered to be within the range -15% to +40%. That is, the estimates could be 40% too low or 15% too high.

In order to accumulate the funds required to cover these future disposal costs, the nuclear power utilities in Canada are already collecting revenues through their electricity rates. The principle behind this practice is that electricity customers pay for the cost of disposing of the nuclear fuel used to generate the electricity they consume and benefit from.

2.1.1.6 Management

No agency has been given the responsibility for implementing the disposal concept. The implementing organization might be an existing organization or a newly created one; it might be a crown corporation, a private company, or some combination thereof.

Management functions to be carried out by the implementing organization would include:

- development of the role of the community;
- long-term planning;
- liaison with regulatory authorities;
- public involvement and public liaison;
- obtaining licences and approvals;
- disposal facility design;
- characterization;
- monitoring;
- component testing;
- environmental assessment;
- excavation and sealing;
- waste packaging and emplacement;
- commissioning and decommissioning;
- establishing and reviewing procedures;
- inspecting and maintaining equipment;
- training of workers;
- conflict resolution;
- environmental protection;
- health and safety of workers and the public;
- safeguards;
- security and fire protection;
- quality assurance;
- emergency response; and
- overall impact management.

These functions and others as required would need to be assigned within the implementing organization to ensure the most efficient and safe operation of the disposal facility. A number of these functions warrant further discussion, as follows:

1. Role of the Community

The organizational structure would allow for the development of mechanisms for participation of the community in the decision-making. A formal procedure would be established to seek and take into account the concerns of those interested and directly or indirectly affected by the project. Active participation of citizens in the management of the facility could be done through representation on the board of directors and other management committees (e.g. committees dealing with emergency response, health and safety, environmental protection, audit, quality assurance, etc.). The public participation mechanisms would need to be negotiated with the local community.

2. Conflict Resolution

Mechanisms for resolving conflicts with workers, and with potentially affected communities, need to be established. Such mechanisms typically include the following stages:

i) facilitation to provide parties involved in the dispute with information that helps them reach an informed decision;

ii) negotiation between the parties involved in the dispute to reach a common agreement;

iii) mediation to help achieve a settlement if negotiation fails; and

iv) arbitration leading to a binding agreement if negotiation and mediation efforts fail.

The conflict resolution provisions for dispute with workers might, however, be dictated by the labour relations code in the particular province, such as the Ontario Labour Relations Act (see Appendix B).

Establishing mechanisms for conflict resolution with potentially affected communities must necessarily involve the communities.

3. Quality Assurance Program

The objective of quality assurance is to reduce uncertainty of performance, maximize equipment reliability and minimize human error.
A quality assurance (QA) program, including appropriate QA manuals, would be developed for the disposal facility. This QA program would ensure that activities during siting, construction, operation, extended monitoring, decommissioning and closure stages of the disposal facility would be done according to established procedures and standards. This would provide confidence in the installations, analyses and interpretations as they are applied to assessing the short and long-term safety of disposal. Detailed requirements would be documented. Careful and complete project records would be kept.

4. UFDC Safeguards

As a signatory of the Non-Proliferation Treaty (NPT) (IAEA 1972a, 1983), Canada has agreed that all used fuel and other nuclear materials in all Canadian civilian nuclear facilities be subjected to IAEA safeguards. National safeguards requirements are regulated by the AECB (safeguards are technical methods for verifying the fulfilment of Canadian obligations in accordance with the NPT). Safeguards personnel in Canada and at the IAEA are responsible for establishing and maintaining a system to account for, and control, all used fuel subject to safeguards. The disposal facility would be fully safeguarded against diversion of used fuel in accordance with IAEA and AECB (as an agent for the Government of Canada).

5. Health and Safety of Workers

There would be a demonstrated management commitment towards safety. A safety program would be established at the disposal facility and worker safety would be a key component of the UFDC operation. This program would comprise:

i) the establishment of safety and health committees;

ii) regularly scheduled safety meetings for all employees;

iii) the implementation of a safety incident reporting and investigation system to achieve accident prevention objectives;

iv) emergency response procedures and drills;

v) employee orientation and instruction program;

vi) employee training;

vii) special group (security, fire protection, medical and first aid, underground rescue and emergency response personnel) training on safety, particularly radiation safety; and

viii) employee Workplace Hazardous Material Information System (WHMIS) training.

6. Physical Security and Fire Protection

Continuous physical security and fire protection would be implemented during the siting stage. This would continue through construction, operation, decommissioning and closure.

The combination of a fire-water system, fire detection and alarm systems, automatic fire extinguisher systems and manual fire extinguishing equipment, and of adequately trained staff are considered to provide adequate fire protection. A minimum of one fully-equipped fire truck would be provided for the site. The number of fire trucks and fire fighters would depend on the number, proximity and experience of the local community fire-fighting forces that can provide backup support under a mutual-aid agreement. The conceptual design specifies a full time staff of 54 during operation of the disposal facility to provide access control, security, site and building inspection, and fire protection. The conceptual design also specifies that an underground rescue response group would be formed to provide fire fighting and rescue efforts.

Protection against forest fires will need to be coordinated with the appropriate provincial ministries (Ministry of Natural Resources (MNR) for a disposal site in Ontario). At the design refinement stage, the MNR could help ensure that the facility design/layout minimizes the effect of forest fires. An outline of some of the design and layout considerations for forest fire protection purposes and applicable regulations within the Forest Fires Prevention Act (Government of Ontario 1990g) are presented in Appendix F.

7. Monitoring

An administrative structure would need to be established to coordinate and implement monitoring activities throughout the preclosure phase. Based on the results of the AECL public consultation program (Greber and Anderson 1989) and feedback obtained at the FEARO scoping meetings (Dowell 1991a), it is clear that the public views monitoring as an essential feature of a used fuel disposal facility.

A successful disposal facility monitoring program would require that the following be established:

i) a mechanism for participation of the public, the regulators, scientific experts and project stakeholders in:
   a) the choice of parameters to measure (indicators of change, see examples in Appendix G);
   b) the type of measurement, measurement techniques and frequency of measurements;
   c) the interpretation of the monitoring results (to establish what is a significant change); and
   d) the decisions that would be made following the detection of significant change in one or more indicators. (see Chapter 10 for a discussion of a framework for this type of participation);

ii) monitoring objectives for each stage; and

iii) monitoring database and routine analysis of results and reporting (reports would be distributed to the local community, regulatory stakeholders and any other interested party).

The program should also include a feedback mechanism by which the data collected would be analyzed and the parameters to be monitored or the monitoring methods adjusted as required given the long time scale of the preclosure phase (reference duration of 89 years excluding possible extended monitoring at the end of operation).

2.1.2 Siting

Two types of activities would take place during the siting stage. First, there would be a series of activities associated with development of the process for selecting a site. Siting process considerations are discussed in Chapter 4. Secondly, there would be activities associated with characterization of candidate regions, candidate areas, and at the end of the siting stage, candidate sites; these various characterization activities are described in Davison et al. (1994a). These activities would be carried out within the framework provided by the siting process, and the scope of the characterization activities would be determined through this siting process. Some of the characterization activities would continue throughout the life-cycle of the facility to gather long-term temporal data on the site characteristics.

The technical characterization activities performed during siting would be similar to many of the activities performed during the geological exploration phase of standard mining projects. They can also be related to the geotechnical investigations performed prior to development of large civil structures such as hydro-electric dams, tunnels and underground powerhouses.

Siting is divided into two successive parts: site screening and site evaluation.

2.1.2.1 Activities During Site Screening

During site screening, characterization of the existing environment would mainly entail analysing existing regional-scale data for the candidate regions (see Table 2-2). Existing data on the hydrogeology, geology, other aspects of the natural environment, and on people and their communities would be gathered and mapped. This data would come from a variety of sources: remote sensing data (satellite or airborne imagery), government agency databases and reports, published scientific literature, and traditional knowledge about the region (Davison et al. 1994a). Some existing region-wide characterization may

TABLE 2-2
Characterization Methods Used During Site Screening

Method and Type of Information
1. COMPILATION AND ANALYSIS OF EXISTING DATA AND MAPS - geologic maps and reports - airborne geophysical surveys and reports - soils and surficial geology maps - surface water hydrology maps, hydrologic records and topography maps - meteorologic data, such as rainfall, precipitation, evaporation - forestry, soils and vegetation inventories - wildlife surveys - mineral exploration records and reports including borehole records - water resource surveys, including any water supply boreholes - seismic monitoring records
2. AIRPHOTO AND TOPOGRAPHIC MAP ANALYSIS - various scales of black and white and colour photographs, thermal infra-red photographs, topographic maps
3. SATELLITE IMAGERY - Landsat TM (bands 1-7) - SAR images from ERS-1 - panchromatic images from SPOT
4. RECONNAISSANCE GEOPHYSICAL SURVEYS - aeromagnetic surveys - airborne EM and VLF-EM - airborne radiometric - airborne and surface-based gravity - reflection seismic profiles
5. RECONNAISSANCE GEOLOGICAL MAPPING - lithologic mapping at outcrops - fracture mapping at outcrops - fracture mapping at outcrops adjacent to potential structural features - petrographic analysis of samples of major lithologic units and fracture infill minerals
6. RECONNAISSANCE HYDROLOGIC/HYDROGEOLOGIC SURVEYS - drainage, runoff patterns, range of water level fluctuations - examine seepage and spring locations, rock outcrops, exposures of surficial deposits for permeability characteristics
7. GEOCHEMICAL SURVEYS - surface water chemistry - chemistry of springs and seepages - reconnaissance soil gas surveys - electrical conductance of land/river bottom sediments and bottom waters

Adapted from Davison et al. (1994a)

provide a starting point upon which to build (e.g. Environment Canada's ecological land survey and classification (Environment Canada 1989b)). In addition, reconnaissance surveys and studies of the candidate regions would be carried out to complement the existing databases. This reconnaissance work would involve surface investigations only, and would be of a relatively short duration (days or weeks) at a given location. Selection of features to be characterized and of the extent of the study areas would be done as part of the siting process (see Chapter 10 to see how public, scientific and project interests could be incorporated). Determination of information needs could be done through scoping workshops. The environmental assessment for the Little Jackfish Hydro-Electric Development in Ontario provides an example of the use of such workshops in the characterization of an existing environment (Ontario Hydro 1988b).

The information gathered during site screening would be fed into the siting process (see Chapter 4 for a general discussion of the siting process) and a short list of potentially suitable areas selected for thorough surface and sub-surface investigation during site evaluation.

2.1.2.2 Activities During Site Evaluation

During site evaluation, field studies would be undertaken to gather more detailed data for analysis and input into the site selection process.

Surface and sub-surface investigations would be done to determine the existing geotechnical, physical and biological conditions of the potential sites, and baseline data on human health and socio-economic conditions would be collected.

During site evaluation, reconnaissance work would start within the areas selected during site screening, and be followed by detailed surface investigations. Sub-surface characterization would follow, which requires the drilling and testing of boreholes. These results are used in safety assessments to evaluate the safety and performance of alternative site locations and disposal facility designs. Finally, based on results of safety and other technical assessments, and socio-economic considerations, a preferred site would be identified for underground exploration, excavation, and characterization.

1. Reconnaissance surveys

As in site screening, the initial investigations conducted in the area during the reconnaissance period of site evaluation, employ traditional methods of field geology, mineral exploration, terrain analysis, and characterization of the physical, biological and socio-economic environments. Subsequently, more detailed investigations are conducted at the surface during this reconnaissance period of site evaluation as shown in Table 2-3.

In many cases, these investigations require the construction of access roads for the transport of equipment and personnel, and the cutting of grids of survey lines for geophysical and geological surveys. Although field investigations during site screening only involved brief visits of a few days or weeks, the reconnaissance field investigations, which are conducted during the site evaluation, are very extensive and would span many months.

TABLE 2-3
Reconnaissance Scale Site Evaluation Methods

Method and Type of Information
1. REGIONAL GEOLOGIC MAPPING - traverses 0.5 km to 2 km apart at a scale of 1:16 000 (more detailed mapping of existing quarried, road cuts of excavations) - percentage of rock type and spatial distribution of large rock units - lineament analysis of satellite data, airphotos, topographic maps and, magnetic survey maps - fracture density - fracture orientations, lengths and infilling minerals - collection of rock and fracture infill samples
2. AIRBORNE GEOPHYSICAL SURVEYS - EM and VLM-EMA - magnetic - gravity - side-scanning radar surveys
3. GROUND-BASED GEOPHYSICAL SURVEYS - gravity transects - reflection seismic profiles along transects - ground penetrating radar surveys along transects on rock outcrops
4. HYDROLOGIC/METEOROLOGIC SURVEYS OF WATERSHEDS - temperature, windspeed and direction, evaporation rates, precipitation, runoff rates and distributions, levels of surface water bodies; examine springs and seeps
5. WATER CHEMISTRY SURVEYS - chemistry of surface waters - chemistry of water in springs and seepage area
6. SOIL GAS SURVEYS AND SURVEYS OF GAS BUILDUP BENEATH ICE-COVERED BOTTOMS - He and Rn concentrations
7. SONAR SURVEYS OF LAKE BOTTOMS - lake bottom bathymetry, thickness of lake bottom sediments, bedrock surface
8. MAPPING SPATIAL DISTRIBUTION OF THERMAL CONDITIONS IN LAKES AND ELECTRICAL CONDUCTANCE OF LAKE BOTTOM SEDIMENTS - temperature and chemistry of lake bottom waters
9. MAPPING PATTERNS OF FLORA AND FAUNA - species and population distribution - studies of habits of individuals such as deer or moose

Adapted from Davison et al. (1994a)

2. Subsurface Investigations

Detailed studies of potentially suitable sites would involve subsurface investigations of boreholes within the areas selected during site screening. These studies would take place over a period of years. It is not possible to specify how many boreholes would be required to characterize the subsurface conditions of the potential site and its surroundings. The number of boreholes would depend on the geological and hydrogeological complexity of each different area being investigated, on the ability to predict the subsurface geologic structure from airborne and surface measurements, and from measurements made within the boreholes. Regardless of the subsurface complexity, a large number of boreholes would eventually be required to define and monitor the physical and chemical properties of the groundwater systems of the area, particularly in and around the small area of the site that appears most suitable for locating the underground disposal vault.

3. Underground Evaluation

Once a preferred site has been identified and selected, underground evaluation would consist of investigations in the exploratory shafts and underground tunnels. This process would take several years. During underground evaluation, observations of actual geological conditions, hydrological conditions and responses, and geomechanical conditions would be made and compared to the predictions that were based on the surface investigations and on the borehole data.

2.1.2.3 Siting Approvals and Licenses

It is assumed that at the end of the siting process, prior to any construction, an environmental assessment of the site-specific project would be submitted. The environmental assessment process (see Chapter 10) to be followed, whether it is a provincial process or a joint federal-provincial process, would require public involvement. It is assumed that the environmental assessment process would be coordinated with the AECB approval/licensing process. As outlined in Appendix B (Section B.1.1), it is assumed that AECB approval or licensing would be required at three stages during implementation of the disposal concept: (i) site approval, (ii) construction approval and (iii) operating license.

2.1.2.4 Environmental Protection

The implementing organization would meet all the requirements of environmental legislation and develop its own standards where regulations do not exist so that adverse effects on the environment are as low as reasonably achievable.

Whether site characterization activities are carried out by contractors or by staff from the implementing organization, it is assumed that the implementing organization would prepare, issue and implement environmental protection procedures to be followed during site characterization activities, and would provide training in the use of these procedures. These would include:

i) waste management procedures for radioactive and non-radioactive waste, with strong emphasis on reduction, re-use and recycling of all material, and clear instructions on disposal of waste material;

ii) procedures for protection of the natural environment, including provisions to minimize the area disturbed and to restore any affected areas; and

iii) provisions to minimize disturbance to the local populations.

In the case of contracted work, these procedures could be part of the contract requirements.

A list of suggested mitigation measures that could be used to protect the environment from the effects of site characterization activities is included in Chapter 4.

2.1.2.5 Occupational Protection Provisions During Siting

The implementing organization would meet all requirements of legislation related to occupational protection and would develop its own standards for occupational health and safety.

As with environmental protection, it is assumed that the implementing organization would prepare, issue and implement occupational protection procedures to be followed during site characterization activities and would provide training in the use of these procedures. These could include:

i) the safe use of equipment;

ii) the use of protective equipment;

iii) first-aid training requirements for each crew (e.g. at least one fully trained member);

iv) strict standards for blasting; and

v) forest orientation training requirements for each crew (e.g., at least one fully trained member).

2.1.2.6 Monitoring

Baseline monitoring data would be used to establish the state of the potentially affected environment prior to the start of the project. The purpose of baseline monitoring is to establish the pre-operational database for later comparison with operational monitoring and post-operational monitoring, i.e. it establishes a benchmark for the assessment of change. Decisions on the scope of the baseline monitoring would be made as part of the siting process and would incorporate public, scientific and project interests (see Chapter 10 for a discussion of the approach). It is envisaged that the scope of baseline monitoring would include health monitoring.

2.1.3 Disposal Facility Construction

Construction of the disposal facility would start after the finalization and approval of all designs and plans, and after receipt of an AECB construction licence. It would continue until such time as all surface and underground facilities are installed, made operational and ready to begin receiving used fuel for disposal. The conceptual design specifies a duration of 7 years for the construction stage.

2.1.3.1 Construction Plan

The construction plan for the UFDC would follow a standard construction sequence typical of any large industrial or mining project. The details of the construction plan would be influenced by the geographical location of the site, means of access and availability of services.

Construction of the main facilities would proceed as follows:

i) development of means of access, utilities and service infrastructure for construction of the major surface and underground facilities;

ii) construction of administrative and support facilities, and security systems;

iii) excavation of tunnels and shafts in addition to the exploratory excavations;

iv) completion of shaft headframe complex;

v) construction of used fuel packaging and container fabrication plants;

vi) construction of waste and materials storage and handling systems;

vii) completion of underground service areas and initial disposal rooms; and

viii) completion of construction and commissioning of all equipment and systems necessary for operation of the disposal centre and emplacement of the waste.

During the construction stage, underground characterization and monitoring initiated in the siting stage would continue as underground excavations are advanced.

2.1.3.2 Requirements Prior to Construction

Construction of the disposal centre would commence when the following conditions have been met (Simmons and Baumgartner 1994):

i) detailed drawings, specifications and construction plans have been produced, checked and approved, and an engineering group is established for design corrections, modifications and remedial actions;

ii) approvals for construction have been received from all appropriate federal, provincial and municipal regulators and authorities following a public and community consultation program;

iii) an appropriate Quality Assurance program has been developed, quality control procedures have been established and qualified inspectors are available;

iv) a qualified underground characterization team has been formed and their activity plans integrated into the underground construction plan; and

v) contracts have been awarded to qualified contractors and sub-contractors.

2.1.3.3 Site Access

It is assumed that the site would be far enough from existing road and railway that construction of access road and rail systems (25 km in length) would be required to provide access to the disposal facility. The basic activities involved in the construction of access roads and railways may include one or more of the following: surveying, clearing, grubbing, ditching, draining,

excavation, blasting, filling holes, surfacing and construction of water crossings. In addition, construction of temporary storage areas and construction camp facilities may be required to support access road construction or other site surveys and scientific studies (Prinoski et al. 1983).

2.1.3.4 Construction of the Surface Facility

1. Site Preparation

Once proper access to the disposal facility site has been provided, a construction camp with storage and yard facilities for materials and equipment may be required. In the event that the site is not clear and levelled, site preparation might be required. Site preparation activities would include: clearing existing vegetation, removing stumps and levelling the site by grading, filling holes and installing a site drainage system. Herbicide might be used to control vegetation at the construction site and along the access road. Portable trailers and permanent buildings may then be located on the site to provide living quarters, offices, workshops and storage areas as necessary. Electricity for the early construction activities might be supplied by fuel-fired generators or by constructing a transmission line to the site (Prinoski et al. 1983).

Vegetation would be cut and cleared as necessary in designated areas for the placement of the construction camp and yards. Excavating, filling, blasting, stripping and grading requirements depend on the existing terrain and the foundation base required to build the particular component.

2. Physical Security System

The security system would meet the AECB requirements (AECB 1983). The protected area would be surrounded by a 2.5 m high chain-link security fence topped by 3 strands of barbed wire leaning outward (Figure 2-9). Seven gates provide access to the area. The fence would be equipped with an intrusion detection system to monitor integrity and motion of the fence. Lighting would be provided along the fence and at the entrance of each building. Closed-circuit television cameras would also be installed.

3. Utilities

A transmission line would be constructed to connect the disposal facility to the regional electrical power grid. Approximately 4 MW of standby power would also be provided by on-site diesel generators (600 V AC) and by an uninterruptible 250 V DC/invertor system.

4. Service Water

The disposal centre is assumed to be located adjacent to a suitable source of fresh water. A pumphouse would be constructed on the water course. The amount of excavation involved in the construction of the intake or discharge would depend on the type of intake (offshore or shoreline intake), and the construction methods used.

Activities involved in the construction of a shoreline intake or discharge may include clearing, stripping, grading, drilling, blasting, excavating and dredging.

Offshore intakes or discharges may be constructed by excavation and backfill. Details of offshore intake and discharge construction can be found in Prinoski et al. (1983).

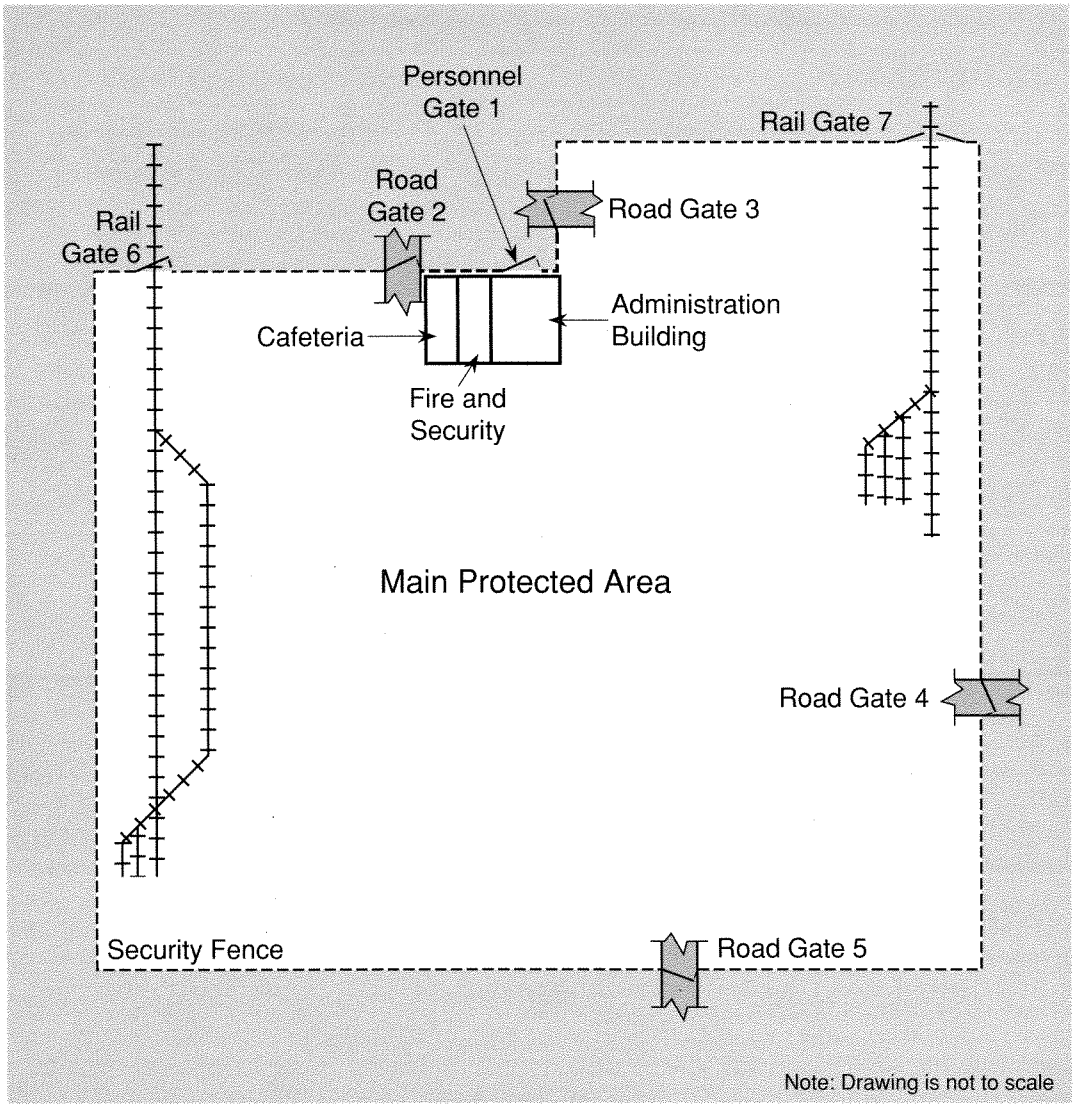


FIGURE 2-9: Conceptual Arrangement of Disposal Centre Security Zones and Access Control

5. Rock Crushing Plant

A rock crushing plant would be constructed to produce crushed rock with a size distribution suitable for preparing backfill material and concrete aggregate to be used in the vault. The crushing plant would be located at least 500 m from the service shaft headframe to separate the main operation areas from the crushing plant noise and dust (see Figure 2-10). Covered conveyor belts and enclosed stock piles or mass flow bins would be constructed for transfer of the rock to the crushing plant.

6. Excavated Rock Disposal Area

Approximately 37% of the excavated rock would be re-used in the underground vault. The remaining excavated rock can be used locally for civil construction or other purposes, but in the interim would be stored in a rock disposal area. This area would be located about 1 000 m away from the service shaft headframe, in the same direction as the crushing plant, to separate the main operation areas from noise and dust.

7. Concrete Batching Plant

The concrete batching plant would be constructed near the rock crushing plant. A conveyor would be built to receive aggregate feed from the crushing plant.

8. Waste Management Systems

Systems would be constructed to control and manage the airborne, waterborne, solid and liquid wastes that would be generated during the operation and decommissioning stages of the facility, as follows:

a) Air Discharge Systems

Air filtration systems would be constructed for facilities housing operations involving radioactive materials, such as the packaging plant, module handling and fuel packaging cell. These systems comprise roughing and High Efficiency Particulate Air (HEPA) filters to collect the particulate contaminants.

b) Water Discharge Systems

Water filtration/ion-exchange systems would be constructed for contaminated process streams. Settling ponds would be constructed to treat water containing particulates from the rock crushing plant and the underground vault (ponds would be located near the rock crushing plant and the upcast ventilation shaft, respectively). A sewage treatment plant, dedicated septic tank or connection to a municipal sewage system would be constructed to handle sewage water.

c) Liquid and Solid Waste Management Systems

A suitable storage building would be constructed on-site to store hazardous liquid waste containers until eventual shipment to licensed disposal facilities. Facilities would be constructed to manage solid radioactive waste. They would include a compactor or cutter to reduce the volume, a packaging system and a storage area. A landfill site may be constructed at the disposal centre for solid wastes with no radioactive contaminants and no economic recycle value, if a suitable municipal landfill is not available. Collection pits would be constructed to dispose of particulates from dust separators and baghouse filters, sediments from the settling ponds and from the underground sumps.

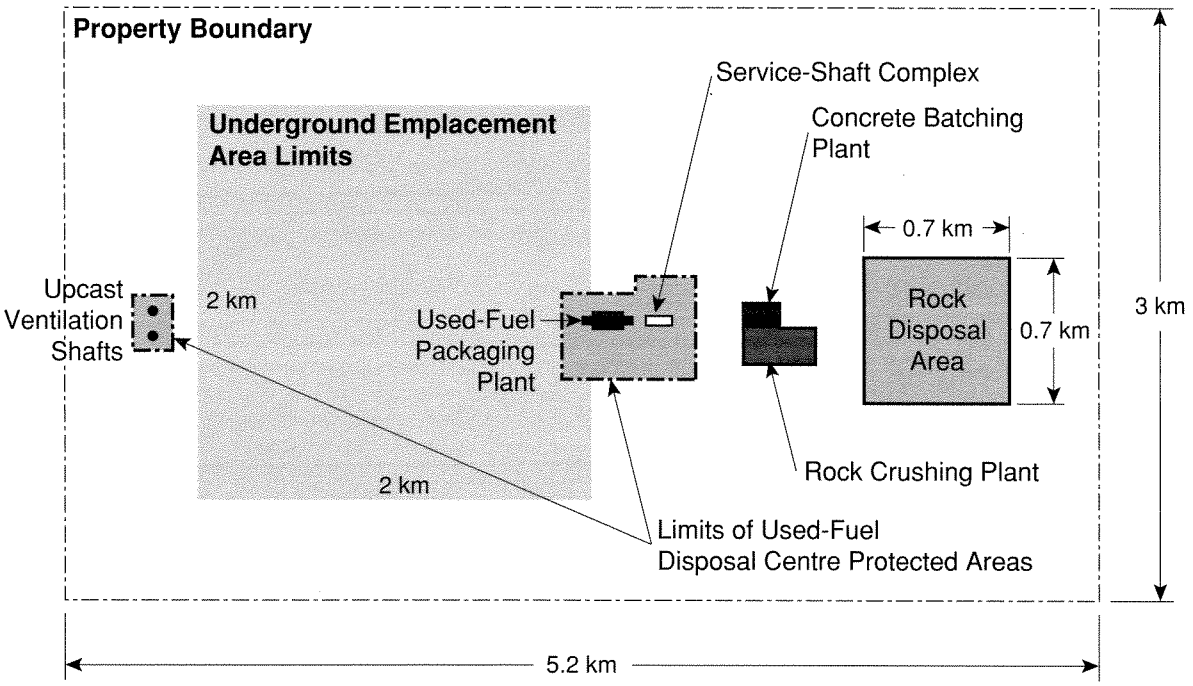


FIGURE 2-10: Rock Crushing Plant Location

9. Used Fuel Packaging Plant

The used fuel packaging plant would comprise a transportation cask laydown area, a damaged cask hot cell (Simmons and Baumgartner 1994), a cask decontamination area, receiving and headframe surge-storage pools, a control room and two parallel waste packaging process lines. These process lines would include: a storage/shipping module handling cell; a front-end packaging cell for used fuel bundle transfers from module to container; a back-end packaging cell for container void filling, sealing, inspection and decontamination; an access and maintenance room with airlocks to provide access to the used fuel packaging cell for workers, equipment and material; and a basket and container-shell storage room (see Figure 2-11).

This two-storey building would be a reinforced concrete structure, designed according to the Canadian design practice for the concrete containment structures of CANDU nuclear generating stations (CSA 1982b). The design would meet seismic loading requirements (CSA 1980).

10. Basket and Container Fabrication Plant

The basket and container fabrication plant would be about 60 m long and 40 m wide with heating, ventilation and other services. The plant would include an area for receiving, inspecting and storing of materials; docking facilities for unloading transport vehicles; overhead crane facilities; and separate areas for the preparation and fabrication of baskets and containers.

11. Other Buildings

Warehouse and storage facilities, including a vehicle garage (1 250 m^2), a general warehouse building (3 000 m^2), a hazardous waste materials storage building (see Section 2.1.4.7), an outdoor storage yard (3 000 m^2) and an active solid-waste storage building (3 720 m^2) would be constructed. An administrative building located on the boundary of the protected area and containing administration offices, security offices, change rooms, security monitoring rooms and fire-fighting facilities would also be constructed.

A 75 m x 50 m auxiliary two-story building with a basement would be constructed adjacent to the used fuel packaging plant. It would house the facilities that are closely associated with the operation of the plant including workshops, stores, laboratories, change rooms and a laundry room. It would be connected to the administrative building by an overhead corridor, and would provide the main access for workers into the potentially radioactive secured area of the site.

2.1.3.5 Construction of the Underground Facilities

Disposal vault construction would begin with the sinking of three shafts and the full development of the underground tunnels and service areas. The service shaft, the waste shaft and an upcast ventilation shaft (see Figure 2-12) would be excavated by standard drill-and-blast sinking methods. On completion of the various shafts, the permanent concrete headframes would be erected.

Two exploration shafts, with exploration tunnels, would have been constructed prior to actual vault construction. The exploration shafts would provide access, ventilation and excavated rock handling services for the enlargement of the exploration tunnels to full-size access tunnels and the excavation of additional vault access tunnels. The underground ancillary facilities, including the service shaft complex, the upcast ventilation shaft complex, and the buffer and backfill plant, would be excavated and constructed, as required.

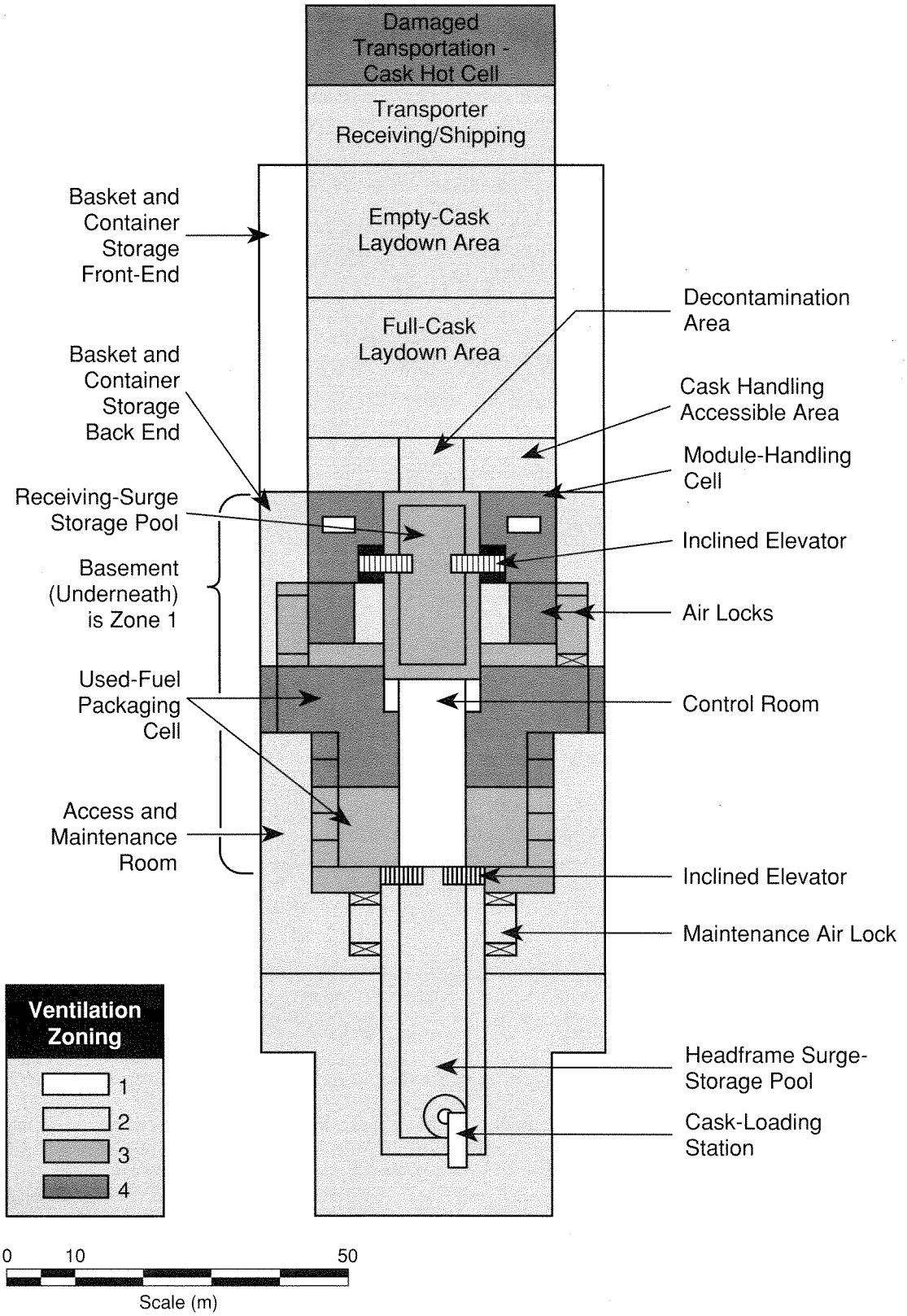


FIGURE 2-11: Used Fuel Packaging Plant

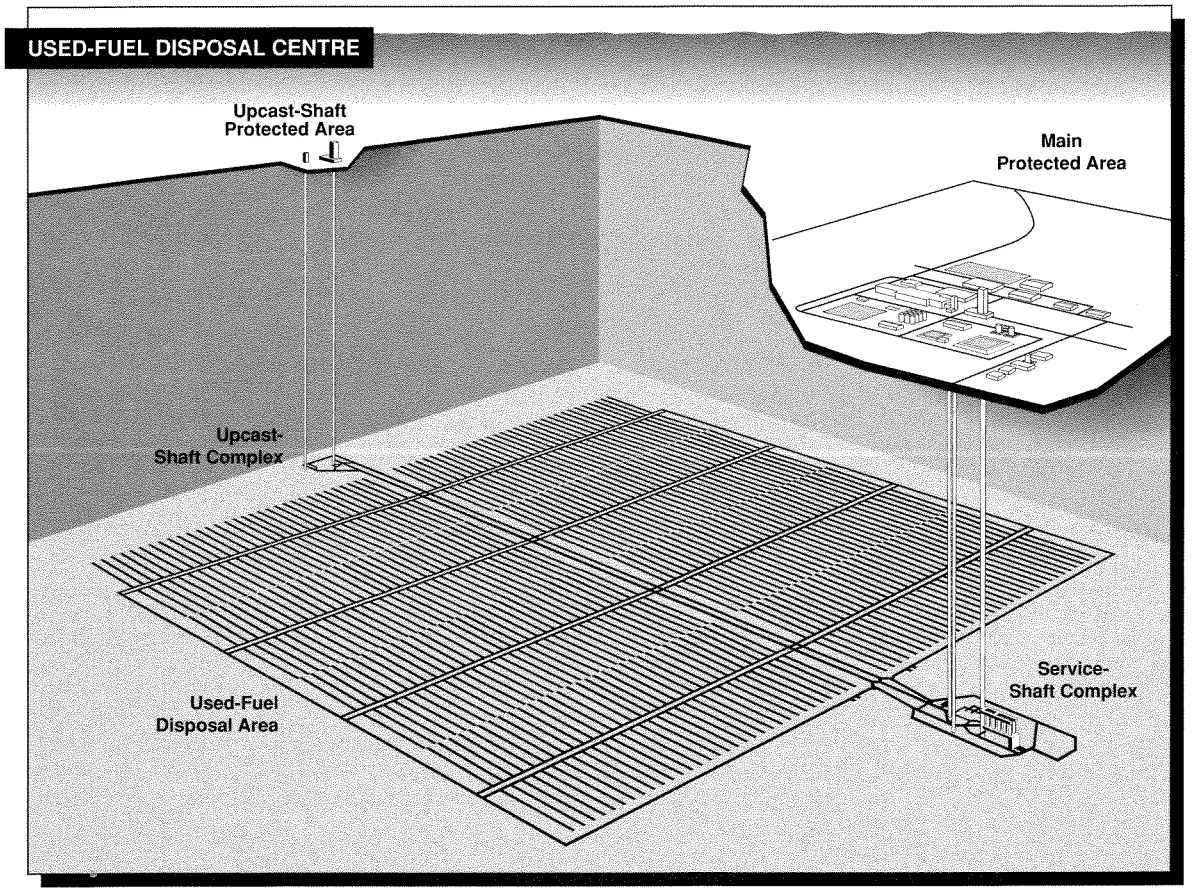


FIGURE 2-12: Shafts in the Disposal Vault

The major underground ancillary facilities would be located at the bottom of the service shaft and upcast ventilation shaft. The service shaft complex (Figure 2-13) comprises: a transfer cask surge storage area; a maintenance service facility; a diesel fuel storage facility; a service shaft rock bin; two explosives and detonator magazines; a first-aid refuge station complete with seals, utilities, oxygen supply and communications for worker emergencies; the service shaft complex drainage water sumps and pumps; offices, washrooms and lunch rooms; access and ventilation tunnels; and a component test area. The upcast shaft complex comprises: a preparation and pumping system for vault drainage water; a ventilation control system; and retrieved-container transfer facility (see Section 2.1.4.10 for container retrieval procedures). The drainage-water systems consist of a series of settling-and clear-water sumps, a pump station with pumps for clear water and sludge, and stand-by pumps. The capacity for this system would be 2 218 $m^3 \cdot d^{-1}$ which assumes a groundwater seepage rate of 1 000 $m^3 \cdot d^{-1}$. The buffer and backfill preparation plant would be located underground adjacent to the service shaft.

The vault access tunnels would be excavated concurrently with new shaft sinking, using the exploration shafts until the service shaft and its excavated rock handling facilities are completed and commissioned. The tunnels would be excavated using drill-and-blast methods.

The new shafts and tunnels would be excavated in close proximity to excavations developed during the siting stage. The ground conditions and locations of fracture zones should be fairly well known and well characterized. Construction grouting may be necessary to control groundwater seepage from fracture zones.

The excavated rock would be removed from the excavation face, loaded onto to trucks, and hauled to bins where it would be hoisted to the surface.

When the shafts and vault access tunnels are complete, the first panel of disposal rooms, and 10 to 12 disposal rooms in each of the second and third planned panels, would be excavated. The rest of the disposal room excavation would take place during the operation stage.

When the excavation is complete, details of exposed geological discontinuities are recorded and added to the geotechnical data base. This data base would be used to project the likely geological conditions in the immediate vicinity of the emplacement boreholes.

2.1.3.6 Monitoring

Monitoring data, collected during construction, would be used to make design refinements. This, along with all previous monitoring results, would be used to support the application for a licence to begin waste emplacement.

Environmental and health monitoring would also take place during the facility construction. The monitoring program would have been negotiated with the local community during siting. Monitoring results would be compiled and made available to the public and government agencies. Further discussion on the role of monitoring in the disposal facility life-cycle is contained in Chapter 10.

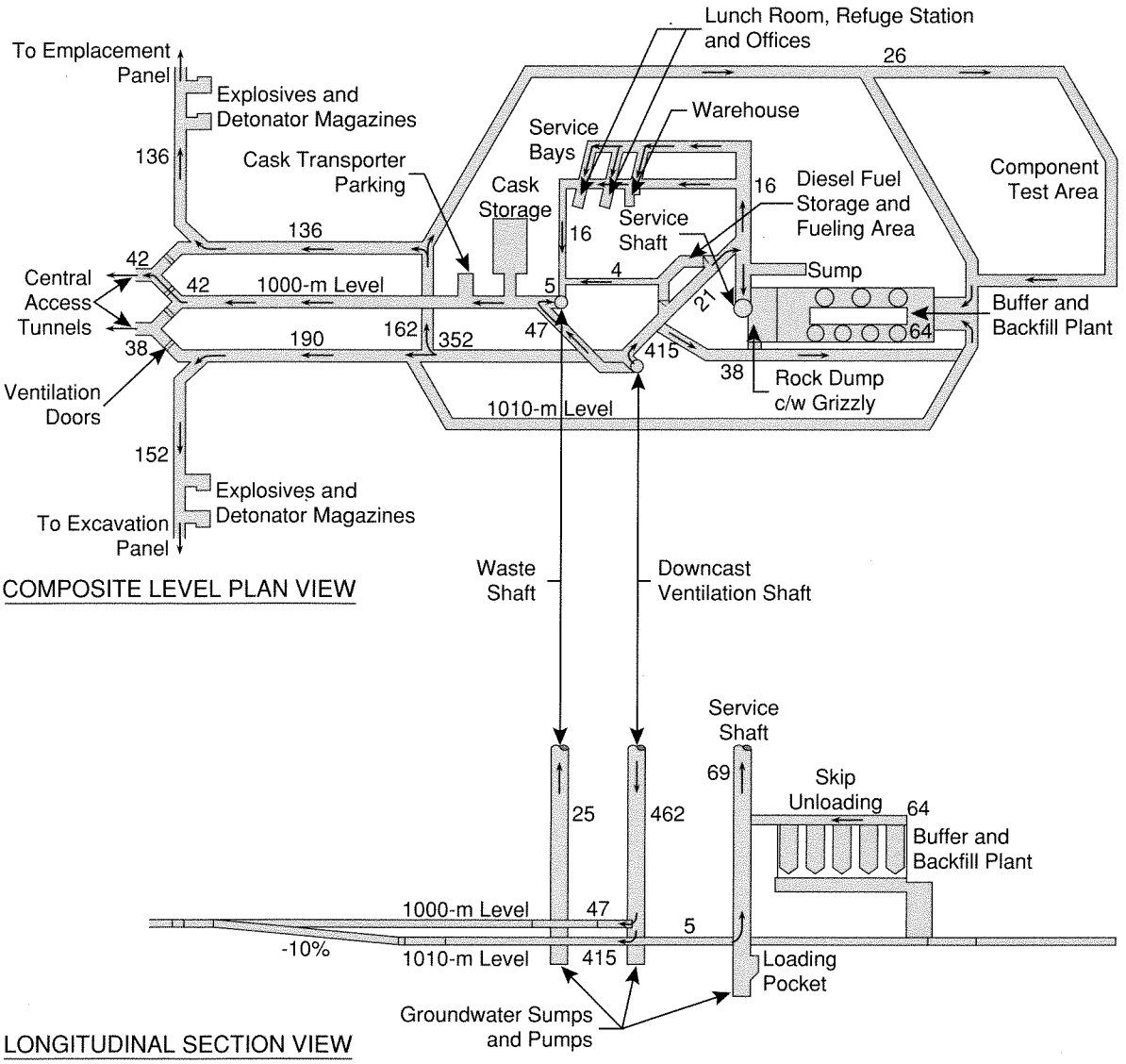


FIGURE 2-13: Underground Ancillary Facilities

2.1.3.7 Quality Control Monitoring

In the construction stage, quality control monitoring would be carried out during and shortly after all excavation and vault construction. Specifications for methods during the construction stage would include methods for drilling and blasting, mucking out, cleaning, scaling, ground support, emplacement hole drilling and grouting. Methods specifications for the sealing systems would include methods for buffer emplacement, buffer augering, container emplacement, sand emplacement, sealing container holes, backfilling and bulkhead construction. Finally, there would be specifications for all materials used in the vault sealing and support system.

The reports from this quality control monitoring would be used to confirm that:

i) the correct procedures are being followed;

ii) any installed materials are to specification;

iii) the methods specifications are appropriate; and

iv) no unusual effects resulted from the activity.

If any unusual effects occurred, then design or construction personnel would institute the appropriate specification change and/or remedial measure. An example would be the case of blast-induced fracturing: a possible remedial measure being to scale off a zone where blast-induced fracturing occurred.

2.1.3.8 Environmental Protection

The implementing organization would meet all the requirements of environmental legislation and would develop its own standards where regulations do not exist so as to keep the adverse effects on the environment as low as reasonably achievable. These would be scrutinized during the project-specific environmental assessment.

It is assumed that the implementing organization would prepare, issue and implement environmental protection procedures to be followed during construction, and would provide training in the use of these procedures.

A list of suggested mitigation measures that could be used to protect the environment from effects of construction activities are included in Chapter 5.

Activities that would require good environmental protection practices include:

1. Waste Management

It is assumed that waste management procedures during construction would strongly emphasize the reduction, re-use and recycling of all material, and provide clear instructions on disposal of waste material.

All oils and chemicals used in excavation equipment would be stored in suitable containers and disposed of according to applicable provincial and federal regulations, e.g. the Ontario Environmental Protection Act regulations. The Environmental Protection Act would also require certificates of approval for:

i) disposal of domestic and construction garbage;

ii) sewage from construction site and construction camp; and

iii) waste disposal of dredge spoil and soil.

Meeting these requirements should ensure that waste management practices during the construction stage would protect the environment.

2. Water Treatment

Water used to wash rock faces and settle dust, and water that collects in the vault during excavation, would be pumped to settling ponds, monitored according to provincial requirements (in Ontario, MISA) and treated accordingly. Water used in the cement batching plant would be treated in the same way. Storm water, which would contain suspended sediments (since ground would be loosened by truck tires and workers), would be directed to ditches and straw barriers, and may then be directed to settling ponds for subsequent treatment. Water would not be released to the environment until applicable regulations are met. Water used for hygiene would be treated in the water treatment plant.

3. Noise Control

It is assumed that the implementing organization would have a noise control protocol to limit noise from equipment and noise levels outside the property line to acceptable levels. An example of such protocol can be found in Ontario Hydro (1981b).

2.1.3.9 Occupational Protection

The implementing organization would meet all requirements of occupational protection legislation and develop its own policies and procedures for occupational health and safety (see Appendix H for an example of an occupational health and safety policy).

As in the case of environmental protection, it is assumed that the implementing organization would prepare, issue and implement occupational protection procedures to be followed during construction and would provide training in the use of these procedures. These would include:

i) procedures for the safe use and maintenance of equipment;

ii) procedures for hazardous material handling;

iii) first-aid training requirements;

iv) standards for handling and use of explosives;

v) monitoring of ambient air quality both underground and at surface facilities; and

vi) mine rescue procedures (see Section 2.1.9.2 on Emergency Response).

In addition, the following would be established during the construction stage:

i) a joint (workers-management) health and safety committee;

ii) worker training programs including emergency response and mine rescue training; and

iii) safety targets against which performance could be audited.

2.1.3.10 Construction Management

Construction management would have the following objectives:

i) to establish and maintain safe working conditions and good employee relations;

ii) to ensure that facilities are constructed in accordance with construction licence requirements, design specifications and an approved quality assurance program;

iii) to comply with all government regulations;

iv) to liaise with the local community, keeping them informed about the progress;

v) to monitor effects of construction, and to adjust mitigation measures as required;

vi) to perform all construction work on schedule; and

vii) to manage and control costs.

Project management procedures would be established to coordinate all activities by the construction crew and contracting and supply agencies. These procedures would define how work would be performed, controlled and renewed; define the implementing organization, engineering and contractor relationships; establish document distribution lists; and define various functions and processes as required.

2.1.4 Disposal Facility Operation

The operation stage, specified to be 41 years in duration, would start when all approvals (including AECB operating licence) have been received from federal, provincial and other relevant jurisdictions. The operation stage involves the receipt, packaging and disposal of used fuel in the underground vault. The conceptual design assumes that 10.1 million used fuel bundles would have been handled during this stage (see Chapter 9 for a discussion of vault capacity related to scenarios of energy production).

2.1.4.1 Disposal Facility Operation Plan

Used fuel would be shipped dry in casks from the CANDU generating stations to the disposal facility by road, rail or water. If water transportation is used, the casks would be transferred to the disposal facility by road or rail from a Transfer Facility (TF).

The major operations at the UFDC would include:

i) receipt of used fuel in transport casks;

ii) transfer of used fuel from the transport casks into baskets which fit into corrosion-resistant disposal containers, followed by filling, compacting of glass beads and sealing of the containers;

iii) transfer of the disposal containers to the underground facility in disposal container casks which are transported to the disposal rooms;

iv) emplacement of the containers into boreholes;

v) sealing of the boreholes;

vi) sealing of the disposal rooms when full; and

vii) excavation of additional disposal rooms.

Disposal facility operations also include support activities such as the preparation of the buffer and backfill material, fabrication of the disposal containers, rock crushing and concrete mixing. A detailed description of these activities can be found in Simmons and Baumgartner (1994).

2.1.4.2 Reference Disposal Container

The reference used fuel disposal container is a sealed cylindrical vessel of all-welded construction, with a maximum outside diameter of about 645 mm and an overall height of about 2 250 mm. All shell materials would be made of ASME Grade-2 titanium. The container is shown in Figure 2-5. When filled and sealed, the container would have a mass of about 2 830 kg.

The container incorporates a basket that would hold 72 used CANDU fuel bundles in four vertically stacked arrays of 18 bundles. The filled basket would be placed in the container, and glass beads poured into the container and compacted by vibration around the bundles and into all empty spaces. Next, the top end-plate would be pressed into place and diffusion-bonded to the container shell. Two inspections would be done: ultrasonic inspection of the final closure weld and a helium leak test of the entire container. If a defective weld was noticed in a container, the container would be sent back to the welding area for repair. If a defect remained after repair, the loaded fuel basket would be removed and placed in a new container. Defective containers would be decontaminated and recycled or disposed of as low-level radioactive waste (See Section 2.1.4.7, under waste management).

The effectiveness of the container as a barrier is shown as the cumulative fraction of containers failed as a function of time (Figure 2-14). Foreseeable developments in container design are discussed in Section 2.4.

2.1.4.3 Used Fuel Handling Sequence at the Surface

Much of the used fuel handling technology for the disposal facility is based on the experience gained in the development of fuel handling equipment for CANDU nuclear generating stations, particularly technologies for the remote handling of used fuel.

1. Transportation Cask Receiving

A receiving facility in the used fuel packaging plant would handle transportation casks from road or rail, or both. Used fuel would be received at the disposal facility in shielded transportation casks (either sized for road, rail or for both modes of transport) and remain secured inside the casks during the routine receiving operations (transporter unloading, placement of the cask in the cask laydown area, and radioactive contamination monitoring of the cask surface and decontamination, if necessary). Empty decontaminated casks (containing empty modules) would be loaded on the transporters for the return trip to the nuclear generating station.

The cask would then be placed in a trolley and transported to the Module Handling Cell (MHC) receiving port. After positioning the cask trolley under the port, the cask lid bolts would be undone in preparation for unloading of the used fuel modules. At this point, the cask would be on a scissors lift, ready to be raised to seal against the receiving port.

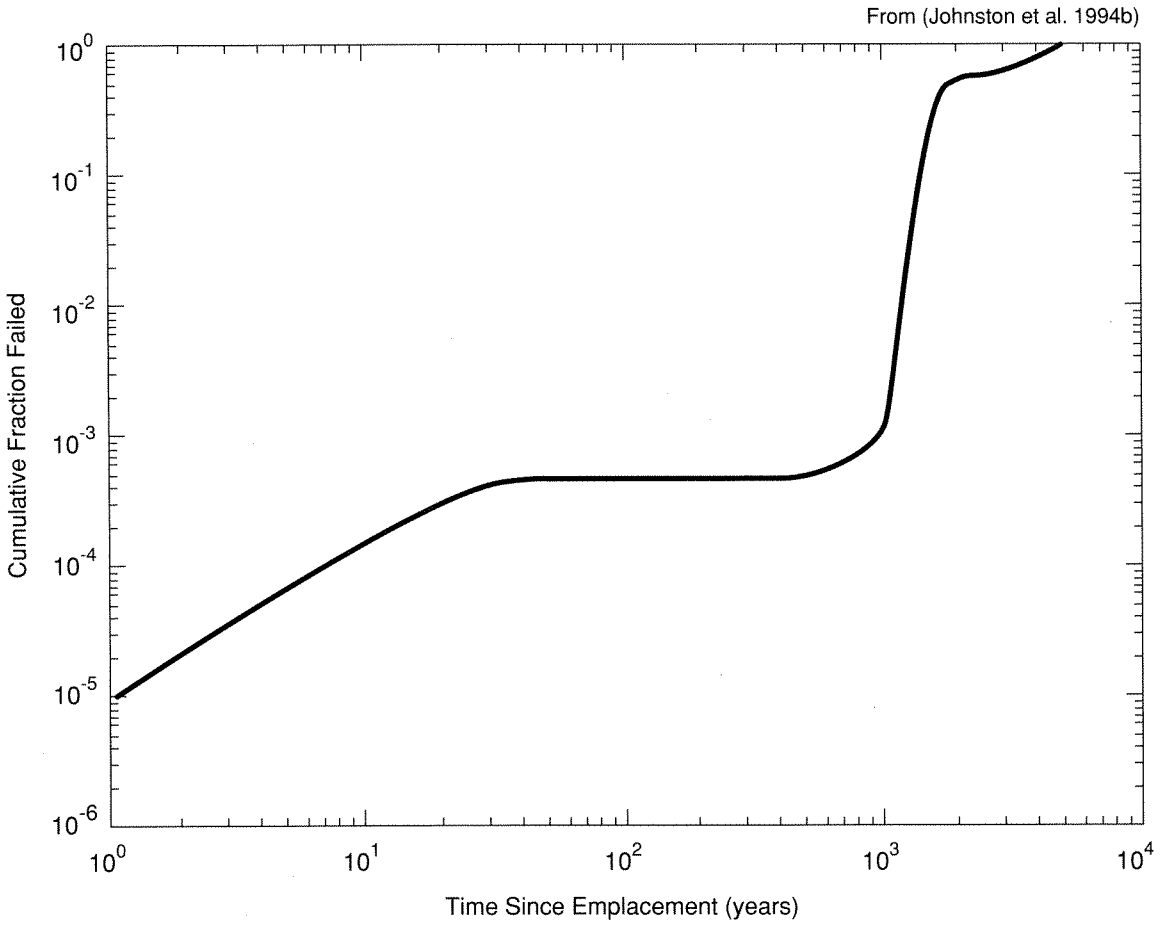


FIGURE 2-14: Expected Container Performance

2. Unloading of the Modules from the Transportation Cask

All transportation cask unloading activities would be done remotely. Through the MHC port, the transportation cask lid would be removed and the storage/shipping modules lifted out by the module handling equipment.

Each module would hold 96 used fuel bundles (see Figure 2-15). The cask sized for road transportation would contain 2 modules and the cask sized for rail transportation would contain 6 modules. The used fuel module would be moved either through a forced-air drier to a module trolley to be transferred directly to the used fuel packaging cell, or to an elevator that would lower it into the receiving surge-storage pool where it would be stacked by module handling equipment. When retrieved, by reversing this process, the modules would be dried by moving them through the forced-air drier and transferred to the Fuel Packaging Cell (FPC) through the module-transfer tunnel and airlock.

3. Disposal Container Loading

All used fuel handling activities in the packaging cell would be done remotely. Used fuel modules would enter the packaging cell through the airlock and would be placed in the transfer bridge from which the bundles would be transferred into a fuel container basket designed to fit inside the disposal container. Empty modules would be placed in the transportation cask for the return trip.

In the event that a bundle has been damaged from shipping or handling, and cannot be transferred to the basket, or cannot be adequately identified and needs further examination, it would be transferred into a special handling area. Here it can either be examined in detail or stored into a 500 mm high broken bundle container.

Full baskets would then be placed in corrosion-resistant titanium containers. The containers are packed full with glass beads, sealed with a diffusion bond, inspected, decontaminated, dried and placed in the headframe surge-storage pool or placed in a disposal container cask and transferred to the container cask laydown area in the headframe to be taken down to the vault.

Disposal containers that failed to pass the inspection tests would be moved to either the container closure station or the container repair station for repair or disassembly.

The shielding provided by the disposal container casks with their 330 mm thick steel shell and 40 mm polythene liner would reduce the radiation field from the full disposal container to 19 $\mu Sv \cdot h^{-1}$ at the outer surface of the cask. The empty transfer cask would weigh about 35 Mg.

Dual hoisting systems would remotely load and unload the disposal container cask with the disposal container, and would accommodate single failure-proof safety features including a mechanical fail-safe cask latching system.

2.1.4.4 Used Fuel Handling Sequence Underground

1. Disposal Container Transfer

On leaving the packaging plant, the disposal container cask would enter the waste shaft headframe and be transferred to a cage (a conveyance which moves vertically within the shaft, like an elevator). In the reference design, the waste shaft is dedicated to the handling of container casks. At the bottom of the shaft, the cask would either be transferred to the underground transporter (a modified, 40 Mg mine truck) for transportation to a disposal room or could

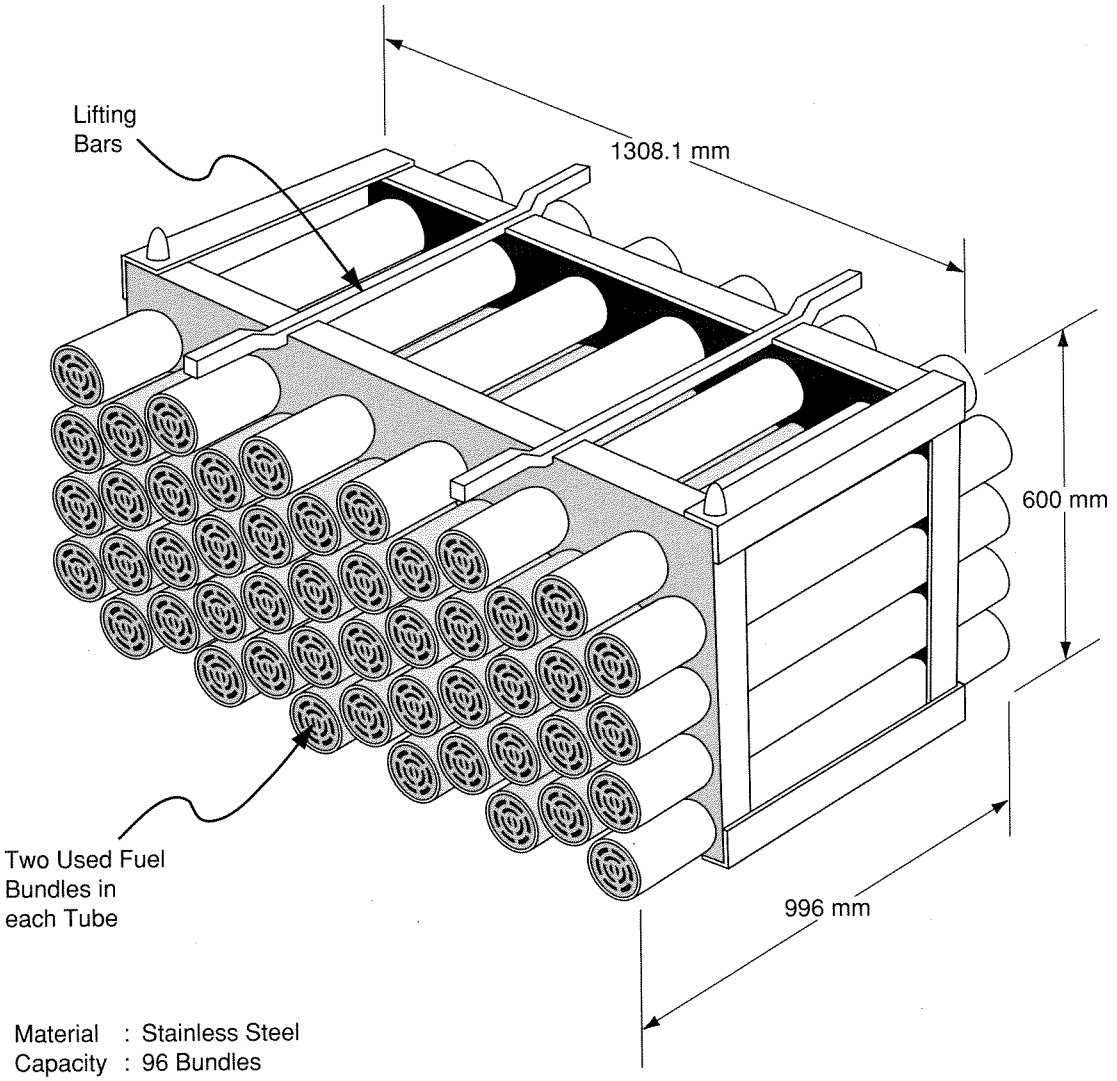


FIGURE 2-15: Used Fuel Module

be transported (by an overhead bridge carriage) to a surge-storage room adjacent to the shaft for temporary storage. The casks would be no more than 2 m above the floor during this procedure.

2. Transport to the Disposal Rooms

The precautions taken during transportation of the cask to the disposal rooms would include restricted access of personnel and vehicles to the transporter route (exclusively used for container transportation) and a maximum speed of the transporter of 8 $km \cdot h^{-1}$. The truck would travel to the disposal room, a distance of up to 3 km. At the entrance to the disposal room, an overhead crane would transfer the cask from the transport vehicle onto the emplacement platform.

3. Disposal Container Emplacement

The steps to be followed in the emplacement sequence are summarized in Figure 2-16 and can be described as follows:

a. Disposal Room and Borehole Preparation

The disposal area is made up of 8 panels, each with 64 disposal rooms. First, all the disposal rooms in one panel would be excavated. Then rails would be laid in each room and a borehole coring drill mounted on a special rail platform. A maximum of 282 boreholes, 5 m deep and 1 240 mm in diameter, would be prepared in each of the disposal rooms. The drilling platform would then be removed and replaced by a buffer emplacement platform. Each borehole would be filled with 3.5 m of buffer material, compacted in layers to a specified density (1 670 $kg \cdot m^{-3}$ dry mass density) to act as a barrier to radionuclide migration. The buffer platform would then be removed. Each borehole would be inspected before emplacement could begin.

b. Container Emplacement Sequence

Three platforms would be used for the emplacement sequence: an auger platform, a platform for a container emplacement, and one for buffer emplacement. Immediately prior to container emplacement, the central portion of the buffer in each borehole would be augered to accommodate the container. The container cask would be brought into the room on the container emplacement platform, positioned accurately over the borehole, and a shielding ring and shielding skirt positioned to shield personnel from the external radiation field. The container would then be lowered into the borehole. The space between the container and the augered borehole wall, as well as the space above the container, would be filled with dry sand. The shielding ring would be raised, the container emplacement platform removed, and the buffer emplacement platform positioned over the borehole. The platform and shielding skirt would provide radiation protection at this time. Buffer material would be fed into the borehole in layers and compacted to the same density as that specified for the initial buffer emplacement. The sand layer above the container would cushion the container from the buffer compaction loads. The container would be isolated from the host rock by at least 250 mm of compacted buffer material. Because of the shielding provided by the buffer, the radiation fields in disposal rooms would be less than 25 $\mu Sv \cdot h^{-1}$. The container would be isolated from the host rock by at least 250 mm of compacted buffer material.

c. Disposal Room Backfilling and Sealing

When all acceptable boreholes in a room are full, the room would be backfilled. The backfill material would be compacted to a specified density using conventional and pneumatic equipment. A concrete bulkhead would be cast

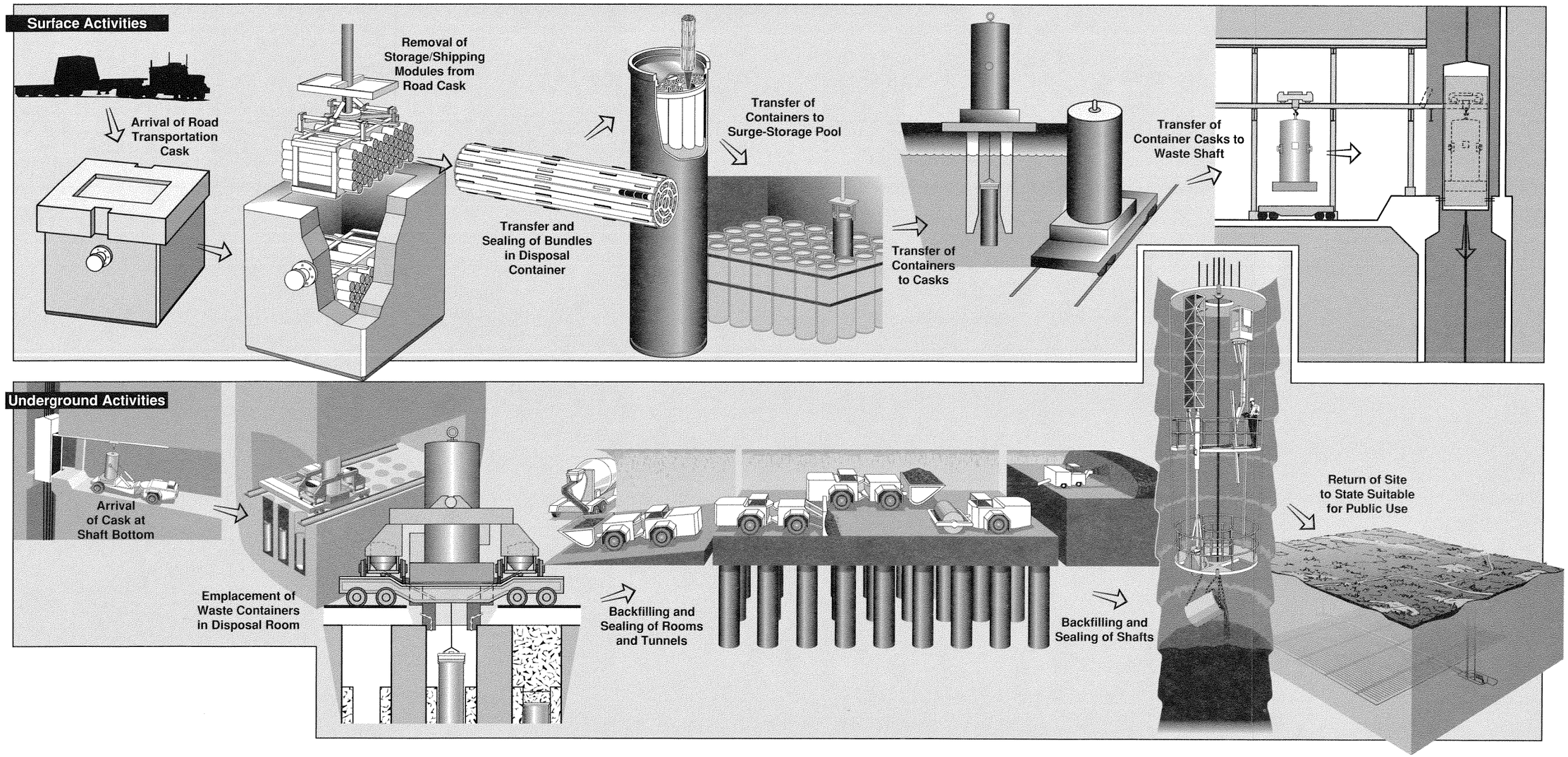


FIGURE 2-16: Reference Disposal Container Emplacement Sequence

and grouted to seal the room entrance. In addition to its sealing functions (to prevent water flowing in and radionuclide transport), the bulkhead would prevent access. With the above sequence,it would take approximately five years to fill a panel. When a panel is full, the same operations would be conducted in another panel on the opposite side of the vault. At the end of the operation stage, access tunnels and service areas would be backfilled using the methods and materials used for the disposal rooms.

2.1.4.5 Other Activities During Operation

1. Basket and Container Fabrication at the Surface

The materials required for the used fuel disposal basket fabrication facility, would be carbon steel tube, plate and bar stock. Basket fabrication activities would include: metal cutting with a turret lathe, forming with a drop hammer, welding and inspection.

The used fuel disposal container would be fabricated from 6.35 mm thick titanium plate. Container fabrication activities would include: metal cutting with a rotary shear cutter, vacuum heat treatment in a heat-treating furnace, preparation of the weld and bonding surfaces with a turret lathe and planer, metal forming with bending rolls, gas-tungsten arc welding and inspection.

2. Preparation of Buffer, Backfill and Vault Sealing Material Underground

The buffer and backfill preparation plant would be located underground adjacent to the service shaft. Silica sand, crushed rock fines and crushed rock would be lowered to the vault level in service-shaft vessels dedicated to handling sealing materials at a rate of 100 $Mg \cdot h^{-1}$. Sodium-bentonite and glacial-lake clays would be pneumatically conveyed from the surface and discharged directly into their respective bins. Trucks would move the material to the entrance of the disposal room.

The quantities of sealing materials that would be required for the facility are shown in Table 2-4.

TABLE 2-4
Quantities of Vault Sealing Materials

Sealing Material Components	Quantities (10^6 Mg)
Bentonite Clay	2.10
Glacial Lake Clay	2.17
Silica Sand	2.23
Crushed Granite	6.92
Cement	0.14
Total	13.56

Concrete would be prepared at the concrete batching plant using special cements, pozzuolana, aggregate, additives and water.

2.1.4.6 Environmental and Performance Monitoring

Monitoring provisions would comprise environmental monitoring to assess the impacts from operation of the disposal facility, and performance monitoring to monitor the effects of the disposal vault on the rock mass and groundwater systems. Environmental monitoring would provide the baseline data and ongoing information necessary to assess compliance with local, provincial and federal environmental guidelines and regulations.

The purpose of baseline monitoring is to establish a pre-operational database for comparison with subsequent operational monitoring and post-operational monitoring data. The role of monitoring in an environmental strategy is discussed in Chapter 10.

Reporting of monitoring results during operation at the disposal facility would also be required by the AECB as a condition to the operating licence and to verify compliance with other regulatory requirements.

Since the disposal facility has both surface and underground components, it is assumed that the disposal facility operation would have to comply with Municipal and Industrial Strategy for Abatement (MISA) monitoring requirements similar to those imposed on the Electric Power Generation (EPG) sector for its surface facilities, and to monitoring requirements similar to those imposed on the Mining Sector for its underground and related facilities.

Data from performance monitoring would provide data to compare predictive models to measured responses, and to refine and validate models.

2.1.4.7 Environmental Protection

This assessment assumes that prior to the start of operation, the implementing organization would have adopted an environmental policy consistent with the guiding principles outlined in Appendix B. Environmental protection systems would be designed to control and manage the waterborne, airborne, solid and liquid wastes that would be generated during the operation of the disposal facility. Wastes would be managed by concentration and long-term storage, or decontamination and release to the environment. All emissions would be monitored, documented and reported to the appropriate public and regulatory authorities. This section reviews the environmental protection provisions included in the conceptual UFDC engineering design (Simmons and Baumgartner 1994).

1. Water Quality Management

Water Supply

The water supply to the disposal facility is assumed to be from a nearby lake or river. The pump house would be located on shore. Three levels of water quality would be required: process/fire water, domestic water, and demineralized water. The gross water supply requirements, without recycling, are shown in Table 2-5. It is assumed that water recycling would be used to reduce these requirements.

1) Process Water

Process/fire water would be fresh water from which the fish, weeds, algae, etc., and large particulates had been removed by screening and straining. The process water would be drawn from the water source through screens and distributed by pumping systems to the surge-storage pools, heat exchangers, crushing plant, underground drilling and washing locations, domestic water treatment facility, and other general surface locations. Fire water would be required only in an emergency, not on a continuous basis.

2) Domestic Water

Domestic water would be process water that has been filtered and chlorinated to satisfy drinking water quality requirements. At the water treatment plant, process water would be subjected to chemical pre-treatment, flocculation and filtering by sand filters to remove suspended solids. The clarified water would then be chlorinated and pumped to a domestic-water storage tank.

TABLE 2-5
Water Requirements of the UFDC
(without recycling)

To be supplied to	Domestic water	Demineralized water	Process/Fire water	
			Process water	Fire water
	$L \cdot d^{-1}$ (max)	$L \cdot d^{-1}$ (max)	$L \cdot d^{-1}$ (max)	$L \cdot d^{-1}$ (max)
SURFACE FACILITY				
Used Fuel Packaging Plant	8 000	6 000	900 000	n/a
Concrete Plant (intermittent, 24 $h \cdot d^{-1}$, 1 or 2 days/month)	34 000	n/a	n/a	
Crushing Plant ($8h \cdot d^{-1}$)	n/a		3 600 000	
General Surface	162 000	n/a	2 000 000	17 280 000
Supply to Domestic & Demineralized Water Systems (rounded off)	n/a		500 000	
Total Surface	204 000	6 000	7 000 000	17 280 000
UNDERGROUND FACILITY				
Buffer/Backfill Plant	267 000	n/a		
Drilling/Washing	n/a		1 200 000	
General Underground	18 000	n/a		
Total Underground	285 000	n/a	1 200 000	
Overall Total	489 000	6 000	8 200 000	17 280 000

n/a: not applicable

3) Demineralized Water

Demineralized water would be process water from which suspended matter and dissolved ions had been removed by ion exchange and activated carbon filtration. It would be used in the used-fuel surge storage pools for the initial fill-up and to make-up for evaporative losses.

Waste Water Management

During the operation stage, waste water management systems would be in place to manage waste water from various facilities. The waste waters are classified as non-radioactive or potentially radioactive. For non-radioactive streams, the emphasis for contaminant control would be on prevention, detection and correction. The waste water treatment requirements for the facility are shown in Table 2-6.

1) Radioactive waste water streams

Radioactive water from the decontamination of casks and containers in the Used Fuel Packaging Plant and from laundries, washrooms and showers for staff working in areas where radioactive materials are present, would be filtered to remove particulates and then collected in storage tanks where it would be sampled for contamination. If clean-up was required, the water would be circulated through a filtration/ion-exchange system to reduce the contaminant levels to within effluent limits for release to the environment. The filters and ion-exchange resins are handled as a radioactively contaminated solid waste.

The receiving surge-storage pool and headframe surge-storage pool would have a cooling and purification circuit to remove the radiogenic heat from the used fuel, to control the water chemistry and remove radioactive contamination. The pool water would be pumped continuously through a heat-exchanger circuit cooled by process water, a filter and an ion-exchange column.

2) Non-radioactive waste water streams

All streams would be sampled and treated to meet local, provincial and federal water quality standards before release to the environment.

Clear water from process heat exchangers, general plant usage and rain water are not expected to contain significant quantities of contaminants and would be released directly to the environment, if not recycled. These streams would be regularly monitored to ensure compliance with water quality standards.

The rock crushing plant would use high-pressure water jets on a multi-deck vibrating screen to remove nitrates and fines before the rock was classified according to its size, then crushed. This water would be pumped to settling ponds designed to reduce the particulate content to acceptable levels for either recycling or discharge to the environment.

The underground drainage water system would consist of a series of settling- and clear-water sumps, and a pump station with pumps for clear water and sludge. The normal throughput of this system would be 2 218 $m^3 \cdot d^{-1}$ which assumes a groundwater seepage rate of 1 000 $m^3 \cdot d^{-1}$. This underground water would be pumped to separate settling ponds near the upcast ventilation shaft complex and the service shaft complex.

During the borehole drilling operations, water would be used to cool and lubricate the drill bits and to flush the cuttings from the holes. This water would first fill other drilled boreholes and then flow through the rail track

TABLE 2-6
Waste Water Production

Source of Waste Water	Low-Level Radioactive Waste Water ($L \cdot d^{-1}$)	Normally Non-radioactive Waste Water ($L \cdot d^{-1}$)
Packaging plant - decontamination of containers and casks	8 000	
Laundry, washrooms, etc. for radiation workers	30 000	
Laundry, washrooms, etc. for non-radiation workers (surface)		132 000 (no settling required)
Return process water from heat exchangers, etc., general usage		2 900 000 (clear water)
Crushing plant		3 600 000 (settling required)
Drilling, rock washing		1 200 000 (settling required)
Treated sewage (underground)		18 000 (settling required))
Groundwater		1 000 000 (settling required)
Total	38 000	8 850 000

curbs into the drainage channels, or flow down the centre of the room to the panel tunnel. As a room of boreholes is completed, each borehole would be pumped dry. This water would join the underground drainage water.

In the unlikely event that the underground water would be contaminated by radioactive material, it would be treated using a filtration/ion-exchange system prior to recycle or discharge. During the emplacement operations, groundwater draining from the disposal room where containers were being emplaced would be diverted to a local sump at the panel tunnel entrance, where it would be monitored and filtered before being allowed to enter the normal underground drainage system.

Sewage water from areas not subject to potential radioactive contamination would be collected and treated locally.

Application of MISA regulations

MISA regulations rely on the best available technology (BAT) concept to achieve the goal of pollution prevention. Best available technology can include:

i) changes in production methods;

ii) chemical substitution;

iii) plant controls;

iv) best management practices;

v) water conservation;

vi) effluent treatment technologies; and

vii) energy conservation.

Application of BAT to the disposal facility would mean that, at the very least, water recycling would be done to minimize the amount of water withdrawn from the surrounding water bodies. It is likely that 90% of the water used at the disposal facility would be recycled. Recycling the water would also reduce siting constraints since a smaller water body would be required to supply the disposal facility.

2. Air Quality Management

Non-radioactive air streams

In facilities that would not contain significant quantities of hazardous materials, or where the materials present could not contaminate the building air, the ventilation systems would discharge directly to the environment. For facilities containing operations in which significant dust or fumes would be generated, such as the rock crushing, excavated rock or buffer/backfill materials handling and transfer, and basket and container welding facilities, they would be equipped with air filtration systems, including baghouse filters, to collect the particulates.

The pneumatic conveyor systems from the sealing material delivery bins to the storage bins, and from the storage bins to the surge bins in the service-shaft complex at the surface, would be enclosed and the air stream cleaned using cyclone separators and filters before discharging the air into the atmosphere.

Potentially radioactive air streams

Facilities housing operations involving radioactive materials, such as the packaging plant, module handling and fuel packaging cells (Zones 3 and 4, see Section 6.1.2.3), would be equipped with air filtration systems comprising roughing and HEPA (High Efficiency Particulate Air) filters to collect the particulate contaminants (see item 3 for the management of used filters). The exhaust air from these areas would be continuously filtered and discharged through the stack.

The storage/shipping module drier in the module handling cell, which dries the modules coming out of the receiving surge-storage pool would be an inlet-outlet air duct enclosure that seals against the open ends of each module and would be equipped with an air filtration system to collect any contamination that would be loosened from the bundles during drying.

Airborne contaminant filtration systems would be installed in facilities with potential for airborne radioactive contamination due to accidents, such as during container handling in the disposal room and the waste shaft.

The waste shaft exhaust ventilation would also be equipped with a HEPA filter system at the surface. Air normally bypasses the filters. In the event of airborne radioactive contamination in the headframe air, an automatic damper system would divert air through the HEPA filter to remove any radioactive particulates before release to the environment. As well, the alarm system would be activated to notify workers. The waste-shaft headframe would be maintained at a negative pressure at all times to ensure that fresh air would enter the building.

The emplacement panel upcast ventilation shaft would be provided with a HEPA filter system that would normally be bypassed. If radioactive contamination was detected in the airflow, automatic control dampers would divert exhaust air through the HEPA filter installation and alarms would be triggered. In addition, the main fans would be throttled back to approximately 50% of normal airflow to reduce the volume of air passing through the HEPA filters, thus improve their filtration efficiency. The HEPA filter system would have a surface area of 75 m^2 and would be rated for a flow of 90 m^3. The reduction in air flow through the vault would not increase the hazard to underground workers. An underground alarm system (e.g. odour alarm, klaxons and flashing lights) would advise them to shut off most diesel equipment and follow emergency response procedures (e.g. use transport vehicles to move toward the first-aid and safety refuge station).

Auxiliary ventilation would be provided during activities in individual disposal rooms, during excavation or emplacement. Filters would be installed to remove dust from the air before discharge into the panel tunnel. A portable HEPA filter system would be provided on the exhaust from the disposal room in which containers are being emplaced. During container emplacement, ventilation ducts would be equipped with by-pass dampers. In the event of airborne radioactive contamination, an automatic damper would direct air into a single duct, trip an alarm and shutdown the auxiliary fans. A third fan would start and would draw the exhaust air through the portable HEPA filter. The airflow provided by this fan would be more than adequate for the needs of the workers as there would be no demand for diesel equipment ventilation in the room. Also, when the alarm sounded, the workers would vacate the disposal room toward the perimeter tunnel (a clean air source).

3. Waste and Hazardous Materials Management

Waste management procedures would emphasize reduction, re-use and recycling of material, and provide clear instructions on the disposal of waste material.

Non-radioactive Waste

The collected particulates and sludge from settling ponds and from underground sumps would be disposed of in the waste rock dump or in other collection pits in the area. Any run-off from this area would be sampled and treated to meet local, provincial and federal water quality standards before release to the environment.

Solid wastes with no radioactive contamination (including used disposable filters) and of no economic recycle value would be either transported to a suitable municipal landfill or disposed of in an approved landfill at the disposal centre.

The excavated rock from the disposal vault would be transferred to a rock disposal area. About 37% of the rock would be reused in the vault for backfill and concrete, and the remainder, if needed, could be used locally for above ground civil construction and site refurbishment.

Radioactive Waste

Solid radioactive wastes would be collected separately from other wastes. They would be classified as low-level (e.g. operating supplies, clothing, rubber gloves, rubber boots, etc.) or intermediate level (e.g. filter units and ion exchange resins from the receiving and headframe surge-storage pool purification circuit and other filtering processes, hot cell equipment, etc.).

Each would be reduced in volume by compacting or cutting, packaged in approved containers and stored in shielded and controlled facilities before being shipped to licensed disposal facilities. The volume of compacted radioactive solid waste for the 41 years of operation is estimated to be 2 000 m^3.

During container disassembly (for containers that have failed the non-destructive tests and cannot be repaired), container shell sections would be removed, decontaminated and may be recycled if suitably decontaminated, or treated as low-level radioactive waste. A vacuum catchment system would contain and recycle the spilled glass particulates.

Hazardous Materials and Wastes Management

A wide variety of materials would be used and produced during operation of a disposal centre. Many of these could be potentially hazardous to human health and the environment, and operating procedures must be developed to manage them. Table 2-7 gives a list of the non-radioactive hazardous materials likely to be present at a used fuel disposal centre. Hazardous liquid wastes at the disposal centre would be collected in approved containers and stored in suitable structures on site until shipment to licensed disposal facilities.

2.1.4.8 Occupational Safety

This assessment assumes that prior to the start of operation, the implementing organization would have adopted a worker health and safety policy similar to the one presented in Appendix H. This section reviews the occupational safety provisions in the conceptual disposal facility design.

1. During Excavation Underground

The proposed drill-and-blast method is routinely used in mining and civil engineering in rock similar to that proposed for the disposal vault. Experience at AECL Underground Research Laboratory (URL) indicates that damage induced in the rock mass by drill-and-blast excavation can be minimized by careful design and application. Ground control would be achieved by standard

TABLE 2-7
Major Non-Radioactive Hazardous Materials at the UFDC

Material	Main Use or Mode of Production	Main Hazard	
		Type	Location of Material
GASES, DUST AND FUMES			
Argon	Used in fabrication of used fuel basket and container and during bonding of container lid.	Asphyxiant	Basket and Container Fabrication Plant, Used Fuel Packaging Plant and compressed gas storage building.
Chlorine	Used for domestic water treatment.	Toxic and corrosive	Water treatment plant and chemical storage building.
Diesel engine exhaust	Produced by transporters and other diesel equipment.	Asphyxiant and health hazard (respiratory diseases).	Surface and underground.
Dust and smoke	Produced during rock crushing, blasting and excavation.	Health hazard (silicosis) and limiting visibility.	Crushing plant, buffer preparation plant, and underground.
Helium	Used for container leak test.	Asphyxiant.	Used Fuel Packaging Plant and compressed gas storage building.
Hydrogen	Radiation-induced decomposition of water.	Explosive and flammable.	Surge storage pools, container emplacement rooms.
Natural gas and propane	Used for heating air supply to underground in the winter.	Asphyxiant, explosive, and flammable.	In distribution piping, downcast ventilation shaft, and in the compressed gas storage building.
Ozone	Produced in the vicinity of high voltage electrical equipment and during welding.	Health hazard (short term change in lung function; cough and pain on deep breathing)	Transformers on surface and underground, and general welding locations surface and underground.
Acetylene	Used in maintenance welding.	Explosive and flammable.	Surface and underground.
Oxygen	Used in maintenance welding.	Explosive and Flammable.	Surface and underground.
Welding fumes	Produced from welding during basket and container fabrication, and during maintenance work.	Health hazard (see ozone)	Basket and container fabrication plant, surface and underground.

Continued...

TABLE 2-7 (Concluded)

Material	Main Use or Mode of Production	Main Hazard	
		Type	Location of Material
LIQUIDS			
Acids	Used to passivate the titanium container, in batteries for underground vehicles and uninterruptible power, and in maintenance and cleaning of equipment.	Toxic and corrosive.	Basket and container fabrication plant, auxiliary building, chemical storage building and general surface and underground locations.
Bases	Used to control pH around 10 in the water pools.	Toxic and corrosive.	Surge storage pools and chemical storage building.
Other solvents	Use in the process of basket and container fabrication, to swab the area to be welded in containers, and in maintenance work.	Toxic and flammable.	Basket and container fabrication plant, used fuel packaging plant, auxiliary building and at general surface and underground locations.
Diesel and fuel	Used to refuel vehicles and machinery.	Flammable.	Fuel tanks at the surface and underground.
Hydrazine	Used in water chemistry control.	Health hazard and flammable.	In the surge storage pools and chemical storage building.
Oil, grease and antifreeze	Used in engines, hydraulic systems and machinery.	Health hazard and flammable.	At surface and underground locations, and in the chemical storage building.
Sewage	From washrooms, showers, kitchen facilities.	Health hazard, air and water pollutant.	At surface and underground locations.
Waste Water	Used in washing of rock, vehicles and physical plant, as coolant, and from groundwater drainage.	Health hazard, air and water pollutant.	At the rock crushing plant, surge storage pools, and various surface and underground locations.
SOLIDS			
Explosives	Used in excavation of rock.	Explosive.	In underground facility and explosive magazines.
Office, kitchen and shop waste	Scrap paper, materials and food.	Health hazard, air and water pollutant.	Primarily at the landfill site on the surface.
Scrap Metal	Produced during container fabrication and maintenance.	Health hazard, air and water pollutant.	At various surface and underground locations.

rock-bolting methods from scissor-lift trucks to prevent rock falling from the tunnel ceiling. For excavation that will remain open for long times, such as access tunnels and ancillary facilities, screens and bolts might be a cost-effective procedure for rock surface maintenance.

2. During Used Fuel Handling

Used fuel would arrive in transport casks and workers would be exposed to low levels of radiation by contact handling. Used fuel bundle handling operations at the disposal facility would take place in shielded facilities and would make extensive use of robotic or remote handling tools. The used-fuel packaging would take place in a hot cell using robotic and remote-controlled equipment.

3. During Container Handling

The used-fuel containers would be stored in a water-filled headframe surge storage pool using remote handling equipment, transferred underground in shielded casks and emplaced in boreholes from casks using contact handling. The shielded, contact-handling transfer concept was selected over the unshielded, remote-handling transfer operations because any failure of, or accident in, the remote-handling system would make access and remedial action slower and more difficult, and might represent greater radiological risks to the workers.

During emplacement of a used-fuel disposal container in a disposal room, the handling equipment, and the rock and sealing materials would provide shielding. A shielding ring would be installed around the mouth of the borehole to protect operators from the radiation from the container as it is lowered. After the emplaced container has been covered with sand, there would remain a significant radiation flux from the borehole to the platform decks. However, the 0.3 m of shielding on the deck of the container emplacement platform would protect operating personnel on the platform. The buffer emplacement platform would also be shielded to protect operating personnel. A radiation detector would warn of unexpected radiation fields at the platforms. The container would be handled remotely based on techniques used for used fuel handling operations at nuclear generating stations and nuclear research facilities.

When the buffer has been emplaced up to the floor of the disposal room, there would be sufficient sand, buffer material and rock surrounding the container to reduce the radiation field in the working areas of a disposal room to 0.7 $\mu Sv \cdot h^{-1}$, well below the regulatory limit for working in radioactive areas (50 $mSv \cdot a^{-1}$ for an occupancy of 2 000 hours per year would give a limit of 25 $\mu Sv \cdot h^{-1}$).

4. Occupational Dose Management Program

In accordance with current practice at nuclear generating stations, a formal occupational radiation management program to minimize occupational dose would be implemented to minimize occupational dose. The radiation management program would first establish an occupational radiation exposure target for the design stage. A monitoring program would be established to verify that the dose targets were not exceeded during operation. Specific dose reduction programs would be created to reduce personnel doses to "as low as reasonably achievable" (ALARA), taking into account social and economic considerations. Both external and internal individual occupational doses would be monitored to assess the effectiveness of the radiation control program.

5. Establishment of Radiation Zones

The facility would be divided into four radiation zones according to the potential contamination in each area. These zones, defined in Table 2-8, are based on current AECB regulations and nuclear facility operating practice. A radioactive work area at the disposal facility would then be defined as any location where any of the following conditions exist (Ontario Hydro 1987 and 1992):

i) a dose rate of 25 $\mu Sv \cdot h^{-1}$ or more (for gamma or neutron radiation);

ii) a dose rate of 250 $\mu Gy \cdot h^{-1}$ or more (for beta radiation);

iii) airborne activity equal to or greater than the maximum permissible concentration of any radionuclide;

iv) detectable loose surface contamination;

v) working with materials having a fixed activity greater than 25 $\mu Ci \cdot m^{-2}$; and

vi) working in an area designated as a radioactive work area.

The most hazardous areas in the disposal centre (Zones 3 and 4) are called "controlled areas". They require special procedures to prevent inadvertent exposures to personnel, and the control and movement of personnel in them would be maintained by stringent operational procedures and physical barriers. All other areas (Zones 1 and 2) are commonly called "supervised areas".

All normal routes between zones would have contamination monitors, and points of entry and exit from zone boundaries would be identified and marked with signs. Ventilation systems would be designed so that air would flow from areas of lower potential radioactive contamination to areas of higher contamination.

Personnel contamination monitors would be located throughout the facility at zone boundaries and other strategic points to detect the movement of radioactive contamination. Each monitor would sound an alarm right at the actual monitor, and also in a control room. Atomic radiation workers who are allowed to enter the "property boundary" are subject to special health supervision and assessment of their individual integrated dose equivalent (with monitoring for both external and internal exposures).

6. Monitoring Provisions

To ensure that contamination levels are below acceptable limits, a swipe-test station would be provided in the Fuel Packaging Cell (FPC) to monitor containers for surface contamination after they have been decontaminated and before they are moved from the FPC.

Fixed-area radiation monitoring would be provided in all areas where radioactive materials are handled. Appropriate alarms would indicate a high level of radiation or a high rate of increase of the radiation level.

TABLE 2-8
Definition of Radiation Zones

Zone	Radiation Hazard		Access Status	Maximum Annual Effective Dose
	Potential for Internal Contamination	External Radiation Dose Rate		
1	No potential for contamination.	Less than 2.5 $\mu Sv \cdot h^{-1}$	Entry would be allowed to all staff. Access area to members of the public.	5 mSv [1]
2	Potential for contamination. Contamination would not be tolerated, and would be eliminated immediately once discovered.	Between 2.5 and 25 $\mu Sv \cdot h^{-1}$	Work zone for Atomic Radiation Workers only.	Between 5 mSv and 50 mSv [1]
3	Contaminated area. Contamination levels are less than the Maximum Permissible Concentration in air and on surfaces.	Between 25 and 250 $\mu Sv \cdot h^{-1}$	Controlled access[2]. Protective clothing would be required.	
4	High levels of contamination. Levels are higher than the Derived Air or Surface Concentration.	Higher than 250 $\mu Sv \cdot h^{-1}$	Normally inaccessible area[2]. Special protective clothing and equipment would be required. Special equipment should also be provided for handling fuel bundle or for decontamination purposes in the UFPP.	

[1] Maximum Annual Effective Dose is based on 2 000 hours in the zone per year.

[2] Controlled access area. Entry permitted only with special authorization. Exposure times will be managed so that an individual's total effective annual dose shall not exceed 50 mSv. Air from these zones is continuously filtered through HEPA filters, for removal of particulates, and discharged through the stack.

7. Operating Procedures

Strict operating procedures (i.e. Operating Manuals), similar to the procedures established at nuclear generating stations, would be developed to protect the workers from radiological and non-radiological hazards. The manuals would include procedures for:

i) all used fuel handling operations;

ii) operation and maintenance of heavy equipment;

iii) dust and fumes associated with diesel equipment operations;

iv) non-radioactive material handling;

v) explosives handling and use; and

vi) working underground.

8. Worker Training Programs

It is assumed that training programs would be established in four main areas:

i) health and safety;

ii) radiation protection;

iii) hazardous material handling; and

iv) emergency response.

Health and Safety

In Ontario, joint (management/worker) health and safety committees are required for any workplace that regularly employs 20 or more workers. Such a committee would, therefore, be required at the disposal facility. Members of the health and safety joint committee would receive, as required under the Occupational Health and Safety Act (Government of Ontario 1990c), special training in occupational health and safety, and would be certified by the Government of Ontario.

Radiation Protection Training

Based on current practice at Ontario Hydro, AECL and other nuclear establishments, all employees of the disposal facility would receive radiation protection training. This training would include the following:

i) definition of ionizing radiation;

ii) identification of sources of various types of radiation;

iii) review of methods to reduce radiation exposure; and

iv) health effects of radiation on human body.

Training in Hazardous Material Handling

The Workplace Hazardous Material Information System (WHMIS) is implemented through a combination of federal and provincial regulations. Related training would be required for all employees working in proximity to hazardous materials.

In Canada, WHMIS training is required under the WHMIS Regulation for workers exposed to a hazardous material on the job (Government of Canada 1985a; Government of Ontario 1990f). At the disposal facility, such workers would be identified and receive training in the following areas:

i) hazardous material labelling;

ii) material safety data sheets; and

iii) hazard training associated with the eight WHMIS hazard symbols (compressed gas, flammable/combustible, oxidizing, poisonous/infectious fast acting, poisonous/infectious long term acting, poisonous/infectious causing disease, corrosive and dangerously reactive)

Emergency Response Training

As part of the facility emergency response plan, trained emergency response teams would be formed, and workers would receive general training on response procedures and equipment. Emergency drills would be conducted at regular intervals, as would employee training sessions.

9. Other Occupational Safety Provisions

Hazardous Material Management

The quantity of hazardous materials in occupied areas would be restricted to limit the potential exposures received by individual workers to an acceptable minimum based on 2 000 hours of occupancy per year.

Communication/Warning

Workers working within site boundaries, but remote from direct telephone or radio system access, would be provided with a portable paging system. A public address (PA) system would be installed in all areas of the disposal centre to provide paging and one-way communication services. The PA system would also be equipped with tone generators, horns and flashing lights (e.g. for noisy underground work areas) to provide fire and radiation hazard warnings as part of the alarm system.

The alarm system warns workers of detected hazards such as fire, hazardous material releases, radioactive exposure and contamination. Specific detectors (e.g. smoke, heat, radiation monitors etc.) would be strategically located in all work areas to monitor work place conditions. Audible and visible alarms would alert control room operations, physical security and fire protection staff, and radiation and industrial safety staff. A stench gas emergency warning system would be provided as specified in the Ontario Mining Regulations (Government of Ontario 1990e).

Underground Ventilation

The ventilation system would be designed to provide sufficient airflow to maintain a safe and comfortable working environment for all underground personnel. It would provide adequate airflows for the operation of diesel-powered equipment and for the dilution of radon gas and progeny products emanating from the rock to acceptable limits.

Protective Equipment

Workers involved in the operation of the crushing plant and heavy diesel equipment, and those handling sealing systems and materials would be required to wear suitable eye, hearing and breathing protection.

2.1.4.9 Reliability of Electric Power Supply

All electrical equipment would be designed, built, tested, installed and operated in accordance with applicable codes, regulations and standards. The electrical loads at the disposal facility would be supplied through electrical distribution equipment and switch gear powered from the regional electrical grid (4 160 V AC), on-site stand-by diesel generators (600 V AC) and an uninterruptible power system (250 V DC/invertor system). The specific power sources would depend on how critical a specific load was for environmental control, occupational and radiological safety, and the size of the load. Large power loads would be supplied from the grid, and possibly the stand-by diesel generators, while smaller loads where continuous operation was critical, would be on uninterruptible power.

2.1.4.10 Container Retrieval Procedure

As early as 1978, during the Royal Commission on Electrical Power Planning hearings (RCEPP 1976, 1980), the public mentioned retrievability as a desirable feature for a used fuel disposal facility. The same view was recorded during the AECL public consultation program (Greber and Anderson 1989) and during the FEARO scoping meetings on the disposal concept (Dowell 1991a). AECB regulatory policy R-71 also requires provisions for retrievability (AECB 1985). Container retrieval procedures were, therefore, included as a contingency in the reference design.

Containers may need to be retrieved if they are defective, if defects occur during buffer placement, if the performance of the disposal system does not meet specifications, or for safeguards verification. Containers could be retrieved as described below during the operation stage, and during the extended monitoring stage prior to decommissioning. After decommissioning, when all underground excavations are sealed, additional work to open new underground access would be necessary for any retrieval operation.

It is assumed that the retrieval operation would require reentering a sealed disposal room. If the disposal room sealing bulkhead had been installed, retrieval would require the removal of the bulkhead and backfill material to gain access to the sealed boreholes, followed by removal of the container(s) from the borehole(s). Bulkheads could be removed by careful drill and blast excavation, or by using hydraulic rock breakers. Precautions would be taken to prevent any damage to emplaced disposal containers during these activities.

Continuous underground excavation equipment could be used to remove the upper and lower backfills. The broken concrete and loosened backfill material could be handled by load-haul-dump vehicles and trucks, and returned to the surface for examination and possible re-use. Since the backfill near the container boreholes may be contaminated, monitoring procedures would be instituted to detect contamination. Special procedures and equipment would be developed to segregate and handle contaminated material. Ventilation and other services would be re-established as necessary.

The equipment proposed for container retrieval would be rail-mounted similar to the arrangement for container emplacement operation, except that the transfer cask would be replaced by a retrieval cask. A remotely-operated core drill, enclosed within a shielded housing and mounted on a rail platform, would be positioned over the borehole from which the container is to be retrieved. The surveying records from the container emplacement operations would ensure that retrieval equipment would be precisely located.

To begin container retrieval, an annular recess would be drilled in the floor around the emplacement borehole. The recess would be wide enough for the shielding ring and deep enough to allow for irregularities in the disposal room floor. The shielding rings would be designed to allow access to the

entire borehole. The buffer augering platform would be positioned over the emplacement borehole and its inner shielding ring would be lowered to fit into the recess drilled around the borehole collar.

The upper 1.65 m of buffer material would be removed, cleaned, and handled as potentially contaminated material.

The shielding ring would be raised, a cover placed over the hole, and the deck supporting the trepanning auger positioned over the borehole. The cover would be set aside and the shielding ring lowered from the new deck into the drilled recess to re-establish ventilation and shielding over the boreholes. The trepanning auger would be lowered into the borehole and would cut an annular slot about 100 mm thick adjacent to the emplacement borehole wall to a depth of about 3 m. The buffer cuttings would be cleaned from the trepanning auger and handled as potentially contaminated material.

When the trepanning operation is complete, the shielding rings would be lifted, and the platform supporting the container retrieval cask would be located over the borehole. Its shielding ring would be lowered into place and the grapple lowered from the retrieval cask in the trepanned slot. The lower edge of the grapple would be equipped with high pressure water jet nozzles to cut horizontally through the buffer material to free the container from the lower mass of buffer. When the grapple had been lowered and inflated, water would be forced through the nozzles. The container would then be lifted into the retrieval cask.

The retrieved container would be handled in a hot cell located in the retrieved container facility in the upcast ventilation shaft complex. The remaining buffer and sand would be removed in the hot cell using dry methods. The container would then be enclosed in a plastic-sealed or metal overpack and placed in a disposal container cask for transfer to the surface.

Provisions for Environmental Protection

1) Waste Water Management

During container retrieval, some of the buffer cutting operation would use a high pressure water-jet nozzle to cut horizontally through the buffer material to free the container from the lower mass of buffer. The water and clay slurry would be discharged through pipes built into the segments of the grapple and collected in a shielded portable holding tank. The tank and contents would be treated as contaminated material until it could be checked for contamination. If not contaminated, the contents would be allowed to settle. The decant liquid would be filtered to remove suspended solids before being released to the underground drainage system. If contaminated, the tank would be moved to the surface active-waste-treatment building for separation and handling.

2) Air Quality Management

During container retrieval operations, a temporary ventilation system would be set up to filter any contaminants drawn from the borehole. The filter system would be designed to remove particulates present in quantities large enough to be a risk to the operators. The air would be monitored for fission product gases and diverted through a filter system if they were detected.

3) Solid Waste Management

At the start of container retrieval operations (i.e. during the removal of the upper and lower backfills), monitoring procedures would be instituted to detect contaminated materials, since the backfill near the container boreholes might be contaminated. Special procedures and equipment would be developed to

segregate and handle contaminated material. During the actual container retrieval operation, buffer cuttings would be treated as potentially contaminated material until proven otherwise.

4) Occupational Safety

The proposed container retrieval equipment would be rail-mounted and supplied with the shielding rings, skirts, decks and housings necessary to minimize the radiation exposure to equipment operators.

The air in the room would be filtered through a dedicated temporary ventilation system designed to remove particulates present in quantities large enough to be a risk to the operators.

2.1.5 Pre-Decommissioning Extended Monitoring

If deemed necessary by the public or regulatory authorities, a period of extended monitoring may be implemented after all the used fuel containers have been emplaced and all disposal rooms are sealed, but before decommissioning and closure of the vault.

2.1.5.1 Definition

At the end of the disposal facility operation, extended monitoring may be required to provide assurance that the disposal vault is performing satisfactorily before vault closure. Duration of this pre-decommissioning monitoring period is undefined: it would last as long as necessary to gather strong evidence on the safety of the disposal vault and to enable verification of the predictive models of long-term performance.

2.1.5.2 Type of Measurements and Instrumentation

After the fuel has been emplaced, measurement of disposal system parameters, disturbances and responses, and environmental monitoring would be done to verify predictive models (Simmons et al. 1994). Both performance and environmental monitoring would be performed. Typical technical parameters that would be measured are given in Table 2-9. Additional tests on borehole, tunnel and shaft seals could be performed to verify the effectiveness of their designs. These tests may include:

i) borehole tests to measure the response of the rock mass and groundwater systems, to the presence of the disposal vault;

ii) emplacement and testing of borehole plugs to monitor their effectiveness; and

iii) emplacement and testing of shaft and tunnel seals to assess their performance.

The primary purpose of these tests would be to confirm the long-term performance of these components of the disposal systems, and to support the application for approval to decommission and seal the vault.

Monitoring systems installed during characterization to regularly sample and analyze the air, surface water, soil, plants and animals, would continue to operate in the pre-decommissioning extended monitoring stage. In addition, instrumentation installed in boreholes during site characterization would allow us to characterize and monitor the natural environment surrounding the disposal centre to a depth greater than the depth of the vault. These systems would continue to operate throughout this stage.

TABLE 2-9
Geotechnical Characterization, Properties and Techniques

GEOTECHNICAL PARAMETER	MONITORING METHOD	EQUIPMENT
In-situ stress magnitudes and directions	Hydrofracturing Overcoring	
Deformation or displacement of rock, structural supports, bulkheads and composite seals[1]	Conventional surveying Construction Records Inspection	Convergence gauges Probe extensometers Fixed borehole extensometers Traverse deformation gauges
Stress change in rock	Geological mapping Overcoring Hydraulic fracturing Construction Records Inspection	Soft inclusion gauges Rigid inclusion gauges
Load and stress in structural supports	Materials testing Construction Records Inspection	Load cells Strain gauges
Thermal response of rock and sealing materials[1]	Materials testing	Thermocouples Resistance temperature gauges Thermistors
Rock mass structure/ properties	Photography (aerial, ground, underground, borehole and crosshole methods) Ground probing (Radar and seismic/ultrasonic) Materials testing Geological mapping (selected areas) Drilling (core or other methods)/logging	
Overburden materials/properties	Field observation Geophysical surveys	
Groundwater pressure, storativity, hydraulic conductivity, velocity of flow and chemistry	Borehole testing Crosshole testing Groundwater chemical sampling	Single and multipoint standpipe piezometers Pneumatic and electric piezometers
Moisture content of sealing materials[1]	Materials testing Construction Records Inspection	Capacitance probe Neutron probe
Pressure of sealing materials		Earth pressure cells
Groundwater inflow volume	Mass water balance Head variation	Flow meter Water collection rings
Air/water vapour chemistry, humidity and temperature (in underground openings)	Air/particulate sampling	Contaminant monitoring devices Psychrometer/hygrothermograph/digital sensors Thermometer/digital sensing monitors
Hydrology and meteorology	Continuous monitoring of pressure Head Atmospheric pressure	Hydrometric monitoring stations Weather stations
Seismic vibrations	Acoustic emission monitoring	Strong motion seismographs

[1] These tests would be done in a component test area which would be located far enough away from any emplaced waste to avoid any adverse effects on its isolation.

The near-field instrumentation installed in the disposal vault to monitor temperature, pressure, rock movement and radioactivity in or near the emplacement rooms, would be progressively removed as the vault was being filled.

Far-field monitoring systems installed to monitor radioactivity in and around the surface and underground facilities, physical changes in the surrounding rock, and groundwater conditions adjacent to the underground vault, would be removed as part of sealing and decommissioning. These systems would be completely shut down only after the final radioactive contamination surveys were completed upon demolition of the surface facility. At the end of the operation stage, when all the disposal rooms are sealed, monitoring could be continued at the surface, in boreholes extending from the surface, and underground in the access tunnels and shafts.

2.1.5.3 Environmental Protection

Environmental protection provisions in place during the facility operation would continue in the pre-decommissioning extended monitoring period (see Section 2.1.4.7).

Water would be used mainly to treat municipal waste at the water treatment plant before releasing it to the environment.

2.1.6 Disposal Facility Decommissioning and Closure Plan

The decommissioning stage of the disposal facility life-cycle would begin when the waste emplacement operations had been completed, sufficient performance monitoring data had been collected to support approval to decommission and seal, the decommissioning and sealing designs and plans had been approved by the regulatory authorities, and a decommissioning licence has been granted by the AECB. The decommissioning plans would outline the specific decontamination, vault sealing, dismantling, demolition, waste removal, and site restoration and marking activities, as well as the timetable for these activities and their likely effects. Decommissioning would end when the vault had been sealed, and all surface facilities had been decontaminated and removed.

The main elements of the decommissioning stage would include:

i) decontamination, dismantling and removal of surface and subsurface facilities;

ii) sealing of the tunnels, shafts and service areas; and

iii) sealing of all surface boreholes and those subsurface boreholes not required for monitoring.

The site would be returned to a suitable state as defined by regulating authorities and permanent markers placed to indicate the vault location. Land use restrictions could be placed in archives in federal, provincial and municipal records and maps.

When decommissioning and closure begin, all activities would take place on a 3 shifts per day, 7 work days per week basis, as in the construction stage. During this period, the surface and vault activities would be integrated to ensure that surface facilities, required to support the underground activities, were available for as long as required.

2.1.6.1 Underground decommissioning

1. Decommissioning of Underground Facilities

Decommissioning of the underground facilities would include removal of permanent operating systems, installation of temporary services, refurbishing or preparation of the exposed rock mass for sealing, and installation of seals. Details of the operations required to prepare for sealing and the sealing systems to be used, would depend on the specific site and disposal system involved (Johnson et al. 1994a).

Sealing operations would be carried out from the furthest disposal rooms back to the main shaft complex.

Exposed rock surfaces in tunnels and ancillary service areas may be coated by debris, engine and hydraulic oil, diesel soot, blasting smoke and paint during the vault operation. Similarly, the floors may be covered with gravel road beds or concrete work pads and have water drainage ditches. All such materials would be removed from the rock surfaces, loose rock would be scaled off and the surfaces cleaned to concrete-placement quality prior to backfilling and sealing.

When all ancillary services areas had been decommissioned and sealed, the underground backfill and buffer preparation plant would be disassembled and moved to the surface.

Concrete bulkheads and compacted bentonite clay seals would be installed in the tunnels at strategic locations in the vault. These bulkheads would be similar to the disposal room bulkheads.

2. Shaft Sealing

Shaft sealing would be the last step in the sealing of the underground facility. Prior to backfilling the shafts, the following would be required:

i) removal of instrumentation from boreholes drilled into the shaft walls, followed by sealing of the holes;

ii) grouting of fracture zones to limit water inflow to the shafts;

iii) localized grouting in the excavation-disturbed zone;

iv) removal of shaft services and shaft furnishings;

v) removal of the concrete liner and a small annulus of rock from the shaft wall by reaming of the shaft walls; and

vi) re-equipment of the shaft to provide temporary access and services for sealing.

These operations would be carried out from working platforms suspended from hoist ropes.

Removal of the shaft lining and a small annulus of wall rock is recommended to expose a sound, clean rock surface for sealing. The liner and rock would be removed by reaming and the debris from the operation transported to the surface.

Shaft sealing would involve the placement of backfill, and composite concrete/compacted bentonite clay material seals. The collar of each shaft would be sealed with a reinforced concrete plug which would be anchored soundly to the surrounding rock.

2.1.6.2 Decommissioning of surface facilities

The purpose of decommissioning the surface facilities is to return the site to a state suitable for unrestricted public access and restricted subsurface use, and to eliminate any possibility of radiation exposure to the public from residual effects of the facilities. The surface decommissioning activities can be divided into three components: decontamination, dismantling/demolition, and site restoration.

A decommissioning sequence for the disposal facility might be as follows:

i) module-handling cells and used-fuel packaging cells;

ii) surge storage pools and pool service systems;

iii) air-locks, decontamination areas, laundry and washrooms;

iv) ventilation systems; and

v) liquid and solid waste treatment facilities.

1. Decontamination

Although no specific criteria have been established for decontamination of the UFDC, requirements for nuclear generating stations are assumed to apply. They are:

i) no detectable loose contamination;

ii) no general radiation fields giving a dose greater than 1 $\mu Sv \cdot h^{-1}$ at 1 m from the surface;

iii) no fixed beta-gamma contamination greater than 37 000 $Bq \cdot m^{-2}$;

iv) no fixed high-toxicity alpha contamination greater than 3 700 Bq/m^2; and

v) no fixed low-toxicity alpha contamination greater than 37 000 $Bq \cdot m^{-2}$.

The required decontamination program would be determined by the total radioactive inventory, the characteristics of this inventory, and the physical state of the contaminants.

The radioactive contamination would be mainly from the corrosion products of the primary heat transport systems in the reactors from which the fuel was taken, and the fission products and fuel material released from failed fuel bundles. Normally, these would only be present in the module-handling cells, the receiving surge-storage pool and the used-fuel packaging cells. Much of the contaminants would have been collected by the pool filtration system, the ventilation system and by routine cleaning of the floors, roofs and walls of working stations.

The contamination would be either loose or fixed. Loose contamination would be easy to remove, while fixed contamination might require partial demolition and removal of structures. Contamination soaked into concrete or into the subsoil would be more difficult to remove. Generally, small areas of high contamination would require less effort to remove than the same amount of contamination dispersed over large areas.

In the decontamination plan for a specific disposal centre design, methods for decontaminating each area of the centre would be specified based on the level

of contamination and the characteristics of the contaminated area. The methods would include collection and containment of loose contamination, and removal and packaging of material with fixed contamination. Loose contamination would be removed and contained using a fluid wash such as air flushing of ventilation systems for collection on filters, vacuuming with special machines, or flushing with water or a solvent into an active drainage system. Materials with fixed contamination would be disassembled or demolished, and placed in containers for disposal in approved facilities. In some cases, it might be safer, simpler and more cost effective to convert loose contamination to fixed contamination (e.g. by painting) and to remove the entire item as contaminated waste.

In the radioactive and potentially radioactive areas, a detailed inventory would be carried out to identify the location and amounts of contamination remaining in the facilities.

When the major areas had been decontaminated, the service systems such as active filter and drainage systems would be decontaminated, disassembled and packaged for disposal. Where these systems would be embedded in structures, a portion of the structure might be disassembled to remove the contamination (e.g. duct or pipe). Finally, following treatment of all collected waste the storage tanks and treatment systems would be decontaminated, and the contents packaged using temporary systems and installations that could be readily disposed.

Normally, the contaminated material would be removed mechanically or chemically by physically separating the contaminated material from the balance of the system, installation or structure. Contaminated pieces would be broken down to sizes that could be efficiently packed in low- and medium-level waste containers. Material separated chemically would be collected, neutralized and solidified for disposal.

The equipment required for decontamination would be similar to that used during routine house-keeping and maintenance of the Used-Fuel Disposal Centre, as shown in Table 2-10.

2. Dismantling and demolition

After decontamination, the facilities would be disassembled and demolished. The technology for demolition, that is the disassembly and disposal of systems, installations, and structures that are not contaminated or have been decontaminated, is well established (Simmons and Baumgartner 1994).

3. Site restoration

After the vault has been sealed, all facilities and buildings removed, and the area shown to meet regulatory contamination limits, the site would be landscaped to promote natural growth and, if appropriate, reforested.

Depending on the policies developed by the regulatory agencies at the time, vandal-resistant structures, access routes and equipment might remain for monitoring and safeguard purposes (see Section 6.8).

Permanent markers would be installed at the site to inform future generations of the presence of the sealed disposal vault.

TABLE 2-10
Required Equipment during Decontamination

EQUIPMENT	DESCRIPTION
Hydrolyser	an electrically-driven, high-pressure (up to 70 MPa) water jet with water flow rate up to 35 l/min
Scarifier	a manually-operated pneumatic hammer with special heads for removing concrete surface layers
Demolition hammer	a standard manually-operated electric or pneumatic hammer/chisel
Underwater vacuum cleaner	a cleaner designed to not only clean underwater surfaces but to pick up loose debris such as bolts, nuts, etc.
Chipping hammer	standard manually-operated electric or pneumatic chisels in various sizes
Portable ventilator	a large extraction fan with HEPA filter and flexible ducts
Wet/dry vacuum cleaner	industrial models with HEPA filter and flexible ducts
Cleaning cabinet	an enclosed cabinet with windows, having connection to an external hydrolyser system, for decontaminating small items

2.1.6.3 Environmental Protection

During decommissioning, the surface and vault activities would be integrated to ensure that surface facilities such as water treatment facilities, required to support the underground activities, were available for as long as they were required. Waste management procedures would emphasize reduction, re-use and recycling of material, and clear instructions would be given on disposal of waste material.

1. Radioactive Waste Management

The contaminated material collected during decontamination and decommissioning (about 2 000 m^3 after compaction) would be additional to the intermediate- and low-level waste accumulated during the operation of the Used Fuel Disposal Centre (also about 2 000 m^3 after compaction). During both stages, the wastes would be temporarily stored on site until sufficient quantities were accumulated to be shipped to a licensed low- or intermediate-level waste disposal facility, assumed to be established prior to the operation of the Used Fuel Disposal Centre.

The low-level radioactive solid waste would be packaged in custom-made rectangular boxes with about 1 m^3 capacity. To maximize the packing density of each box, a compactor/baler would be used, or the material would be cut to fit.

The small volume of solid waste with higher levels of contamination, such as spent resin and filters from the pool water purification circuits and the liquid waste treatment systems, would also be packaged in boxes or in drums. These boxes may require shielding during storage and transportation.

The radioactive liquid wastes collected during decommissioning would be treated in ion-exchange columns and filters to reduce or remove the contamination. The cleaned water would be released to the environment in the plant water discharge flow, and the ion exchange resins and filters handled as solid radioactive waste.

2. Non-Radioactive Waste Management

The waste from demolition would comprise metal and non-metal (e.g. timber, concrete) materials. Disposal of these wastes would depend on the location of the site. Many system components and metallic wastes, free of contamination, could have scrap or resale value if the disposal centre is close enough to suitable markets. Otherwise, the materials would be buried in a landfill location on the site.

3. Waste Waters

During decommissioning and decontamination of the vault, radioactive contaminants would be present in the water. This water would be treated in a series of ion exchange columns and filters to remove contaminants. Water which had accumulated or had been used for decontamination would be collected, treated and recycled for further decontamination activities.

2.1.6.4 Occupational Safety

Workers would be thoroughly instructed on radiation protection procedures and all necessary precautions would be taken to ensure worker safety during decommissioning.

Following shaft reaming, and prior to shaft sealing operations, the shaft walls would be re-supported with rock bolts and mesh, if necessary, to provide a safe working environment.

2.1.7 Post-Decommissioning Extended Monitoring

This would be implemented if the regulatory authority responsible for issuing the permit for closure decided that the monitoring data collected through all previous stages was insufficient to demonstrate the long-term safety of the disposal system. This could delay the closure stage until sufficient performance monitoring data were collected.

Post-decommissioning extended monitoring would provide additional data on the performance of the sealed disposal vault. This would likely be done using instrumentation already in place, such as surface-based geotechnical monitoring systems. The resulting data would provide the information for testing and improving the models being used in the performance assessment activity, and would provide confirmation that any changes to the rock mass, groundwater, sealing system and air/water vapour were as predicted, and that sealing systems had been placed properly.

2.1.8 Closure

The closure stage would involve the removal of monitoring instruments from the surface boreholes and the sealing of these boreholes. This stage would be separated from decommissioning only if extended monitoring is required after decommissioning. Final regulatory approval of closure would mean that the safety of the site and the disposal vault would not require continuing institutional control.

2.1.9 General Safety Provisions for the Used Fuel Disposal Centre

2.1.9.1 Safety Design Principles and Approach

The UFDC design would utilize the principle of defence in depth, where several lines of defence act in series. If the first line is breached, a second, and then a third, and so on, would provide the protection needed. The ordered lines of defence against abnormal events that may lead up to accidents are prevention, mitigation and accommodation.

This approach, which is used in the design of nuclear facilities, incorporates a number of reliable, independent and effective barriers to minimize, or prevent, the release of radioactivity from the fuel to the environment. These barriers can be classified in three groups: engineered barriers (process systems and safety systems), natural barriers (rock) and institutional barriers (access control). The UFDC design incorporates the following barriers to release during operation: the ceramic uranium oxide (UO_2) fuel pellets, the zirconium alloy fuel sheaths, the used fuel packaging plant (structure, process systems, safety systems etc.), access control and other security measures for the used fuel packaging plant, the titanium disposal containers, the buffer and backfill, and the stable geological formation following emplacement. Reliability, independence and effectiveness of the barriers are achieved through the use of high quality components, and physically and functionally independent equipment and systems where practicable.

1. Specific Requirements for the UFDC

In accordance with current nuclear industry practices, the UFDC design would meet the following criteria:

Systems and Operations

All process operations, including safety functions, and related equipment would be designed to have a probability of being unavailable, due to maintenance etc., of less than 10^{-2} (one in one hundredth). This is the number used in components of currently licensed nuclear facilities (Ontario Hydro 1990a). This level of reliability can be achieved with commercially available components. In addition, the objective of the design would be to minimize the release and spread of radioactivity, and the ambient radiation field to meet the occupational and public dose limits specified by the AECB (1978 and 1991a). The design of systems would also facilitate inspection, maintenance and testing of equipment to improve reliability and reduce malfunction.

As the first line of defence against the spread of radioactivity, all equipment that handles used fuel (grapples, cranes, hoists, etc.), would be conservatively designed, maintained, inspected and tested, before use and on a regular basis during their use. For example, grapples for handling used fuel containers/modules would be designed to provide positive engagement, the capability to determine that engagement has been achieved, and a method of preventing inadvertent disengagement. This approach coupled with the implementation of rigorous procedures and training would minimize the possibility of active radiation exposure or the release of radioactivity during used fuel handling.

Health Physics/Plant Design

The main potential radiological hazard to site personnel and the public from construction, operation, and decommissioning of the UFDC would be from the used fuel packaging plant, where the major handling of radioactive material occurs.

The design of the plant would ensure that the AECB regulatory requirements, which are based on the recommendations of the International Commission on Radiological Protection (ICRP), are met. This applies to the concentration of radioactive materials, radiation fields in the different areas of the plant, effluent from the plant, and occupational radiation doses.

Ventilation systems would be designed so that air flows from areas of lower to areas of higher potential radioactive contamination, to minimize the spread of contamination in the event of an incident. Monitoring systems for gaseous and particulate radioactivity would be installed in strategic locations.

Fixed area radiation monitoring would be provided in all areas where radioactive materials are handled to detect occurrence of radiation hazards. Alarms, indicating a high level of radiation or a high rate of increase of radiation level, would be installed. Currently in nuclear facilities, personnel monitors placed between radiological zones and non-radioactive areas will alarm in the control room. Hand and foot monitors between two radiological zones will alarm locally but not in the control room. It is assumed that this would be done at the UFDC. Personnel monitoring, and dosimetry facilities and equipment, would be in place to monitor external and internal individual radiation exposures, to assess the effectiveness of the radiation control program.

Table 2-7 shows a list of major non-radioactive hazardous materials at the UFDC. At the surface and underground facilities, the concentrations of non-radiological hazardous materials in occupied areas would be controlled to keep exposure of individual workers within federal and Ontario regulations and guidelines for such exposures (considering 2 000 hrs.a^{-1} occupancy) (see Appendix B for a discussion of health and safety regulations). Labelling of hazardous materials and the availability of information on handling of these materials would be done in compliance with the requirements of the Workplace Hazardous Material Information System (WHMIS) regulations (see Appendix B).

Protection Against Common-Mode Events

Common-mode events are single events that could cause multiple equipment/system failures within the facility. They include natural phenomena such as earthquakes, tornadoes, hurricanes, temperature extremes, precipitation, floods, lightning and fires, as well as anthropogenic events including fires/explosions, aircraft crashes, etc. The factors that govern the impacts of these events are largely dependent on site-specific characteristics. Detailed assessments of the consequences and probabilities of occurrence of these events where meaningful data were available, or could be inferred are presented in Chapter 6. The general procedures for establishing the design protection against common-mode events are summarized below.

The UFDC facilities would be designed to protect against earthquakes according to the recommendations of the National Research Council of Canada on the National Building Code (NRCC 1985). The design would cover the range of credible seismic events at a specific site and would be based on a complete set of historical earthquake data for the reference environment in the Canadian Shield region of Ontario. This method is intended to provide assurance that the integrity of the containers and facilities is maintained under earthquake conditions. Underground operations would also comply with the Regulation for Mines and Mining Plants (Government of Ontario 1990e).

To protect against floods, the UFDC would be designed to the same standards as currently licensed nuclear facilities, that is to limit the consequences of a worst credible flood to an acceptable level. A disposal site near a dam or on the shore of a confined body of water would be evaluated to determine the acceptability of the potential consequences of such events. If the

consequences were unacceptable, then the site would either be rejected or further engineering design would be carried out until safety could be ensured.

The forces generated by tornadoes and hurricanes, as well as the potential impacts of high-speed missiles that may result from these phenomena are also considered in the design of the disposal facility. The design of the ventilation system prevents the reversal of air flows within the facility that may be caused by atmospheric pressure changes during hurricanes or tornadoes.

Fires can result from events occurring inside or outside the facility and can have potentially serious consequences in terms of radiological releases. For these reasons, fire/explosion protection is an integral part of the design, construction and operation of the facility. For example, safety-related equipment would be protected from fires by a fire zone or boundary of sufficiently high resistance that a fire would burn out before breaching the boundary. Ventilation systems would be isolated from outside air to prevent smoke and heat from fires of external origin from affecting the operation of the UFDC. The twin-central access tunnel concept used in the design of the vault allows us to separate excavation and waste emplacement activities, thereby limiting the potential for an explosion hazard involving a used fuel container.

For the natural phenomena discussed here, the UFDC is designed to limit the consequences of the worst credible events to a level that would not result in an unacceptable risk to the public. Credible anthropogenic events, such as an airplane crash and some events beyond the specification of the design, are also considered in the design of the facility so the consequences of these events to the public are within the regulatory limits.

2. The Application of Human Factors Engineering to UFDC Design

Human factors engineering is the study of the interaction between people and their working environment. Its application is aimed at reducing the potential for human error, thus maximizing safety, efficiency and comfort of the work environment (Humphreys 1988; Kirwan and Ainsworth 1992; Price 1992). Human factor engineering could be applied to the following areas during the design of the disposal facility:

i) equipment design and layout;

ii) the working environment (e.g. temperature, illumination);

iii) training and procedures;

iv) communications;

v) emergency planning; and

vi) staffing requirements and the allocation of tasks between staff and machines.

The following methods could be applied at the design optimization stage to ensure that the design promotes safe and efficient operations.

(i) Task Analysis

Task analysis methodologies could be used to identify and evaluate the tasks that must be completed to operate the facility. The data yielded from the task analysis could include the following: operator information requirements, required actions, feedback, communications and factors such as noise, confined space and stress. This information could be used to specify the most appropriate equipment such as displays and controls for the tasks to be

performed. The task analysis also provides a valuable input into the development of procedures, analyses of communications and training needs, and the assessment of workload.

(ii) Human Error and Human Reliability Analysis

The task analysis forms the basis for a human error analysis aimed at identifying operations that may be subject to human error. A human reliability analysis could then be conducted to predict the probabilities of human error, and the extent to which they may affect safety. The results of the analyses could be used to evaluate alternative design configurations, and to assist in cost/benefit decisions relating to the disposal facility design and the training programs.

(iii) Human Performance Evaluation

Various methods could be employed to evaluate human performance under specified conditions such as the response to alarms. These include the construction of mock-ups, experimental trials and the recording of measures of performance. The results could be used to evaluate alternative designs and highlight areas where further performance enhancements could be achieved.

(v) Communications Analysis

Communications analysis is a systematic method of identifying and assessing tasks which require communication with other people both within and external to the facility. The objective of the analysis would be to identify the necessary communication links, and communications facilities and their capabilities, and to provide input into procedural documents.

(vi) Training Needs Analysis

Training needs analysis defines the skills, knowledge and abilities required to perform the tasks identified during the task analysis, and categorizes them into recruitment and training requirements (including retraining and refresher training). Information obtained from the analysis could be used to produce job descriptions and to develop the training program and material.

(vii) Workload Assessment

Workload analysis techniques could be used to estimate operator workload to assess required staffing levels. The results would also assist in decisions about job organization, and the allocation of tasks between staff and machine.

2.1.9.2 Emergency Response Plan

Under the General Amendments to the Atomic Energy Control Regulations, a description of the measures to be taken to control hazards in the event of an accident is required in an application for an operating licence. In addition, during AECL's Public Consultation Program (Greber and Anderson 1989) (see Section 1.3), the public gave clear indication that they viewed an emergency response plan as an essential feature of a used fuel disposal facility. Emergency response measures would include protection of the workers on site, and liaison with and notification of authorities off-site of the occurrence of an emergency, to ensure protection of the public.

Based on the safety analysis of the UFDC (see Chapter 6) it is not anticipated that any off-site emergency measures would be required even in the worst case scenario. However, the Ontario Nuclear Emergency Plan covers such an eventuality (Government of Ontario 1986).

An underground rescue plan would also be required, in case of an emergency involving the underground facilities.

1. Province of Ontario Nuclear Emergency Plan

The legal basis in Ontario for emergency planning and response is the Emergency Plans Act. The Ontario Nuclear Emergency Plan (Government of Ontario 1986) has been developed under this Act by the Ontario Government, Ontario Hydro and municipalities where nuclear facilities are located. The plan provides the basis upon which nuclear emergency planning, preparation and implementation are undertaken to safeguard the health, safety and well-being of Ontario residents, and to protect their property.

The UFDC would be subject to such a plan and would make use of any provincial or federal emergency response infrastructure present at the time of implementation.

2. UFDC Emergency Response Plan

A UFDC Emergency Response Plan would be set up for both radiological and non-radiological emergencies which might arise during development and operation of the disposal facility. The plan and its procedures for public notification would be developed in consultation with the local community.

Such a plan would provide the earliest possible response to an emergency, and thereby minimize its effects on the employees, the public, the site and the environment, as well as the costs of restoring the facility to its normal state.

A number of details in the Ontario Nuclear Emergency Plan, described below, would be incorporated in the UFDC Plan.

Planning Zones

For emergency response planning, the area around a nuclear facility is divided into zones. The purpose of establishing zones is to mitigate possible effects on humans of airborne radioactive releases. The approximate sizes of the zones for the designated nuclear facilities in Ontario are as follows:

Contiguous Zone	-	3 km radius
Primary Zone	-	10 km radius (includes Contiguous Zone)
Secondary Zone	-	50 km radius (includes Primary Zone)

A higher level of emergency planning is required for the area within the Contiguous Zone, compared to the outlying area, due to its proximity to the potential hazard.

The Primary Zone is the area around a nuclear facility within which planning and precautionary measures, including evacuation, are taken against exposure to the atmospheric plume. It is expected that this zone would be much smaller for the UFDC than for nuclear reactors because no nuclear reaction would occur at the disposal facility.

The Secondary Zone is a larger zone within which planning and precautionary measures are taken against exposure from ingestion of radioactivity and exposure to the plume.

Protective Action Levels

Protective Action Levels (PALs) are used as aids in decision-making and planning in an emergency. These are expressed in terms of projected radiation doses and provide guidance on whether there is a need to take special protective measures and, if so, what type of measure should be taken.

The specific Protective Action Levels to be used in Ontario are contained in Table 2-11 (Government of Ontario 1986).

There are two guideline levels of projected radiation doses, an upper and lower. Below the lower level, protective measures are not justified. Between the lower and upper levels, protective measures are required, unless valid reasons exist for deferring action. At or above the upper level, protective measures are implemented unless this action presents greater risk to the people involved.

TABLE 2-11
Ontario Protective Action Levels (PALs)

Measure	Lower Level		Upper Level	
	Effective	Thyroid	Effective	Thyroid
Sheltering	1 mSv	3 mSv	10 mSv	30 mSv
Evacuation	10 mSv	30 mSv	100 mSv	300 mSv
Thyroid Blocking	--	30 mSv	--	300 mSv
Banning Food/Water Consumption	0.5 mSv	1.5 mSv	5 mSv	15 mSv

Note: These PALs are expressed in terms of the highest projected dose likely to be received by the most exposed individual in the relevant critical group.

Emergency Worker Safety Guidelines

A system for ensuring the safety of the emergency workers is required in an emergency response plan. Emergency worker safety guidelines involve a system of colour codes which provide an indication of the safety status of the sector within which emergency personnel are working. As well, one or more exposure control centres would be set up to monitor the radiation exposure levels of workers, provide personal monitoring devices and protective equipment, and decontaminate personnel, if necessary.

Phases of Operation

There are two phases of operation in a nuclear emergency following an accident involving release of radioactivity. Phase 1 is the emergency phase, requiring urgent action involving plume exposure control, ingestion control and restoration. Phase 1 ends when the nuclear facility is in safe shutdown condition and systems exist to prevent further uncontrolled emissions.

The follow-up phase, Phase 2, is the ingestion control and restoration phase (the purpose of restoration is to restore conditions to normal after a nuclear emergency). At this time, the long term potential effects of the emission are assessed and clean-up initiated, and any health protection measures taken as required.

Emergency Management Organization

As stated in the Ontario Nuclear Emergency Plan, a nuclear facility must notify provincial and municipal authorities of the existence of an off-site emergency as soon as possible. When this occurs, a provincial operations centre (OpsCentre) is set up to take over operational control and direct activities. The OpsCentre controls all operations in Phase 1, and becomes the focal point of coordinating actions to deal with the emergency.

The overall organization of the emergency management system is illustrated in Figure 2-17 (Government of Ontario 1986). If designated, the Solicitor General would exercise the emergency powers of the Premier, and would provide overall control and direction to emergency management operation. Other agencies which have roles set out in the Ontario Nuclear Emergency Plan are as follows:

i) Ministry of Agriculture and Food
ii) Ministry of Community and Social Services
iii) Ministry of Environment and Energy
iv) Management Board of Cabinet (formerly Ministry of Government Services)
v) Ministry of Health
vi) Ministry of Housing
vii) Ministry of Labour
viii) Ministry of Municipal Affairs
ix) Ministry of Natural Resources
x) Ministry of the Solicitor General
xi) Ministry of Transportation and Communications
xii) Director of Emergency Information
xiii) Atomic Energy of Canada Ltd.
xiv) Ontario Hydro
xv) Designated Municipalities
xvi) Atomic Energy Control Board
xvii) Emergency Preparedness Canada (EPC)
xviii) Health and Welfare Canada

3. Underground Rescue Plan

The underground rescue plan would be organized in a way similar to conventional mine rescue plans.

Selection of mine rescue team members would be consistent with the qualifications outlined by the Ministry of Labour (1984) in the "Handbook of Training in Mine Rescue Operations".

All mine rescue teams would have knowledge of the following:

i) the object of rescue and recovery work;

ii) the constituents and properties of normal air and gases which may be encountered in abnormal circumstances in mines;

iii) methods of detecting these gases;

iv) methods of protection of persons travelling in atmospheres contaminated by noxious gases;

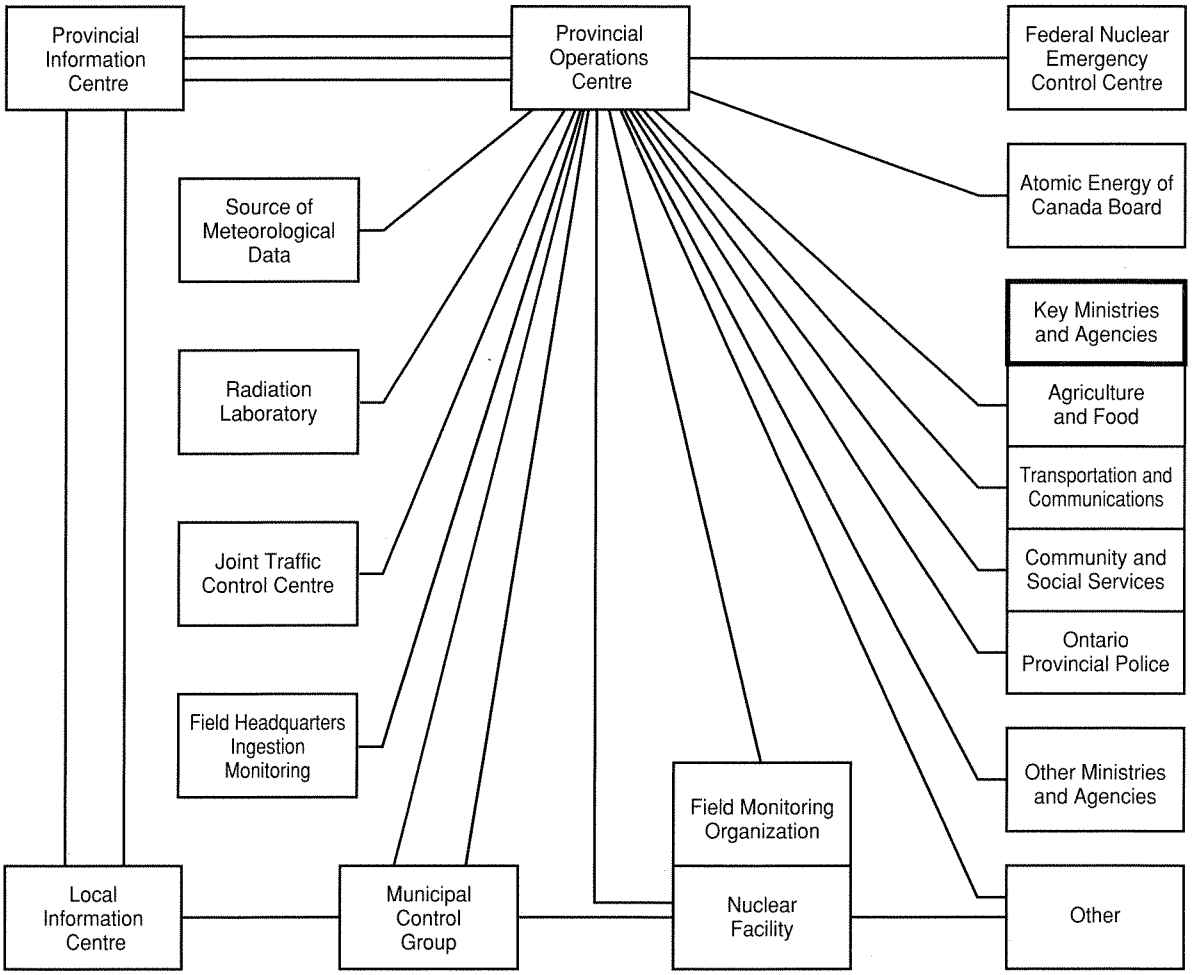


FIGURE 2-17: Overall Organization of Emergency Management System

v) a preliminary training period in the actual wearing of the protective devices; and

vi) in addition, all rescuers, both surface and underground, would be trained to deal with accidents involving radioactive material and contamination.

Mine rescue drills would be part of the fire drill (Ministry of Labour 1984).

2.2 REFERENCE DESIGN FOR A USED FUEL TRANSPORTATION SYSTEM

A reference transportation system has been developed by Ontario Hydro for road, rail and water transportation of used nuclear fuel from the storage sites (the nuclear generating stations) to a disposal centre (Ulster 1993a). Air transportation is not considered feasible for a number of reasons, including: absence of air access provisions both at nuclear generating stations and the UFDC, and costs and problems related to the concentrated weight of the transport cask (see following sections for weight specifications).

The three transportation modes were considered equally in the reference design. Public consultation on used fuel transportation gave no clear indication that the public preferred a particular mode (Decima Research Ltd. 1985; Pieroni 1981, 1986) (see Appendix A for a summary of the public views).

The reference used fuel to be transported is 10-year-cooled CANDU used fuel.

The reference transportation system was designed to transport 180 000 bundles of used fuel per year from Ontario Hydro's nuclear generating stations. This capacity was selected because it is the amount that could be handled annually at Ontario Hydro's used fuel storage facilities with the current pool design. A transportation season of 231 days was assumed for transport by water, and 275 days for transport by road or rail. The length of the transportation season was based on external constraints such as weather conditions and vehicle breakdown. Data and analyses presented in Sections 7.1 - 7.7 assume this transportation capacity.

However, the UFDC was designed for a larger annual capacity, 250 000 bundles per year, to provide for disposal of fuel from Quebec and New Brunswick, and from a possible future 600 MW reactor outside Ontario. The UFDC design also assumed a different length of operating season, 230 days. The reason for these differences is that the designs of the transportation and UFDC systems were developed independently, by Ontario Hydro (Ulster 1993) and AECL (Simmons and Baumgartner 1994), respectively. Both designs were based on total disposal of about ten million bundles. Section 7.8 presents a generic analysis of potential effects of transporting used fuel from provinces other than Ontario. Finally, Section 7.9 presents an analysis of potential effects of transporting the total 250,000 bundles per year, extrapolated from the analyses in Sections 7.1 - 7.7 and 7.8.

At the implementation stage, the designs of the UFDC and the transportation system would be fully integrated. If necessary, surge-storage pools at the UFDC would temporarily store fuel that could not be packaged immediately for emplacement underground in the vault.

The technology for used fuel transportation can be separated into two components: the transportation package (cask) and the transporter (tractor-trailer, locomotive-railcar, tug-barge).

The design of the transportation package is based on certified technology and is regulated by the AECB through the Transport Packaging of Radioactive Materials (TPRM) regulations (AECB 1991b). Development of the Ontario Hydro

demonstration cask is discussed below (in Section 2.2.1). To date, Ontario Hydro has designed a demonstration transportation cask, known as the Irradiated Fuel Cask (IFC) (Ontario Hydro 1986), which, in 1987 was granted a design approval certificate by the AECB. One full-scale demonstration cask has been manufactured. Although it could be transported by any mode, this cask was designed such that its weight would allow transportation by road in Ontario. A larger cask design has also been developed to the conceptual stage for rail transportation, based on similar technology.

The TPRM regulations cover external radiation levels, allowable external surface contamination, leakage of radioactivity in normal conditions, and retention of shielding capability and containment of radioactive material in severe accident conditions. These regulations are intended to reduce the hazards to transport workers and the general public to a safe level. The technology for the "transporter" component of a used fuel transportation system is also well established. Ontario Hydro has developed three transporter concepts for road, rail and water. They are intended to be safe and workable, but have not yet been optimized. Together with the cask designs, they provide a realistic reference design for this assessment.

2.2.1 Transportation Cask Design

The design of the Ontario Hydro demonstration cask (full scale and licensed) was based on the following criteria:

i) the cask must be licensable as a type B(U) package under the AECB Transport Packaging of Radioactive Materials (TPRM) Regulations;

ii) the cask must be easily transportable (e.g. no special permit required for travelling on the highway) (i.e. weight would be limited);

iii) loading and unloading of used fuel must be easily accomplished; and

iv) occupational doses for the operation must be kept as low as reasonably achievable.

In addition, the public was consulted to allow incorporation of public concerns into the design and testing criteria. Focus groups suggested that the following features would be desirable in a used fuel transportation cask design (Pieroni 1984; Ontario Hydro 1984d):

i) a large margin of safety must exist between operating conditions and cask design requirements;

ii) occupational dose levels should be reduced closer to the dose limit for the general public; and

iii) strict enforcement of the regulations should be emphasized.

The selection of cask shape, material and manufacturing techniques was based on thorough analysis and testing. A rectangular monolith made of stainless steel with a capacity of 192 bundles of 10-year-cooled fuel, was selected.

The demonstration cask was designed to withstand extreme Canadian weather, including a temperature range between -40°C to 40°C. It is equipped with a weather cover, and was designed to withstand the effects of rain, snow, ice formation and the spray of saline solutions under winter driving conditions. Consideration has also been given to the effects of freezing of any intended or residual liquid contents of the cask, and of water that may become trapped in any component of the cask, cask closure system or cask body.

The demonstration cask has been designed to be wet loaded in a nuclear fuel bay at the generating station, drained, transferred by tractor-trailer, barge or railcar, and unloaded in a dry cell at the disposal centre. In order to protect both the workers and the public, the demonstration cask design and all cask operations are based on the ALARA principle of dose control. The demonstration cask has been designed to a dose limit of 0.1 $mSv \cdot h^{-1}$ at a distance of one metre from the cask, equivalent to a contact dose of around 0.2 $mSv \cdot h^{-1}$.

In order to facilitate lifting, the demonstration cask has been designed with two lifting trunnions. The lifting trunnions are essentially two hollow, capped cylinders, which project from opposite sides of the cask. Each trunnion is attached to the side of the cask by six bolts. Vertical motion of the trunnion is restricted by a shear disk. The trunnion has been designed to withstand at least three times the weight of the cask.

The demonstration cask will always be lifted and transferred using a specially designed lifting beam. The lifting beam consists of a rigid welded structural steel frame with recessed slots on the inside of the lifting arms to engage the cask trunnions. The lifting beam can be used to lift the loaded cask with or without the impact limiter which is made of redwood encased in stainless steel and acts as a shock absorber upon impact. Lifting beams are kept at each nuclear generating station and at the UFDC, as well as with the emergency response team.

As a safety precaution, the cask has been designed so that there are no other features besides the trunnions that could be used for lifting.

Prior to transportation, the cask is fastened to either the trailer, railcar or barge cargo hold with a specially designed tiedown system. The tiedown system has been designed to restrain the cask during normal acceleration conditions expected to occur during transportation. In the event of a severe accident, the tiedown system is designed to release the cask without affecting the cask's shielding or containment integrity.

During road transportation, the transportation package will be subject to normal vibrations as a result of bumps, pot-holes and uneven surfaces on the road. Although vibrations are a catalyst for fatigue, it is not anticipated that the containment would ever weaken. This is because of the size and strength of the package. Since the cask lid bolts are weaker than the cask, the bolts could be identified as the critical component of the entire cask. To prevent any weakening of the bolts, they are subject to a strict inspection program and replaced at regular intervals. The inspection program also includes the cask seals and seal surfaces. The seals are replaced annually. In addition, in order to maintain cask integrity, the cask surface is continuously inspected for corrosion and other damage. In the event of a severe transportation accident resulting in any physical damage to the cask, the cask will be taken out of service permanently.

2.2.1.1 Selection of Cask Material

The selection of material is based on shielding, structural and weight requirements, availability and cost. Based on shielding requirements, the demonstration cask uses approximately 260 mm thick stainless steel. Other cask designs use materials such as depleted uranium, or a combination of steel plus lead or depleted uranium. The density of the material governs the thickness required for the necessary radiation shielding.

Monolithic stainless steel was chosen for the cask construction rather than ferritic grade steels and cast iron because of its resistance to brittle fracture at low temperatures. Stainless steel is also readily available, is suitable for a cask of this size and is easier to decontaminate than most

metals. The cost associated with the monolithic stainless steel design is comparable to that of a laminated design (e.g. a combination of steel and lead). Both Japan Steel Ltd. and Kobe Steel have manufactured stainless steel casks similar in size and thickness to the Ontario Hydro cask design.

Stainless steel has a high melting point and it retains its shielding capacity in a 30 minute 800°C regulatory fire test. It also retains its toughness at low temperature and is, therefore, less susceptible to brittle fracture. Although the stainless steel cask is bulkier than an equivalent lead/steel cask, its total weight is only marginally greater, and it meets weight restrictions for travel on Canadian highways. Stainless steel is also less susceptible to corrosion than other materials. In terms of material costs, stainless steel is more expensive than ferritic steel. However, this is offset by the cost of (1) the high alloy ferritic steels needed to provide the low temperature material properties, (2) post-forge and/or post-weld heat treatment of ferritic steels needed to provide the required material properties, and (3) cladding the ferritic steel cask with stainless steel to provide a surface that can be adequately decontaminated.

The demonstration cask is licensed by the AECB to be constructed as either a one-piece casting, a single forging or a welded fabrication. The single forging method was chosen for the demonstration cask to show manufacturing capabilities. There are sufficient examples of one piece casks produced throughout the world to guarantee the supply.

Viton elastomeric o-rings were selected as seals for the lid, drain and vent openings. 'Viton' has been used in most cask designs throughout the world since it withstands a wide temperature range, is resistant to radiation and has low permeation leakage.

2.2.1.2 Selection of Cask Loading Method

The demonstration cask has been designed to be wet loaded in a nuclear fuel bay at the generating station. Wet loading has been chosen instead of dry loading for the following reasons:

1. existing nuclear generating stations have facilities suitable for wet loading only (Darlington NGS is the only station that can accommodate wet and dry loading); and

2. with wet loading, it is simpler and less costly to minimize exposure to workers.

2.2.1.3 Comparison with International Cask Designs

There are a number of similarities between Ontario Hydro's demonstration cask and other casks throughout the world (Table 2-12). First, all casks which transport high-level radioactive material must obtain a type 'B' licence and are, therefore, required to pass the same internationally recognized regulatory tests. In terms of appearance, the majority of casks have impact limiters (or shock absorbers) to protect the lid bolts during impact and to protect the lid seals in a fire. They also have 'Viton' elastomeric seals with a double seal arrangement, because of its strong performance over a wide temperature range. Most casks also have bolted lids and have a trunnion on each side of the cask to facilitate handling.

Ontario Hydro's cask has a simpler design than most other casks. It is manufactured out of one material only - stainless steel. It is rectangular, has no fins, and does not have to be vacuum-dried prior to shipping. The reason for the simple design is primarily due to the type of fuel being shipped and its age. A large number of utilities throughout the world use PWR (Pressurized Water Reactor) or BWR (Boiling Water Reactor) fuel, both of which

TABLE 2-12
Comparison of Type 'B' Packages[1]

Type 'B' Cask	Dimensions	Weight Loaded	Capacity & Fuel Characteristics	Construction and other Features
Ontario Hydro Irradiated Fuel Transportation Cask (Canadian Design)	rectangular 2.2 x 1.6 x 1.9 m	35 Mg	192 CANDU bundles each 0.5 m long, 0.1 m diameter, minimum 10-year cooled	forged monolithic stainless steel, impact limiter - redwood in stainless steel, 'Viton' elastomeric O-rings, 2 lifting trunnions, transport dry, no fins
British Nuclear Fuel Limited (BNFL) Excellox 6 (British Design)	cylindrical 6.1 m long 2.1 m diameter	97 Mg	Pressurized Water Reactors (PWR) & Boiling Water Reactors (BWR) each 5 m long, minimum 1-year cooled	monolithic stainless steel, forged lid, transport wet, fins.
BNFL Excellox 7 (British Design)	cylindrical 5.6 m long 2.1 m diameter	89 Mg	PWR & BWR each 4.5 m long, minimum 1-year cooled	monolithic, transport wet, fins.
Magnox Mk 2c (British Design)	rectangular 2.6 x 2.2 x 1.9 m	47 Mg	200 Magnox fuel elements each 0.9 m long	forged, load wet or dry, transport wet, fins.
Ontario Hydro Flask NOD-F1 (Canadian Design)	rectangular 1.8 x 0.9 x 0.9 m	14 Mg	2 CANDU fuel bundles each bundle < 350 watts	laminated steel rectangular plate, welded into a cuboid, Zircaloy inner sheath liner.
AGR A1 (British Design)	rectangular 2.7 x 2.3 x 2.0 m	54 Mg	20 AGR fuel elements each 1.0 m long	steel body, lead shielding liner, clad in stainless steel, shock absorber, fins, lid: double O-ring.
AGR A2 (British Design)	rectangular 2.6 x 2.2 x 2.3 m	53 Mg	15 AGR fuel elements each 1.0 m long	single carbon steel forging, shock absorber, fins welded on, purge valve.
MOX PWR & MOX BWR (British Design)	cylindrical 5.5 m long 1.3 m diam		2 to 6 LWR fuel elements	stainless steel, silicon rubber neutron shielding, shock absorber, internal fins.
HZ-75T (Japanese Design)	cylindrical 5.9 m long 2.3 m diam	74 Mg	7 PWR or 17 BWR elements PWR: 4.2 m long, 120 days cooling BWR: 4.5 m long 120 days cooling	stainless steel, neutron shielding, shock absorber, fins, lead shield.
TN-Gemini (Transnuclear Design-United States/France/Germany)	cylindrical 3.0 m long 2.7 m diam	16 Mg		2 stainless steel concentric ring circular cylinders, bolting and double O-ring.

continued...

TABLE 2-12 (concluded)

Type 'B' Cask	Dimensions	Weight Loaded	Capacity & Fuel Characteristics	Construction and other Features
MONJU (Japanese Design)	5.5 m long 1.6 m diam	41 Mg	1 to 3 Fast Breeder Reactor fuel elements	single forged stainless steel, lead liner, shock absorbers, fins, transport wet.
TN-24 (Transnuclear Design-United States/France/Germany)	cylindrical 6.0 - 6.4 m long 2.2-2.5 m diam	93-103 Mg	24-32 PWR assemblies 52-68 BWR assemblies 5 years cooling	forged carbon steel containment vessel, welded bottom, flanged and bolted top lid, polyester resin for neutron shielding, 4 trunnions.

Used for transportation of used fuel. Note that since all designs are based on international (IAEA) standards, they can be used anywhere in the world.

are light water reactor fuel. This type of fuel is much hotter (mainly because of the higher burnup and shorter cooling time), more enriched with ^{235}U, and each element is almost eight times the length of a CANDU fuel bundle.

No fins are required for heat dissipation, because CANDU fuel is much cooler than used fuel from Light Water Reactors. This feature facilitates decontamination, and makes the cask cheaper to manufacture. Also, because CANDU fuel is cooler, the cask does not have to be purged of air in order to prevent fuel oxidation.

Because Ontario Hydro's CANDU fuel is 0.5 metres in length, as compared to most reactor fuel types which are between 4 and 5 metres in length, there are more options when selecting the shape of the cask. The length of the fuel and the rectangular shape of the modules (96 bundles per module) with approximately equal height and depth, resulted in the choice of a cubic shaped cask, 2 modules per cask. If a cylindrical cask (with equal height and diameter) was used, an internal rectangular framework would have been required to prevent movement of the rectangular payload. This would have increased the cask weight and manufacturing costs. Heat dissipation, performance in a regulatory fire test and resistance to impact are insensitive to whether a cask with approximately equal height and depth is rectangular versus cylindrical in shape. Most international casks are rectangular or cylindrical, and are long and narrow. This is because PWR and BWR fuels are much longer. The Magnox cask (U.K.) is similar in appearance to Ontario Hydro's demonstration cask. Because the fuel used in a Magnox reactor is short (1 metre in length), the Magnox cask is cubic in shape.

Weight played a major role in the design of the demonstration cask. Most casks throughout the world have a weight between 45 and 90 Mg, whereas the demonstration cask weighs only 35 Mg. The demonstration cask is much lighter than the other casks because it was a design objective that used fuel be transportable on Ontario Class-A highways without a special axle load or weight permit.

2.2.1.4 Cask Quality Control

A quality control program would need to be instituted for the design and large scale manufacturing of transportation casks and systems. It is assumed that such a program would be similar to the quality control program that was applied to the design and manufacturing of the Ontario Hydro demonstration cask described here. A summary of the details of such a program can be found in Appendix I.

2.2.1.5 Cask Maintenance

The maintenance program for any transportation cask would be similar to that specified in order to obtain a licence for the demonstration cask. There are three types of maintenance: on-going, annual and 5 year maintenance. On-going maintenance would include visual inspection of the cask and seals after each use. Prior to each shipment, the cask lid seal and orifice interspaces would be pressurized to a specific level. The pressure would be monitored at 3 points. If the pressure fell beyond the limits, the bolts and plugs would be checked for tightness. If after a second pressure test, the pressure again fell below the limit, the seals would be checked and replaced, if necessary.

All seals would be replaced annually. Also on an annual basis, the cask would be helium-leak tested at all penetrations. In addition, there would be an annual inspection program, where components would be replaced if needed. The inspection would include the bolt threads, cover plate threads, vent and drain plug, trunnions, impact limiter and bolts, and threaded bolt holes in the cask body. The cask surface finish would also be inspected and polished when necessary (to facilitate decontamination).

In addition to both the on-going and annual maintenance programs, a dye penetration test would be performed on the lid bolts (ASTM 1980).

The 275 day operating season for the road and rail mode allows for 25% down-time. This would include annual and 5-year maintenance programs for the cask, as well as on-going maintenance for the tractor/trailer or dedicated rail car. In addition, it is possible that support equipment, such as cranes at the station, may require maintenance. In the case of road transportation, the down-time would also include times when the weather made it unsafe for travel. Weather is not expected to significantly affect the rail system.

The logistics for the water mode are based on a 231 day shipping season. The shipping season covers the period from the last week of April to the first week of December. This may be extended depending on weather conditions. There is not the same degree of down-time included in the shipping schedule as there is for road and rail, since most ship maintenance would be done in the off-season. However, there is still the possibility of minor maintenance throughout the shipping season.

2.2.1.6 Other Considerations

The demonstration cask has not been chosen as the final design for transportation of used fuel to a Used Fuel Disposal Centre. Details of the design may change when a transportation system has been specified in detail. In addition, as design and testing programs continue, alternative options for cask design are being explored (see Section 2.4 on foreseeable development in the conceptual designs).

2.2.2 Experience with Transportation of Radioactive Materials and Cask Design and Testing

2.2.2.1 Transportation Experience

Based on data provided to the IAEA, 20 to 40 million packages of radioactive material are shipped annually worldwide (Pope and McClure 1986). In 1981, over 4 million shipments of radioactive material were made in Canada; however, 86% of these were shipments of exempt packages, that is, they contained only very small amounts of radioactive material. Only 1.8%, or about 80 000 shipments, were type B packages.

Used fuel, mainly from research reactors, has been transported safely in Canada since the late 1940s. Ontario Hydro has been involved in shipments of used fuel, tritiated water, and reactor wastes since 1964. Over 1 000 shipments of these types are made each year. Historically, about 20 of these have been shipments of used fuel for examination or storage. Three types of casks of capacities 2, 25 and 72 bundles each, have been used for this purpose. With the shutdown of the NPD reactor, only a few (1-4) shipments of used fuel are now made each year.

Extensive experience with the transportation of used fuel has been gained outside Canada, particularly in those countries that have chosen reprocessing as a preferred route for management of used fuel. In the United Kingdom, more than 10 000 safe shipments of used fuel by road and rail were made over 20 years, up to the early 1980s (Mummery 1985). A comparable volume of used fuel was shipped in France: approximately 4 000 casks were transported to reprocessing plants, mainly by rail and sea, in the years 1966-1985 (Lenail and Curtis 1986). Used fuel has also been shipped by sea from Japan to both the U.K. and France (Spink 1983). In the U.S.A., an average of 291 shipments per year were made between 1964 and 1984 (Jefferson 1985). Approximately 90% of all shipments were made by truck, and the remainder by rail.

There has been no transportation accident world-wide involving used fuel in which people were injured or property damaged as a result of the radioactive nature of the fuel (Lenail and Curtis 1986). The accidents and incidents that have occurred were ones in which there was no damage to the cask, and where detected contamination of external surfaces of casks was due to wet loading in fuel bays rather than release from the cask (Emerson 1983; Gelder et al. 1986). In the U.S.A., Jefferson (1985) reports that of 50 Type B packages involved in accidents, none released any radioactive material.

For all radioactive material, the AECB reports 234 incidents over the period 1979 - 1990 (AECB 1991c). Of the 12 incidents in 1990-91, only one was significant, involving spread of carbon-14 contamination during road transportation from Mirabel airport to Ottawa. On a truck's arrival at an Ottawa terminal, it was discovered that an international shipment of radioactive carbon-14 powder had broken open during the road transport from Mirabel Airport in Quebec. Before the nature of the incident was fully realized, low-level contamination had been spread throughout the warehouse, involving 15 employees, vehicles and other goods. Some contamination was spread off-site. AECB inspectors responded quickly and verified clean-up. No significant health detriment is anticipated from this incident.

In 1989-90, the only significant event concerned contamination by uranium residues leaking from uranium hexafluoride cylinders. After off-loading, the contaminated equipment was isolated and later decontaminated with some effort. The problem was due to inadequate tie-downs on the heavy uranium hexafluoride cylinders. Corrective action has been taken to ensure that the situation will not be repeated.

None of the other events involved leakage from the package. Incidents typically concern events such as dose rates above the regulatory limits, loss of packages, transport accidents with no damage to the package, and minor damage to package with or without a small release of contents. They are reported every year by the AECB in their annual report (AECB 1992).

Ontario Hydro Experience

Figure 2-18 illustrates Ontario Hydro's experience in transporting radioactive materials from 1969 to 1990. Although Ontario Hydro experience dates from 1964, there is insufficient data during the years 1964 to 1968. There were three accidents involving shipments of radioactive material, one each in the years of 1976, 1977 and 1979. All of these involved "strong industrial containers", a type of package used for low-activity material of less integrity than the Type A or B packages. Although there was severe damage to the vehicles involved, in no case was there any release of radioactive contents.

Over the period 1964 to 1990, the accident rate (i.e. the number of accidents per 1 000 000 km travelled), was 0.82. The highest annual shipment over this time period was in 1990, with about 1 500 shipments over a distance 266 000 kilometres.

2.2.2.2 Cask Design and Testing Experience

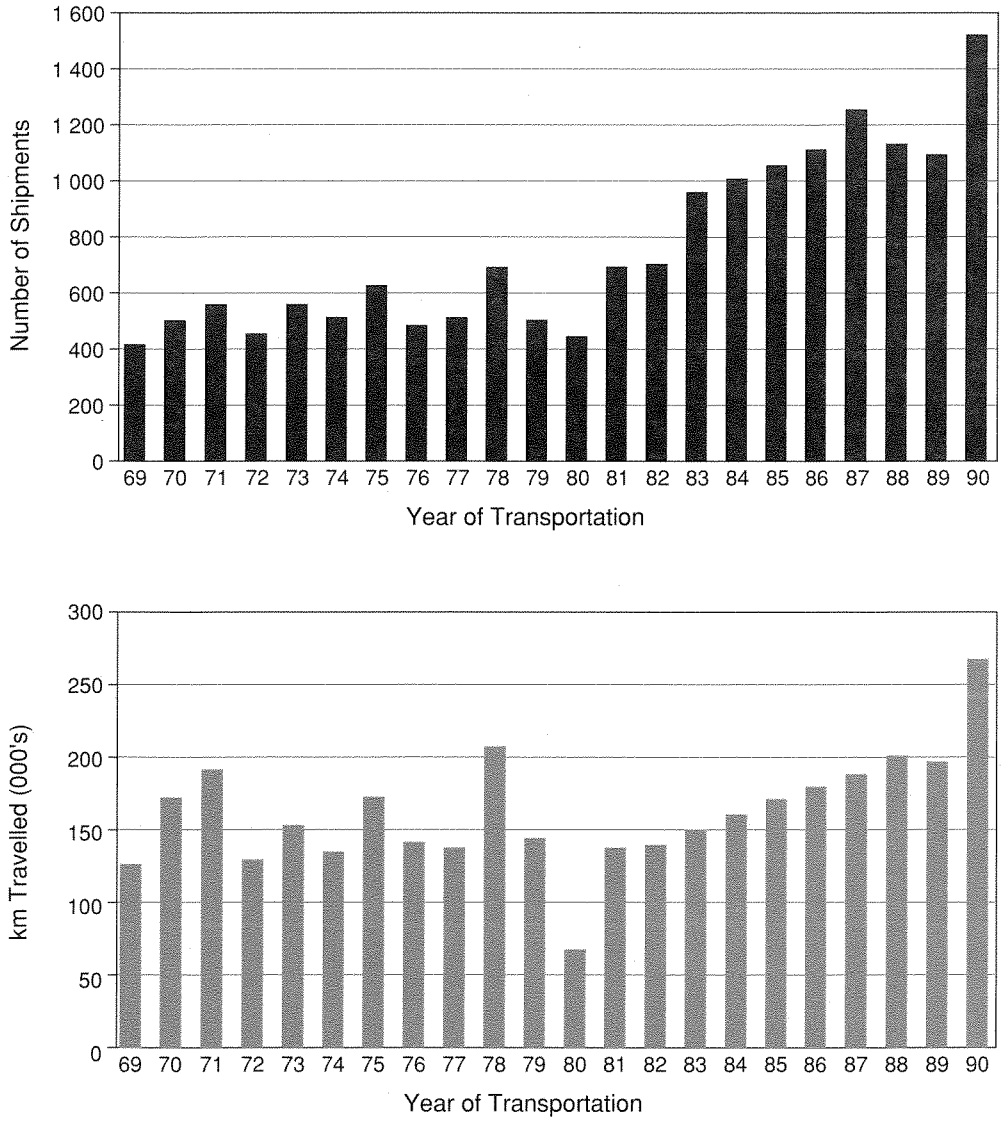
Impact tests were carried out on an empty half-scale model of the demonstration cask at AECL's Chalk River Laboratories in 1986 (Ontario Hydro 1986) to demonstrate compliance with the Transport Packaging of Radioactive Materials regulations (see Figure 2-19) (see Appendix B for a description of the AECB test conditions). Public opinion was sought on the use of a half-scale model for cask testing. Results of a public opinion survey (Decima Research Limited 1985) showed that 82% of the respondents would find the knowledge that a half-scale replica of the cask has successfully passed the regulatory test convincing evidence about the safety of the full-scale cask. This indicated public acceptance of using scale models for testing. Public opinion was also sought on the actual tests carried out with the cask (Pieroni 1981). A summary of the public input on cask design and testing can be found in Appendix A.

Four separate 9-metre drops and two separate 1-metre drops onto a steel bar (puncture test) were carried out in different orientations to ensure maximum damage. The 9-metre drops were onto an unyielding steel plate mounted on concrete. The cask was checked for any pressure drop during the test, and the leakage through the seal was measured using sensitive helium leak testing equipment. The leak rate was within the allowable limits in all measurements.

Damage to the cask during the tests was minimal. The only loss of shielding was a small deformation of one corner of the cask. The impact limiter remained attached. In a top corner drop, the steel sheathing of the impact limiter was torn; however, the loss of thermal protection (normally provided by the impact limiter) was not significant.

The thermal response of the cask was simulated using a finite-difference computer code developed by Ontario Hydro (Ontario Hydro 1986) and validated against full-scale thermal testing. The temperature distribution throughout the cask was shown to be well within acceptable limits for normal operation, and to have a large margin of safety for the regulatory accident conditions.

A number of test programs were carried out in addition to those required for the design approval certificate (Ribbans 1988). These included shock and vibration tests to verify the structural stability of the fuel in normal transportation conditions, investigation of oxidation and fission product



Notes: (1) Includes all Ontario Hydro shipments of radioactive materials within Ontario, and shipments of used fuel to AECL Research, Whiteshell Laboratories, Pinawa, Manitoba.
(2) Estimated values from 1983 to 1986 were obtained by interpolating within available data.

FIGURE 2-18: Transportation of Radioactive Materials, Ontario Hydro Experience, 1969 to 1990

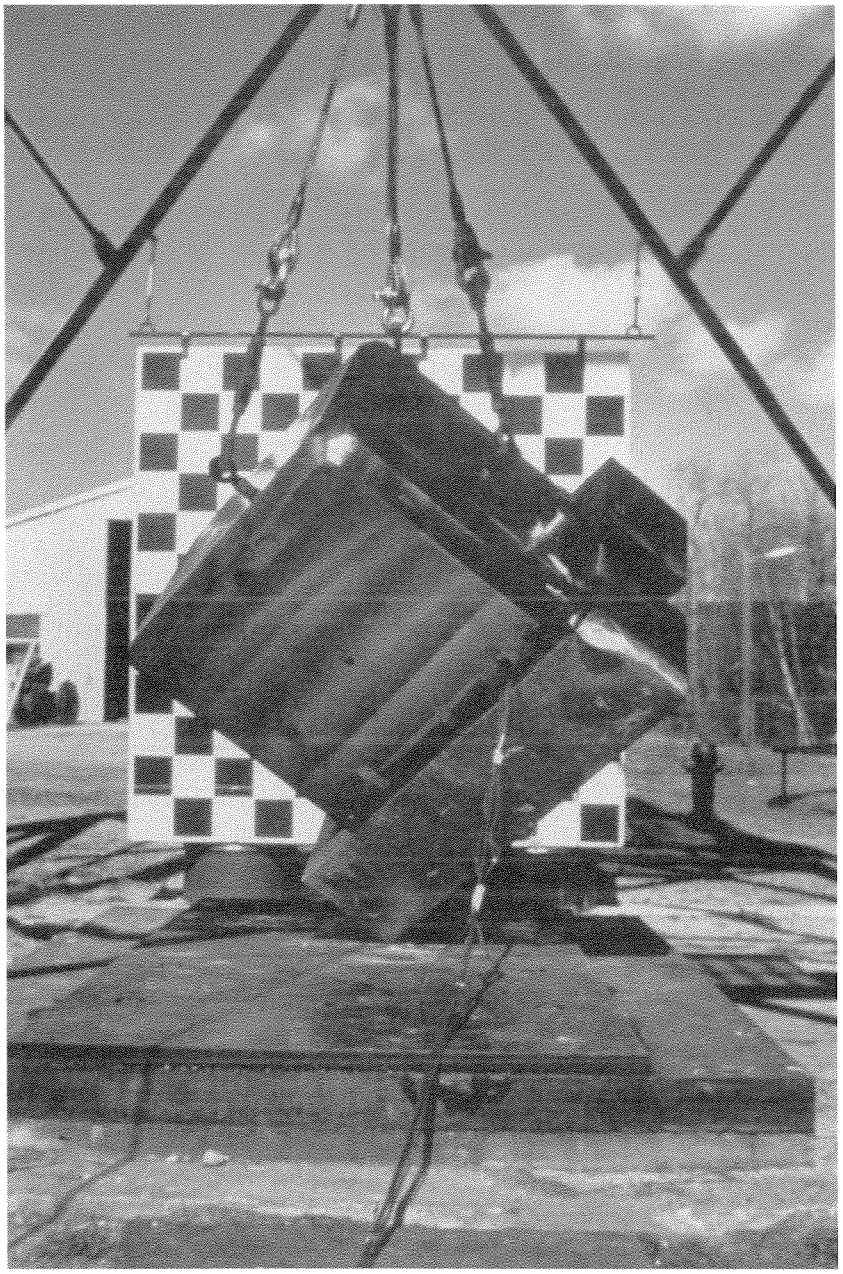


FIGURE 2-19: Cask Drop Test Facility

release in normal and accident conditions, seal performance tests at high and low temperatures, and impact limiter material performance tests. After obtaining the design approval certificate for the road cask, 'extended' fire testing was carried out using the half-scale cask model (Taralis and Morandin 1988). The test showed that the cask seals remained intact in a one hour fire at the 800°C temperature specified for the regulatory thermal test.

An impact test was carried out on a one-seventh model of the cask. This non-regulatory test showed that the cask would remain intact in a high-speed impact with a locomotive (reported in Kempe 1993a). The locomotive and coupler were modelled at one-to-seven scale. The cask model was dropped on guide wires onto the coupler. The speed, assisted by a solid-fuel rocket attached to a sled supporting the cask, reached 104 $km \cdot h^{-1}$ at impact. The locomotive model suffered extensive damage; however, the cask model was only superficially scarred and the bolts maintained their integrity. The AECB tests and the additional testing carried out demonstrate the high degree of safety provided by the demonstration cask design.

Major investigations of the behaviour of transport packages in "real" accident situations have also been carried out in the United States by Sandia National Laboratories, and in the United Kingdom by the Central Electricity Generating Board (Wilmot et al. 1980; Mummery 1985; Holt 1985; Hart et al. 1985a, 1985b). These programs demonstrated the adequacy of the regulations in preventing releases from transportation casks during real accident situations and the validity of scale model tests.

Although the 9-metre drop represents an impact speed of about 50 $km \cdot h^{-1}$, the impact target is specified as "essentially unyielding", which results in a very severe test with most of the impact energy being absorbed by the cask. In real-life situations, much of the impact energy is absorbed by damage to the target, for example, deformation of the other vehicle involved in vehicle-vehicle collisions, or cracking and disassembly of concrete or masonry in collisions with stationary objects.

2.2.3 Review of Used Fuel Transportation Systems Around the World

Used fuel transportation systems throughout the world have similar features since used fuel casks are governed by universal recommendations, such as those of the IAEA and IMO that were adopted by the countries' regulatory bodies. For example, as shown in Table 2-13a for water transportation of used fuel, most vessels have the following characteristics:

i) double bottom and double hull for protection during a collision;

ii) duplicate equipment, such as engines, propellers and electrical systems;

iii) radio beacons for salvage operations and satellite communication systems; and

iv) below deck cargo.

The differences in used fuel water transportation systems are primarily related to where the vessel is travelling and for what purpose. For example, used fuel water transportation in the United Kingdom and in Japan involves sea transportation by ship over long distances. On the other hand, Ontario Hydro's system involves transportation on lakes using an integrated tug/barge. Tug/barges have a better safety record than ships on the Great Lakes, are more versatile (unloading a barge while the tug picks up a second barge), and for the purposes of travel on lakes, tug/barges are less expensive than ships in terms of capital and operating costs.

For rail transportation (Table 2-13b), used fuel casks and transportation systems are quite similar. As discussed above, all casks are governed by the same international recommendations from the IAEA, so their designs are similar. Their designs are also similar because of common height constraints on various rail lines. In addition, most rail lines have similar weight restrictions. The most common rail car for transporting radioactive materials is a 100 Mg capacity 4 axle flat car. The car is usually modified for cask tie-downs. A major difference between Ontario Hydro's rail car and those in the U.S. is that some U.S. rail cars, such as the GE car, are equipped with cooling systems. This is because BWR and PWR fuel is much hotter than CANDU fuel.

Road transportation of used fuel is the most common mode and the one in which there is very little variation among individual transportation systems. The majority of road transportation systems use a standard tractor with a custom trailer (Table 2-13c). Modifications to the trailer include a tiedown system which holds the cask on the trailer, and modifications to the height at which the cask is off the ground. The latter modification is for trailer stability. As with rail transportation, the weight of the vehicle is restricted by law. This restriction plays an important role in cask design.

2.2.4 Reference System for Road Transportation

The road transportation system is at a more advanced design stage than the two other modes. Ontario Hydro demonstration cask received a design approval certificate from the AECB in July 1987 (see Section 2.2.1 for a detailed description of the cask design). Once the AECB design approval certificate is obtained, manufacturing of the cask can start. Transportation cask certificates have to be renewed every 5 years under current AECB regulations (AECB 1991a).

2.2.4.1 Hardware

The road transportation system consists of an engineered tractor/trailer cask system. The tractor/trailer would transport one cask per trip.

The road cask (the Ontario Hydro demonstration cask) is designed to transport 192 bundles weighing approximately 5 Mg (Ulster 1993a). The main cask body, illustrated in Figure 2-20 and 2-20A, is a rectangular monolithic stainless steel construction, forming a hollow rectangular shape with solid walls and base weighing approximately 28.3 Mg when empty. A lid containing an 'O'-ring-type double seal is bolted to the tops of the four walls to form a sealed enclosure. An impact limiter (weighing approximately 1.4 Mg) is fitted onto the upper end of the cask when it is ready for shipment. It is held in place by 8 bolts attached to the cask lid. This device, constructed of blocks of redwood encased in a steel sheath, provides impact protection and serves as thermal insulation to protect the seals between the cask lid and body under accident conditions. The redwood itself is protected from exposure to a fire during accident conditions by the sheathing. This sheathing has been shown to survive the regulatory accident conditions. In the event of severe heating, the redwood would char but not burn. The reference design specifies a cask life of 20 years.

The cask is to be transported on a flatbed trailer weighing approximately 10 Mg (Figure 2-21). The trailer has four axles, all with dual tires. A tiedown system (resisting both horizontal and vertical forces) firmly secures the cask to the trailer. The reference design assumes a trailer life of 8 years.

TABLE 2-13a
Comparison of Radioactive Transportation Systems
Water Transportation

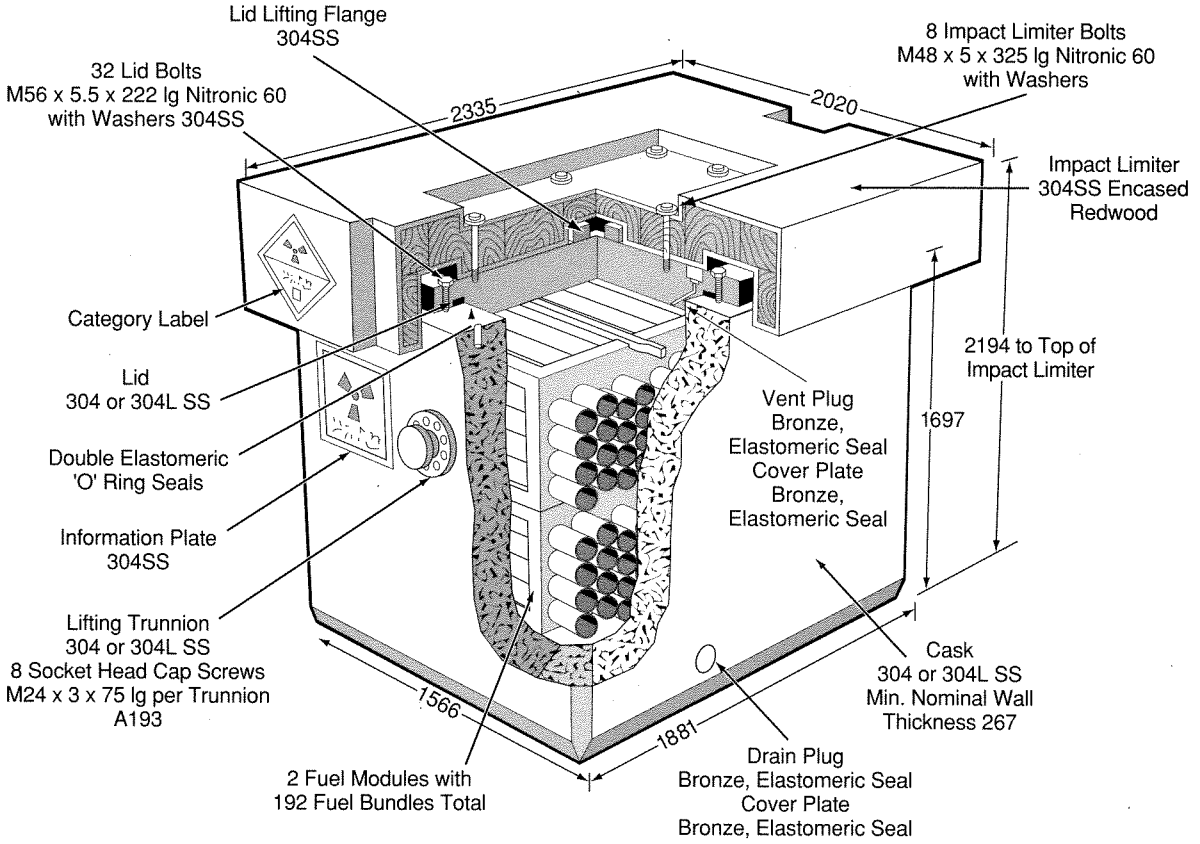
Owner/Operator	Type	Description	Experience	Regulations	Reference
Ontario Hydro (conceptual) (Canada)	Integrated Tug/Barge	- double bottom - ice-strengthened for medium ice conditions, Ice Class 1B - holds 36 road casks (192 fuel bundles each) or 12 rail casks (576 fuel bundles each) - four cargo holds - 13 person crew - system capital cost of 8.5 M$ (1987) per Tug/Barge - yearly operating/maintenance $772,458 per Tug/Barge (1987) - duplication of equipment	- conceptual stage - projected: 26 trips per year - a total of 938 road casks or 313 rail casks per year - 4500 Mg of used fuel per year	- design and construction must adhere to Transport Canada (Canadian Coast Guard) and St. Lawrence Seaway Authority - Atomic Energy Control Board - IMO Regulations	Ulster, 1993a; 1993b
Swedish Nuclear Fuel (SKB) (Sweden)	Ship - M/S Sigyn (Designed by Salen Technologies AB, Saltech)	- double bottom, double hull - ice breaking bow/ ice knives aft of the rudders, Ice Class 1A - machinery and electrical equipment duplicated - casks secured to deck of cargo hold - cargo driven on board - holds 10 TN MK2 casks (7 PWR or 1 BWR fuel assemblies), 80 Mg each, or 10 ILW containers (ion exchange resins) - satellite communications/navigation - 25 person crew - system capital cost of 40 M$ US (1983) - yearly operating/maintenance cost of 2.5 M$ US (1989)	- 30 trips per year - in operation since 1983 - 1000 Mg of irradiated fuel, 25,000m^3 of reactor waste - 111 Mg of fuel annually	- built to comply with Bureau Veritas and Lloyd's Register of Shipping - meets International Maritime Organisation (IMO) Regulations for type I Ship	Gustafsson 1989
British Nuclear Fuel Limited (BNFL) (Britain)	Ships: - Stream Fisher - Pool Fisher - Lever Fisher - Pacific Fisher - Pacific Sandpiper - Pacific Pintail	- Stream Fisher has capacity of 15 Mg U - Lever Fisher has capacity of 30 Mg U - Pacific Fisher has capacity of 45 Mg U - Pacific Sandpiper holds 8 Magnox flasks or 18 Oxide flasks (introduced into service in 1985) - 11 person crew - strengthened hulls and bulkheads - additional watertight subdivisions and bulkheads give reserve buoyancy - duplication of equipment: eg. rudders, engines, propellers, electrical - satellite navigation	- over 4,000 Mg of spent fuel - Italy to UK and Japan to UK - since 1969 - 174 Mg of used fuel annually		Elder 1983
Japan	Ship - Hinoura Mura	- double bottom, double hull - horizontal beams to absorb collision energy - cooling equipment to keep cask surface temperature below 82°C - shield water tanks around holds - capacity of 4 casks (Excellox-3A, HZ-75T, NH-25)	1978-1980: - 50 casks (121 Mg U of Fuel) - 90 Mg of fuel to be transported annually	- Ministry of Transport, Ship Bureau - "Regulations for Carriage and Storage of Dangerous Goods in Ships" - ship must harbour if wind speed is more than 23 m/s or wave height is greater than 4 m.	Keisuke 1980

TABLE 2-13b
Comparison of Radioactive Transportation Systems
Rail Transportation

Owner/Operator	Cask/car	Description	Experience	Regulations	Reference
Ontario Hydro (conceptual) (Canada)	Rail cask Standard car	- 4 axles, 100 ton standard flat car - loaded cask weight 82 Mg - rail car weight 29 Mg - gross vehicle weight 111 Mg - 1 Rail Cask per car - 300 HP locomotive - a caboose - four buffer cars, two to separate the occupied locomotive and caboose, respectively, from the cask cars - 4 person crew	- conceptual stage - projected: 31 trains per year with a total of 21 rail casks in system	Atomic Energy Control Board (Canada) Transport Canada	Ulster 1993a; 1993b
General Electric (United States)	IF-300 GE car	- IF-300 cask holds 7 PWR or 18 BWR fuel assemblies - loaded cask weight is 63.5 Mg - 100 tonne capacity, 4 axle rail car - flat car - slightly modified car - cooling system - gross vehicle weight is 120 Mg - rail car weight 34 Mg - capital cost is $ 4 mil (1978$)	- 9 BWR/9.3 PWR number of trips/reactor year - 4 casks in U.S.	United States Nuclear Regulatory Commission	Elder 1983
National Lead Industries Inc. (now owned by Nuclear Assurance Corporation) (United States)	NLI-10/24 NLI car	- NLI-10/24 cask holds 10 PWR or 24 BWR fuel assemblies - loaded cask weight is 91 Mg - rail car weight 59 Mg - gross vehicle weight is 160 Mg - specially designed rail car with cask tie-down arrangement built into car frame - capital cost is $ 4.4 mil (1978$)	- 6.7 BWR/6.5 PWR number of trips/reactor year - 2 casks in U.S.	United States Nuclear Regulatory Commission	Elder 1983.
Transnuclear (United States/Germany/France)	TN-12	- TN-12 cask holds 12 PWR or 32 BWR fuel assemblies - loaded cask weight is 105 Mg - gross vehicle weight is 147 Mg - capital cost is $ 5.5 mil (1978$)	- 5 BWR/5.5 PWR number of trips/reactor year	United States Nuclear Regulatory Commission	Elder 1983

TABLE 2-13c
Comparison of Radioactive Transportation Systems
Road Transportation

Owner/Operator	Cask/Vehicle	Description	Experience	Regulations	Reference
Ontario Hydro (Canada)	Demonstration Cask Tractor-Trailer	- 192 CANDU fuel bundles, 5 Mg - 35 Mg loaded cask - custom designed flatbed trailer, 10 Mg - 4 axles, dual tires - tiedown system - standard 3 axle tractor. 9 Mg	- demonstration purposes	Atomic Energy Control Board (Canada)	Ulster 1993a; 1993b
Ontario Hydro (Canada)	NOD-F1 Tractor-Trailer	- 2 CANDU fuel bundles, 44 kg - 14 Mg loaded cask - custom designed flatbed trailer - standard 3 axle tractor	- from 1987 - 1990 12 shipments (averaging 2175 km per year)	Atomic Energy Control Board (Canada)	Howe 1987
Commonwealth Edison (US) and other European companies (United States/Germany/France	TN-9 Tractor-Trailer	- 7 PWR fuel assemblies - 35 Mg loaded cask - custom designed flatbed trailer, 36 Mg - 3 axles - tiedown system - sliding tarpaulin enclosure - 3 or 4 axle tractor - 2 separate king-pin positions to adjust axle weight load distributions	- 400 Mg U of spent fuel in Europe	United States Nuclear Regulatory Commission	McCreery 1981
Germany	PWR Tractor-Trailer	- 2 PWR fuel assemblies - 6.6 Mg loaded cask - custom designed tractor-trailer - security features	- 70 shipments in Germany, 1 in Switzerland	PTB	Bergmann 1989
Swedish Nuclear Fuel (Sweden)	LWR Cask Special Vehicle	- LWR fuel assemblies - custom designed vehicle - vehicle and load 155 Mg - 7 axles, 26 wheels - hydraulically driven powered by diesel engine above ground and electric motor in tunnels - maximum above ground velocity of 10 $km \cdot h^{-1}$	- 150 casks per year	IAEA	Gustafsson 1989



Notes:
1. Empty Package Mass ..... 29 700 kg
   Mass of Fuel Bundles in Two Fuel Modules ..... 5 000 kg
   Total Loaded Weight ..... 34 700 kg
2. Minimum Cooling Time for Fuel ..... 10 Years
3. Reference Drawings ..... TRA 1 D5H 03700 0056
   TRA 1 D0H 03700 0057
   TRA 1 D5H 03700 0062
4. All Dimensions are in Millimetres

FIGURE 2-20: CANDU Used Fuel Road Cask

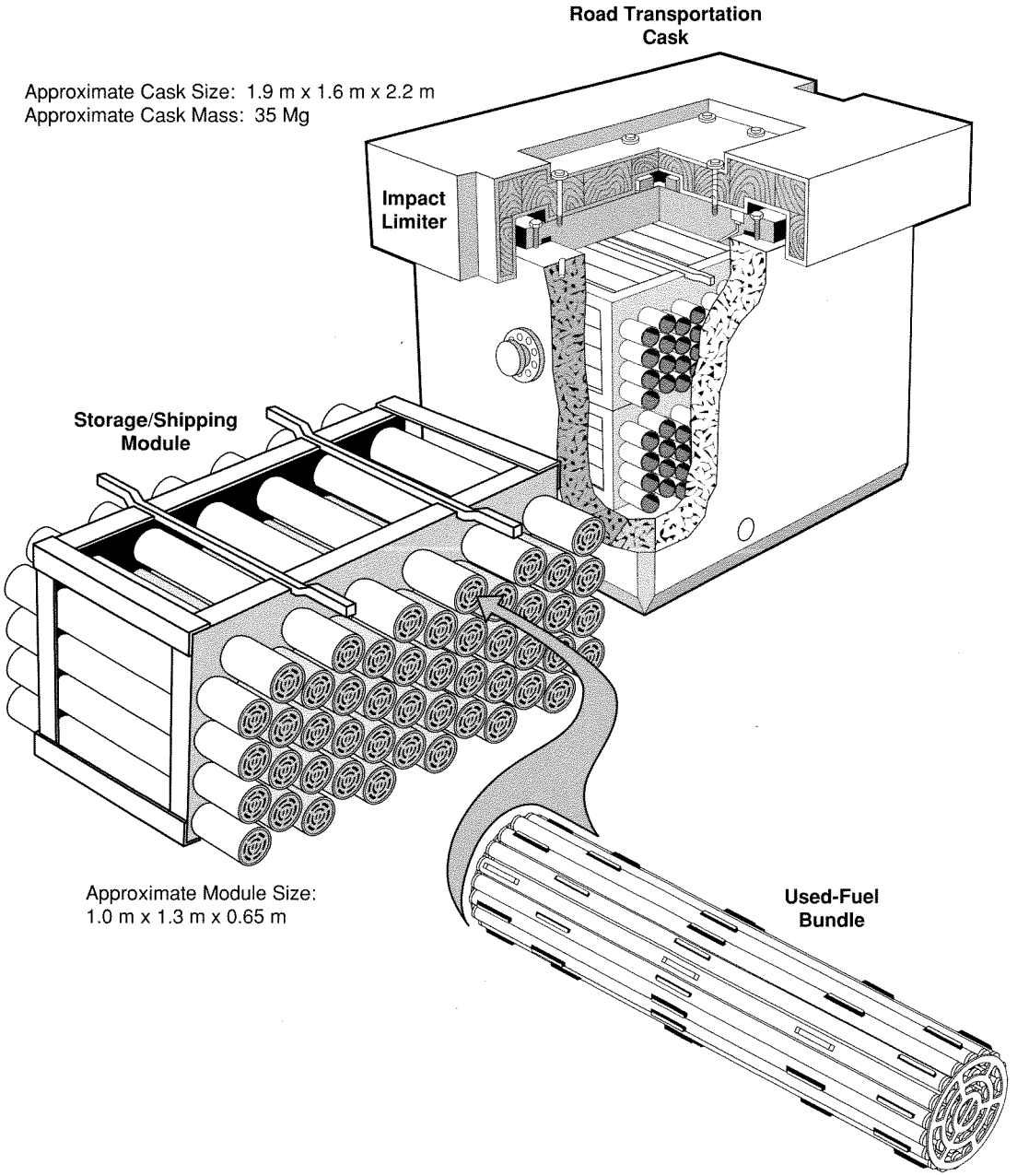


FIGURE 2-20A: Detailed Road Transportation Cask

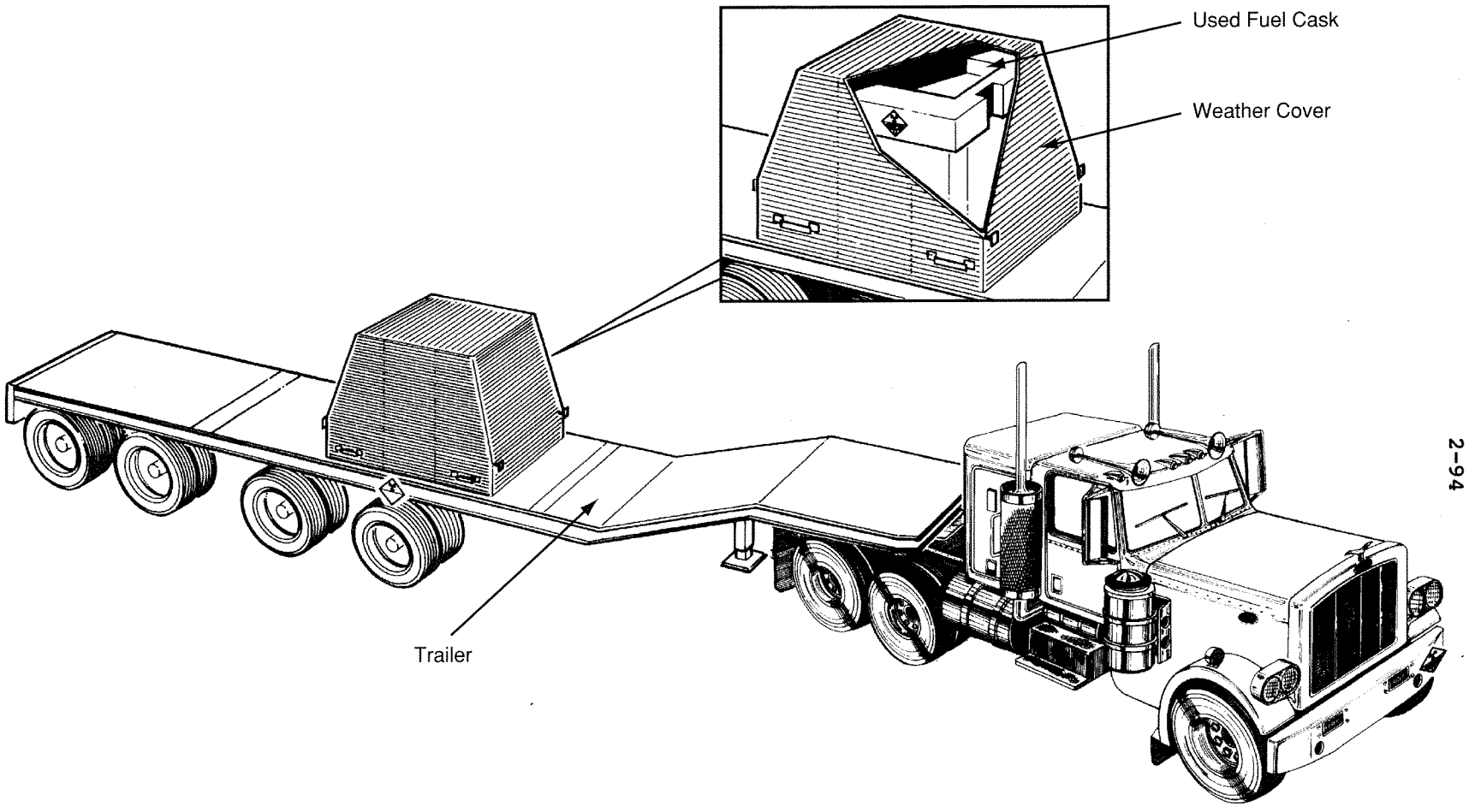


FIGURE 2-21: Used Fuel Cask and Truck Trailer

The tractor is a standard unit normally used in handling heavy loads. It has three axles in total, a single front axle with single tires and a tandem axle with dual tires, and weighs approximately 9 Mg. An adjustable fifth wheel connects with the trailer unit, allowing some flexibility in load distribution. The reference design assumes a tractor life of 5 years. The total weight of the loaded tractor-trailer assembly is approximately 54 Mg.

2.2.4.2 Used Fuel Handling Operations at the Nuclear Generating Station

The reference transportation system specifies wet loading of the cask. The loading sequence would be as follows:

1) decontamination (if necessary) of trailer and empty cask;
2) filling of cask with demineralized water;
3) lowering the cask into the fuel bay;
4) removal of the cask lid and inspection of the seals;
5) removal of the empty modules;
6) placement of the modules containing the used fuel into the cask;
7) identification and recording of used fuel loaded into the casks (according to safeguards requirements);
8) repositioning of the lid;
9) spraying of the cask for decontamination while being lifted out of the fuel bay;
10) emplacement and tightening of the lid bolts;
11) radiation monitoring;
12) surface wipe and decontamination if necessary;
13) drainage of the fuel bay water;
14) repeat surface wipe and decontamination if necessary;
15) leak test of all valve plugs or closure devices, and
16) attachment of IAEA safeguard seals.

The cask would then be fitted with the impact limiter, loaded and tied down on the trailer (2 trunnions for the road cask). Prior to the vehicle's exit from the loading site, the cask and trailer would be labelled as prescribed by the Transportation of Dangerous Goods regulations and the AECB regulations (Government of Canada 1992; AECB 1991b). The empty cask could be transported under less stringent regulations provided it met the criteria of the AECB packaging regulations (AECB 1991b). The criterion is based on the level of non-fixed surface contamination on the inside of the cask.

Used fuel cask handling at the station would take an average of 62 person-hours of effort per road cask (53 person-hours for cask filling and decontamination and 9 person-hours for trailer loading/unloading).

To ensure proper execution of their functions, the used fuel handling personnel would receive training on the cask handling procedures, including a knowledge of the various applicable dangerous goods regulations.

2.2.4.3 Off-site Transportation

The cask and vehicle would travel on Class A roads, assumed to be available for unlimited cask movement at least 275 days per year without load restriction. The maximum vehicle speed is assumed to be 100 $km \cdot h^{-1}$ and the average vehicle speed estimated at 50 $km \cdot h^{-1}$ to allow for rest stops (Ulster 1993a).

Table 2-14a shows the trip duration for three general reference destinations in the Ontario Shield (described in Section 3.7), and the average speeds in each population zone (Grondin 1993a; Ulster 1993b). Speed estimates are low, providing conservatism for the public safety analysis.

TABLE 2-14a
Tractor Trailer Trips Details for the
Three Reference Destinations

TO SOUTHERN REGION[1]	
one-way distance (km)	400
number of round trips per year	938
total one-way-trip duration	8 h
driving time	7 h
number of drivers required (max. 10 h driving)	1
person-hours per year	15 000
average speed in rural zone	85 $km \cdot h^{-1}$
average speed in suburban zone	50 $km \cdot h^{-1}$
average speed in urban zone	15 $km \cdot h^{-1}$
TO CENTRAL REGION[1]	
one-way distance (km)	900
number of round trips per year	938
total one-way-trip duration	18 h
driving time	15.5 h
number of drivers required (max. 10 h driving)	2
person-hours per year	67 500
average speed in rural zone	75 $km \cdot h^{-1}$
average speed in suburban zone	50 $km \cdot h^{-1}$
average speed in urban zone	25 $km \cdot h^{-1}$
TO NORTHERN REGION[1]	
one-way distance (km)	1900
number of round trips per year	938
total one-way-trip duration	38 h
driving time	31 h
number of drivers required (max. 10 h driving)	2
person-hours per year	213 900
average speed in rural zone	74 $km \cdot h^{-1}$
average speed in suburban zone	49 $km \cdot h^{-1}$
average speed in urban zone	27 $km \cdot h^{-1}$

[1] To the geometric centre of the region

TABLE 2-14b
Road System - Annual Inspection, Breakdown and Repair Time

Destination	Number of Inspections	Inspection Time (person-$h \cdot a^{-1}$)	Number of Breakdowns	Repair Time (person-$h \cdot a^{-1}$)
Southern Centroid	2	156	12	24
Central Centroid	4	313	27	54
Northern Centroid	9	704	56	112

One of the driving crew would perform inspections of the tractor, trailer and cask en route to check for mechanical problems (e.g. brakes, tires), as well as carry out security checks. It is assumed that an inspection occurs prior to leaving the station and every 4-5 hours when a stop takes place (i.e. about every 200 km).

For the occupational safety assessment, it was also assumed that some mechanical problems develop which would delay the tractor/trailer/cask system, while a driver or emergency crew resolve the problem. Although regular maintenance of the system fleet would minimize the number of truck breakdowns en route, it is conservative to assume that some breakdown would occur.

The annual inspection and repair time on the road system en route are shown in Table 2-14b.

2.2.4.4 Cask Unloading

When the cask arrived at the UFDC, it would be inspected for damage and any evidence of leakage. If damage or leakage was suspected, remedial actions as prescribed in the Transportation of Dangerous Goods and AECB regulations would be followed (see Section 2.2.7.3 for criteria and procedures for damaged cask handling). Otherwise, the unloading sequence would follow normal procedures, as detailed in the UFDC conceptual design (Simmons and Baumgartner 1994).

2.2.5 Reference Rail Transportation System

2.2.5.1 Hardware

The reference rail transportation system consists of a number of casks designed specifically for rail transport (see Figure 2-22), plus a dedicated train. The train includes 10 rail cars, each loaded with one rail cask (see Figure 2-23), plus four buffer cars, a caboose and a locomotive.

Each rail cask (weighing approximately 62 Mg when empty) is designed to transport 576 bundles in 6 modules of 96 bundles each (weighing approximately 15 Mg total). The rail cask design has the same basic configuration as the road cask, but the impact limiter configuration is different. The rail cask has two impact limiters, one at each end as illustrated in Figure 2-23 (the two impact limiters weigh approximately 2 Mg). The reference design specifies a cask life of 20 years.

The cask is to be transported on a 100 ton rail flat car (weighing approximately 29 Mg) modified to meet Ontario Hydro's specific requirements. The flat car has four axles and is equipped with cushioning couplers in order to reduce the forces on the cask due to normal train operation such as shunting. Another safety feature is double-shelf couplers and locking centre pins to keep all cars and components together in the event of a derailment. The railcar is provided with a cask transportation support frame (weighing approximately 5 Mg). The car floor is made of stainless steel designed to facilitate decontamination. The reference design assumes a railcar life of 35 years. The total weight of the full cask-railcar assembly is approximately 111 Mg.

CAPACITY:
6 modules / 576 bundles

SIZE:
4.3m x 1.9m x 1.6m

WEIGHT: (loaded)
79 Mg

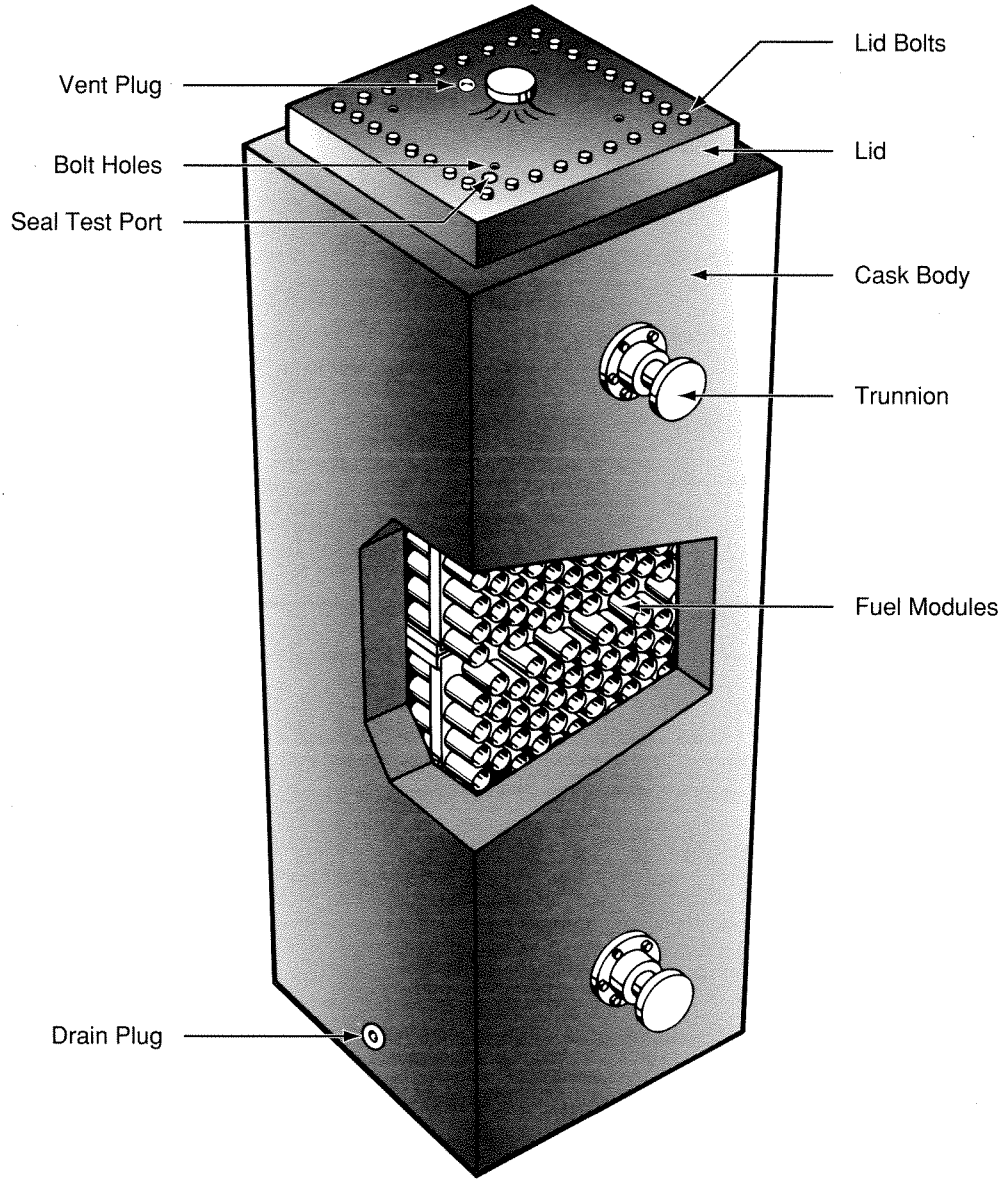


FIGURE 2-22: CANDU Used Fuel Rail Cask

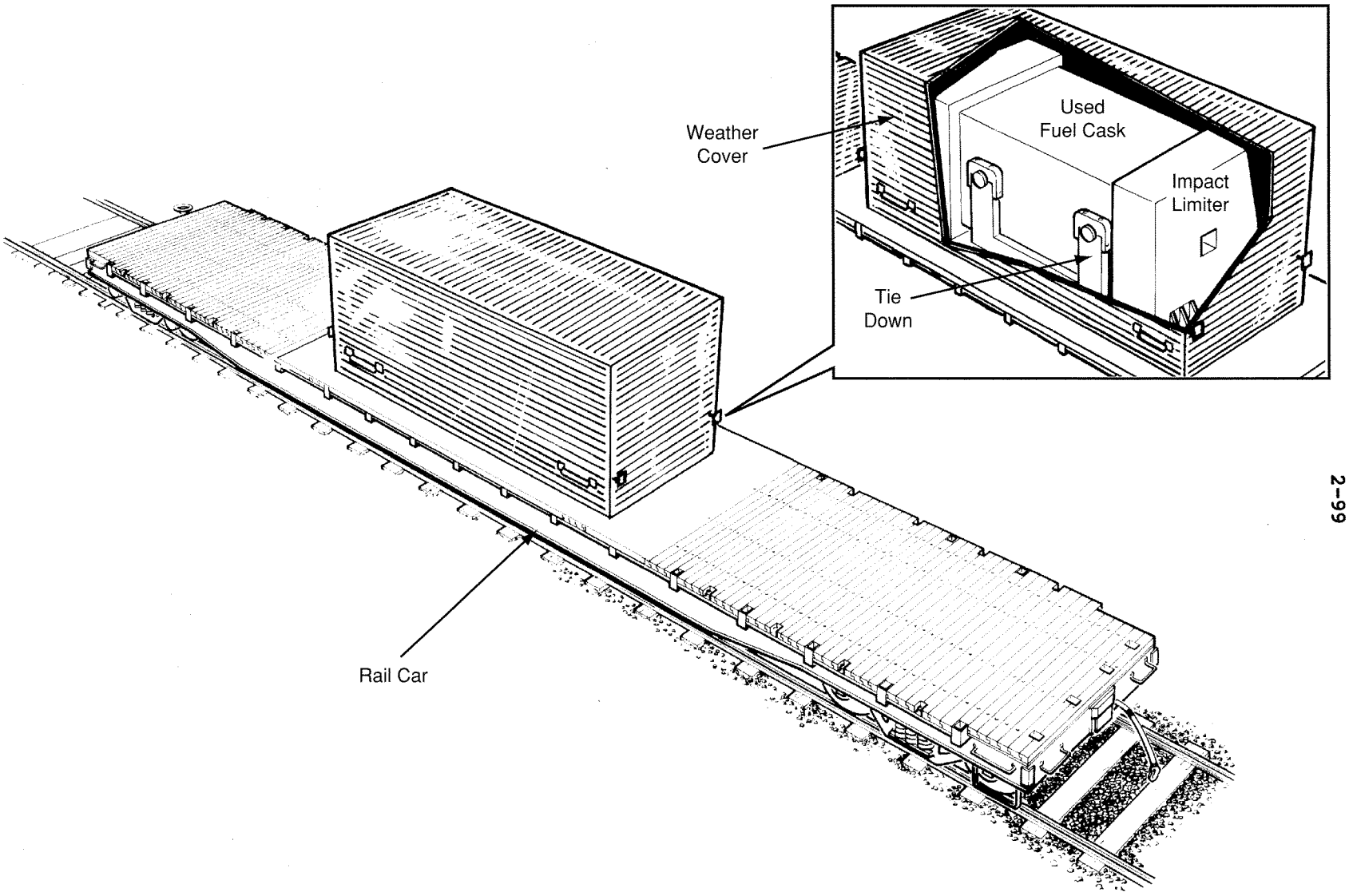


FIGURE 2-23: Rail Car

The railway company would be responsible for supplying the locomotive and backup facilities. The train components include:

i) a 3 000-hp locomotive;

ii) a caboose; and

iii) four empty buffer cars, two at each end to separate the occupied locomotive and caboose, respectively, from the cask cars.

2.2.5.2 Station Operations and Cask Unloading

Cask loading and unloading would be done vertically in the same fashion as for the road cask. An impact limiter would be placed at both ends of the cask.

Prior to the vehicle's exit from the loading site, the cask and railcar would be labelled as prescribed by the Transportation of Dangerous Goods and AECB regulations (Government of Canada 1992; AECB 1991b) in the same fashion as described for road transportation. These duties would be performed by employees at the nuclear generating stations.

2.2.5.3 Off-site Transportation

The rail crew of 4 would pick up the loaded flat cars at the siding next to the fuel bay area and take them to the specified destination.
The train crew would be supplied by the railway company. They would have received special training, including the application of the Transportation of Dangerous Goods Regulations.

Trip distances and duration for the three destinations in the Ontario portion of the Canadian Shield and the average speeds are shown in Table 2-15a (Grondin 1993a; Ulster 1993b).

As in the case of road transportation, inspections of the trains loaded with full rail casks would be carried out to look for mechanical problems and as security checks. Empty trains would also be inspected briefly for mechanical problems. The inspection and repair times are shown in Table 2-15b.

2.2.6 Reference Water Transportation System

Since the UFDC reference locations may not be on the shore of a navigable water body, the use of water transportation would be combined with one of the land modes of transportation described earlier (road or rail). A transfer facility would be required to connect the two transportation modes.

2.2.6.1 Hardware

Shipment of used fuel on the Great Lakes could be achieved using either a conventional ship or a tug/barge combination. Preliminary investigations indicate that the tug/barge combination have a number of advantages over conventional ships. Some of the advantages include an excellent safety record on the Great Lakes (Grondin 1993a), the versatility of unloading a barge while the tug is free to pick up a second barge, and lower capital and operating costs (Elste et al. 1974; MacDonald 1986).

TABLE 2-15a
Train Trips Details for the Three Reference Destinations

TO SOUTHERN REGION[1]	
one-way distance (km)	400
number of casks transported per year	313
number of casks per trip	10
number of round trips per year	32
total return-trip duration	16 h
person-hours per year	2 048
average speed	49 $km \cdot h^{-1}$
TO CENTRAL REGION[1]	
one-way distance (km)	800
number of casks transported per year	313
number of casks per trip	10
number of round trips per year	32
total return-trip duration	31 h
person-hours per year	3 968
average speed	51 $km \cdot h^{-1}$
TO NORTHERN REGION[1]	
one-way distance (km)	1400
number of casks transported per year	313
number of casks per trip	10
number of round trips per year	32
total return-trip duration	52 h
person-hours per year	6 656
average speed	54 $km \cdot h^{-1}$

[1] To the geometric centre of the region

TABLE 2-15b
Rail System - Annual Inspection, Breakdown and Repair Time

Destination	Number of Inspections	Inspection Time (person-$h \cdot a^{-1}$)	Number of Breakdowns	Repair Time (person-$h \cdot a^{-1}$)
Southern Centroid	1	7	1	6
Central Centroid	2	14	2	12
Northern Centroid	3	21	3	18

The water transportation reference design consists of an integrated tug/barge unit. The tug would be rigidly attached to the back of the barge and push it rather than tow it. The tug boat would fit in a notch at the back of the barge where it could be rigidly connected to the barge. When in this configuration, the tug boat would push the barge and they would form an integrated vessel. The barge could transport either road or rail casks depending on the system chosen for ground transportation. The reference barge would normally be loaded with 36 road casks or 12 rail casks or some combination, but it could be loaded to accommodate a maximum cargo equivalent to 48 road casks or 20 rail casks. Rail and road cask designs are as described earlier. Transfer of the cask from the fuel bay to the dock site would be achieved by a rubber-tire multi-axle vehicle, capable for use both inside the fuel bay loading areas and outdoors on-site.

The specially-designed barge (Figure 2-24) includes two longitudinal side bulkheads, one forward collision bulkhead and five transverse bulkheads to subdivide the barge into four cargo holds with ballast tanks at the sides and in the double bottom. These ballast tanks allow the stability, draft and trim of the barge to be controlled. In addition, the barge would feature a forecastle where mooring and anchoring equipments are located. The shell and internal structure at the bow and waterline would be ice-strengthened for medium ice conditions. A bow-thruster would be fitted below the waterline to further enhance the manoeuvrability of the integrated tug/barge system. The back of the barge would have a deep notch properly designed to provide a rigid structural attachment for the tug.

Cask tiedowns would be permanently fixed to the decking of the barge and designed to accommodate loading conditions arising from vessel movements under normal and accident conditions. Quick release indicator buoys would be attached to each cask prior to the start of a voyage to enable one to locate a cask in the event of submersion. The reference design assumes a barge life of 40 years.

The tug, chosen from commercially available models, should be able to move a 76.2 m barge loaded with 1 704 Mg (maximum) of cargo on the Great Lakes, as well as the inter-connecting rivers and waterways for the full navigation season. A locking device consisting of a hydraulic ram would be mounted on the bow of the tug to provide a smooth and rigid mating of the two units.

A towing bollard would allow towing of the barge in the conventional manner. Sufficient officer and crew accommodations, and associated facilities would be a necessary part of the tug's construction. The tug would be provided with all the required state-of-the-art navigational and communications equipment as specified in the Navigating Appliances and Equipment Regulations (see Appendix B), which would allow for the safe passage of the vessel at all times and in all conditions.

The crew requirements for the tug/barge would meet the Safe Manning Regulations (see Appendix B) as laid down by the Canadian Coast Guard and would comprise one master, one chief officer, one cook, one chief engineer, one second engineer and three general purpose crew.
The dock construction would be able to bear the weight of the casks, mobile gantry, crane and loaded transporters. The dock face would be constructed of reinforced steel, together with heavy horizontal rubber fendering. The dock would have sufficient mooring bollards for the tug and barge to secure itself alongside. The docks would be fitted with all the required tug/barge servicing facilities. A dock laydown area, suitable for temporary placement of 15 road casks or 5 rail casks, and 2 cask-lifting beams would be provided.

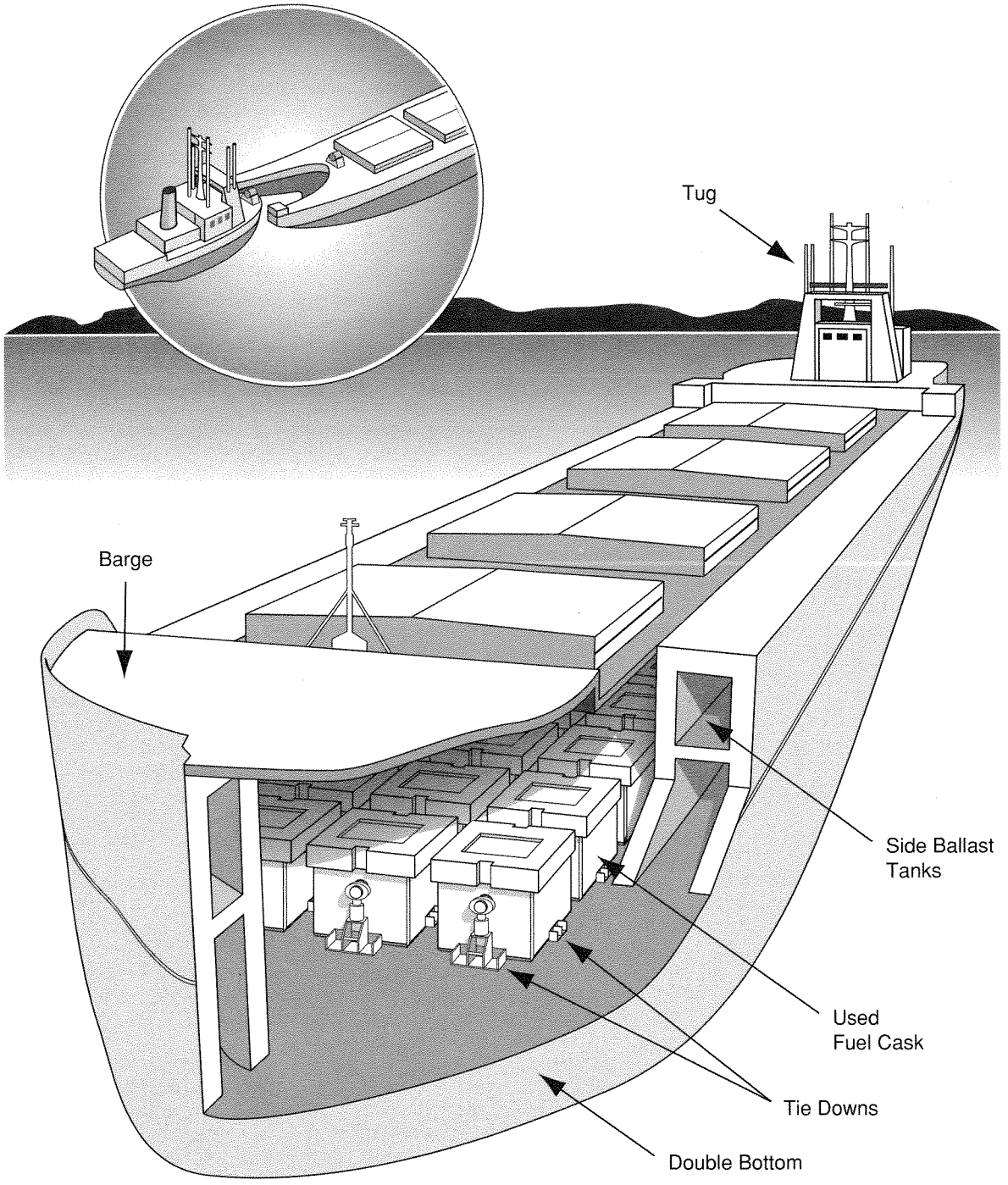


FIGURE 2-24: Integrated Tug-Barge System

The Transfer Facility serves as an off-loading port to transfer the casks from the water transporter to the land transporter (road or rail). A schematic layout of the facility is shown in Figure 2-25. A dock 125 m long would be required. The approach to the dock must allow for a 61 m wide, 4.6 m deep dredged channel extending out into the lake for a distance of 1.6 km. A reinforced, vertical dock front would be required to enable the barge to moor at the dock face. A two-rail gantry dock crane, capable of accessing all points along the length of the dock would be provided. Two cask-lifting beams (one operational and one stand-by) would reside in the transfer facility cask laydown area for use in all barge loading and unloading operations. Periodic maintenance dredging of the dock and access channel areas would be performed to ensure navigable requirements are maintained during the shipping season. Dredging approvals would be required as shown in Appendix B. Security at the transfer facility would have similar features as those at the UFDC facility.

2.2.6.2 Station Operations and Cask Unloading

Cask wet loading would be done as described in the previous sections. The fully loaded and decontaminated cask would then be lifted and lowered onto the on-site transporter. The transporter would be checked for surface contamination and decontamination procedures initiated if required. It would then be driven through station and/or fuel bay access doors, to the dock site where the cask would be placed in the cask laydown/storage area, or directly onto the barge. An empty returning cask would be loaded onto the transporter for return to the fuel bay. These cask filling and transfer procedures would be continued until a designated barge load is assembled and waiting at the dock site.

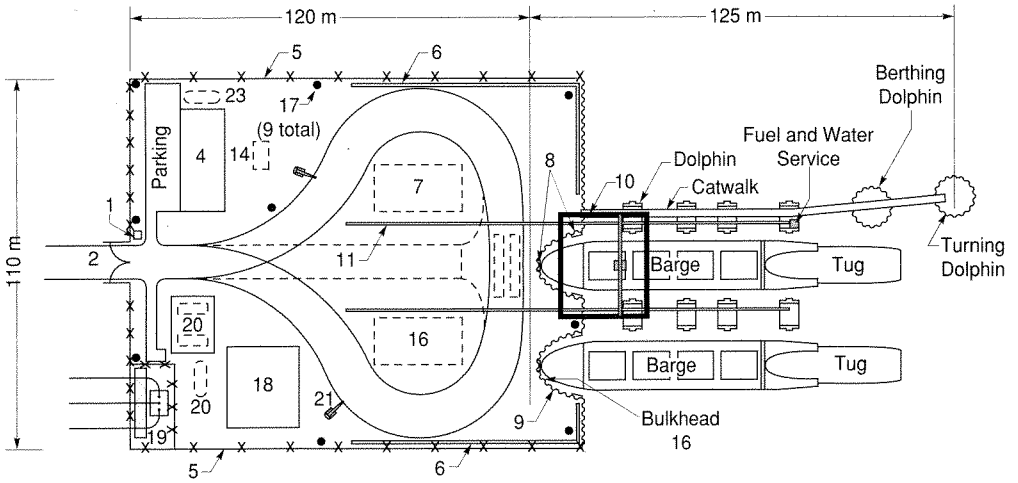
With the integrated tug/barge system, the tug would be rigidly connected to the barge during open water and confined water operation. The tug would be released from the barge at a dock only when it was necessary to collect another barge, or for maintenance and repair. This is envisaged to occur only at the transfer facility. The tug would be ballasted to almost the same draft as the barge during connection and disengagement. When loading commences, the anti-heeling tanks would be automatically activated, which effectively moves a weight of water from one side of the barge to the other to compensate for off-centre weights and to keep the barge on the horizontal.

2.2.6.3 Off-site Transportation

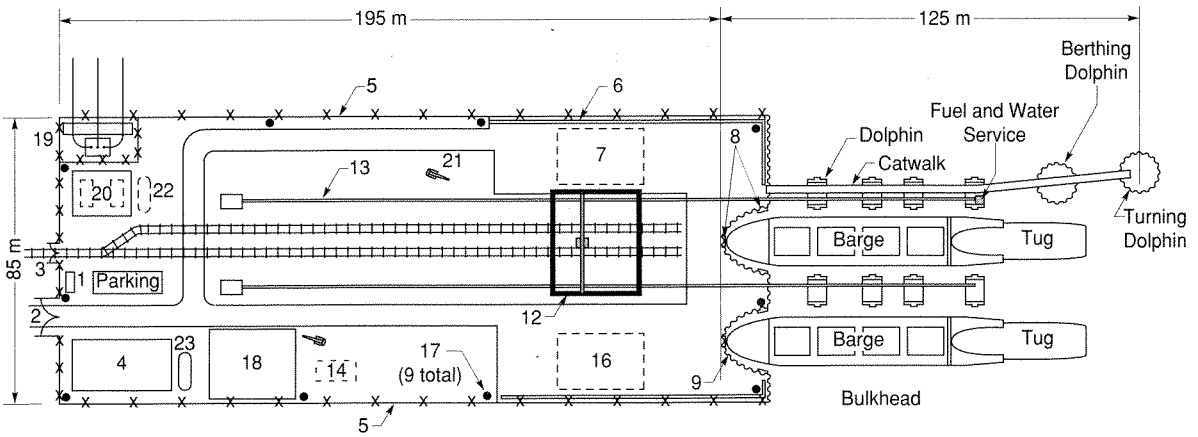
The day-to-day operations of the system would be run from a marine head office based ashore, which would organize and control the daily activities of the seagoing staff and equipment. The tug/barge would be operated on a twenty-four hour basis. Standard shipboard practices would be maintained. The work day would be split into two watches, six hours on and six hours off. These watches would be maintained regardless of whether the ship was in port or in transit. The wheelhouse would never be left unattended.

The crew of 8 would normally reside on the tug. It is assumed that several times during the trip, 2 crew members would climb aboard the barge and walk past the casks to the bow. Activities performed on the barge would include: preparing for docking, operating winches, looking out in foggy weather, etc. During these activities, crew members would be in closer proximity to the casks than while on the tug.

Trip distances and durations for the central and northern destinations in the Ontario portion of the Canadian Shield and the average speeds are shown in Tables 2-16a and 2-16b for the Water-Road and Water-Rail modes, respectively (Grondin 1993a; Ulster 1993b; Zeya 1993b). Annual inspection and repair times are shown in Table 2-16c.



Truck-Barge Option



Rail-Barge Option

1. Guardhouse
2. Road Access
3. Rail Access
4. Administration Maintenance And Utility Building
5. Security Fence
6. Steel-clad Security Wall
7. Storage Area for Full or Empty Casks (about 19m x 24m)
8. Wood and Rubber Bumper Guards
9. Vessel Mooring Cleats
10. Overhead Crane
11. Overhead Crane Rails
12. Gantry Crane
13. Gantry Crane Rails
14. Septic Tank and Tile Bed
15. Bulkhead
16. Cask Storage Area (19m x 24m)
17. Light Standards
18. Equipment Storage Area
19. Substation (Crane, Fire, Lights)
20. Backup Generators w/House
21. Fire Protection Equipment
22. Generator Fuel Storage Tank
23. Boiler Fuel Storage Tank

FIGURE 2-25: Layout of the Transfer Facility

TABLE 2-16a
Water-Road Trip Details for the
Central and Northern Reference Destinations

TO CENTRAL REGION[1]	**BARGE**	**TRUCK**
one-way distance (km)	960	340
number of round trips per year	26	938
one-way trip duration (h)	72	4
number of crew required	8	1
person-hours per year (full casks)	14 300 + 620[2]	3 752
average truck speed	--	80 $km \cdot h^{-1}$
average tug/barge speed - open waters	15 $km \cdot h^{-1}$	--
average tug/barge speed - channel/river	4 $km \cdot h^{-1}$	--
TO NORTHERN REGION[1]		
one-way distance (km)	1 110	590
number of round trips per year	26	938
one-way trip duration (h)	84	7
number of crew required	8	1
person-hours per year (full casks)	16 800 + 620[2]	6 566
average truck speed	--	80 $km \cdot h^{-1}$
average tug/barge speed - open waters	15 $km \cdot h^{-1}$	--
average tug/barge speed - channel/river	4 $km \cdot h^{-1}$	--

[1] To the geometric centre of the region
[2] For tug + barge, respectively

TABLE 2-16b
Water-Rail Trip Details for the
Central and Northern Reference Destinations

TO CENTRAL REGION[1]	**BARGE**	**TRAIN**
one-way distance (km)	940	360
number of casks transported per year	313	313
number of casks per trip	12	6/10[2]
number of round trips per year	26	52/32[3]
total return - trip duration (h)	144	50/14[4]
person-hours per year (full casks)	14 300 + 620[5]	5 200[4]
average train speed - rural ($km \cdot h^{-1}$)	--	14/51[4]
average tug/barge speed - open water	15 $km \cdot h^{-1}$	--
average tug/barge speed - channel/river	4 $km \cdot h^{-1}$	--
TO NORTHERN REGION[1]		
one-way distance (km)	1 140	460
number of casks transported per year	313	313
number of casks per trip	12	6/10[2]
number of round trips per year	26	52/32[3]
total return - trip duration (h)	168	64/17[4]
person-hours per year (full casks)	16 800 + 620[5]	6 656[4]
average train speed - rural ($km \cdot h^{-1}$)	--	14/54[4]
average tug/barge speed - open water	15 $km \cdot h^{-1}$	--
average tug/barge speed - channel/river	4 $km \cdot h^{-1}$	--

1 To the geometric centre of the region.

2 The reference UFT train design accommodates 10 casks. For the combined water-rail mode, however, transfer facility logistics may reduce shipments to 6 casks per train (Ulster 1993b). The natural environment analysis used the reference design. The radiological safety analyses for public and workers used the smaller train size for additional conservatism.

3 The smaller train size (6 casks) would increase the number of trips (52 per year), compared to reference design.

4 A slower average speed (14 $km \cdot h^{-1}$) was used for worker safety analysis compared to the other analyses, for additional conservatism. This, in turn, results in longer trip duration than used in the other analyses. The annual person-hours, used for worker safety analysis, are also based on the slower speed.

5 For tug + barge, respectively.

TABLE 2-16c
Water System - Annual Inspection and Repair Time

Mode	Destination	Inspection Time (person-h·a^{-1})	Repair Time (person-h·a^{-1})
WATER-ROAD			
- water	Central Centroid	52	0[1]
	Northern Centroid	52	0
- road	Central Centroid	78	20
	Northern Centroid	156	32
WATER-RAIL			
- water	Central Centroid	52	0[2]
	Northern Centroid	52	0
- rail	Central Centroid	26	12
	Northern Centroid	26	12

[1] Barge breakdowns are repaired in port when no full casks are on board. Report of tug breakdowns on route would not result in additional occupational radiation exposure.

An inspection of the tug and barge would be performed prior to leaving port with full casks. No other inspections are required during the trip except for brief checks when crew members board the barge. Some tug and barge breakdowns might occur en route. Tugs would either be repaired en route by the crew, or a substitute tug would be supplied. Breakdown of equipment on barges would be repaired in port when no full casks were on board. There is no large breakdown anticipated which would need immediate repair resulting in significant radiation exposure.

2.2.6.4 Operations at the Transfer Facility

At the transfer facility, the tiedowns are removed on the barge, the casks are lifted with the fixed dock crane onto trailers or railcars, as the journey from the transfer facility to the UFDC can be done by either road or rail. The casks are tied down. The vehicles are then monitored and inspected prior to leaving the transfer facility. Cask handling times at the transfer facility are given in Section 7.3.1 (estimation of occupational impacts).

2.2.7 Transportation Contingency Measures and Emergency Response Provisions

This section presents a review of the contingency measures and emergency response provisions included in the reference used fuel transportation system design (Ulster 1993a). See "Appendix J" for further details.

As mentioned earlier, public consultation on the subject of used fuel transportation showed that the public views emergency response measures as an essential feature of a used fuel transportation system (Decima Research Ltd. 1985; Greber and Anderson 1989).

2.2.7.1 Measures in Response to Transport Delay

Operation of the transportation system in abnormal and accident conditions requires that provisions be in place to respond to the following situations:

i) traffic congestion;

ii) delays;

iii) mechanical problems;

iv) traffic accidents - undamaged cask;

v) traffic accidents - potential loss of integrity of the cask; and

vi) traffic accidents - damaged cask.

These are discussed in the following sub-sections.

1. Road

All road shipments would be carried out on designated routes. In the event of traffic congestion, it would be the duty of the driver to contact the shipping manager (using radio, telephone or satellite communication). The shipping manager must then contact an appropriate contact at the destination to avoid the situation where the shipment is late and the whereabouts of the shipment are unknown. Because of road weight restrictions, as well as for security, it would be necessary for the driver to remain on the designated route. If for some reason the driver was unable to take the designated route, the driver must contact the shipping manager for an alternative route.

In order to provide a speedy response to a traffic accident, a vehicle problem, or to monitor the whereabouts of a shipment, all tractors would be equipped with either a telephone, radio or satellite communication system.

In the event of a road accident, the shipping manager would be contacted using telephone, radio, or satellite tracking technology (by pressing a key and sending a pre-coded message). If the driver is physically unable to contact the shipping manager, satellite tracking could be used to locate the whereabouts of the vehicle. At that time, the shipping manager would notify the transportation emergency response team via an emergency 1-800 phone number. As part of the emergency plan, local emergency services would be notified. If satellite tracking was not available, the transportation emergency response team and emergency services would travel along the designated route starting at the last point of contact.

In the event where there are significant traffic delays, the driver would be able to contact the shipping manager via the communications link.

If there was a situation in which a shipment was late, or the driver had not responded according to plan, the shipping manager would first try and contact the vehicle. If this was unsuccessful and satellite tracking was available, the shipping manager would be able to locate the vehicle and if necessary, dispatch the transportation response team or the proper emergency services. Otherwise, the shipping manager would send the transportation emergency response team and emergency services along the designated route starting at the last point of contact.

In the event of tractor problems, the driver must park the vehicle in a safe location and if appropriate, set up flares. The driver must then contact the

shipping manager and arrange for a replacement tractor. The shipping manager must contact the appropriate personnel at the destination and notify them of the delay.

In the event of trailer problems (such as a broken axle), the procedures mentioned above would also apply. However, it would also be necessary to dispatch a mobile crane to the scene in order to transfer the cask from one trailer to the other.

In any other unusual circumstance (such as a blockade), it would be necessary for the driver to contact the shipping manager. It would be the responsibility of the shipping manager to notify the appropriate parties (such as the police).

2. Rail

In the event that there was a delay during rail transportation, a member of the train's crew would contact the shipping manager, and notify him/her of the delay and the current location of the train. The shipping manager would then contact the destination and notify the appropriate personnel of the delay.

In any other unusual circumstance, it would be necessary for a member of the train's crew to contact the shipping manager. It would be the responsibility of the shipping manager to notify the appropriate parties.

3. Water

In the event that there was a mechanical problem with the tug/barge, or in the event that the tug/barge ran into bad weather, the ship's captain would notify the shipping manager and would then dock the tug/barge at the nearest pre-designated port (pre-designated port is a port along the route which has previously agreed to receive a tug/barge containing radioactive materials in such an event). The shipping manager would then contact the destination and notify the appropriate personnel of the delay.

In any other unusual circumstance (e.g. a blockade), it would be necessary for the captain to contact the shipping manager. It would be the responsibility of the shipping manager to notify the appropriate parties (e.g. police, Coast Guard).

4. Effect of delay: Road, Rail or Water

The casks are designed and licensed to hold the contents at a specific pressure and temperature for at least one year, and thus any delay would not affect safety.

2.2.7.2 Emergency Response Training

Emergency response training for radioactive materials transportation is already in place at Ontario Hydro. The Ontario Hydro emergency response teams consists of qualified personnel at the nuclear generating stations who are trained to provide technical support and response assistance during a transportation emergency. The training is described in, and complies with, the Nuclear Operations Branch Training Policy - Transportation Emergency Response Plan (TERP) Response Team Training.

Response team training would include as a minimum the following elements:

i) radiation protection training for some team members (this includes being able to confirm the presence of radioactive material and ascertaining whether a radiation or contamination hazard exists, use of radiological monitoring instruments, implementation of

protective measures, and the use of protective clothing and equipment);

ii) leadership and management training for response team leaders and assistant team leaders;

iii) training in contaminated casualty handling procedures;

iv) familiarization with the containers used and radioactive material transported, and the hazards associated with these. Familiarization with the regulations which govern the packaging and transportation of radioactive materials;

v) familiarization with the Transportation Emergency Response Plan (including the awareness of other Hydro departments and external agencies involved during a response and their expectations); and

vi) training in the use of the specific response procedures and equipment for incidents involving transportation of radioactive material.

On an annual basis, all emergency response personnel would undertake refresher training to maintain their competence. In addition, all UFDC employees would receive WHMIS training.

2.2.7.3 Emergency Response Plans

According to the Transportation of Dangerous Goods Regulations, a shipper of dangerous goods should have an up-to-date and operational emergency response plan that:

i) identifies hazards associated with the transportation of hazardous materials;

ii) identifies means of dealing with the hazards, whether to people or the environment, and indicates ways of containing or cleaning up any release;

iii) identifies emergency response resources in-house, through a mutual aid plan or externally through a contractor;

iv) provides technical advisors to handle all informational aspects of an accident involving the company's product or waste material;

v) provides specialized equipment and materials required for responding to an accident;

vi) provides assistance in training first responders along the transportation corridors;

vii) facilitates co-operation with government or other agencies at the accident scene; and

viii) is sensitive to, and provides for evaluation with appropriate authorities, the need for immediate and short-term assistance for persons who are evacuated because of a transportation accident.

In the event of a transportation accident, Ontario Hydro's emergency response team, in conjunction with the appropriate design engineers, will assess the situation and determine which of the following two scenarios exist and thus which procedure should be applied:

i) the emergency response team has determined that radiation levels are below the regulatory limit and that there is no loss of integrity to the package. It must be assumed that the fuel inside the cask is damaged, so the cask would be sent to the UFDC and unloaded in the hot cell. Ontario Hydro has experience in dealing with damaged fuel and thus this would be more or less routine.

ii) the emergency response team has determined that there is leakage from the cask. Based on the results of the regulatory tests, the probability of a cask with leakage or radiation levels above the regulatory limit for accident conditions is highly unlikely. However, procedures would be in place to deal with this scenario. The emergency response team, wearing protective clothing if necessary, would determine the source of the leak and seal it using an appropriate method. Based on results of the safety analysis (see Chapter 7), the leak would most likely come from seal failures (either lid, drain or vent seals). If the leak was from the lid area, the lid could be welded closed. If the leak was from either the vent or drain, a plate could be welded over the area. Once the leak had been sealed, and with the AECB permission, the cask would be transported, under escort, to either a nuclear station or to the UFDC, whichever is closer. The cask would be unloaded into either the fuel bay or the hot cell and procedures would be followed under the assumption that the fuel inside the cask would be damaged.

In either of the two scenarios, it may be necessary to replace the damaged tiedowns, trunnions or the tractor/trailer with equivalent or temporary equipment. There is no circumstance in which fuel modules would have to be removed from the cask at the site.

As part of the three reference designs, specific emergency response plans were developed. They are included in Appendix J.

2.2.8 Transportation System Management

2.2.8.1 Organizational Structure

An organizational structure for transporting used fuel on a large scale, where responsibilities and functions were specifically defined, would have to be established before the start of transportation. Based on the organizational structure in place at Ontario Hydro for the transportation of radioactive materials, it is assumed that the used fuel transportation organizational structure would include the following functions:

i) long-term planning and strategies;

ii) transportation system design;

iii) liaison with the public, the regulatory authorities - AECB, Transportation of Dangerous Goods Directorate, and the provincial transportation and environment authorities (spill management departments; in Ontario, the Spill Action Centre under the Regional Operations Division of the Ministry of Environment and Energy); regarding cask licensing, licence renewal and emergency response plan Transportation of Dangerous Goods approval;

iv) establishment and review of procedures for equipment;

v) equipment inspection and maintenance;

vi) emergency response planning including interaction with local municipal emergency response services along the route, and emergency response training;

vii) driver training;

viii) transport package loading;

ix) transportation safeguards;

x) transportation documentation; and

xi) transportation operation coordination, routing and scheduling (including weather forecasting and provision of up to date information on the state of the road, railway or shipping lanes).

These functions and others as required would need to be assigned within the implementing organization to ensure the most efficient and safe operation of the transportation system.

The transportation organizational structure should also allow for the development of community involvement mechanisms. A formal procedure to seek and take into account the concerns of all interested and directly/in-directly affected individuals and groups should be established. Concerned individuals may include: residents along the transportation routes, business owners/operators, employees, groups and organizations, etc. The public involvement mechanisms would be negotiated with the affected public.

As indicated in Appendix B, the activities of handling, transport and offering for transport of used fuel would be subjected to the requirements of the federal Transportation of Dangerous Goods Act and Regulations, as well as the corresponding dangerous materials transport legal arrangements within each of the provinces involved. To coordinate, formalize and standardize procedures for transportation of used fuel between the provinces, the utilities and the implementing organization would seek to establish an intergovernmental Protocol for Interprovincial Transportation of Used Fuel. Interprovincial transportation is discussed in Section 2.3.

2.2.8.2 Conflict Resolution

Mechanisms for resolving conflicts with workers and with potentially affected communities need to be established as part of the transportation system management. This mechanism would typically define the following stages:

i) facilitation to provide information to parties involved in the dispute that would help to reach an informed decision;

ii) negotiation between the parties involved in the dispute to reach a common agreement;

iii) mediation to help achieve a settlement if negotiation failed; and

iv) arbitration leading to a binding agreement after negotiation and mediation efforts have failed.

The conflict resolution provisions for dispute with workers might, however, be dictated by the labour relations code in the particular province (e.g. Ontario Labour Relations Act). Establishing mechanisms for conflict resolution with potentially affected communities must necessarily involve the communities.

2.2.8.3 Occupational Protection

Occupational radiation exposure is regulated in Canada by the Atomic Energy Control Regulations, as described in Chapter 1 and Appendix B. In addition, specific radiation dose limits for transport are laid down in the transport regulations. The demonstration cask was designed for a dose rate of less than 0.1 $mSv \cdot h^{-1}$ at one metre, corresponding to a transport index of less than 10, well below the exclusive use criterion (the transport index is a number, defined in the TPRMR, equal to the radiation level at 1 m from the package surface in units of microsieverts per hour, divided by ten).

All activities involved in the reference transportation of used fuel to the UFDC would be subject to Ontario Occupational Health and Safety legislation (Government of Ontario 1990c). As a federally-regulated facility, the transfer facility itself would be subject to AECB and Labour Canada. However, for the purposes of this assessment, it is assumed that a letter of understanding among AECB, the Ontario Ministry of Labour and Labour Canada, similar to that applying to the nuclear stations, would exist, and that the provincial regulations would apply.

In addition to regulations, there would be standards and guidelines applicable to the various occupational hazards. For example, within Ontario Hydro, corporate safety rules and programmes are used to enhance worker safety. Specific examples are given below.

All of the safety features incorporated in existing operations for handling heavy loads would be utilized in the design of transportation system. The occupational safety aspects of the reference system would be optimized in accordance with the ALARA principle.

1. Occupational Safety Regulations and Standards

Transportation operations at Ontario Hydro generating stations are subject to the Ontario Occupational Health and Safety Act (OHSA) (Government of Ontario 1990c). Occupational hazards are regulated as follows:

i) Sources of worker exposure to air pollution include particulates, sulphur dioxides, carbon monoxide, hydrocarbons, nitrogen oxides and others. Air quality standards for these emissions are set under the Ontario Environmental Protection Act, as discussed in Section 1 of the Act. In addition, worker exposure is limited under Regulation 213/91 of the OHSA, applying to the construction phase (e.g. during construction of the transfer facility for the water system), and Regulation 854, applying to the operating phase of an industrial establishment. Exposure limits for diesel fumes are based on the threshold limit values (TLVs) of the individual components.

ii) Exposure to noise is currently regulated under OHSA Regulation 854. The maximum sound level for an 8-hour exposure is specified as 90 dB(A), before measures must be taken to reduce the sound level. At levels between 90 dB(A) and 115 dB(A), the exposure duration is regulated. Above 115 dB(A), hearing protection must be worn.

A separate regulation on noise is currently being prepared under the OHSA.

iii) No regulations presently exist limiting the intensity, time or frequency of whole body vibration (WBV). However, International Standard (#ISO 2631 or SAE J1013) can be consulted as guidelines. Adherence to the Ministry of Labour guidelines for truck drivers

may also minimize health effects from WBV (Helmkamp et al. 1984).

iv) Cask lifting activities would be governed by OHSA Regulation 692, which governs health and safety procedures in industrial establishments.

v) All construction activities at the transfer facility (for the water mode) would involve standard building materials and techniques, and would, therefore, be governed by the Occupational Health and Safety Act of Ontario, Regulation 231/91 (Government of Ontario 1992b).

In addition to the Regulations, industry standards would be consulted. For the reference system, the Ontario Hydro Corporate Noise Control and Hearing Protection Program (Ontario Hydro 1984b) outlines control and surveillance programs to minimize the hearing loss of noise-exposed workers. Ontario Hydro's Corporate Safety Rules include regulations for the safe operation of cranes (lifting devices). Cask lifting activities would be based on safe practices such as those described in the Construction Safety Association's Rigging Manual and Crane Handbook (1975).

The Ministry of Labour guidelines for truck drivers, mentioned above, place a limit on driving time between breaks, and list other working conditions. The guidelines were put in place to assist in preventing accidents.

2.2.8.4 Safety Features and Procedures

Safety design features and operating procedures would be used to reduce occupational hazards at the stations and during transport. Measures would be taken to avoid certain handling accidents (for example, dropping a cask onto the fuel in the Irradiated Fuel Bay (IFB) or onto the floor in the bay area, accidentally removing the lid from a full cask, or dropping the lid into the IFB). For example, in the reference system, once modules were in the cask, and the lid was lowered on, four lid bolts would be put in place from the gantry before the cask was lifted out of the IFB. This would prevent an operator from accidentally lifting the cask lid off.

Once the full casks were ready for shipment, there is no accident which could occur during cask handling at the station, transfer facility or station dock which could result in an acute radiation dose to the workers.

Chronic hazards such as exposure to noise would be limited, for example, in the case of noise from railway locomotives, by not operating locomotives near the station loading bays. Instead, railcars would be brought in by a smaller rail power truck.

During travel, there is a large margin of safety under the regulated value, in the reference system, in the radiation dose rate at occupied positions of the transport vehicles. Both conventional and radiological hazards would be reduced by the use of short, direct transport routes, and dedicated vehicles and drivers. In the reference system, stopping the movement of fuel during inclement weather is facilitated by a 275-day-operating season.

The reference system has not been optimized. Ergonomic aspects are among those that would be used in system optimization for occupational protection.

2.2.8.5 Environmental Protection

The utilities responsible for the transportation of used fuel would meet all the requirements of environmental legislation and develop their own standards where regulations do not exist so that adverse effects on the environment from the used fuel transportation activities are as low as reasonably achievable.

Whether used fuel transportation activities are carried out by contractors or by staff from the utilities, it is assumed that the operator would prepare, issue and implement environmental protection procedures to be followed during transportation activities, and would provide training in the use of these procedures. These would include:

i) waste management procedures, with emphasis on reduction, re-use and recycling of all material, and clear instructions on disposal of waste material (e.g. used tires);

ii) procedures for protection of the natural environment, including provisions to minimize emissions and noise from vehicles, and in the case of transfer facility construction, to minimize the area disturbed by construction and operation of the facility; and

iii) provisions to minimize disturbance to the local populations (e.g. regular inspection of muffling device to minimize noise).

In the case of contracted work, environmental protection procedures could be part of the contract requirements.

A list of suggested mitigation measures that could be used to protect the environment from the effects of used fuel transportation activities is included in Chapter 7.

2.3 INTERPROVINCIAL TRANSPORTATION

The UFDC would receive used fuel from Canadian CANDU reactors. Reactors are currently operating in Ontario, Québec and New Brunswick. Interprovincial transportation of used fuel may, therefore, be required between New Brunswick, Québec and Ontario.

As mentioned in Chapter 1, used nuclear fuel is classified as a dangerous material under the federal Transportation of Dangerous Goods Act. Interprovincial transportation of other classes of dangerous materials is a common occurrence in Canada. Transportation of dangerous materials is subjected to both federal and provincial legislations. Interprovincial transportation of dangerous materials has, therefore, to comply not only with the federal requirements applicable across Canada, but with the specific regulations of the provinces through which the materials are being transported.

2.3.1 Regulatory Framework

The regulatory framework that would impact on interprovincial transportation of dangerous materials is discussed here in relation to transportation of used nuclear fuel across New Brunswick, Québec and Ontario.

At the federal level (see Chapter 1 and Appendix B), the transportation and handling of dangerous materials is governed by the Transportation of Dangerous Goods Act. This federal regulatory scheme has been adopted by each of the provinces for intraprovincial movements. This means that as long as used fuel transportation complies with the federal TDG regulations, the provincial requirements would also be satisfied.

The handling and packaging of used nuclear fuel is also subject to regulations under the Atomic Energy Control Act (AECB 1978). Application of this Act would be the same in all three provinces.

In addition to the above regulations, transportation of used nuclear fuel waste by rail would also be subject to other federal legislation and regulations that would have common applicability (e.g. the National

Transportation Act (Government of Canada 1985b), Nuclear Liability Act (Government of Canada 1985c), the Railway Act (Government of Canada 1985d); the Canada Shipping Act (Government of Canada 1985e); and the policies, fees, and regulations of the St. Lawrence Seaway Authority).

2.3.2 Establishment of a Protocol for Interprovincial Transportation of Used Fuel

The utilities and the implementing organization would seek to establish an intergovernmental Protocol for Interprovincial Transportation of Used Fuel to coordinate, formalize and standardize procedures for transportation of used nuclear fuel between provinces. This Protocol would be negotiated between all applicable levels of government (e.g. federal, provincial, municipal and possibly Aboriginal).

The protocol may include definitions of terms and terms of agreement, as well as standardized guidelines and procedures for material handling and transportation, in addition to those common to the legislative arrangements in each of the jurisdictions. The Protocol may also include standardized procedures for the communication of planned movements and transportation schedules to, as well as between, the responsible agencies in each jurisdiction. The Protocol should also cover procedures for non-routine events and emergency response. Public and government involvement would be an integral component of the development of the Used Fuel Transportation Protocol. Potentially affected communities and Aboriginal groups would also need to be involved in the development of this Protocol.

2.3.3 Applicability of Conceptual Transportation Systems to Used Fuel Transportation from Quebec and New Brunswick

The interprovincial 'transportation system' for movement of used fuel waste from New Brunswick and Quebec to a UFDC in Ontario may be either a road, rail or water transportation system. Regardless of the mode selected, the term "transportation system" is understood to refer to the modules, casks, vehicles and tie-downs, as well as site handling facilities necessary for such movements (Ulster 1993a). The applicability of the reference transportation systems design, presented in Section 2.2, to transportation in Québec and New Brunswick, is briefly reviewed.

The first difference in the transportation of used fuel from Québec and New Brunswick applies to all modes of transportation. It is in the used fuel storage assembly. The reference storage transportation assembly used in the present analysis is the used fuel module (Figure 2-7). Used fuel in other provinces is not stored in modules but in baskets or trays.
The transportation cask would either need to be modified for transportation of baskets (or trays), or the used fuel would need to be transferred to modules prior to shipment.

2.3.3.1 Road Transport

Should the movement of used fuel waste occur by way of road transport, it would be necessary for the reference tractor/trailer/cask system to conform to the vehicle dimensions and weight limitations regulations within each of the three provincial jurisdictions. The reference road transportation system incorporates an engineered seven-axle tractor/trailer/cask system weighing approximately 54 Mg when loaded. For road transportation in Ontario and Québec, no special permits would be necessary for the vehicle hauling the cask, i.e. the vehicle would not be overweight or oversized.

In New Brunswick, however, special permits would be required. Regulation 83/42 under New Brunswick's Motor Vehicle Act places a 50 Mg limit on vehicles with the axle configuration and size of the tractor-trailer outlined within the reference transportation system design.

2.3.3.2 Rail Transport

Should the movement of used fuel occur by rail transport, it would be necessary for the reference rail/cask transportation system to conform to the weight limitations placed on any proposed railway routes within each of the three provincial jurisdictions. The weight of the reference railcar/cask system (approximately 111 Mg when loaded) is below the limit of 119 Mg set by CN for the gross weight of so-called 100-ton railcars. The reference transportation system for rail transport of used fuel waste assumes the use of dedicated trains. Each train would consist of a locomotive, 4 buffer cars, 10 flat cars (each loaded with one used fuel cask), a caboose and crew.

For rail transportation, no special permit would be necessary for used fuel movements across Québec and New Brunswick in excess of the requirements already applied to the Ontario rail transportation system, since the railway system is administered by the same company across the country.

2.3.3.3 Water Transport

All of Canada's nuclear generating stations are located on navigable bodies of water. Movements of used fuel may involve water transportation (conventional ship or tug/barge), in combination with road or rail transport. Since shipping is a federally regulated activity, transportation of used nuclear fuel by water from Québec and New Brunswick should not impose any requirement other than those already applied to the Ontario water transportation system.

2.4 FORESEEABLE DEVELOPMENT IN THE CONCEPTUAL DESIGNS

Both the UFDC and the used fuel transportation system designs are at a conceptual stage using both current and achievable technologies. The reference designs used in this assessment have not, therefore, been refined, as that would be premature at this stage. For eventual implementation, the design of a disposal facility would have to be adapted to site-specific conditions. However, these reference designs are considered to be an effective method, using both current and achievable technology, of meeting the objectives of the Canadian Nuclear Fuel Waste Management Program. In addition to the overall system refinements that would take place prior to concept implementation, this section presents a discussion of possible design improvements for the UFDC, disposal container and used fuel transportation system designs.

2.4.1 Disposal Centre Design Flexibility

The UFDC design is at a conceptual stage, sufficiently advanced to allow us to assess its safety, and the general environmental effects and costs of its life-cycle. The next stage of the design would be to produce more detailed and accurate costs, safety analysis and construction plans, so that the ALARA (As Low As Reasonably Achievable) principle could be applied. Subsequently, detailed designs would proceed so that construction and operations could begin.

Design details would have to be developed and the concept would have to be refined as experience is gained through practical application of the design concepts and as regulatory requirements develop.

Many rapid changes are occurring in technologies today. Due to those changes and the time frame of this program, it is foreseeable that many changes to design details would be made before the concept is implemented. The disposal

concept has been developed so as to be flexible and adaptable to site-specific conditions at the time of implementation. For example, options are available for underground vault design, disposal container design and materials.

2.4.1.1 Surface Design Considerations

Despite the lack of Canadian experience in the remote packaging, sealing and inspection of full used fuel containers, such operations are deemed to be practical given the rapid development in the field of robotics and the fact that both Ontario Hydro and AECL have proven experience in remote fuel handling (Simmons et al. 1994).

The development of an internationally accepted warning/identification system for use at the site after the vault has been sealed is being considered.

The parameters that are likely to be monitored in the vault can be measured with available instrumentation. However, in many cases, further development may be required to improve the longevity and reliability of instruments under disposal vault conditions. Technology is rapidly advancing in this field and should be available for the implementation stage.

2.4.1.2 Underground Design Considerations

The actual waste emplacement technique is still conceptual. Emplacement times are only an estimate, due to the absence of production-scale operations on which to base such estimates. However, these uncertainties are within the cost range given. As further development of the emplacement technique takes place and more is understood about its performance, the emplacement design and estimates would be updated.

Quality testing of sealing materials, to ensure that specifications for mixing and transport are met, would have to be developed. Experiments with respect to the emplacement of buffer and backfill materials would be carried out to assess the practicality of the concept design. Development is also anticipated on the sealing of fractured areas (Johnson et al. 1994a).

A retrieval method for disposal containers has been proposed (Simmons and Baumgartner 1994) for the reference container for borehole emplacement. Details of retrieval methods would be developed when disposal containers, buffer and backfill materials, and emplacement methods have been finalized.

2.4.2 Container Design Considerations

Other disposal container concepts are being studied, in addition to the reference titanium shell container. Some of these are the Iron-Based Stressed-Shell container, the copper container and the Dry Storage Container made of concrete. Details of these other container designs can be found in Johnson et al. (1994a).

The Iron-Based Stressed-Shell container would hold 72 used fuel bundles and have a carbon-steel inner shell to provide structural strength against external pressure loading, and a titanium-shell overpack for corrosion durability.

The copper container would hold 72 used fuel bundles and have a 25.4 mm thick shell of high purity copper. A granular material (such as glass beads) would be compacted by vibration into all residual space inside the container to resist any external pressure on the shell after emplacement in the vault.

The Dry Storage container would hold 384 used fuel bundles. It is proposed as a waste package suitable for storage, transportation and, possibly, disposal. Development efforts on these alternative container concepts have been

conducted in parallel with the joint AECL/Ontario Hydro studies of the corrosion-resistant metal-shell options.

2.4.3 Transportation System Considerations

A variety of transportation cask seal materials and groove designs will be tested and characterized. Impact limiter materials will also be tested and characterized. The rail cask design will need to be developed in more detail. Design refinements to the transportation systems to maximize safety, while maintaining reasonable costs, would also be carried out (for example, in the area of emergency response). The road and rail systems are based on standard technology. The water system would need to be refined based on a review of available options (e.g. tug/barge versus boat).

CHAPTER 3

3. REFERENCE DISPOSAL AND TRANSPORTATION ENVIRONMENTS

This chapter presents a description of the reference disposal and transportation environments used for the assessment of all stages of the UFDC life cycle and used fuel transportation.

As mentioned in Chapter 1, it is assumed that the disposal centre would be located somewhere in the Ontario portion of the Canadian Shield.

3.1 CHARACTERIZATION OF A NON-SITE SPECIFIC ENVIRONMENT

In a project environmental and safety assessment, baseline environmental conditions are usually established to provide some context to the assessment of potential changes arising from the project and significance of these changes. As mentioned in Section 1.5, baseline information on the community characteristics and participation of the affected public is essential to the determination of the significance of socio-economic impacts. This argument can be extended to the assessment of effects on the natural environment. Although some indication of significance can be drawn from a non-site specific assessment, the full significance can only be determined with the proper site-specific ecological context.

The characterization used in this assessment evolved from a fundamental principle established early in the Nuclear Fuel Waste Management program by the governments of Canada and Ontario (Joint Statement 1981). The Governments agreed that site selection for a disposal facility would not begin until after the disposal concept has been assessed and accepted by the public and the regulators. It followed that an environmental and safety assessment of the concept had to be performed in a way that would not prejudge the location of the disposal site. This was a major challenge because the assessment could not rely on site-specific baseline environmental data and because of the large study area to be investigated (the Canadian Shield area of Ontario).

True baseline environmental conditions were, therefore, not established for the study area (see Chapter 10 for strategy for environmental characterization at the site-specific/implementation stage). The approach to characterization for this assessment was to give as much context as possible by describing, in general terms, the socio-economic and natural environment of the study area, without trivializing the wide local variations and their influence on the actual effects. This general description, presented in Section 3.2, was compiled into a database of region-wide data for the Ontario portion of the Canadian Shield documented in Grondin and Fearn-Duffy (1993a). The region-wide parameters contained in the database are summarized in Appendix K.

In addition, the study area was described with reference to the ecoregions of Ontario (Environment Canada 1989b). A summary of this description is found in Section 3.3 and the full description in Appendix L.

Finally, conservative parameters for the natural and socio-economic environment were derived for the safety analysis, based on region-wide data. These data are presented in Section 3.4.

The same type of approach was used for the transportation reference environment. The general description of the transportation socio-economic and natural environment is presented in Section 3.6, based on region-wide data (Grondin 1993a). The natural and socio-economic environment parameters derived for the safety analysis, based on region-wide data, are described in Section 3.7.

3.2 GENERAL DESCRIPTION OF THE DISPOSAL ENVIRONMENT

The following general definition of the study area was used in the socio-economic and natural environment analyses to provide some context to the assessment of potential effects during the life-cycle of the UFDC. It is based on region-wide characterization data (Grondin and Fearn-Duffy 1993a). Selection of the parameters for the region-wide characterization is also documented in Grondin and Fearn-Duffy (1993a).

3.2.1 The Reference Disposal Environment

The study area is the Ontario portion of the Canadian Shield. It is approximately 650 000 km^2 in area and extends from the border of Manitoba, to the St. Lawrence River and the Quebec border. It is bounded by the Hudson Bay Lowlands to the north and by Lake Superior, the North Channel of Lake Huron and Georgian Bay to the south. From approximately Coldwater (near Georgian Bay), the Shield-Great Lakes-St. Lawrence Lowlands boundary extends generally eastward through the northern portions of Simcoe and Victoria Counties, central Peterborough County and southern Hastings, Lennox, Addington and Frontenac Counties to Gananoque on the St. Lawrence River. From the St. Lawrence River at Brockville, the Shield boundary traverses Leeds and Lanark counties into Quebec near Arnprior.

For purposes of the preclosure assessment, the Canadian Shield region of Ontario has been divided into three smaller regions - Southern, Central and Northern, as illustrated in Figure 3-1. The Southern region is approximately 51 000 km^2 in area and includes the southern portion of the Shield from the St. Lawrence River north to the French and Mattawa Rivers and Lake Nipissing. The Central region, approximately 207 000 km^2 in area, is bounded by the French and Mattawa Rivers and Lake Nipissing to the south, the Quebec border to the east, the Hudson Bay Lowlands to the north, and the boundary between Algoma and Cochrane Districts (in the Central region), and Thunder Bay district (in the Northern region) to the west. The Northern region contains the remaining portion of the Shield in Ontario to the Manitoba boundary, with an area of approximately 385 000 km^2.

Climate

The climate of the Ontario Shield is continental and becomes increasingly rigorous northward. In the Northern region, mean July temperatures are approximately 10°C lower and mean January temperatures approximately 20°C lower than in the south. The Central region receives the highest snowfall of the three regions, and the Northern region has the lowest mean annual total precipitation of the three regions.

Topography and Soils

The topography of the Ontario Shield shows very little relief; elevations vary within 100 metres, except in the Southern region where elevations vary within 150 metres. The soil is a relatively thin mantle of surficial sediments, largely of glacial origin. Most of the surficial soils are humo-ferric podzols, and most overburden can be characterized as sandy with increasing proportions of clay and organic soils towards the Hudson Bay Lowlands. The organic soils are largely associated with the poor drainage (muskeg) conditions of the northern areas.

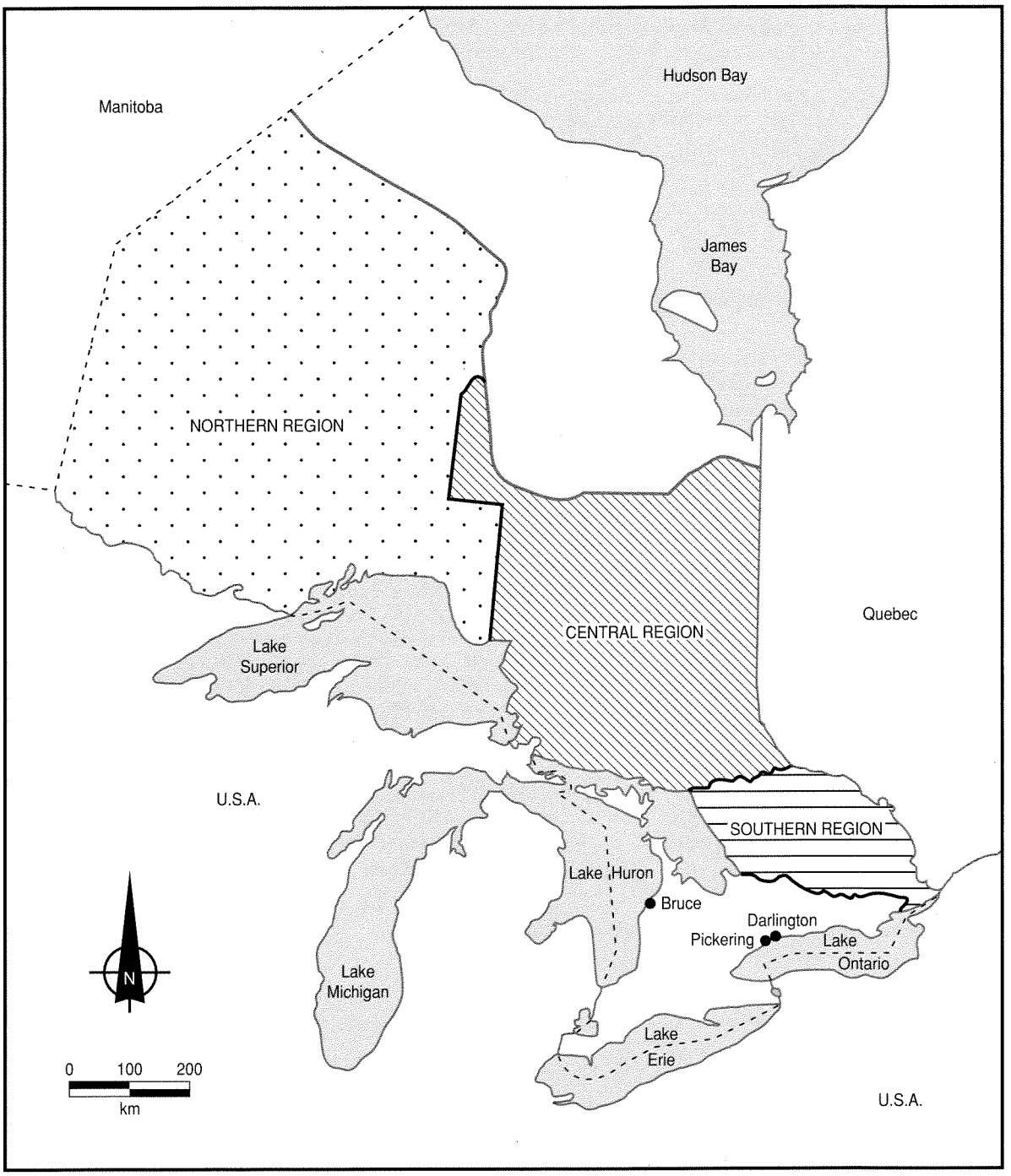


FIGURE 3-1: Three Regions of the Study Area

Flora and Fauna

The Shield region is characterized by a wide variety of flora and fauna, which generally becomes less diverse northward. The region supports 72 species of fish, of which 24 species are found throughout the region. Three hundred and six wildlife species inhabit the region, of which 202 are birds, 44 are reptiles and 60 are mammals. Sixty-two species of flora and fauna have been identified as rare, threatened or endangered (Grondin and Fearn-Duffy 1993a).

The Ontario Shield is covered by two major forest regions: Boreal and Great Lakes-St. Lawrence (Energy, Mines and Resources 1986; Environment Canada 1989a). Boreal forest occurs over large portions of the Central and Northern regions and eventually gives way, with increasingly rigorous climatic and soil conditions, to sub-arctic open lichen-woodland towards the Hudson Bay Lowlands. The mixed deciduous Great Lakes-St. Lawrence forest occurs in southern portions of the Central and Northern regions, and throughout the Southern region.

Wetlands are found in all three regions (Energy, Mines and Resources 1986; Environment Canada 1989a). The low subarctic wetland, continental high boreal, humid high boreal, continental mid-boreal, humid mid-boreal, and low boreal wetland regions are present in the Northern region. The humid mid-boreal and low boreal wetland regions are present in the Central region, and the low boreal and eastern temperate wetland regions are present in the Southern region.

Sensitive Features

Areas of natural and scientific interest (ANSIs) have been identified in the three regions by the Ontario Ministry of Natural Resources (Grondin and Fearn-Duffy 1993a). Such features include unique geological and landmark sites (e.g. a soapstone quarry, sand dunes and volcanic agglomerates), rare vegetation sites (e.g. climax forest, a sugar maple stand and prairie-type vegetation), and wildlife sites (e.g. blue heron rookeries, bald eagle nests and trout streams).

Other sensitive features of an historical or archaeological value are contained in the study area. Historical sites include: abandoned town sites, old mining sites, Hudson Bay Posts, mechanical portages, museums, old sawmills, etc. Archaeological sites include aboriginal burial grounds, aboriginal village sites and explorer camp/trading posts.

The ANSIs and other sensitive features of the study area are described in detail elsewhere (Grondin and Fearn-Duffy 1993a).

Surface Water

The drainage patterns in the three regions are as follows:

i) Southern region basins drain into the Great Lakes;

ii) Central region basins drain into Hudson Bay (59% of the area) and into the Great Lakes (41% of the area); and

iii) Northern region basins drain either into Manitoba waterways (29% of the area) or into Hudson Bay (57% of the area).

A list of the rivers found in each region can be found in Grondin and Fearn-Duffy (1993a).

An estimated 14.5% of the Northern region is covered by water in either lake or river form. This is the highest percentage of the three regions.

Land Use

The capability for forestry is extensive in each of the three regions. Approximately 80% of the land in the Southern region is of moderate to high timber capability and it produces the greatest volume of timber per unit land area. In Central and Northern regions, the timber use capability is considered to be moderate to high in 39% and 27% of the forested areas, respectively.

Climate and soil conditions restrict agriculture to a few areas of the Ontario Shield, the largest single area being the Cochrane Clay Plains in the Central region. Less than 2% of the Ontario Shield area is farmland, with less than half of this in improved farm land. Livestock (dairy and poultry) and some cereals for consumption by livestock are the most significant agricultural commodities produced in the Shield region.

Opportunities for recreational land use abound in the Ontario Shield region. Land capability to support intensive (for a large number of people) and extensive (dispersed low density) recreational use is greatest in the Southern region, and tends to decrease toward the Northern region. The Southern region has a greater number and density of cottages, parks and other recreational facilities used by the local population and by tourists from the densely populated areas of Southern Ontario.

Mineral exploration and mining land uses are also prevalent in the Ontario Shield region. The Southern region contains a small fraction of the Sudbury mining district, the rest being part of the Eastern Ontario mining district. The Central region, which has most of the mining land use on the Ontario portion of the Canadian Shield, comprises all of the Lader Lake mining district, most of the Porcupine, Sault St. Marie and Sudbury districts, and a small fraction of the Thunder Bay district. The Northern region comprises all of the Patricia mining district, most of the Thunder Bay district, and a small fraction of the Larder Lake and Sault St. Marie districts (Lemieux et al. 1987).

Population

The Ontario portion of the Canadian Shield is generally sparsely populated with a mean population of 1.5 person per km^2, compared to 9.0 for the province. Approximately 70% of its population lives in cities, towns and villages.

The Southern region comprises only 7.5% of the Ontario portion of the Canadian Shield but contains 25% of its population. This population is, however, more dispersed than in the other two regions. It has no large centres, but has a larger number of towns and villages than the other two regions.

The Central region covers 32.5% of the Ontario portion of the Canadian Shield and contains 52% of the population. Sudbury, Sault Ste. Marie, Timmins and North Bay are the major population centres, representing 52% of the region's population. Population centres are generally located along the main transportation routes.

The Northern region is the least densely populated of the three regions covering 60% of the Ontario portion of the Canadian Shield but having only 23% of its population. Thunder Bay accounts for 50% of this population. As with the Central region, population centres are usually located along main transportation routes.

Employment

The labour force by industrial sector in each region is summarized in Table L-2 in Appendix L. The manufacturing and service sectors are the largest employers in all three regions.

Aboriginal peoples and communities

Aboriginal peoples and communities (living on and off reserves) are a significant component of the socio-economic environment within the three regions of the Ontario Shield. In this context, Aboriginal refers to Indian, Inuit and Metis. The entire area of the Ontario Shield is encompassed by Treaties between the First Nations, and Federal and Provincial Governments.

The political interests of Aboriginals in the Shield are represented by the following Aboriginal Organizations:

i) The Association of Iroquois and Allied Indians;

ii) The Nishnawbe-Aski Nation;

iii) The Union of Ontario Indians;

iv) Grand Council Treaty #3;

v) The Ontario Metis and Aboriginal Association; and

vi) The Chiefs of Ontario.

Geographical Identity of People Living in the Ontario Shield Region

Geographically, approximately 65% of Ontario is considered Northern (Statistics Canada 1988; Bone 1992). Using this definition, only southern parts of the Ontario Shield region would not be considered a northern area. People living in the northern sections of the provinces have a special identification with the northern environment. This concept is discussed in more detail in Section 6.5.

3.2.2 Use of the Reference Environment Description in the Analyses

3.2.2.1 Socio-Economic Impact Analysis

The general description of the environment presented in Section 3.2 was used to give some context for the socio-economic impact analysis. The disposal and transportation socio-economic analyses are not based on a pre-defined reference socio-economic environment. They are based generally upon case studies of comparable projects; studies of public opinions and concerns over comparable projects and in particular nuclear facilities; and community dynamics and the social processes which determine the nature and extent of changes resulting from project implementation in any location (see Section 6.5.2 for a detailed description of the methodology). The general description was, therefore, used in such areas as the assessment of the relevance of case studies and to assist in the understanding of the public opinions and concerns.

3.2.2.2 In the Natural Environment, Radiological Pathways and Safety Analyses

Table 3-1 shows how the general description of the environment was used in the natural environment, pathways and safety analyses. Environmental parameters that were characterized for use in these analyses are listed in Table 3-1. The environmental factors and specific considerations used in the selection of these parameters are defined in greater detail in Grondin and Fearn-Duffy (1993a).

3.2.3 Selection of Reference Environment Factors

This section describes the types of factors included in the region-wide characterization of the disposal environment documented in Grondin and Fearn-Duffy (1993a).

3.2.3.1 Natural Environment Factors

The natural environment factors for characterizing the non site-specific disposal environment were selected based on a review of :

i) the kind of region-wide data available for the Ontario portion of the Canadian Shield from federal and Ontario government databases;

ii) environmental factors usually considered in environmental assessments (Jain et al. 1977; Ontario Hydro 1988b); and

iii) the federal codes of practice (Environment Canada 1985, 1987a, 1989a).

The following natural environment factors were selected: flora and fauna, non-renewable resources, land use, air and water. Although these factors divide the environment into somewhat arbitrary compartments, use of such factors help to organize the information on the non site-specific disposal environment in a systematic manner. Information on these factors provide the context for the study of effects of the UFDC on the natural environment.

3.2.3.2 People and their Communities

Region-wide data were collected to provide some context on the people that inhabit the Ontario Shield, their communities and the types of regional economic activities. The data included: population density, natural and historical features, agricultural production, aboriginal communities, and labour force by industrial sector.

3.2.4 Data Collection and Processing

Comprehensive regional information was collected for each environmental factor.

Geographical Information System Data

A Geographical Information System (GIS) was used to represent and analyse geo-referenced data (i.e. data in reference to a geographical location on a map). An example of the use of the GIS to represent data is shown in Figure 3-2 (map of annual snowfall). The environmental data for each factor were reviewed for appropriateness, converted to numerical values by digitizing, and represented on a map. For each map, the relational database part of the GIS estimated the area covered by each environmental factor value or range in terms of percentage of each of the three regions in the Ontario portion of the Canadian Shield.

TABLE 3-1
Summary of Environmental Factors and Parameters Used in the Preclosure Environmental and Safety Analysis

Environmental Factor	Environmental Parameter	Data used in:
Flora and Fauna	Number of common wildlife species in a region (as an indicator of biological diversity)	Natural Env. Effect[1] Analysis
	Number of common fish species in a region (as an indicator of biological diversity)	Natural Env. Effect Analysis
	Number of forest tree associations in a region (as an indicator of biological diversity)	Natural Env. Effect Analysis
	Number of endangered species in a region	Natural Env. Effect Analysis
	Forest fires data	Natural Env. Effect Analysis and Public Safety Analysis[2]
	Wetlands	Natural Env. Effect Analysis
	Areas of Natural and Scientific Interest (ANSIs)	Natural Env. Effect Analysis
Non-renewable Resources	Reserves of metal and non-metal mineral resources	Natural Env. Effect Analysis
Land Use	Presence of permafrost	Natural Env. Effect Analysis
	Timber use capability	Natural Env. Effect Analysis
	Intensive and Extensive Recreational Use	Natural Env. Effect Analysis
	Parks	Natural Env. Effect Analysis
	Agricultural land	Natural Env. Effect Analysis
Air	Meteorological data	Pathways Analysis
	Emissions data	Natural Env. Effects Analysis[1]
	Background radiation	Pathways Analysis[1]
Water	Mean lake size	Pathways[1] and Natural Env. Effect Analyses
	Lake size distribution	Pathways Analysis[1]
	Mean lake depth	Pathways and Natural Env. Effect Analyses[1]
	Mean river discharge	Pathways Analysis
Human Environment	Population density	Pathways and Public Safety Analysis
	Natural and historical features	Natural Env. Effect Analysis
	Food production data	Pathways and Public Safety Analysis
	Aboriginal	Natural Env. Effect Analysis

(1) See Sections 4.5, 5.4, 6.4, 7.4 and 8.4
(2) See Section 6.1

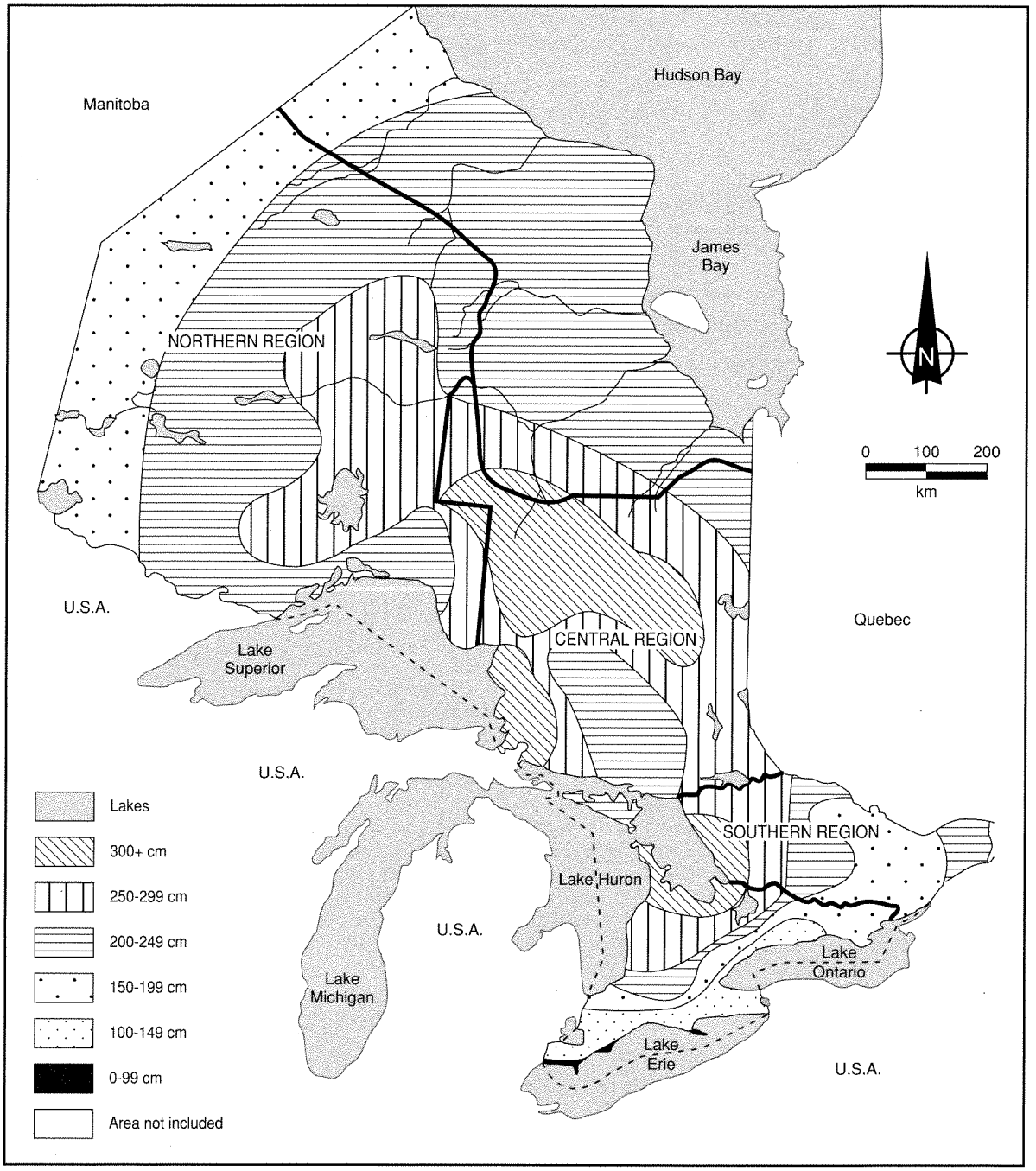


FIGURE 3-2: Example of a Map of an Environmental Characteristic Generated by a GIS – Mean Annual Snowfall over the Ontario Portion of the Canadian Shield

This data served two purposes:

i) to illustrate differences between the regions; and

ii) to indicate the probability of encountering certain environmental conditions (value ranges) within each region.

For example, the importance of the various types of possible land use could be determined based on the percentage of the region covered by each type of land use, as calculated by the GIS.

Although not all the data processed by the GIS represents the environmental characteristics of the three regions of the Ontario portion of the Canadian Shield, they were relevant to the analysis (e.g. annual snowfall), and they nevertheless provided some context for the analysis.

3.3 AN ECOREGION BASED DESCRIPTION OF THE STUDY AREA

In its Ecological Land Classification Series, Environment Canada has divided Ontario into a number of ecoregions (Environment Canada 1989b). These ecoregions and their characteristics were correlated to the three regions of the Ontario Shield used in this assessment (see Appendix L). This type of information would be used early in the siting process to provide a study area-wide characterization of the existing environment (see Chapter 10).

The Southern region comprises 79% of the Nipissing and 33% of the Saint-Laurent ecoregions. The climate of these two ecoregions is characterized by warm summers and cold snowy winters. The natural vegetation type is deciduous forest. Forestry, hydroelectric power, tourism and mining (in part of the region) are the main activities in the Nipissing ecoregion, while dairy farming and agricultural crop dominate the Saint-Laurent region. North Bay is the major urban centre in the Nipissing ecoregion, and Ottawa is the largest urban centre in the Saint-Laurent ecoregion.

The Central region comprises 46% of the Superior Highlands, 21% of the Nipissing, 97% of the Chapleau Plains, 91% of the Lac Matagami, 11% of the James Plains, and 2% of the Lake St-Joseph Plains ecoregions. The climate of these ecoregions is generally characterized by warm summers and long cold winters, with varying snowfall. As one moves northward, the natural vegetation changes from mixed forests to boreal forests. Forestry, mining and tourism are the dominant activities. Sudbury, Sault St. Marie and Timmins are the major urban centres in the region.

The Northern region comprises 4% of the James Plains, all of the Nipigon, Thunder Bay and Lake of the Woods Plains, 96% of the Big Trout Plains, 54% of the Superior Highlands, all of the Gods Plains, 8% of the Spector Plains, 98% of the Lake St-Joseph Plains, 9% of the Lac Matagami, and all of the Berens Plains ecoregions. The climate of these ecoregions is generally characterized by short warm summers and long cold winters, with snowy winters in some ecoregions and cool summers in others. Some of the areas are only accessible by forest access roads. Forestry, tourism and recreation are the dominant activities across the region. Mining is also found in some areas. Thunder Bay, Kenora, Fort Frances, Red Lake, Dryden and Sioux Lookout are the major population centres.

3.4 SPECIFIC DATA USED IN THE RADIOLOGICAL PATHWAYS AND SAFETY ANALYSIS

1. Population

The population distribution around the site is used to calculate the potential impacts on public health due to emissions from a disposal facility. Since the cumulative public exposure to airborne emissions from a nuclear facility will increase with increasing population density around the site, the generic population density around the site has been estimated conservatively, i.e. it overestimates the population within a 100 km radius from the disposal facility.

The generic population densities around the UFDC were estimated as follows. The region within the 100 km radius was divided into 9 radial intervals, as shown in Figure 3-3 (Russell 1993a). The population density of each of the census division (counties, municipalities, etc.) was then determined. For each of the three Shield regions, the highest value was chosen and was used to estimate the population within the radial interval closest to the facility (i.e. up to 4 km). The census division with the next highest population density was used to estimate the population within the second radial interval (4 to 8 km). This procedure was continued out to the radial interval within 100-km radius. This method of estimating the potentially affected population gives conservatively high values because it postulates that the highest population densities in each Canadian Shield region would be within a 100 km radius of the UFDC.

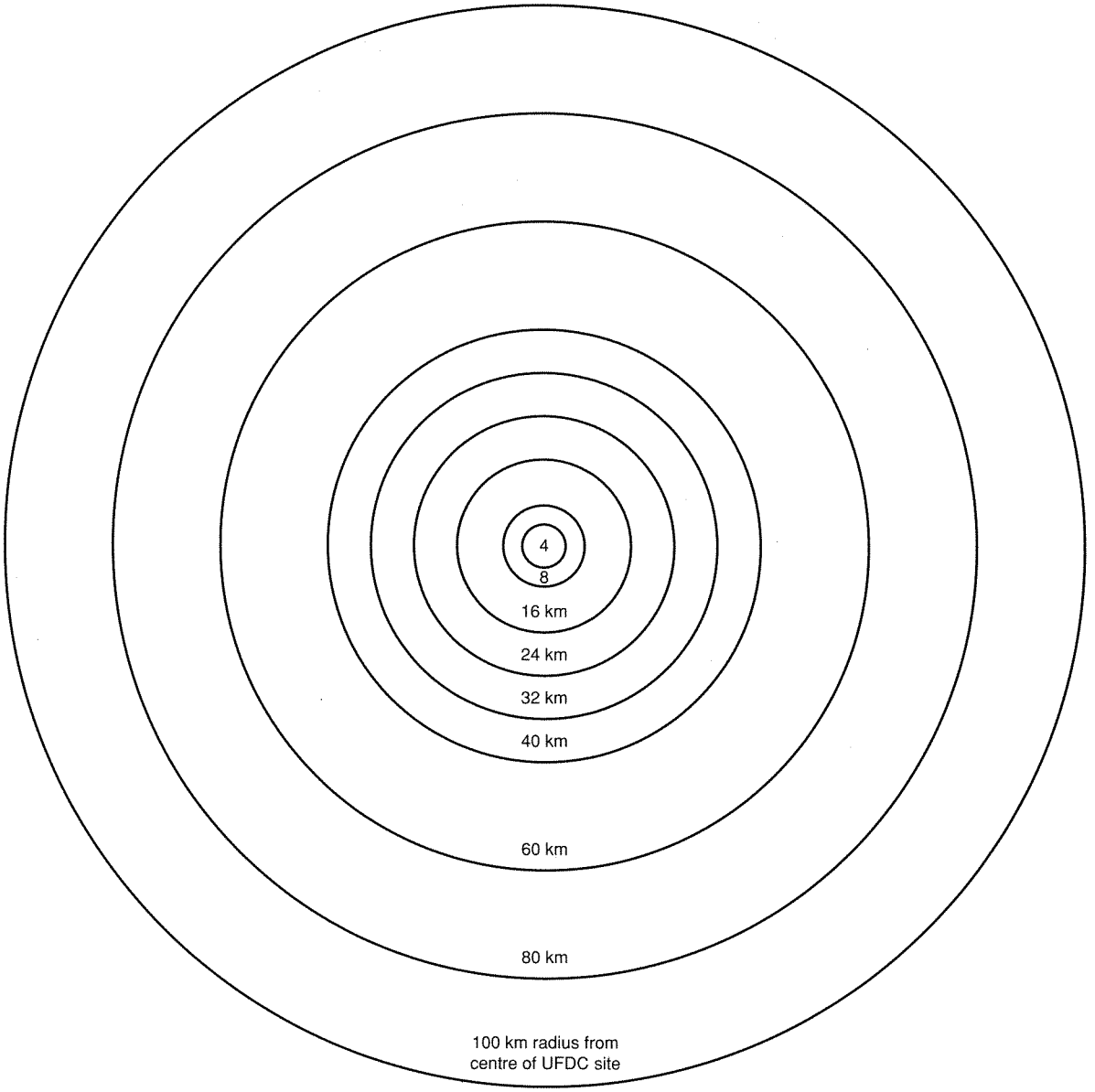
In this generic assessment, the population is assumed to be evenly distributed among the 16 compass directions within each radial interval. The population data for the Northern, Central and Southern regions are given in Table 3-2 for each of these 9 radial intervals.

2. Food Production

Food production within 100 km of the UFDC has been tabulated using the reference environment data (Grondin and Fearn-Duffy 1993a). The data consists of the following food groups of milk, beef, pork, eggs, poultry, fruits and vegetables. It has been specified in terms of the 9 radial intervals from the UFDC and is assumed to be distributed uniformly within each radial interval. Food production is conservatively assumed to be situated as close to the facility as possible. Data for the Northern, Central and Southern regions of the Shield are listed in Tables 3-3, 3-4 and 3-5, respectively.

3. Meteorology

The meteorological data for the reference UFDC location were based on representative weather stations in each region of the Ontario Shield (Grondin and Fearn-Duffy 1993a). The meteorological data was obtained from 17 stations across the three regions. The variance within each region was small enough to permit the use of a representative station as the source of the weather frequency distribution for each region. Given the generic nature of the study, this assumption seems reasonable. However, for accident conditions, the weather conditions providing the least dispersion were assumed. The implications of changes in meteorological and other environmental parameters are examined in Section 9.2.2.2 as part of a sensitivity analysis.



Population and food production data are defined for 9 radial intervals from the UFDC (1.5-4, 4-8, 8-16, 16-24, 24-32, 32-40, 40-60, 60-80, 80-100 km). These data are used to calculate the collective dose to the population within 100 km of the UFDC.

FIGURE 3-3: Radial Intervals to 100 km Radius from the Disposal Centre

TABLE 3-2

Population Data

Region	Persons		
	Radial Interval (km)		
	1.5 to 4	4 to 8	8 to 16
Northern	1.63×10^3	5.74×10^3	2.29×10^4
Central	2.36×10^3	8.30×10^3	3.32×10^4
Southern	1.03×10^4	3.62×10^4	3.27×10^4
Region	Radial Interval (km)		
	16 to 24	24 to 32	32 to 40
Northern	3.82×10^4	5.35×10^4	4.60×10^4
Central	5.53×10^4	7.28×10^4	6.15×10^4
Southern	3.12×10^4	4.36×10^4	5.13×10^4
Region	Radial Interval (km)		
	40 to 60	60 to 80	80 to 100
Northern	3.27×10^4	0	0
Central	1.86×10^5	1.01×10^5	3.99×10^4
Southern	1.57×10^5	1.43×10^5	1.21×10^5

(Grondin and Fearn-Duffy 1993a)

TABLE 3-3

Food Production Data for the Northern Region

Food Group	Food Production ($kg \cdot a^{-1}$)		
	Radial Interval (km)		
	1.5 to 4	4 to 8	8 to 16
Milk	1.20×10^{3}	4.21×10^{3}	1.68×10^{4}
Beef	3.22×10^{5}	1.13×10^{6}	4.52×10^{6}
Pork	1.21×10^{4}	4.24×10^{4}	1.69×10^{5}
Egg	2.34×10^{3}	8.22×10^{3}	3.28×10^{4}
Poultry	3.88×10^{2}	1.36×10^{3}	5.44×10^{3}
Vegetables	2.00×10^{5}	7.01×10^{5}	2.80×10^{6}
Food Group	Radial Interval (km)		
	16 to 24	24 to 32	32 to 40
Milk	1.02×10^{4}	0	0
Beef	2.74×10^{6}	0	0
Pork	1.03×10^{5}	0	0
Egg	1.99×10^{4}	0	0
Poultry	3.30×10^{3}	0	0
Vegetables	1.70×10^{6}	0	0
Food Group	Radial Interval (km)		
	40 to 60	60 to 80	80 to 100
Milk	0	0	0
Beef	0	0	0
Pork	0	0	0
Egg	0	0	0
Poultry	0	0	0
Vegetables	0	0	0
Fish Yield	3.5×10^{-4} $kg \cdot m^{-2} \cdot a^{-1}$		

No production was assumed for radial intervals beyond 24 km because all the regional production was assumed to be in the closest intervals to the UFDC.

(Grondin and Fearn-Duffy 1993a)

TABLE 3-4

Food Production Data for the Central Region

Food Group	Food Production ($kg \cdot a^{-1}$)		
	Radial Interval (km)		
	1.5 to 4	4 to 8	8 to 16
Milk	1.23×10^{3}	4.33×10^{3}	1.73×10^{4}
Beef	3.23×10^{5}	1.13×10^{6}	4.53×10^{6}
Pork	9.48×10^{3}	3.33×10^{4}	1.33×10^{5}
Egg	2.29×10^{3}	8.04×10^{3}	3.21×10^{4}
Poultry	1.20×10^{3}	4.22×10^{3}	1.68×10^{4}
Vegetables	1.93×10^{5}	6.79×10^{5}	2.71×10^{6}
Food Group	Radial Interval (km)		
	16 to 24	24 to 32	32 to 40
Milk	2.88×10^{4}	7.71×10^{3}	0
Beef	7.55×10^{6}	2.02×10^{6}	0
Pork	2.22×10^{5}	5.93×10^{4}	0
Egg	5.35×10^{4}	1.43×10^{4}	0
Poultry	2.81×10^{4}	7.52×10^{3}	0
Vegetables	4.52×10^{6}	1.21×10^{6}	0
Food Group	Radial Interval (km)		
	40 to 60	60 to 80	80 to 100
Milk	0	0	0
Beef	0	0	0
Pork	0	0	0
Egg	0	0	0
Poultry	0	0	0
Vegetables	0	0	0
Fish Yield	3.1×10^{-4} $kg \cdot m^{-2} \cdot a^{-1}$		

No production was assumed for radial intervals beyond 32 km because all the regional production was assumed to be in the closest intervals to the UFDC.

(Grondin and Fearn-Duffy 1993a)

TABLE 3-5

Food Production Data For the Southern Region

Food Group	Food Production ($kg \cdot a^{-1}$)		
	Radial Interval (km)		
	1.5 to 4	4 to 8	8 to 16
Milk	1.44×10^{3}	5.04×10^{3}	2.01×10^{4}
Beef	4.33×10^{5}	1.52×10^{6}	6.08×10^{6}
Pork	2.60×10^{4}	9.13×10^{4}	3.65×10^{5}
Egg	2.78×10^{3}	9.77×10^{3}	3.90×10^{4}
Poultry	1.40×10^{4}	4.91×10^{4}	1.96×10^{5}
Vegetables	9.71×10^{4}	3.41×10^{5}	1.36×10^{6}
Food Group	Radial Interval (km)		
	16 to 24	24 to 32	32 to 40
Milk	3.36×10^{4}	4.70×10^{4}	6.04×10^{4}
Beef	1.01×10^{7}	1.42×10^{7}	1.82×10^{7}
Pork	6.08×10^{5}	8.51×10^{5}	1.09×10^{6}
Egg	6.50×10^{4}	9.10×10^{4}	1.17×10^{5}
Poultry	3.26×10^{5}	4.57×10^{5}	5.88×10^{5}
Vegetables	2.27×10^{6}	3.18×10^{6}	4.09×10^{6}
Food Group	Radial Interval (km)		
	40 to 60	60 to 80	80 to 100
Milk	6.74×10^{4}	0	0
Beef	2.03×10^{7}	0	0
Pork	1.22×10^{6}	0	0
Egg	1.31×10^{5}	0	0
Poultry	6.56×10^{5}	0	0
Vegetables	4.57×10^{6}	0	0
Fish Yield	3.4×10^{-4} $kg \cdot m^{-2} \cdot a^{-1}$		

No production was assumed for radial intervals beyond 60 km because all the regional production was assumed to be in the closest intervals to the UFDC.

(Grondin and Fearn-Duffy 1993a)

4. Aquatic Environment

The aquatic environment near the UFDC is assumed to be either a river or a lake which receives the liquid effluent from the UFDC. A reference lake, and river sizes and flow rates were derived for the Northern, Central and Southern regions of the Ontario portion of the Canadian Shield by Grondin and Fearn-Duffy (1993a, 1993b). These data are presented in Table 3-6.

To estimate the airborne deposition of radionuclides to water, the average distance from the airborne release point at the UFDC to the water body was assumed to be the 1.5 km (the radius of the land use control zone) plus the radius of the lake.

The maximum routine water requirements of the UFDC are about 190 $L \cdot s^{-1}$ maximum (Simmons and Baumgartner 1994). This water is assumed to be returned to the water body after processing.

The maximum water withdrawal from a river for protection of the aquatic environment is assumed to be 15% of the river's flow rate (Knox 1978). The flow rate of a river supplying water to the UFDC must then be at least 1 200 $L \cdot s^{-1}$ to ensure protection of the aquatic environment (Grondin and Fearn-Duffy 1993a). It is assumed by Environment Canada that 5% water withdrawal from a lake (of the lake volume) is sufficient to protect the biological resources in a lake. This will however vary greatly with lake morphometry, and characteristics of the littoral zone (Environment Canada 1989b). The minimum lake volume of a lake supplying water to the UFDC is derived from that assumption (see Grondin and Fearn-Duffy 1993b for further details).

5. Background Radiation

Neil (1985) has summarized the average background dose to the public from natural sources and routine exposure to technical processes (e.g. coal burning and nuclear power plant operation), consumer products and services (e.g. radioluminous watches, smoke detectors, glassware and air travel), nuclear weapons testing fallout and potential medical exposures. The analysis was recently updated to include a revised dose from radon and thoron daughters (NCRP 1987). The resulting background radiation doses are given in Table 3-7. The average annual background dose to the public in Ontario from natural sources is approximately 3.0 $mSv \cdot a^{-1}$.

3.5 DATA UNCERTAINTY

Many sources of information were used to prepare these region-wide data bases for the disposal environment. Although the data presented for some factors are based on relatively few years of data or on a limited number of data points, every effort has been made to use the best available data from recent years on a province-wide scale, and to ensure that the data presented are accurate and as representative as possible of actual conditions. However, this data is not meant to replace baseline environmental data that will need to be collected during implementation.

The population data used in the safety analysis (Table 3-8) was overestimated on purpose, such that when used in the calculation of dose it leads to conservative results.

A sensitivity analysis to changes in the reference environment data has been carried out to test the robustness of the analysis results. It is documented in Chapter 9.

TABLE 3-6
Lake Data

Parameter	Region		
	Northern	Central	Southern
Estimated From Data (rounded off)			
Lake Surface Area (m^2)	104×10^4	151×10^4	211×10^4
Mean Lake Depth (m)	6.2	5.2	4.6
Annual Precipitation ($mm \cdot a^{-1}$)	750	850	850
Annual run-off ($mm \cdot a^{-1}$)	300	400	300
Calculated			
Lake Volume[1] (L)	6.45×10^9	7.85×10^9	9.71×10^9
Lake Flow[2] ($L \cdot s^{-1}$)	74	144	150

Grondin and Fearn-Duffy (1993a)

1 Calculated based on Ministry of Natural Resources definition of mean lake depth

$V = A * D$ V = lake volume
A = lake area
D = mean lake depth

2 Lake flow = Annual run-off x drainage basin area / (365x24x3600 s) where the drainage basin is assumed to be 7.5 times the average lake area (normally drainage basins are between 5 and 10 times the lake area)

TABLE 3-7
Estimated Average Values of Background Radiation Dose to Individual Members of the Public in Ontario

Source of Irradiation	Annual Dose ($mSv \cdot a^{-1}$)
Natural	
- cosmic rays	0.3
- ^{14}C	0.01
- ^{40}K (internal exposure)	0.3
- radon and thoron progeny	2.0
- irradiation from ^{238}U and ^{232}Th	
- internal	0.17
- external	0.23
- other natural	0.01
Total Natural (rounded)	3.0
Nuclear Weapon Test Fallout	0.02
Exposures from Technological Processes	0.04
Consumer Products and Services	0.02
Total Background (rounded)	**3.1**
X-ray Diagnosis	0.39
Nuclear Medicine	0.10
Total Annual Individual Public Dose from all Sources	**3.6**

Sources: National Council of Radiation Protection and Measurements Report No. 94, December

TABLE 3-8
Definition of Population Zones

Population Zone	Population Density (persons/km^2)
RURAL	0 - 149
SUBURBAN	150 - 649
URBAN	greater than 650

Grondin (1993a)

3.6 GENERAL DEFINITION OF THE USED FUEL TRANSPORTATION ENVIRONMENT

The study area for this assessment extends from the existing used fuel storage sites in Ontario (Pickering/Darlington and Bruce) to the geometric centre of the three regions in the Canadian Shield. The environment is different for each transportation mode: road, rail and water. The assessment assumes that used fuel transportation would use the existing road, rail and water networks.

For the road and rail modes, the transportation environment comprises the land, and all natural and built features on each side of the transportation corridors, the people that live on and use this land, and the people that travel along the transportation corridors.

The description of the Ontario Shield environment (Section 3.2) covers, in general terms, the environmental conditions that would be encountered along the transportation route for the northern part of the journey. In rural areas, the population will tend to settle along the major roads. The southern part of the route is closer to large population centres, especially for Pickering and Darlington with predominantly residential, commercial and industrial land use. The area near the Bruce Generating Stations is not as densely populated, and is dominated by recreational/outdoor and agricultural land use. Depending on the actual route selected at the time, some travel by road and rail could go through protected lands such as parks and Aboriginal reserves.

Some road travel will be on multiple lane highways, some on rural roads and some on residential streets with varying levels of traffic. The proportions of each of these are given in Section 3.7.3.2 (Table 3-9). The majority of the journey by road (or rail) would be in rural areas with a population density less than 149 persons per km^2.

Travel by water would be on the Great Lakes and interconnecting waterways. Part of the route will, therefore, be close to populations in the channels and rivers, and part would be in open waters. Part of the route would be in the relatively shallow waters of Lake Ontario, Lake Erie and the channels and rivers, and part would be in Lake Superior with water depths up to 400 m. Some of these routes would be used for pleasure boating by tourists and the local communities. The reference location for the transfer facility is the northern shore of Lake Superior. This area contains a number of areas of natural and scientific interest (ANSI's), as identified by the Ontario Ministry of Natural Resources. They are listed in Grondin (1993b).

TABLE 3-9
Reference Environment Parameters for the Reference Road Routes to the Three Assumed Locations for the Conceptual Disposal Facility

Parameter	to Southern Region[1]	to Central Region[1]	to Northern Region[1]
Total Distance (km)	400	900	1900
Distance in Each Population Zone			
rural (km)	371	871	1846
(% of total distance)	(93%)	(97%)	(97%)
suburban (km)	20	23	48
(% of total distance)	(5%)	(3%)	(3%)
urban (km)	9	6	6
(% of total distance)	(2%)	(<1%)	(<1%)
Distance in Each Population Zone by type of road			
rural - highway (km)	347	871	1846
(% of rural zone)	(93%)	(100%)	(100%)
rural - freeway (km)	24	0	0
(% of rural zone)	(7%)	(0%)	(0%)
suburban - highway (km)	18	23	48
(% of suburban zone)	(89%)	(100%)	(100%)
suburban - freeway (km)	2	0	0
(% of suburban zone)	(11%)	(0%)	(0%)
urban - city street (km)	7	6	6
(% of urban zone)	(76%)	(100%)	(100%)
urban - freeway (km)	2	0	0
(% of urban zone)	(24%)	(0%)	(0%)
Population Density (persons/km^2)			
rural	19	13	12
suburban	370	314	318
urban	922	885	885
Traffic Count (# of vehicles/24h, each way counts for one)			
rural	3617	4197	3153
suburban	10303	4337	3056
urban	7364	5144	5154
Accident Rate (# of accidents per 10^6 vehicle-km travelled)			
rural	1.12	1.00	1.00
suburban	0.91	1.14	1.21
urban	1.02	1.38	1.38
overall	1.11	1.01	1.01

[1] to the geometric centre of the region

(Grondin 1993a)

3.7 SPECIFIC DATA USED IN THE TRANSPORTATION SAFETY ANALYSIS

For each of the three regions in the Ontario portion of the Canadian Shield, a database was developed using transportation environment data for routes originating at the existing sources of used fuel and ending at the geometric centre of the particular region. The resulting data is presented in the form of reference routes which are composites of real routes within each region. The detailed methodology can be found in Grondin (1993a).

This transportation study area could be expanded or adapted to include interprovincial transportation.

3.7.1 Selection of Reference Environment Parameters

The environmental parameters required to assess the public safety during the transportation of used fuel are:

i) distance travelled along the reference routes;

ii) population density along the reference routes;

iii) population zones along the reference routes;

iv) traffic count along the reference routes;

v) number of persons sharing the transportation corridor with the used fuel transportation vehicle (road, rail or water) along the reference routes;

vi) accident rate along the reference routes;

vii) general atmospheric dispersion data (Pasquill stability category and frequency of occurrence) and severe weather data along the reference routes; and

viii) maximum depth of navigable waters along the reference water routes.

3.7.2 Definition of Reference Routes

As mentioned earlier, the transportation study area is defined as being from the used fuel storage sites (Pickering/Darlington and Bruce) to a destination assumed to be the geometric centre of the three regions. In this context, a reference route is defined as a composite route, without specific geographical location, with environmental characteristics constructed from a number of existing possible routes. The data used for each of the reference routes are distance-weighted averages of the data along the existing routes from which the reference routes are constructed.

3.7.3 Acquisition and Interpretation of Route Data

3.7.3.1 Alternative Routes

Characteristics of the transportation reference routes (road, rail, road/water and rail/water) to the three regions are based on data from existing road, rail and water network from the two sources of used fuel: Bruce and Pickering/Darlington (because of their proximity, Darlington and Pickering are considered as one location).

The alternative routes were selected based on the following criteria:

i) only existing roads, railways and waterways may be selected;

ii) the shortest transportation distances are preferable;

iii) only class A roads (permitting heavy traffic), main tracks and standard shipping lanes may be used;

iv) the roads and railways should lead to the vicinity of the regional geometric centre (the assumption in Chapter 2 is that a 25 km access road/railway to the UFDC would be required);

v) the water routes should lead to locations that are accessible by road or rail;

vi) for the water-road and water-rail modes, the distance covered by the water mode should be maximized while minimizing the total distance (otherwise a more direct land route would be used instead); and

vii) sufficient water depth must be available along the routes.

A reference water route to the Southern region was not considered because it does not satisfy criterion (vi) above. Using these criteria, the reference port location for water-land transfer was chosen to be on the northern shore of Lake Superior.

The impacts of changes in data with time and other factors are discussed in the sensitivity analysis found in Chapter 9. Details of the alternative routes used can be found in Grondin (1993a).

3.7.3.2 Parameter Evaluation

Along each of the alternative routes, published data on the following parameters were evaluated: distance, traffic count, accident rate, population density, type of population zone, population density ratio along rural roads and maximum water depth. Three types of population zones were defined: rural, suburban and urban. The corresponding population densities based on actual population density data, are shown in Table 3-8. The reference parameters for each route are shown in Tables 3-9, 3-10, 3-11 and 3-12 for the three regions and all modes of transportation.

3.7.3.3 Data Variability

The reference environment approach has been found to be sufficiently flexible to enable various forms and types of data to be incorporated.

The reference road, rail and water traffic volumes are based on current traffic data on existing roads, railways and waterways in the study area. Since used fuel transportation would not start until well after the year 2000, it is likely that traffic volumes would have changed. A sensitivity analysis was, therefore, carried out to assess the effects of changes in traffic and other environment parameters (see Section 9.1).

The population density in the three population zones (rural, suburban and urban) is based on current population data. A corridor of 800 m on each side of the road was assumed to be populated at the average population density of the zone. Although the population in the transportation study area is expected to have changed by the time used fuel is transported, the wide range of population densities covered in the database is still expected to be representative.

TABLE 3-10
Reference Environment Parameters for the Reference Rail Routes to The Three Assumed Locations for the Conceptual Disposal Centre

		to Southern Region[1]	to Central Region[1]	to Northern Region[1]
Total Distance (km)		400	800	1400
Distance in Each Population Zone km (%)				
rural		320 (80%)	720 (90%)	1330 (95%)
suburban		40 (10%)	48 (6%)	42 (3%)
urban		40 (10%)	32 (4%)	28 (2%)
Distance in Each Population Zone by rail type km (%)				
rural	single	240 (75%)	720 (100%)	1330 (100%)
	multiple	80 (25%)	0	0
suburban	single	4 (10%)	32 (67%)	14 (33%)
	multiple	36 (90%)	16 (33%)	28 (67%)
urban	single	24 (60%)	24 (75%)	28 (100%)
	multiple	16 (40%)	8 (25%)	0
Population Density (persons/km^2)				
rural		23	14	11
suburban		344	359	297
urban		1038	1525	1647
Traffic Count (# of trains/24h, each way counts for one)				
rural		12	12	12
suburban		27	9	4
urban		24	7	5
Accident Rate (# of accidents/million railcars-km)				
rural		1.73	0.23	0.20
suburban		0.54	0.29	0.28
urban		0.89	0.49	0.51
overall		1.53	0.24	0.21
Persons Traffic (# of persons/24h, sharing the transportation corridor)				
rural		936	347	274
suburban		1892	392	187
urban		1879	376	340

[1] to the geometric centre of the region

(Grondin 1993a)

TABLE 3-11
Reference Environment Parameters for the Reference Road-Water Routes to the Central and Northern Destinations

	to Central Region[1]	to Northern Region[1]
Total Distance (km)	1 300	1 700
Distance in Each Population Zone km (%)		
road-rural	339 (26%)	550 (32%)
road-suburban	0	43 (3%)
open waters	849 (65%)	998 (59%)
channel/river waters	112 (9%)	109 (6%)
Population Density (persons/km^2)		
road-rural	19	18
road-suburban	--	345
open waters	0	0
channel/river waters	559	559
Traffic Count (# of road vehicles/24h, each way counts for one; # of water vessel passages per year)		
road-rural	781	1 404
road-suburban	--	3 767
open waters	12 183	11 974
channel/river waters	10 842	10 842
Accident Rate (# of accidents/million vehicle-km)		
road-rural	1.49	0.68
road-suburban	--	1.05
open waters	1.05	0.81
channel/river waters	18.91	18.91
Maximum Water Depth (m) (averaged over all route segments)		
open waters	123	157
channel/river waters	10	10
Extreme Maximum Water Depth (m) (maximum of all route segments)		
open waters	201	304
channel/river waters	17	17

[1] to the geometric centre of the region

(Grondin 1993a)

TABLE 3-12
Reference Environment Parameters for the Used Fuel Rail-Water Reference Routes to the Central and Northern Destinations

	to Central Region[1]	to Northern Region[1]
Total Distance (km)	1 300	1 600
Distance in Population Zone km (%)		
rail-rural	358 (28%)	462 (29%)
open waters	833 (64%)	1026 (64%)
channel/river	109 (8%)	112 (7%)
Population Density (persons/km^2)		
rail-rural	9	21
open waters	0	0
channel/river	559	559
Traffic Count (# of 2 way trains/24h, # of water vessel passages per year)		
rail-rural	11	7
open waters	12 183	11 974
channel/river	10 842	10 842
Person Traffic (# of 2 way persons on board trains/day)	129	246
Average Number of Persons on board vessels	24	24
Accident Rate (# of accidents/million railcars-km)		
rail-rural	0.21	1.87
open waters	1.05	0.81
channel/river	18.91	18.91
Extreme Maximum Water Depth (m)		
open waters	201	304
channel/river	10	17

[1] to the geometric centre of the region

(Grondin 1993a)

CHAPTER 4

4. ANALYSIS OF UFDC SITING

This chapter presents an analysis of the effects of siting activities on the public, workers and the natural environment. The conceptual reference UFDC design specifies a duration of 23 years for the siting stage (see the implementation schedule, Figure 2-6).

The technical characterization activities performed during siting are similar to many of the activities performed during the geological exploration phase of standard mining projects (see Table 2-3). They can also be related to the geotechnical investigations performed prior to development of large civil structures such as hydro-electric dams, tunnels and underground powerhouses. General knowledge of the effects of these site investigations can, therefore, be used to identify possible effects on the environment from the site characterization activities for a disposal facility (Marshall 1982). Technical site characterization activities are described in Chapter 2.

The manner in which a site is selected would have a profound influence on the socio-economic impacts, not only during the siting stage, but throughout the life-cycle of the disposal facility. The siting process would provide a framework for planning and assessment of the siting activities. Siting process considerations are, therefore, discussed in Section 4.1.

4.1 SITING PROCESS CONSIDERATIONS

In order to assess the effects of each stage of the disposal facility life-cycle, it is necessary to make some assumptions about the kind of process that would lead to the selection of a disposal site and the transportation routes. These are discussed below.

4.1.1 General Considerations

As mentioned in Chapter 1, no siting activities will be undertaken until the disposal concept has been determined to be acceptable. The organization that would be responsible for implementation of the disposal concept, if accepted, has not been identified at this time. It is, therefore, premature to detail the siting process that would be used.

Nevertheless, it is reasonable to assume that the siting process will follow a cooperative approach. In general, the objective of the siting process would be to identify a site for the disposal facility which is:

(i) technically suitable based on the fundamental directives of protecting human health and safety, and the natural and social environment; and

(ii) socially acceptable to the local communities.

Without preempting the public consultation process, it is further assumed that some basic principles would govern the interaction between the implementing organization and the public during the siting process and subsequent stages of disposal concept implementation (Greber et al. 1994). These principles are summarized as follows:

(1) Commitment to safety and environmental protection;

(2) Commitment to voluntarism;

(3) Commitment to shared decision-making;

(4) Commitment to fairness; and

(5) Commitment to openness;

A more detailed description and discussion of these principles is presented in R-Public (Greber et al. 1994). However, for purposes of this assessment, it is emphasized that the "voluntarism" principle means that no community would be forced to host a disposal facility. A community would have the right to determine whether or not it is willing to be a host community. A disposal site would be sought in a particular area only with the support of the community that has jurisdiction over the area. In areas of crown land, a site would be sought only with the consent of the government that has jurisdiction. In such areas, the government would be encouraged to identify a potential host community.

A joint problem solving and consensus building process based on these principles would give the public and, in particular, the potential host communities, an effective involvement in facility planning and development. It would ensure that the communities' needs and concerns have a priority in siting and facility development.

A conventional top-down approach to site selection (not proposed) is not likely to receive significant public acceptance. A site selection process that is based on the principles outlined here is more likely to be acceptable to the public. For example, the voluntarism principle was used in the siting of hazardous waste management facilities in Alberta and Manitoba. A similar approach is being followed in siting a facility in Ontario for disposal of low level radioactive wastes.

From here on, for convenience, the assumed siting process involving the principles of fairness, openness, voluntarism, shared decision-making and safety/environment protection will generally be referred to as the "cooperative" siting approach.

4.1.2 Role of the Public in Disposal Site Screening and Evaluation

The conceptual process design (Davison et al. 1994) envisages that the siting process would take place in two sub-stages: site screening and site evaluation. The technical aspects of these sub-stages are summarized in Section 2.1.2.

A cooperative approach to siting would involve the communities in developing, or at least finalizing, both the procedures and the criteria for identifying and evaluating sites (Greber et al. 1994). The role of the public during site screening and evaluation would be determined jointly as part of the initiation of the siting stage. This initiation would include a broad-based public communication program on the disposal facility, in order to help the public understand the nature of the used fuel waste disposal problem, the concept proposed for its disposal, alternatives, the decision-making process and how to take part in it. Participation of First Nations would involve specialized forms of cross-cultural communication (e.g., document translations) and methods of interaction or exchange of information that are culturally appropriate to, and selected by, the First Nations.

The roles of different participants must be clearly defined for a successful implementation of this process.

4.1.3 Considerations Specific to Transportation Mode and Route Selection

Based on recent hazardous waste site selection processes in Canada, that include a transportation component (Hardy Stevenson and Associates 1992b), public participation in the transportation studies varied as follows:

i) public participation intensified from the early part to the concluding part of the siting process;

ii) public participation depended on the level of voluntarism in the siting process; and

iii) public participation depended on how much of the transportation considerations had been incorporated in the site selection studies.

Acceptance of the transportation of hazardous waste depended in large part on early and extensive public participation in resolving transportation issues within the siting process.

Transporting used fuel produced in southern Ontario largely for the benefit of southern Ontario, for disposal in the Canadian Shield region of Ontario is an equity issue that has been raised by Aboriginal groups (Hardy Stevenson and Associates 1993). Also, individuals and interest groups have expressed the concern that burying the waste far away from where it is created increases the risks associated with transportation (IPPANI 1985). This is supported by focus group research in northern, eastern and southern Ontario who considered it dangerous to transport used fuel from southern Ontario to a northern Ontario disposal site. Many in the focus groups who opposed the disposal concept did so because of their fear of a transportation accident (Goldfarb Consultants 1991). Issues such as these would have to be addressed early on in the siting process and may well influence which disposal sites should be considered.

In hazardous waste transportation cases, where there was a voluntary site selection process with the right of communities to refuse a site, the communities along potential routes focused their attention on ways of reducing transportation risks and improving emergency response planning, and in the end accepted the transportation routing decisions for optimal routes (Hardy Stevenson and Associates 1992b). During the period when a single disposal site is being evaluated, the alternative used fuel transportation routes and modes would be studied in greater detail. Again, public input would be required to determine socially acceptable criteria for characterizing these routes, and to decide whether or not a route selection process is desirable.

4.2 POTENTIAL EFFECTS ON PUBLIC

Considering the kinds of activities likely to occur during the siting stage, as outlined in Section 2.1.2 and detailed in R-Siting (Davison et al. 1994a), no significant adverse physical effects on public health and safety are expected. This does not take into account the possibility of stress which some members of a local community might feel, as discussed in Section 4.5. As indicated in Section 4.3, depending on proximity to a community or individual residence, the most likely potential physical effects would be some noise, traffic and other nuisance effects associated with access road construction, drilling and blasting. However, assuming that a cooperative siting process (as outlined in Section 4.1) and reasonable mitigation measures (as outlined in Section 4.3) are used, it is considered unlikely that any public health and safety effects would be significant.

Sealed radioactive sources would be used in borehole geophysical logging instruments to determine the density and porosity of the rock. Radioactive materials are routinely licensed by the AECB for characterization during siting and exploration activities. Their effects were not evaluated in this assessment.

4.3 POTENTIAL EFFECTS ON THE NATURAL ENVIRONMENT

Site characterization surveys and ancillary physical work can be classified as either disruptive or non-disruptive to the surrounding environment. Normally there should be little or no significant disturbance of the land surface during the regional characterization, during site screening and in the early part of site evaluation. The activities occurring at the end of site evaluation, particularly during underground evaluation, would be more disruptive. These disruptions are common to exploration activities for natural resources.

The environmental factors that could be affected were identified by reviewing the site characterization activities with respect to potential interactions with the environmental factors. An interaction matrix between the natural environment and the site characterization activities was derived from that review. This interaction matrix was refined based on a review of observed and estimated effects of geological exploration (Bates et al. 1980, Marshall 1982) and effects during the early phases of hydraulic dam construction (Ratchford and Chubbuck 1983). The interaction matrix for our study is shown in Table 4-1. This table is used as a checklist in the analysis to ensure that all potential effects have been considered. Only those interactions identified as having a potential for affecting the environment are discussed.

The exact nature of the effects or their actual significance could not be determined without a real environmental setting (see Section 1.5). However, the environmental effects of site characterization activities, including exploration and site development, would probably lead to local disturbances of the land, air and water (Ripley et al. 1979). Regional effects are expected to be fewer and more moderate.

4.3.1 Effects During Site Screening

The reconnaissance surveys during site screening are of short duration, and are expected to have minimal effects on the existing environment, provided that the implementing organization respects legislation designed to protect sensitive natural, cultural and historical features (see Section 4.5.1 for the social, cultural and economic impacts associated with site screening).

Legislation exists to protect some natural and human environment features such as park lands (National Parks Act), endangered species habitat (Endangered Species Act), fish habitat (Fisheries Act), conservation areas (Conservation Authority Act), forest (Crown Timber Act and Forest Fire Prevention Act), river banks and lake shores (Beach Protection Act), Indian reserves (various treaties), archaeological and historical sites (Ontario Heritage Act) etc. (see Appendix B). It is assumed that the implementing organization would have a policy during site screening and site evaluation to meet all requirements of the above legislations.

TABLE 4-1
Potential Interactions between Site Characterization and Site Development Activities and the Natural Environment

Activities	Environmental Factor					
	Air	Noise	Ground water	Surface Water	Flora & Fauna	Land Use
RECONNAISSANCE SURVEYS - SITE SCREENING		✓			✓	
RECONNAISSANCE SURVEYS AND SURFACE ACTIVITIES - SITE EVALUATION						
- Construction of access roads for the transport of equipment and personnel (clearing of vegetation, grading, etc.)	✓	✓		✓	✓	✓
- Cutting grids of survey lines (operation of equipment and removal of vegetation)		✓		✓	✓	
- Geophysical surveys (land based)					✓	
- Survey of physical and chemical characteristics of groundwater and discharge areas			✓		✓	
- Survey of surface water, and soil moisture				✓	✓	
- Survey of flora and fauna					✓	
SURFACE INVESTIGATIONS (more site-specific)						
- Construction of an access/haul road	✓	✓		✓	✓	✓
- Rock sampling (equipment operation, vegetation removal, topsoil removal, etc.)	✓	✓	✓	✓	✓	✓
- Soil investigations (vegetation removal, topsoil removal)					✓	✓
- Hydrometeorology of the site and surrounding area.					✓	✓
- Seismic monitoring					✓	✓
- Inventory of flora and fauna at site and surrounding area					✓	
SUBSURFACE INVESTIGATIONS (boreholes)						
- Construction of access road for the transport of equipment and personnel (clearing of vegetation, grading, etc.)	✓	✓		✓	✓	✓
- Construction of drill pad (equipment operation, vegetation removal, topsoil removal, etc.)	✓	✓		✓	✓	
- Construction of sump (equipment operation, vegetation removal, topsoil removal)	✓	✓	✓		✓	
- Operation of Drill	✓	✓	✓	✓	✓	
- Borehole Surveys: Geophysical, hydrogeological, hydrogeochemical sampling; hydraulic testing, sampling, pumping tests; piezometer installation and monitoring.		✓	✓			
UNDERGROUND EVALUATION						
- Drill and blast	✓	✓	✓	✓	✓	✓
- Construction of facilities	✓	✓	✓	✓	✓	✓
- Waste management			✓	✓	✓	✓

4.3.2 Effects During Site Evaluation

During site evaluation, the reconnaissance surveys are performed over a number of years and to a greater level of detail than those during site screening. Surveys would be similar to those carried out during site investigation for typical mining and civil engineering projects. Activities such as construction of access roads, exploration trenches, pits and drill pads cause dust, noise and disturbance to the local land surface and drainage patterns.

Construction of an access road would typically involve clearing rights-of-way, building stream crossings and excavating borrow pits, each of which may lead to accelerated erosion and particulate loading of streams and lakes. The removal of overburden (top layer of soil) for exploration trenches and pits disturbs vegetation and soil, and may produce significant sedimentation of lakes and streams. Establishing geophysical grids, for land-based survey purposes, requires a system of grid lines to be cut through vegetation and surface soils. This can result in visual changes, and vegetation damage and removal, and may cause local sedimentation and wildlife disturbance.

Other survey activities would primarily affect local flora and fauna, surface water and/or groundwater. However, these effects would be localized and would cease once the survey was completed.

The effects of all of these activities are intensified in environmentally sensitive areas such as the tundra (Marshall 1982). However, with careful planning and with the use of specialized equipment, such as remote sensing technologies and helicopters, these effects can be minimized.

(1) Effects During Surface Investigations

Activities at this stage of site characterization include construction of an access/haul road, rock sampling, soil investigations and inventory of flora/fauna. Both road construction and rock sampling affect the natural environment in similar ways: equipment movement and operation, removal of vegetation and overburden, and noise. The rock that is retrieved from the boreholes would be boxed and saved for analysis, and would not affect the surface environment.

In the case where protected surface features, such as archaeological and historical sites, are present at the site to be investigated, special precautions would be taken and a permit would be required under the Ontario Heritage Act. If the proposed alteration to the feature is judged to be significant, investigation at that particular site would be stopped. If an endangered species habitat might be affected by the surface investigation, special precaution would be required so that the habitat or the species are preserved during site investigation.

(2) Effects During Subsurface Investigations

During subsurface investigations, effects from construction of access roads, drill pads, etc., are similar to those mentioned above. Of more concern at this stage, however, may be the physical and chemical disturbances that could occur as a result of exploratory borehole drilling.

Physical and chemical disturbances to the groundwater flow system are possible as a result of exploratory drilling, and hydraulic testing and sampling in boreholes. The quantity and quality of drinking water supply, irrigation supply, or other surface water supply could be affected by these operations. Appropriate steps need to be taken to ensure that any valuable groundwater supplies are not contaminated or reduced. No oils, muds or other additives are used as lubricants for the diamond drilling (Davison et al. 1994).

Water from nearby surface ponds or streams is generally used for cooling and flushing during drilling operations (Davison et al. 1994). As a result of the extraction and use of water for drilling purposes, the supply and quality of drinking water, irrigation water or other surface water could be affected. Because small volumes of waste water, contaminated with drilling particulates or other material, can be produced from drilling operations, it is important that the drilling water is suitably contained and recirculated, to ensure that other water supplies are not contaminated.

(3) Effects During Underground Evaluation

Drilling, blasting and waste management activities during site preparation affect almost all sectors of the natural environment. Drilling and blasting affect the environment in ways similar to those mentioned above, although the construction of the exploratory shafts and excavations could potentially disturb the hydrogeological regime at the site and in the surrounding area to a greater degree than the previous characterization activities. Waste management activities associated with operating the facilities for the exploratory shaft could affect groundwater, surface water, flora and fauna. However, proper pollution control devices and measures could minimize these effects.

Land use changes would be more pronounced at this stage including: structures, open trenches and pits, and waste management activities that are not easily reclaimed (Ripley et al. 1979). If a protected archaeological feature is found at the surface, a permit would be required under the Ontario Heritage Act to excavate the site. In the case where protected archaeological features not apparent from the surface, are discovered during the excavation, provisions of the Ontario Heritage Act would come into play and a permit would be required to continue excavation. In either case, if the proposed alteration to the feature is judged to be significant, investigation at that particular site would be stopped.

4.3.3 Potential Mitigation Measures

Most of the effects of the site characterization activities, although widespread over the study area, could be mitigated with sound environmental practices. These include:

i) minimizing vegetation clearing;

ii) establishing good waste management practices for lubricants, waste oil and other wastes generated by the characterization activities, especially drilling;

iii) reclaiming as much of the area as possible when digging trenches or removing overburden for rock sampling;

iv) ensuring that no long-term damage results from stream crossings during access road construction activities;

v) designing and operating a temporary oil and fuel storage facility in accordance with the Gasoline Handling Act;

vi) storing, handling and disposing of water containing oils or chemicals (from drilling) together with liquid fuels, lubricating oils and other potentially toxic liquids in accordance with industrial safety and environmental regulatory requirements;

vii) obtaining permits from the Ministry of the Environment for controlled burning of slash material. Controlled burning, if necessary, must comply with air quality criteria as specified in Regulation 346 of the Environmental Protection Act of Ontario. A fire permit might also be required from the local jurisdiction;

viii) controlling noise as much as possible and in accordance to regulations;

ix) preventing disturbance to sensitive environmental areas, and avoiding endangered species habitat as much as possible;

x) preventing or avoiding disturbance to protected historical, cultural or natural features in accordance with regulations;

xi) controlling erosion, by avoiding vegetation removal on slopes and shorelines, and by promoting revegetation of disturbed land preferably with indigenous species; and

xii) monitoring extracted groundwater for contaminants to ensure compliance with regulations prior to discharge at the surface.

4.4 POTENTIAL EFFECTS ON WORKERS

This section presents an analysis of the health and safety of workers during the 23 years of the siting stage. Workforce numbers (in person-years) are given for the siting stage (and other stages) in Section 2.1.1.5.

4.4.1 Hazard Identification

Typical occupational hazards associated with geological site characterization activities, along with mitigative measures, are shown in Table 4-2.

The potential occupational hazards that would exist during this stage would be similar to those that occur in the forestry, mining and civil engineering sectors as similar techniques and equipment are used.

Exposure to extreme weather conditions, noise, vibration and emissions from diesel powered equipment are likely to occur. It is difficult to quantify these conventional safety hazards at this preliminary assessment stage. Therefore, it is assumed that the implementing organization would maintain levels of these hazards below the values recommended by the American Industrial Hygiene Association (1982) and would follow existing regulations regarding these hazards.

Since the details of the site characterization activities depend to a large extent on the site to be characterized, the above hazards to the workforce cannot be quantified.

4.4.2 Potential Mitigation Measures

A high degree of training in identifying and assessing potential safety-related situations would mitigate occupational hazards for workers. Safety awareness programs and the correct use of safety equipment as part of induction training would enhance safety at the UFDC. Periodic safety audits would help verify adherence to procedures and correct any deficiencies.

TABLE 4-2
Hazard to Workforce Associated with Site Characterization Activities

Hazard	Mitigation
Physical Hazards	
Routine Conditions	
Exposure to noise	Installation of muffling devices on equipment and use of protective equipment (e.g. ear plugs)
Exposure to oils and/or chemicals used in drilling	Establishment of strict handling procedures, use of protective equipment (e.g. eyeshields) and protective clothing
Accident Conditions	
Transportation, Vegetation clearing, Drilling, and Blasting accidents	Training in the use of equipment and safety equipment Inspection and enforcement of routine precautions including crew training and first aid course Use of appropriate standards
Isolation hazards	Forest orientation and survival training Provision of appropriate survival and communication equipment

Based on: (Bates et al. 1980)

4.5 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENT

This section presents a summary of the potential impacts on the socio-economic environment during siting of the disposal facility and associated transportation routing. It is based on a review of experiences with siting of industrial facilities, including hazardous waste management facilities (Paez-Victor 1993). Due to the generic nature of this assessment, it has not been possible to predict the extent to which a cooperative siting process (as outlined in Section 4.1) would avoid or reduce the impacts based on more traditional siting processes. However, it is reasonable to assume that impacts would be avoided or reduced. More detailed discussions of the potential impacts of disposal facility construction and operation and used fuel transportation are included in Sections 5.2.4, 6.5 and 7.5, respectively.

4.5.1 Identification of Potential Impacts

During the 23 years of the siting stage, socio-economic impacts are expected to result from the interaction between the implementing organization siting activities (the project) and the community, defined in terms of three main community characteristics (socio-cultural vitality, economic viability, and political efficacy, see Section 6.5 for definitions).

It is expected that a siting process based on the principles outlined in Section 4.1 would in itself help mitigate the potential socio-economic impacts of siting. This has been demonstrated in a number of cases studied (see Appendix D, Table D-6).

4.5.1.1 Potential Impacts During Site Screening

The source of the impacts from the project at this stage is within the planning process used by the implementing organization for siting the facility. Political efficacy would be the community characteristic most likely to be affected during site screening. There would be public reactions to the announcement and to the implementation of preliminary siting activities. These would include the responses of the media, and specialized professional and academic publications and journals. Groups and organizations that have a special interest in energy and environmental issues may become involved in the siting process. Aboriginal groups and professional organizations would follow the siting process closely and may choose to become involved.

4.5.1.2 Potential Impacts during Site Identification and Evaluation

During site identification and evaluation, integration of mutually acceptable criteria with the technological criteria would be required in order to select and evaluate potential sites.

In general, the siting stage sets many of the parameters that determine whether or not socio-economic impacts will occur. The relationship established between the implementing organization and the affected community or communities through the siting process is a major factor because it usually determines the type of interaction that the project characteristics will have with the affected communities. With a voluntary site selection process guided by the principles listed in Section 4.1, the negative impacts, particularly the political and social disruptions, caused by a technically-driven process would be reduced.

The community characteristics of social and cultural vitality, economic viability and political efficacy might all be affected. The criteria, processes and potential results of the siting process as well as the risks involved would all be reviewed by the community. The political efficacy of communities may be affected as the municipal leadership tries to control and manage the outside influences upon it, and at the same time, tries to maintain their political authority and good standing within their communities. These impacts on the political dynamics of the community can also affect municipal facilities and services, as their future plans may be put on hold until the siting uncertainties are resolved.

Political activity, labour unions and the political life of Aboriginal people may be affected through the deliberation within communities over the possibility of deciding to host a site. Site evaluation activities such as access road construction, cutting grids of survey lines, and surveying of flora and fauna may affect Aboriginal traditional land use and rights. For example, there could be increased hunting by local residents and exploration crews. Also, local wildlife will likely be temporarily disturbed by construction of an access route, survey and drilling activities. The degree of conflict and cohesion within and between communities can also be affected by siting activities.

The social and cultural vitality of communities can be affected by impacts stemming from questions related to future radiological risk to the public, workers and the environment, causing stress among community members. Given

the long duration of the siting stage, this stress can be prolonged and can potentially affect not just one community but a series of communities near the site or the transportation routes.

The well-being of Aboriginal communities may be affected if traditional hunting capacity is hindered. Accidental disturbance of burial grounds (protected by legislation) could affect the community's cultural heritage. Nuisance effects such as traffic, noise and improper waste management practices (see Section 4.3) could affect the daily life of local residents. The cumulative impacts of these changes in their immediate environment can diminish the level of satisfaction of its members towards the community.

Positive and negative impacts on the economic viability of the communities can result from site evaluation. There could be positive impacts on the local employment, goods and services. There could be negative impacts on the traditional Aboriginal economy, particularly related to hunting. Farming activities may be particularly affected if access road and survey lines cut across farming land.

Other impacts might occur depending on the intensity of the site investigation activities and if the quality of the living environment is affected. They might include: resident displacement; family impacts; demographic changes; impacts on housing; nuisance impacts; impacts on recreational activities, local services, business activity, property values and taxes. However, as indicated in Section 4.5.2, potential adverse impacts can be avoided or mitigated through a joint impact management program. Furthermore, with a cooperation siting process as outlined in Section 4.1, the process would only proceed from site screening to site evaluation with the consent of the communities involved.

4.5.2 Socio-Economic Impact Management Measures

Adverse socio-economic impacts can be prevented, mitigated and managed, and positive impacts enhanced by implementing an impact management program, jointly developed and managed by the community. An impact management program would be characterized by a decision-making framework that includes the local community, with shared rights and responsibilities for impact management. The program related to siting could include:

i) measures such as optimization of the technical operations necessary for site investigation and strict adherence to jointly developed avoidance criteria;

ii) establishment of public health and safety programs: including health monitoring and research programs, joint programs with the communities on the notification of hazardous events, community awareness, and monitoring;

iii) management and standard mitigation of nuisance effects following jointly developed criteria; and

iv) compensation and impact assistance grants, local planning and assistance grants, property value protection, direct financial compensation, in-kind replacement/restoration and community liaison measures.

4.6 RESIDUAL EFFECTS

Residual effects are the effects that remain after the application of impact management measures. The concept of residual effects is also linked to significance, since an effect that cannot be mitigated or managed is more likely to be significant. As discussed in Section 1.5, the significance of effects cannot be fully determined without the affected public and baseline environmental conditions to provide the social and ecological contexts. This is also the case for residual effects. The residual effects discussed here are, therefore, our best judgement on what effects might remain after the application of impact management measures. This would need to be validated with the site-specific population and natural environment settings.

Given that the activities and potential effects during the siting stage are common to other sectors (e.g. civil engineering, exploration geology), methods and technologies exist to mitigate them. Based on the available information, residual effects on the natural environment are expected to be minimal during the siting stage provided that adequate environmental protection measures are taken and that the potentially affected public is involved in the scoping of the characterization activities.

Social impact management measures should minimize any negative impacts and, as well, enhance the positive impacts that have been foreseen. Nevertheless, during siting, a potential residual impact could be continuing political disagreements and conflicts between community groups associated with the siting process. The length of the siting process could mean some period of uncertainty and possible stress, although this would be expected to be offset to a significant extent by the cooperative nature of the siting process. Concern about radiological risk and its associated stress-related impacts may remain to some degree even after impact management measures have been implemented.

It is assumed that through time, residual socio-economic impacts are likely to result from changes in project and community characteristics. Therefore, it is not possible to preclude residual impacts; rather, it is necessary to expect them. However, if a vigorous and continuous impact management program is implemented, they can be addressed. The impact management program would include shared decision-making, monitoring of the effectiveness of the measures and periodic review (see Section 6.5).

CHAPTER 5

5. ANALYSIS OF UFDC CONSTRUCTION

This chapter presents an analysis of the effects on the public, the natural and socio-economic environment and workers from UFDC construction activities. Details and socio-economic of these construction activities are given in Chapter 2.

The construction stage of the UFDC, as defined in Simmons and Baumgartner (1994), is the period starting when the site and disposal facility design have been approved for construction, and continues until the surface and underground facilities are installed and operational, and an initial set of disposal rooms excavated and serviced. The construction stage is expected to last 7 years.

During this period, the conceptual design estimates that over 7 000 person-years of labour would be required at the facility, for an average work force of about 1 000 workers.

5.1 RADIOLOGICAL EFFECTS

Used fuel would not be on site during construction of the UFDC surface facilities or during the first stage of vault construction. Excavations on site would release naturally occurring radon (Rn) and radon progeny to the atmosphere. The radioactivity due to the release of ^{222}Rn from an underground vault constructed in granite has been estimated to be 7×10^{11} $Bq \cdot a^{-1}$ (U.S. Department of Energy 1980). The natural ^{222}Rn emission from surface soil depends on the radon concentration in the soil and other soil parameters. Using a value of 2.4×10^{-2} $Bq \cdot m^{-2} \cdot s^{-1}$ (UNSCEAR 1982), the natural radon emission from an area the size of the UFDC site (15.6 km^2) would be about 1×10^{13} $Bq \cdot a^{-1}$. Therefore, radon emissions from construction of the UFDC is expected to present a very small increase over the natural radon emission to the atmosphere from the surface soils at the UFDC and are expected to be well within the normal fluctuations in outdoor radon concentrations. Thus, radon emissions are considered to have a negligible impact on the public, the workers or the environment.

5.2 NON-RADIOLOGICAL EFFECTS

5.2.1 Effects on Public Safety

Transportation of construction material to the site will result in an increase in traffic in the region. The estimated increase in road and rail traffic due to transportation of construction materials is shown in Table 5-5. The maximum increase in road traffic would be 31-32 trucks per day. The actual effect of this increase would depend on a number of factors including the types of road, the actual traffic and accident statistics on the road, the duration of the trip and the seasonal transportation variations. Based on the traffic data for the reference routes derived for the used fuel transportation assessment, this traffic increase corresponds to 7 to 10% of the average traffic on the reference route. Although this increase would have most the effect on traffic flow and number of accidents on roads already operating at full capacity, it would also be noticeable on other roads. The actual impact of transporting materials traffic on public safety could only, therefore, be accurately assessed at the site-specific stage, because at the concept assessment stage, the origin of the construction material and the traffic on the transportation network leading to the facility are not known.

The maximum increase in rail traffic would be 21-22 railcars per day. This is about one third of the number of railcars on an average freight train (Statistics Canada 1982) and would contribute about 3% of the reference route traffic in the rural zone.

No other aspects of the UFDC construction are expected to affect public safety, because access to the site would be restricted.

5.2.2 Effects on the Natural Environment

Potential interactions with the natural environment from activities associated with the UFDC construction (see Chapter 2) were identified and analyzed. The analysis used data from the region-wide environment characterization presented in Chapter 3 and detailed in Grondin and Fearn-Duffy (1993a).

Although no used fuel disposal site has ever been constructed, many of the project characteristics are similar to those of other nuclear and non-nuclear projects. Thus, when insufficient information was available, assumptions would be made based on similar industrial construction projects.

Using a matrix system (Grondin and Fearn-Duffy 1993b), the potential interactions of primary concern were identified. The matrix of the construction stage is shown in Table 5-1.

5.2.2.1 Effects from Construction of the Surface Facilities

It is assumed that prior to the start of construction activities, all environmental permits would have been obtained from relevant government agencies. A list of the typical permits is included in Appendix B.

(1) Air Quality

(a) Fugitive Dust

Local on-site atmospheric emissions during the construction stage would include dust and particulates from clearing, excavation, grading, filling and operation of construction vehicles or equipment. Off-site sources would include airborne particulates generated by the construction of site access/service corridors (e.g. roads and transmission rights-of-way) and dust produced by vehicles transporting construction materials (e.g. aggregate and ready-mix concrete) to the site.

The quantity of dust emissions depends on the area of land being cleared, intensity of construction, silt content of the soil, wind direction and speed during construction, and soil moisture content (Jain et al. 1977; U.S. Environmental Protection Agency 1978). The soils (predominantly humo-ferric podzols) and overburden (predominantly glacial drift, sand and gravel) in the Canadian Shield region of Ontario contain variable quantities of silt, clay and sand.

The nature of the effects depend on the concentration of the particulates. If the concentration is greater than 25 $\mu g \cdot m^{-3}$, visibility would be affected. The regulatory limit in Ontario is 100 $\mu g \cdot m^{-3}$ (Government of Ontario 1990d). Given that the dust-creating activities would be at ground level, particulates would not likely be carried into the surrounding areas to the extent that they would exceed the regulatory limit on off-site property (the property boundary would be at least 1.5 km from the centre of the site).

Dust in the presence of free moisture (dew) would form a crust on vegetation. As a result, some sensitive species might suffer foliage damage, but the number of plants affected is expected to be small.

TABLE 5-1
Potential Interactions between Site Construction Activities and the Natural Environment

Activities	Environmental Factor						
	Air	Noise	Ground water	Surface Water	Flora & Fauna	Soil, Land Use and Forest Fires	Non-Renewable Resources
CONSTRUCTION OF THE SURFACE FACILITIES							
- Clearing and Stripping	o	o		o	o	o	o
- Grading/filling	o	o		o	o	o	o
- Excavating	o	o		o	o	o	o
- Operation of construction equipment	o	o			o		o
- Hauling of construction material	o	o			o		o
- Shoreline construction (water supply intake)	o	o		o	o	o	o
- Management of solid wastes from construction . open burning of slash and waste construction material . disposal	o				o	o	
- Construction of road, rail line to the facility for the transport of equipment, personnel and used fuel (clearing of vegetation, grading, roadbed preparation, surfacing, drainage alteration, stream crossing/bridging, etc.).	o	o		o	o	o	o
- Construction camp and influx of construction personnel					o	o	
- Security facilities (fence)					o	o	
- Construction of support facilities and utilities . water supply (surface water) . transmission line (electrical) . service buildings . parking lot		o		o	o	o	

continued...

TABLE 5-1 (concluded)

Activities	Environmental Factor						
	Air	Noise	Ground water	Surface Water	Flora & Fauna	Soil, Land Use and Forest Fires	Non-Renewable Resources
CONSTRUCTION OF THE SURFACE FACILITIES (continued)							
- Finishing/grading/landscaping	o	o		o			o
- Construction of UFDC surface buildings		o				o	o
- Construction of conventional waste disposal facilities . waste dump . rock disposal area . sewage treatment . runoff controls				o		o	
SUBSURFACE CONSTRUCTION							
- Sinking of ventilation shafts and other underground excavations prior to start of operation	o	o	o	o	o	o	
- Underground dewatering	o	o	o	o	o	o	
- Sinking of ventilation shafts and other underground excavations prior to start of operation	o	o	o	o	o	o	

Paving of roadways and parking areas, periodic water sprinkling, the use of covered trucks where possible and keeping the roads near the site free of heavy dust deposits would help minimize dust erosion. Potential effects from the construction of the access road or railway can be inferred from the Ontario Ministry of Natural Resources (MNR) Class Environmental Assessment for access roads (Ministry of Natural Resources 1986). The Class Environmental Assessment concludes that dust emissions from access road construction would have a minor effect on air quality.

(b) Other Sources of Air Emissions

Experience at other large construction projects, such as construction of the Darlington Nuclear Generating Station, indicates that air quality is not likely to be altered appreciably by emissions of combustion gases from construction equipment, and that any changes in air quality would be temporary and localized. Construction equipment would be properly maintained to reduce exhaust emissions and would not be left idling unnecessarily.

Incineration and open burning of waste construction materials, slash and general refuse are potential sources of emissions of particulates and combustion gases to the air, but the area affected would usually be localized. Effects would be minimized by conforming to the Ministry of the Environment Code of Practice for Open Burning and Ministry of Natural Resources Guidelines for Controlled Burning (see Appendix B) (Section B.2.2.2). Estimates of air emissions from the burning of unspecified forest slash have been taken from Grondin (1993b). Based on the area required for the facility and assuming that all forest slash included within the property boundary would be burned, estimated emissions from slash burning during the construction stage are shown in Table 5-2.

These are small compared to the routine emissions in each of the three regions documented in Grondin and Fearn-Duffy (1993a). Particulate emissions are expected to be small because of the short duration of these activities. This effect can be reduced by minimizing the cleared area and by ensuring that no usable lumber is destroyed.

Emissions from transportation of construction material were calculated from emission factors for heavy duty diesel vehicles for an average traffic speed of 90 $km \cdot h^{-1}$ and a vehicle age of five years (Grondin 1993b). The assessment is restricted to the effect within the site boundary and along the 25 km access route. Based on 22 trucks per day (as calculated later in this section) the estimated emissions due to construction traffic are shown in Table 5-3.

These are small compared to the emissions in each of the three regions documented in Grondin and Fearn-Duffy (1993a). All emissions are well below 1% of the regional values, except for sulphur oxide emissions which are 3% of the median value for the Northern region emissions.

TABLE 5-2
Conservative Estimates of the Total
Emissions from Slash Burning during UFDC Site Clearing

Emission Type	Total Emissions
Carbon monoxide	19.8 Mg
Hydrocarbons	3.3 Mg
Nitrogen oxides	0.6 Mg

TABLE 5-3
Estimated Emissions from Construction Truck Traffic
During UFDC Construction

Emission Type	Emission Factor ($g \cdot km^{-1}$)	Emission per day ($g \cdot d^{-1}$)	Emission per year of construction ($Mg \cdot a^{-1}$)
Nitrogen Oxides	9.30	5 115	1.87
Carbon Monoxide	3.22	1 771	0.65
Hydrocarbons	0.81	446	0.16
Sulphur Oxides	1.70	935	0.34

(2) Surface Water Quality

(a) Suspended Solids

Effects on surface water quality during construction would largely be associated with the construction of the water supply intake and discharge facilities. This would involve dredging and blasting, and depending on the characteristics of the bottom sediments and shoreline soil, it might result in prolonged elevated water turbidity levels.

Effects of site preparation activities (e.g. clearing and grubbing) on water quality would include sediment deposition from runoff into neighbouring waterbodies. Although all reasonable measures would be taken to control erosion, surface runoff may occasionally result in increased turbidity. This could affect local fish habitat and other aquatic organisms. Ditching and storm drainage systems would control erosion over large areas. It is not expected that site runoff would be altered significantly. However, the runoff lagtime would probably decrease due to the removal of overburden (thus exposing bedrock), the clearing of vegetation and the construction of more direct drainage systems. This would reduce the sedimentation of suspended material prior to discharge to the water bodies and could result in increased turbidity. The significance of this increase would depend on the change in the runoff lagtime, the quantity and quality of overburden, and the prevailing concentration of suspended solids in the affected watercourse.

(b) Oil and Chemical Contaminants

As discussed in Section 2.1.3.8, all oils and chemicals would be stored in suitable containers and disposed of according to the Ontario Environmental Protection Act regulations. Nevertheless, site drainage may contain oils, chemicals and liquid fuels from various open area construction activities and could pose a risk to water quality. Compliance with established refuelling procedures would help reduce spillage of fuels. The quantities of these materials are expected to be small, and the possibility of spills would be reduced by managing these materials in accordance with regulatory requirements of the Ontario Gasoline Handling Act, the Ontario Environmental Protection Act and the Occupational Health and Safety Act (see Appendix B).

(c) Nutrients, Dissolved Oxygen, Biological Oxygen Demand and Fecal Coliform

As mentioned in Section 2.1.3.8, sewage effluent would be treated to meet regulatory requirements and should not adversely affect the quality of the surface waterbody or the groundwater.

(d) Effects of Construction Activities on Aquatic Life

The water supply intake and discharge facilities are assumed to be shoreline structures. If drilling and blasting are required for construction of these structures, these activities would be undertaken in accordance with Ontario Ministry of the Environment's Marine Construction Guidelines (Ministry of the Environment 1974) to minimize detrimental effects on fish. Shoreline construction may result in localized destruction of benthic communities and fish spawning beds. The spawning beds of 35, 41 and 49 species of fish in the Northern, Central and Southern regions, respectively, may be affected. The majority of fish species in each region spawn in the spring. To minimize any adverse effects on fish spawning, any shoreline or offshore construction activity should be scheduled so as not to coincide with the peak spawning period. After construction activities cease, recolonization of disturbed areas will occur, provided that the habitat has not been permanently altered. Careful planning and review of construction procedures to help prevent habitat destruction would be undertaken before the start of construction. Shoreline protection measures, such as installation of rip-rap or re-vegetation, should also be applied (Prinoski et al. 1983).

(3) Groundwater Quality

No effects on the groundwater are expected to occur during the construction of the surface facility because there is little excavation (see Section 5.2.2.2 for effects on groundwater from underground construction).

(4) Soil Erosion and Drainage Pattern

Site clearing and access/service route preparation would remove the native vegetation cover, thereby exposing the soil to erosion. Clearing, grubbing, grading, excavating and stockpiling would result in channel cuts, dikes and similar embankments. Wind erosion could be significant during the construction of the site and service routes (e.g. after final grading, and before surfacing or re-vegetation). By keeping exposed areas to a minimum, the amount of erosion would also be minimized.

Construction of a facility on permafrost (permanently frozen ground) might result in altered soil stability and drainage. Since permafrost does not occur in the Southern or Central regions or in most of the Northern region, it is not likely to be present at a disposal facility and is not dealt with further in this analysis.

Clearing of vegetation would change the drainage pattern of the site and might increase site drainage onto surrounding lands.

(5) Solid Waste Production

Solid wastes would be generated during construction. These wastes would include broken concrete, glass, scrap metal, scaffolding, lumber, slash timber and brush. As mentioned in Section 2.1.3.8, waste management procedures would emphasize reduction, re-use and recycling of all material, and clear instructions would be established for the disposal of waste material. Burning of slash and wood waste might be carried out. Waste that cannot be re-used or recycled would be disposed of at a licensed disposal site. The construction site would also accumulate domestic wastes in the form of waste paper,

material wrappings and general daily refuse. These would need to be disposed of in a safe and sanitary manner, which would require designated land at or near the disposal facility.

(6) Land Use

The UFDC would require 5.2 km x 3 km of land (see Section 2.1.1.2), totalling 15.6 km^2. In addition, the land area required for access and service routes/corridors would be 0.9 km^2 for road and 0.08 km^2 for rail (assuming 25 km long access route/railway). The total land area required for the facility is, therefore, 16.5 km^2 or, conservatively, 17 km^2. Some additional land would be required for construction of a transmission line to the facility. Other land requirements might also result from the construction camp and accommodations for workers and their families. Since no detail is available on these types of requirements, they are not dealt with explicitly here.

The total land mass area of the Ontario portion of the Canadian Shield is about 650 000 km^2 (Grondin and Fearn-Duffy 1993a). Of this, the area of the Northern, Central and Southern regions are about 385 000 km^2, 208 000 km^2 and 56 000 km^2 respectively. The amount of land that would be required for a disposal facility is, therefore, a minute portion of the total area.

In addition to the land commitment, the two most significant potential effects on surrounding land use are:

(1) construction of new roads to the facility may increase the accessibility to the area, thereby increasing the opportunity for, and competition for, recreational use of land, hunting, fishing and wildlife habitat; and

(2) potential changes in property values around the facility, due to increased risk perception (negative change) or due to competition for existing serviced sites (positive change).

These types of changes are discussed in the socio-economic impact analysis in Section 6.5. Sensitive land uses may also be affected by emissions (e.g. herbicides used in on-site maintenance activities could potentially affect adjacent agricultural land if not used properly).

Because of the long duration of the UFDC life, the facility could potentially affect not only existing land use, but also future plans for land use in the area. These could include: municipal land use plans, resource management plans and plans for proposed developments. Assuming the siting process follows the co-operative process discussed in Section 4.1, land-use planning would probably be considered at the siting stage and agreements would be established with the affected communities so that their planning would take into account the disposal facility.

The following land uses could be affected by construction of a disposal facility:

i) protected lands;

ii) forestry (capacity);

iii) agricultural; and

iv) recreational

Because it is not known at this time which land use would be present around the facility, the effects of the UFDC construction on each type of land use were examined. Note that, in general, many potential land uses are mutually exclusive, e.g. if the disposal facility were built on agricultural land, it could not simultaneously occupy parkland.

Protected Lands

For the purpose of this assessment, protected lands included native lands and sites of natural or historical importance.

(i) Indian Reserves and Land Use

The location of Indian Reserves in the study area is given in Grondin and Fearn-Duffy (1993a). They occupy a small percentage of the study area, 2%, 1% and 2% of the Northern, Central and Southern regions, respectively. The facility and access road or railway may affect hunting, trapping and fishing on tracts of land surrounding reserves.

(ii) Wetlands

The Province of Ontario has adopted a planning policy for the protection of wetlands that applies to "Provincially Significant Wetlands". This policy is summarized in Appendix B. In addition, planning jurisdictions, including municipalities and planning boards, may have wetland protection provisions.

The most common wetland types in the Northern region are the humid-mid boreal and the continental high boreal, with 47% of the region having 26-50% wetland coverage. A wetland area could, therefore, be affected by the facility. In the Central region, the most common wetland type is the humid-mid boreal and the area covered by wetlands is much greater (40% of the region has 51-75% wetland coverage). The Southern region has the least probability of a wetland area (65% of the region has 0-5% wetland coverage). Since wetlands are extremely important for many ecological processes (e.g. waterfowl nesting), siting must be done so as to preserve the most sensitive of these areas.

Although siting the facility in a wetland should be avoided if possible, the potential effects of a disposal facility on a wetland is included in a discussion on sensitive environment scenarios (Section 9.11.1.3).

(iii) Sites of Natural or Historical Importance

In 1977, the Ontario Ministry of Natural Resources (MNR) undertook two surveys to identify natural landscapes, environments and biotic communities in Ontario. This identification program supported the objective of the Ontario Provincial Parks Policy (Government of Ontario 1978), which is "to protect provincially significant elements of the natural and cultural landscapes of Ontario" (see Appendix B).

Between 1980 and 1982, evaluations of remnant natural areas were undertaken in the Central and Southwestern regions. Through these assessments, the finest natural and geological areas were identified to complement natural features already represented within the Ministry's Natural Reserves. These areas were called "Areas of Natural or Scientific Interest" (ANSI's).

ANSI's represent features of regional, provincial or national uniqueness or rarity, which have either an aesthetic, historical, cultural or archaeological value. To date, 564 ANSI's have been identified in the Province of Ontario. Although not all ANSI's have been mapped, they probably account for less than 2% of the provincial land area. A list of the ANSI's in the Ontario portion of the Canadian Shield is given in Grondin and Fearn-Duffy (1993a).

Although ANSI's are not legal entities, the Ontario Ministry of Natural Resources strives to ensure that the land uses and activities which occur within ANSI's do not degrade them. Most ANSI's are considered to be sensitive to excessive human intrusion. It is, therefore, assumed that the implementing organization would have a policy to protect these features during construction of the UFDC.

In addition to potential direct effect on these natural features, construction of a disposal facility access road could provide access to any features near the site. The influx of construction workers, construction activities and other human intrusion, could result in the degradation of these features if they are not protected. The aesthetic and scenic value of features could be reduced by the development of large buildings in their vicinity. Sensitive areas include: ecological sites such as wildlife habitat sites, vegetation sites, geological features, and historical and archaeological sites.

Protective measures to ensure that sensitive natural or historical features at or near a site, are not adversely affected by the construction activities could include:

i) careful siting of roads, facilities and construction areas;

ii) provision of fencing and similar measures to restrict access;

iii) provision of protective devices (i.e. markers and plaques) to prevent accidental damage;

iv) training programs for construction staff on environmental protection practices in construction;

v) removal of the significant articles to a protected area; and

vi) establishment of a local museum to house and preserve significant articles.

Forestry

In the Southern region, 47 600 km^2 (85% of the total area) is covered with forest, with predominately moderate timber use capability (86% of the forested area). It is, therefore, assumed that a disposal facility located in the Southern region would remain unavailable for forestry purposes until after closure. The land requirement of the facility is small, representing less than half of 1% of the land with moderate timber use capability lands in the Southern region.

Using the same criteria, the Central region reference site is assumed to be located on land of low timber use capability, since 61% of the Central region is rated as such and the site area would constitute less than 1% of both low and moderate timber use capability in this region.

The location of the disposal site in the Northern region is assumed to be on land of low timber use capability (68% of the total area of the region), and the site area would constitute much less than 1% of the low, moderate and high timber use capability lands in this region.

Measures to minimize the effect of UFDC construction on forest resources include:

i) preservation of high timber use capability lands;

ii) reduction of unnecessary clearing (would also reduce erosion and site runoff effects); and

iii) reforestation of the site after closure and decommissioning.

Agricultural Land Use

Up to 18 km^2 of farm land could potentially be taken out of production should the disposal facility be located entirely on farmland.

There is substantially more farmland in the Southern region, in absolute terms and as a percentage of total land, than in either the Northern or Central regions. Thirteen percent of the Southern region is devoted to agricultural use, compared to less than 1% of the Central and Northern regions. Although the amount of land required for the site, 18 km^2, is a very small fraction of the total farmland, the displacement of any farmland would have an effect. This would be particularly important in the Southern region, where agricultural land has been depleted by ever increasing demands for residential and industrial uses. Since this region has the potential for the greatest crop production, the loss of agricultural land in the Southern region would lead to the greatest crop loss. The rarity of agricultural land in the Northern and Central regions, be it less productive than in the South, would also increase the importance of agricultural land losses in these regions.

In addition, a significant amount of surrounding farmland may be adversely affected if herbicides are incorrectly used on the site or adjacent to access roads and railway to control vegetation (Jain et al. 1977).

Measures would, therefore, be taken to minimize the effects of the UFDC construction on agricultural land use. These include:

i) preservation of agricultural land;

ii) restricted use of herbicides especially near site boundaries; and

iii) siting and clearing to prevent changing site drainage patterns and increased site drainage onto surrounding lands.

Recreational Land Use and Parkland

Recreational land in Ontario is categorized according to its capability to support intensive or extensive recreational use, or its designation as a provincial or national park. These are discussed in Grondin and Fearn-Duffy (1993a).

(i) Recreational Land Use

Development of a disposal facility may directly or indirectly affect existing or future recreational land uses (Grondin and Fearn-Duffy 1993b). The direct effect could be the displacement of existing recreational land use or the prevention of potential future use. On the other hand, constructing access roads to the site could open up additional land for recreational use that was previously inaccessible. The indirect effect could be a reluctance to use or to develop recreational areas near the disposal facility due to public views on the potential risk (see Section 1.4 and 6.5 for discussions of public views on risk and its associated socio-economic impacts). Recreational use of the reference site itself could not be resumed until after closure of the facility.

More than 70% of each of the three regions of the Ontario portion of the Canadian Shield has low intensive recreational use capability. It is assumed that these lands would be the most likely to host the disposal facility. The disposal facility land requirement would only be a minute fraction of these lands (much less than 1 %). More importantly, there is an area of intensive recreation use capability land that is rated as outstanding in each regional

reference environment. Since this is small, especially in the Northern region (1% of total land), preserving this land would be a major consideration when siting the facility.

The direct effects of the disposal centre land requirements on recreational use capability are, therefore, expected to be small, representing a minute fraction of the area of the high, moderate or low capability land in each region of the Canadian Shield in Ontario.

(ii) Parks

The extent and location of provincial and national parks, and conservation areas are given in Grondin and Fearn-Duffy (1993a). Since the total parkland area in each of the regions represents less than 20% of the total land area, and the land uses in these parks are restricted under regulations (see Appendix B), it is assumed that a disposal facility would not be located in a public park. The conditions of acceptable land use outlined in the National Parks Businesses Regulations under the National Parks Act indicate that the disposal facility would not be a compatible land use project (see Appendix B). Potential effects, depending on proximity to a park, could include:

i) increased road traffic volumes from material shipments and construction personnel;

ii) increased traffic and construction noise levels; and

iii) increased dust levels.

As well, the influx of construction workers, their families and secondary population may increase park use.

Based on the number of parks and their areas for each reference environment, the probability of a disposal facility being located in the vicinity of a park or conservation area is least in the Central region reference environment (less than 6%) and greatest in the Southern region reference environment (20%). Preservation of the integrity of the park should be strongly emphasized if a UFDC is sited in the vicinity of a park.

Measures to minimize effects of UFDC construction on recreational land use and parkland could include:

i) preservation of high intensive or extensive recreational land use areas;

ii) siting the UFDC more than 25 km from a national or provincial park; and

iii) provision of funding to develop or create new recreational areas for site personnel and their families to reduce their effect on existing areas and facilities.

(7) Fire Hazards

Construction of the disposal facility could influence the frequency of occurrence of forest fires. According to Ontario statistics, forest fires caused by lightning or human accidents increase in areas of higher populations.

Lightning-related fires can increase due to changes in the relative height of the general topography in an area. Construction activities that can affect the number and extent of lightning-caused fires are land clearing, re-grading, and the construction of buildings, towers and devices that attract lightning.

Population-caused forest fires could increase during the construction stage, primarily during site clearing activities and road paving. Increased population influx into the area due to construction activities and associated recreational activities could also contribute to an increase in the number of forest fires in the area.

As mentioned under Section 2.1.1.6, the facility management would cooperate with the Ministry of Natural Resources to prevent forest fires. Applicable regulations within the Forest Fires Prevention Act are given in Appendix F.

It is imperative that forest fire hazards from UFDC construction be kept as low as possible. Measures to minimize effects could include:

i) proper installation of lightning rods on tall site structures;

ii) ensuring metallic equipment is properly grounded, especially near forest edges;

iii) avoiding high or changeable wind conditions when burning slash and forest cuttings;

iv) provision of fire breaks around the construction site area;

v) elimination of sparking equipment near explosive or forested areas on dry days or without proper fire-fighting equipment;

vi) avoiding road paving in extremely dry weather to prevent sparks from the asphalt heating equipment;

vii) training and equipping construction staff in fire-fighting procedures;

viii) providing funding to establish or improve local fire-fighting services; and

ix) providing additional forest surveillance to detect fires at an early stage.

(8) Flora and Fauna

(a) Natural Vegetation

Preparation of the site and access/service route would result in the loss or disruption of the natural vegetation cover. Taking the extreme case, approximately 18 km^2 (the entire area of the site), may be cleared or otherwise disrupted through changes in drainage patterns or surface and groundwater levels (Prinoski et al. 1983). As illustrated in Grondin and Fearn-Duffy (1993a), the vegetation communities that would most likely be affected in each Shield region are forests and wetlands (effects on wetlands are discussed earlier in Section 5.2.2.1).

The tree species most likely affected in each region of the Canadian Shield in Ontario are:

Southern: Great Lakes-St. Lawrence deciduous forest, which is characterized by sugar maple, beech, basswood, yellow birch, red maple, white ash, eastern white pine and eastern hemlock.

Central: Boreal forest, which is characterized as a transitional coniferous forest of balsam fir, black spruce, white birch with scattered white spruce and trembling aspen.

Northern: Boreal forest, with black spruce predominant.

Mitigation measures could be used during the construction stage to minimize effects (Prinoski et al. 1983). They include:

i) preservation of as much of the existing vegetation cover as possible to prevent erosion, and for aesthetic and landscaping purposes;

ii) total clearing of only those areas required for the construction camp, surface facilities and site access/service routes;

iii) salvaging of commercial-grade timber;

iv) preservation of shoreline wetland areas which are unique and valuable ecologically in the regions of the Canadian Shield in Ontario; and

v) use of road salt on the access roads only when necessary because of its potential affect on road side vegetation.

Insufficient regional information was available to enable other plant communities, such as meadows and shrubs, to be considered. Further consideration will be given at the site specific stage.

(b) Large Animals, Small Animals and Predatory Birds

The number of common species of birds, mammals and reptiles (i.e. species with a known breeding range greater than 40% of the area of the region) in each of the Shield regions is discussed in Grondin and Fearn-Duffy (1993a). The occurrence of a particular wildlife species and its abundance at a specific site would vary according to the habitat, climate and other local characteristics. Although the effects of construction on wildlife would depend on the species and the site characteristics, it is possible to make some general observations on the basis of the regional distribution of the normal ranges and populations of wildlife species in each Shield region.

There are 257, 254 and 263 species of wildlife in the Northern, Central and Southern regions respectively, of which 55, 47 and 50 are mammals, 182, 176 and 173 are birds and 20, 31 and 40 are reptiles. Most of these species are considered to be regionally common (58%, 64% and 71% for the Northern, Central and Southern regions respectively). Some of these species could be affected by site development. The actual effect on the regional populations can only be assessed at the site specific stage. However, it is expected that changes in local populations of regionally common species, as a result of construction activities, would not affect regional populations.

Seventy-three, 55 and 33 wildlife species are considered to be regionally uncommon in the Northern, Central and Southern regions, respectively. Because these have relatively less extensive ranges in each region, they are less likely to be encountered by site development than are the regionally common species.

If they are encountered, measures must be developed to prevent any significant loss to the regional population.

Effects of construction activities on wildlife may result from the release of contaminants, increased noise, traffic and land clearing. Small amounts of heavy metals released by construction vehicles would be deposited on roadside soils and enter the foodchain via initial plant uptake. The concentrations of these emissions would be minimized by avoiding unnecessary engine idling.

Construction activities could displace some wildlife either permanently or temporarily. Those most likely to be affected are the rarer, larger animals and predatory birds. Species that are mobile would attempt to locate to a suitable habitat elsewhere. Some species of large mammals may be attracted to the newly created forest edges along the side of the road/rail and transmission corridors, as well as to the site itself. This could result in road kills and an increased hazard to construction personnel. The composition of the bird community may change due to the introduction of road and rail corridors. Some species would benefit and thrive along the edge and open habitat; others could be adversely affected.

Direct effects (i.e. displacement and mortality by habitat loss and traffic increase) could result in a decrease in the wildlife population on-site. Conversely, there could be a possible increase in certain species due to habitat diversification. Indirect effects of displacement could also occur. Those species that move off-site to search for new habitat would likely enter the territories of outlying populations. This influx could result in some disturbance to the ecological balance of the area. Competition for food and habitat, and alteration of predator-prey dynamics would likely affect the displaced animals. Construction of the fence around the protected area would act as a barrier to wildlife movement in the short term. However, avoidance of important wildlife habitat would be a consideration during the siting process in the first place.

Measures to minimize effects of UFDC construction on fauna include:

i) provision of warning signs and speed limits on access roadways to reduce roadkills;

ii) provision of protected habitat areas on-site or funding to improve habitat in the area;

iii) labelling and strict control of harmful substances, and proper disposal of residues;

iv) engine maintenance to reduce emissions;

v) dust control through watering of stockpiles and use of blasting mats; and

vi) hunting restrictions on-site.

(c) Waterfowl

Transient species such as migrating or staging waterfowl can be expected to temporarily avoid the construction areas.

Although the Canadian Shield region is generally not within any of the major North American flyways, there are waterfowl migration routes in all three regions. Migrating waterfowl that use areas adjacent to the site would be temporarily disturbed by construction activities (especially noise). However, these areas would likely continue to attract migrating birds after construction is complete. Migrating birds may temporarily change their routes, but are likely to re-establish the original routes once the disturbances have subsided.

Land clearing during the waterfowl nesting season could disturb nesting adults, and destroy eggs and nestlings. Although the disturbed adults might try to breed again, the success rate would be lower if the disturbance occurs late in the season. Provided that clearing is not carried out during the prime nesting season (late spring), disturbance to waterfowl population would be minimized. However, if the drainage patterns of the wetland area are

significantly altered and the natural flora destroyed, the waterfowl may be displaced by upland birds.

Measures to minimize effects of UFDC construction on waterfowl include:

i) preservation and protection of waterfowl nesting wetland areas and other habitat at the siting stage;

ii) prohibit clearing during prime nesting season and minimize at all other times; and

iii) if wetland drainage is disturbed, improve other local wetland regions to provide alternate breeding grounds.

(d) Threatened, Rare or Endangered Species

The Northern, Central and Southern regions, respectively, are inhabited by 30, 36 and 37 species of wildlife, 6, 3 and 5 plant species and 3, 1 and 1 fish species that are considered to be rare or threatened in Ontario. Five wildlife species in the Northern region and 4 in the Central and Southern regions are considered to be endangered and are protected by the Endangered Species Act. These species are listed in Grondin and Fearn-Duffy (1993a). Because of their scarcity, the possibility of encountering any of these species is very small.

Further discussion of the effects of the facility construction on endangered and threatened species habitat is included in Chapter 10 as a sensitive environment scenario.

Measures to minimize the effects of UFDC construction on threatened, rare or endangered species would include:

i) early identification of threatened species habitat at the site characterization stage;

ii) preservation of threatened habitat at the siting stage; and

iii) transplanting species (if possible) to an off-site or protected on-site area.

(9) Noise

Noise levels are expected to increase in the vicinity of the disposal facility construction areas. Assuming that normal noise control practices are in effect (Ontario Hydro 1981b), noise levels at the site boundary during the construction stage should be within the regulatory limits (see Appendix B). During construction of the Darlington Nuclear Generating Station, the noise increase due to the construction activities was 5-10 dB(A) (the A refers to the spectrum of frequencies heard by the human ear) over the background noise levels of 38-49 dB(A) at the 1.0 km site boundary (Osman 1987). Since facilities at Darlington Nuclear Generating Station are larger than those specified for the disposal facility, therefore, use of these construction noise levels for the UFDC is conservative. The increase in noise level at the UFDC site boundary is also expected to be smaller because the property boundary extends out to 1.5 km. A noise reduction of 6 dB(A) normally results for every doubling of the distance from the source; therefore, there should be no change in noise level from the UFDC construction activities at 4 to 6 km from the site in any direction.

Noise levels due to the construction and use of the access roadways and transmission line during UFDC construction are expected to be more severe because the construction activities would be much closer to the boundary of

the road or railway and would extend for approximately 25 km (assumed length of the access road). This could intrude upon some wildlife habitat.

Generally, noise becomes a source of annoyance for humans if it exceeds 60 dB(A). Since most of the construction would be more than a kilometre away from the edge of the exclusion zone, construction noise is not expected to intrude significantly on the surrounding community. Noise at the site would be controlled to meet regulatory limits (Ministry of Environment 1978).

The socio-economic impacts of noise and other disturbances on the local community are discussed in Section 6.5.

Measures to minimize effects from UFDC construction on ambient noise include:

i) provision of muffling devices on construction equipment;

ii) prohibition or reduced operation of heavy construction activities during night hours; and

iii) scheduling of activities to reduce effect on wildlife during sensitive periods.

(10) Non-Renewable Resources

As recommended in the AECB regulatory document R-71 (AECB 1985) (see Appendix B), it is assumed that the site on which the UFDC is located would not contain commercial grade minerals.

Construction of a disposal facility would require the use of certain non-renewable resources. The effects of this consumption on the supply capability and known reserves of these resources in Ontario, Canada and the world have been assessed. Many factors affect the supply capability and reserves of natural resources, including supply and demand, accessibility, stockpiling and inventory practices, conservation and recycling practices. As noted in Section 2.1.3.8, some of the resources would be recycled during the construction stage or retrieved for re-use when the facility is decommissioned and demolished. Procedures for reduction, re-cycling, re-use and substitution of scarce material would be followed during all stages of the facility's life cycle.

(a) Non-Fuel Resources

The non-fuel resources that would be consumed during construction of the disposal facility have been estimated by breaking down each project activity into component materials. These are presented in Table 5-4. Resource requirements are taken from the UFDC design study (AECL CANDU et al. 1992) and are detailed in Grondin and Fearn-Duffy (1993b).

The major non-fuel resources which would be required for the construction of the disposal facility, but would not be generated on-site by excavation activities are cement, sand, bituminous paving, steel (both stainless and carbon), aluminum, copper, and gravel and/or crushed stone.

TABLE 5-4
Summary of Net[1] Construction Material Requirements

Material	Requirements
Gravel/rock/crushed stone	318 760 m^3
Steel	113 000 Mg
Copper	30 Mg
Sand	311 580 m^3
Bituminous Paving	105 000 m^3
Titanium	Minimal
Aluminium	200 Mg
Bronze	Minimal
Cement	80 780 m^3

[1] "Net" refers to the quantities of materials which would be required to be brought to the site, a certain amount of resources being available at the site (i.e., earth/clay for construction backfill; gravel/rock/crushed stone for foundations and concrete mixes).

Concrete and Sand

Approximately 1 154 000 m^3 of concrete would be required for construction of the major surface facilities. It is assumed that 50% by volume would be foundation grade concrete and 50% reinforced concrete (27 MPa tensile strength) for building material. The constituent materials of this concrete mix are cement 7%, sand 27%, gravel/crushed stone 54% and water 11% by volume. The component raw materials of cement are lime, silica, aluminum, iron oxide and gypsum, which are relatively abundant throughout Canada and the world. Canada is a net exporter of cement, and production capacity in Ontario and Canada exceeds actual production. Since the major user of cement is the construction industry, potential markets are in areas of expansion. The price of cement is very sensitive to transportation costs. The distance separating the source (cement factory) and the market (i.e. the disposal facility) is more likely to limit the availability of cement in the future than is the reserve/resource situation (Monenco Ontario Limited 1990).

Sand and gravel, which are the other principal components of concrete, are also abundant in Ontario and Canada. Like cement, the main limitation on the supply of this resource is distance to the markets.

Steel and Major Constituents

Approximately 113 000 Mg of structural steel would be required for construction of the surface facilities. A further quantity of carbon steel and stainless steel would be required for the equipment, piping, etc.

The basic raw ingredients for steel are iron ore and metallurgical coal, and any limitation on the availability of steel in the future would depend on the reserves of these two commodities. There is at least several thousand years' worth of coal reserves if consumption rates remain stable. Reserves of iron ore in Ontario are abundant (Ministry of Northern Developments and Mines 1987) and present recovery rates (4 000 000 $Mg \cdot a^{-1}$) would not deplete them excessively. The facility's steel requirement represents a very small fraction (less than 1%) of Ontario's current annual raw steel production capacity of 15 100 000 Mg.

Stainless steel contains 12%-27% chromium (the minimum of 12% is based on the required corrosion resistance of the final product), 1%-22% nickel and minor amounts of manganese, silicon, phosphorous and sulphur. Other metals such as molybdenum, selenium, titanium, tantalum, etc. may be added for special duty stainless steels. The requirements for constituents other than chromium and nickel are not expected to be significant.

Assuming that 10% of the steel required for the site would be stainless steel, between 1 300 Mg and 3 050 Mg of chromium (based on 12-27% content) would be required during the construction of the disposal centre. There are fairly large deposits of chromite in Canada (Quebec and Manitoba), but they are considered uneconomical at the present time and are not being mined. Currently, Canada depends heavily on imports of chromite and ferro-chromium (Monenco Ontario Limited 1990; Energy Mines and Resources 1983). Although chromiumis not expected to become a critical resource, in terms of world demand exceeding world reserves, in the foreseeable future (Monenco Ontario Limited 1990) the facility requirements would be dependent on world supply.

Up to 2 500 Mg of nickel may be required as a steel additive during the construction of the disposal facility (based on a 22% content). In Ontario, nickel is usually associated with copper and there are many major copper/nickel mines in the province. Canadian reserves of nickel were estimated to be 7 000 000 Mg in 1985 (of which 5 000 000 Mg were in Ontario) (Energy Mines and Resources 1987). This represents a decrease of 15% since 1981. Nevertheless, the present production rate of 170 000 $Mg \cdot a^{-1}$ in Canada (130 000 Mg in Ontario) exceeds the demand, and the small amount which would be committed to the site during construction is not expected to put a strain on the supply.

Copper

The estimated amount of copper for the facility is approximately 30 Mg. Compared to the known reserves and present production rates of copper in Ontario and Canada, this is a minor amount. However, world-wide copper demand beyond the year 2015 is anticipated to put a strain on supply sources (Grover 1990). In 1985, Canada produced 500 000 Mg of refined copper (280 000 Mg in Ontario) and the estimated reserves were 14 300 000 Mg. This represents a decrease of 15% in the known reserves since 1981 (Energy Mines and Resources 1987). Considering the proposed start-up date of the facility, it is recommended that copper use in the optimized design be re-examined to reduce our dependency on a potentially limited commodity.

Bituminous Paving

The total estimated quantity of bituminous paving required for the site construction would be 105 000 m^3 (136 500 Mg). Bituminous paving is an agglomerate of 6% by weight asphalt filler (a petroleum by-product) and 94% sand aggregates. The limiting factor is the asphalt filler, of which 64 000 Mg was produced in Ontario in 1987. This amounts to an annual bituminous paving production of over 1 000 000 Mg in 1989. The quantities required for the UFDC construction represents 13% of this total. Since it is likely that most of the paving would be done during one year of construction, this could affect the supply of this resource during that year.

Aluminum

Approximately 200 Mg of aluminum would be used in the ducting and equipment installed during construction of the UFDC. This represents 13% of the 1988 Canadian production of 1 534 Mg. Production in Canada is centred in British Columbia and Quebec. No reserves have been identified in Ontario and the known reserves in the British Columbia and Quebec are not considered to be extensive. The world production rate in 1988 was 13 750 Mg, and the world

consumption 14 000 Mg. If this continues, it will lead to a rapid reduction of stockpiled inventories. Furthermore, the consumption rate is expected to grow at a rate of 1.5% per annum until the year 2000. Therefore, although the site requirements represent only 1.5% of the annual production rate, depletion of the reserves before site construction commences must be taken into account.

(b) Fuel Resources

The method for calculating the quantities of fuel required during the construction stage could comprise the following steps: evaluating the type and quantity of fuel utilizing equipment on site; evaluating the rate of fuel consumption of each machine and the length of service expected; and comparing the calculated consumption of the annual production rates and known reserves of these fuels. These quantities have not been estimated for this concept assessment, however, they are not expected to have an impact on availability of the resources.

(11) Transportation of Construction Materials

Delivery of materials to the site during the construction stage would increase traffic on the transportation network leading to the site and on the road/rail access. The delivery traffic to the site was estimated using the non-renewable resource requirements for the construction stage, and the assumption that delivery of the materials would be spread over the seven-year construction stage. The total number of trucks and/or rail cars required to transport the construction material to the site is given in Table 5-5. The upper limit would be if all materials arrived by dump truck. The lower limit would involve semi-trailer or flat-bed railcar transportation. Realistically, materials would be transported in the most appropriate manner according to cost and handling conditions. Using an average capacity for the possible road transport vehicles, and assuming that road transport is used exclusively, the expected increase in traffic to the site over the 7 years of construction would be around 32 vehicles/day. Similarly, if rail transport is used exclusively, the increase in the number of rail cars would be around 22 vehicles/day. Combination of the two systems (the most likely scenario) would result in an average increase of around 25 vehicles/day.

5.2.2.2 Effects from Construction of the Underground Facilities

(1) General Effects of Excavation

The effects of shaft sinking and underground excavation would be similar to the effects during underground evaluation (exploration shafts) at the siting stage (see Section 4.3.5).

Drilling and blasting activities would generate noise and dust. As the excavation proceeded to greater depth, the effects on the surface environment would be expected to diminish. Waste rock would be disposed of in a special area called the rock disposal area. Water pumped out of the facility would be monitored before discharge and treated if necessary.

(2) Effects of Excavation on Groundwater Supplies

As with some of the activities conducted during site evaluation and the construction of the exploration shafts and tunnels, construction of the access tunnels and waste emplacement rooms of the UFDC could have an effect on nearby groundwater supplies. Drainage of groundwater into the underground openings of the UFDC would lower the groundwater levels in the rock surrounding the facility. Although it is unlikely, these effects could extend beyond the site property. Local site conditions, such as the permeability of the rock immediately surrounding the excavations and the distribution and

TABLE 5-5
Estimates of Maximum Road or Rail Traffic for each of the Non-renewable Resource Construction Material Deliveries to the UFDC Facility

Material	If Transported by Road			If Transported by Rail	
	Number of Dump Truck[1] Trips	Number of Flat Bed Truck[2] Trips	Number of Semi-Trailer Trips	Number of Rail Box-Car[1] Trips	Number of Flat-Bed Railcar[2] Trips
Cement	9 100	4 300	4 300	5 800	2 400
Sand	20 300	9 700	9 700	13 100	5 400
Asphalt	5 400	2 600	2 600	3 500	1 400
Gravel	21 000	9 900	9 900	13 500	5 600
Copper (pipes)	30	7	5	6	8
Steel (pipes)	1 800	400	300	400	400
Steel (re-bars)	4 400	2 100	2 100	2 800	1 200
Aluminum	8	4	4	5	2
Total	62 000	29 000	28 900	39 100	16 400
Average number of vehicles from transportation of construction material using a combination of road and rail: 31 000 trips Expected daily increase in road traffic (in-full; out-empty): 24-25 vehicles/day					
Average number of vehicles from transportation of construction material using road (averaged over all types): 40 000 trips Expected daily increase in road traffic (in-full; out-empty): 31-32 vehicles/day					
Average number of vehicles from transportation of construction material using rail only (averaged over all types): 27 723 railcar trips Expected daily increase in rail traffic (in-full; out-empty): 21-22 railcars/day					
Note: These traffic figures are based on flow in and out of the site 365 days/year over a 7 year construction period. [1] or truck of an equivalent capacity for metal products [2] or truck of an equivalent capacity for sand, cement and asphalt					

characteristics of permeable fracture zones elsewhere in the rock, will determine the extent of any such disturbance. The effects of any such changes would be estimated using information derived from a thorough evaluation of the site prior to and during construction of the underground facilities. Monitoring of these changes in the groundwater regions would also be carried out using a network of site and offsite observation wells. If any negative impacts to surrounding groundwater supplies are either estimated or observed, mitigative actions could be taken. These could involve altering the design and layout of the underground facilities to avoid intersecting groundwater features that would cause such a disturbance; grouting or sealing off locations of inflowing groundwater in the underground facility; or providing alternative water supplies to those affected.

(3) Effects of Excavation on Flora and Fauna

Any lowering of groundwater levels could potentially also affect local vegetation and any wildlife using it as habitat. The effect would depend in part on the nature of local surface soils (water retention characteristics essentially). Vegetation growing in soil containing clay would be less likely to be affected than vegetation growing in more porous soil. Again, it is considered unlikely that such groundwater related effects would extend beyond the disposal site boundary. Mitigative measures, if necessary to protect local groundwater supplies, could also contribute to the protection of local vegetation and wildlife.

(4) Effects from Excavated Rock

This section discusses the effects of the excavated rock pile during construction and operation of the UFDC. Decommissioning effects are discussed in Chapter 8.

(a) Effects on Air Quality

The characteristics of the excavated rock depend on the type of rock and the excavation method used. The method of vault excavation is assumed to be a smooth-wall blasting technique, which is a widely accepted method for controlling overbreak in mines. This method usually produces only small quantities of fine size particles (Simmons and Baumgartner 1994), therefore, the rock disposal area is not expected to be a major source of dust emissions.

(b) Effects on Surface Water Quality

Runoff from the rock disposal area might result in sedimentation of surrounding surface waters, which could affect aquatic flora and fauna. The mean annual total precipitation and runoff in the three regions of the Ontario Shield are very similar (800-899 $mm \cdot a^{-1}$ precipitation for both the Central and the Southern regions, 700-799 $mm \cdot a^{-1}$ for the Northern; 250-349 $mm \cdot a^{-1}$ runoff for the Northern and Southern regions, 350-449 $mm \cdot a^{-1}$ for the Central region). The magnitude of the runoff effects are, therefore, expected to depend mostly on the characteristics of the receiving waters.

Sediment concentrations in surface waters across the Ontario portion of the Canadian Shield vary from essentially zero to around 200 $mg \cdot L^{-1}$ (Grondin and Fearn-Duffy 1993a). The significance of the increase in sediment concentrations from rock pile runoff would depend on local conditions. Canadian water quality guidelines (Environment Canada 1987b) for the protection of aquatic life suggest that concentration of suspended solids should not increase by more than 10 $mg \cdot L^{-1}$ when background concentrations are equal to or less than 100 $mg \cdot L^{-1}$. For background concentrations exceeding 100 $mg \cdot L^{-1}$ the increase should not exceed 10% of the background value.

Experience at AECL's Underground Research Laboratory (URL) shows that the contribution to turbidity and suspended sediment concentration from runoff can be greatly reduced by carefully designing the settling pond and discharge path to increase precipitation of the suspended solids on site (Lemire and Acres 1990). No significant changes in the off-site surface water quality were recorded.

Weathered rock products might contain toxic substances that could contaminate the receiving surface waters. Release of these substances would only occur if they were sufficiently mobile or in high concentrations. The amount and rate of erosion and weathering of the rock excavated from the vault would be determined by the environmental conditions (e.g. precipitation, temperature, etc.), the extent of the exposed surface and the mineralogical composition of the rock. The exposed surface area depends upon the vault excavation technique and the mechanical characteristics of the rock.

Four types of rock are being considered: granite, gabbro, syenite and anorthosite.

Granite is composed of minerals which are high in aluminum silicates. Gabbro contains minerals which have a high concentration of ferro-magnesium silicates. Syenite and anorthosite are considered to be intermediate between granite and gabbro, syenite having more aluminum silicates and anorthosite having more ferro-magnesium silicates (Potter and Robinson 1975). Silicate minerals are some of the more stable components of the earth's crust; mechanical and chemical weathering of these minerals occur very slowly (Hunt 1972; Blyth and de Freitas 1974).

In addition to the major elements, there are small amounts of minor elements which may be trapped or occur as accessory elements in the host rock. Weathering of the excavated rock may cause dissolution of these minor elements. This has been identified in some mine tailings areas where arsenic, cadmium, copper, iron, nickel, mercury and zinc have degraded natural waters, and cobalt, lead, manganese, molybdenum and selenium have been identified as potentially degrading (Hawley 1977, 1979).

The concentrations of sulphur and arsenic, and other potentially toxic elements, are low in igneous rocks (e.g. granite, gabbro) compared to those in mine tailings disposal piles (Hawley 1977, 1979). Given the relatively high resistance to weathering of igneous rocks and the expected low concentrations of toxic substances, detrimental effects on water quality in neighbouring water bodies from the rock disposal area runoff are expected to be negligible. This is supported by results at the URL, where no significant changes were measured in the off-site surface water (Lemire and Acres 1990).

Acidic or basic runoff from the mined rock disposal areas may affect the pH of neighbouring waterbodies. The major minerals of granite are quartz and orthoclase feldspar which, when pulverized in water, have a pH of 6-7 and 8, respectively. The remaining minerals have a pH of 7-9 (Hawley 1979). Thus, a pH of 7-8, which is essentially neutral, might be expected in runoff water if precipitation falling on the mined rock disposal area were neutral, since granite is quite resistant to weathering. There will be monitoring of run-off from the rock pile disposal area, and remedial action will be taken if the run-off is found to be unduly contaminated.

The major minerals of gabbro tend to be basic having a pH of 8-11 when pulverized in water (Hawley 1979). A pH of 9-10 in runoff water might be expected from neutral precipitation falling on mined rock storage/disposal areas. Since precipitation in the Shield region is slightly acidic, and given that gabbro is resistant to weathering (although less resistant than granite), a slightly beneficial neutralization of the rain water may occur prior to entering the receiving waters.

It may be concluded that runoff from granite, gabbro, syenite or anorthosite disposal/storage areas would have little effect on the pH of receiving surface water bodies or groundwater.

5.2.2.3 Summary of Mitigation Measures

As described in the preceding sections, a number of measures could be applied to minimize the effects of the UFDC construction on the natural environment. These are summarized below:

i) minimize vegetation clearing, especially near shorelines;

ii) do not waste commercial-grade timber;

iii) preserve shoreline wetlands as much as possible;

iv) mitigate effect of changes in the water table from excavation;

v) monitor extracted groundwater before discharge;

vi) minimize dust emissions by paving roadways and parking areas, periodic water sprinkling, the use of covered trucks where possible and keeping the roads near the site free of heavy dust deposits;

vii) minimize sedimentation effects on surface water quality by establishing ditching and storm drainage systems to control erosion;

viii) schedule construction activities which are near or at the shore, so as to preserve aquatic life;

ix) preserve sensitive environment areas;

x) preserve valuable agricultural land;

xi) preserve recreational land;

xii) implement forest fire protection measures; and

xiii) protect existing flora and fauna.

It should be noted also that the potential impacts described could not all occur in one location as many are mutually exclusive. For example, if a disposal facility were sited on agricultural land, it could not affect forestry resources.

5.2.3 Potential Effects on Workers

5.2.3.1 Analysis Methodology

The first step in an occupational safety assessment is to identify the hazards associated with construction activities. Typical hazards to workers include noise, vibration, slips and falls, suspended or moving objects and moving vehicles.

An estimate of the exposure time (person-hours) to the identified hazards is then obtained. The basic UFDC labour estimates given in Section 2.1.1.5 are augmented using experience from comparable industries. Any regulatory requirements, limits, guidelines or procedures for performing the task are identified if they affect worker safety.

Once all the foreseeable non-radiological hazards have been identified, they are quantified, where possible. Estimates of potential non-radiological hazards are based on experience in comparable industries, using equipment of similar sizes and types. When quantification is not possible, a qualitative analysis is performed. Acute non-radiological hazards are estimated from risk factors associated with workers' activities. The risk factors are given as the number of injuries or fatalities per 10^8 person-hours worked.

5.2.3.2 Analysis of Potential Effects

(1) Standards, Targets and Guidelines

Regulatory requirements for conventional health and safety are included in provincial regulations (Government of Ontario 1990c) and the Canadian Labour Code (Government of Canada 1985a). In Ontario, all construction activities would be governed by Regulation 213/91 of the Act, and underground activities by Regulation 854 (see Appendix B). The safety standards and guidelines prepared by Ontario Hydro also provide a number of methods that can be used to assess conventional hazards and verify that working conditions meet the regulatory requirements (Ontario Hydro 1977, 1979).

(2) Hazards During Normal Conditions

The chronic non-radiological occupational hazards from UFDC surface construction result mainly from operating large vehicles and machinery. The exhaust fumes from the machinery that would be used for land clearing and site preparation would result in the release of airborne pollutants, but in open air working conditions should not affect workers. More care should be taken during construction of the buildings because the enclosure would not allow rapid air changes in work areas. Noise generated from construction machinery and rock crushing operations would be a hazard to machine operators, drivers, construction workers and supervision personnel.

Vibration from engines and machinery would also pose some occupational health risk. Dust and airborne particulates would also affect the external working environment.

The hazards to the workers associated with surface and underground excavation are presented in Table 5-6, together with commonly used mitigation measures.

It is not possible at this conceptual stage of the UFDC design to quantify all occupational hazards to which workers would be subjected during construction. It can, however, be said that these hazards would be similar to hazards associated with comparable large construction and mining projects.

Exposure limits for diesel exhaust fumes are based on the threshold limit values (TLVs) of individual components, since the fumes contain a large number of chemical compounds. It is assumed that working conditions at the UFDC would be in agreement with the Occupational Health and Safety Act of Ontario (Government of Ontario 1990c), and that worker exposure to diesel exhaust fumes would be within the TLVs.

Worker exposure to noise is currently regulated under the Ontario Occupational Health and Safety Act (Government of Ontario 1990c). The Act stipulates that an equivalent sound level of 90 dB(A) (the equivalent noise level is the average noise level over an hour that would contain the same amount of energy) is the maximum to which a worker can be exposed for a normal work period of eight hours. At levels between 90 dB(A) and 115 dB(A), the exposure duration is reduced. Above 115 dB(A), hearing protection must be worn. It is assumed that these limits would be followed and that no unacceptable noise exposure to workers would result from UFDC construction, operation and decommissioning. At present, there is no regulation to limit the intensity, time or frequency of whole body vibration.

TABLE 5-6
Hazard to the Workforce Associated with
Surface and Underground Excavation

Hazard	Mitigation Measures
Physical injury from blasting and ground falls	Rigid procedures of control
Physical injury, vibration and noise from drilling	Limitation on time of exposure to vibration Hearing protection
Physical injury from heavy equipment operation	Worker education/experience, good operating practice
Diesel fumes from heavy equipment operation	• Use of catalytic afterburners on the engine exhausts • Strict ventilation standards enforced
Dust from drilling and excavation	Elimination of dust by wet drill surveillance and monitoring, protective respiratory masks
Extreme temperatures	Protective clothing

(3) Hazards During Abnormal Conditions

The proposed drill-and-blast method is used routinely in mining and civil engineering projects in rock similar to that proposed for the UFDC. Ground control would be achieved by standard rock-bolting methods from scissor-lift trucks. Massive rock burst are not expected in the underground vault (Simmons and Baumgartner 1994). Minor rock bursts, from accident statistics of the mining industry, are used as a basis for calculating risks from underground excavation.

The nature of acute non-radiological hazards can be inferred from injury and fatality statistics associated with industries using comparable types of equipment. Forestry, construction, mining and light manufacturing industries were chosen for sources of statistical data on worker injuries and fatalities. Slips and falls, strikes by moving objects, trapping by objects, vehicle accidents (see Section 5.2.2 for transportation of construction material), explosions and tripping accidents are typical industrial accidents. Labour requirements given in Section 2.1.1.5 are used to estimate conventional risks for UFDC employees.

5.2.3.3 Analysis Results

Estimated annual acute non-radiological risks to workers are presented in Table 5-7. The total risk from all construction stage activities has been estimated as 0.06 fatalities per year and about 11 lost-time injuries per year. This is considered to be a conservative estimate, based on Ontario industry statistics. It is expected that a disposal facility for used nuclear fuel would achieve better than industry average worker safety, more comparable to that of crown corporations. For example, Ontario Hydro experienced no worker fatality during the 50 million person-hours worked to construct the Darlington Nuclear Generating Station (Zeya 1993a).

TABLE 5-7
Estimated Annual Acute Non-radiological
Risks for the UFDC Construction

Activity	Labour (person-h• a^{-1})	Fatality Rate per 10^8 person-hours	Injury Rate per 10^8 person-hours	Annual Fatalities	Annual Injuries
SURFACE CONSTRUCTION					
SITE SURVEY	299	40	5200	1×10^{-4}	0.016
SITE PREPARATION					
Clearing & Stripping	14 694	40	8 130	5.9×10^{-3}	1.20
Rough Grading,	4 081	10	8 130	4.1×10^{-4}	0.33
Excavating and Filling	12 786	10	3 250	1.3×10^{-3}	0.42
SITE ACCESS					
Roads:Clear./Stripping	766	40	8 130	3.1×10^{-4}	0.062
Foundation	613	10	3 250	6×10^{-5}	0.020
Surfacing	367	10	3 250	4×10^{-5}	0.012
Rail: General	474	40	8 130	1.9×10^{-4}	0.038
SITE SECURITY					
Standard	3 030	10	3 250	3×10^{-4}	0.098
Guard House	320	10	3 250	3×10^{-5}	0.010
SITE IMPROVEMENTS & FINISHED GRADING	3 959	10	3 250	4×10^{-4}	0.129
ONSITE TRANSPORT					
Roads & Parking	3 001	10	3 250	3×10^{-4}	0.097
Railway	720	10	3 250	7×10^{-5}	0.023
BUILDINGS & STRUCTURES					
Excavation and Backfill	18 927	10	3 250	1.9×10^{-3}	0.62
Construction	20 909	10	3 250	2.1×10^{-3}	0.68
SYSTEMS					
Electric Power	22 839	10	3 250	2.3×10^{-3}	0.74
Instr. and Control	5 639	10	3 250	5.6×10^{-4}	0.18
Common Processes and Services	12 889	10	3 250	1.3×10^{-3}	0.42
TOTAL - SURFACE	126 331			0.0175	5.09
UNDERGROUND CONSTRUCTION					
SHAFTS					
Sinking Operations	26 920	30	4 700	8.1×10^{-3}	1.27
Permanent Plant Structure	3 750	30	4 700	1.1×10^{-3}	0.18
VAULT EXCAVATIONS					
Central Access Drifts	5 809	30	4 700	1.7×10^{-3}	0.27
Panel Access Drifts	28 251	30	4 700	8.5×10^{-3}	1.33
Perimeter Access Drifts	10 054	30	4 700	3×10^{-3}	0.47
UNDERGROUND EXCAVATION/ BACKFILL					
Shaft Facilities	46 671	30	20.0144 180	0.014	1.95
Underground Ancillary Facilities	10 514	30	4 470	3.2×10^{-3}	0.47
TOTAL UNDERGROUND CONSTRUCTION	131 969			0.0396	5.94

5.2.3.4 Mitigation Measures

As mentioned in Chapter 2, establishing and implementing comprehensive employee training and safety programs would be prerequisites for the Used Fuel Disposal Facility. Training in conventional safety for UFDC workers would be an integral part of the orientation process. Formal training sessions would include the use of safety equipment, WHMIS (see Appendix B) training, and methods to identify and mitigate occupational hazards. In addition, arrangements would be made for informal safety meetings where workers can discuss and exchange information, and/or address occupational safety hazards. Use of protective equipment such as respiratory masks and noise protection equipment would be required when conditions warrant them.

5.2.4 Potential Impacts on the Socio-economic Environment

This section is a summary of the potential impacts on the socio-economic environment during the construction stage. For a detailed discussion, see Section 6.5, and Paez-Victor (1993).

The opportunity for project employment is often of interest to local residents and others with skills applicable to the project. Participants in AECL's public consultation program (Greber and Anderson 1989) identified employment and employment security as important considerations in decision-making regarding the UFDC, and they expressed concern that few local people would be employed because of a possible lack of required skills. Generally, residents from northern Ontario placed greater emphasis on increased employment than did residents from other regions in Ontario (Greber and Anderson 1989).

During the seven-year construction period, the procurement of materials and services, and workforce requirements would create the potential for increased business activity, employment opportunities and increases in personal income. The construction stage represents an opportunity for local residents and businesses to share the economic benefits of the project.

Generally, communities that provide a substantial share of the project's employees experience population growth as a result of an influx of workers and their families and generate secondary employment opportunities, for example, as a result of expansion of housing and community services. These communities also benefit from a planned expansion of infrastructure, for example, health care, shopping and recreational infrastructure. They are likely to benefit most from the economic expansion. There could also be impacts on housing and property values, local taxes, and Aboriginal businesses and activities. The economic changes resulting from increased population and employment can result in positive change if the development meets community needs, and if the rate and process of change reflect community goals.

The influx of workers and their families, and the procurement of project materials and services are the major project characteristics that influence relationships with local people and their communities. Large demographic changes can occur that affect not only community facilities and services, but the fundamental way of life of communities. These changes can affect housing and family living which in turn influence community cohesion, and educational and recreational activities and services. The impacts of concerns for public and occupational health and safety would likely be more centred on non-radiological risks (there would not be any radioactive waste at the facility during the construction stage). All of these impacts can affect the social and cultural vitality of communities.

For Aboriginal communities, for whom wildlife represents not only an important economic resource, but a cultural and spiritual symbol of their identity, construction effects that curtail or impede their traditional land use could have major impacts. Aboriginal people may have to give up hunting in that area for that period or relocate their hunting territory. The latter could cause difficulties, as hunting territories are culturally determined by long-standing customs and rights.

The construction stage could also affect the political dynamics of communities through its demands upon facilities and services, and its hiring policies. Impacts on municipal facilities and services, municipal finance and administration, political activities including labour unions, and the political life of Aboriginal people are possible. These impacts could affect the political structures of communities.

5.2.4.1 Impact Management Measures

A fundamental premise for the prevention and mitigation of impacts during the construction stage is the successful completion of the siting stage. Impact management measures would have been developed, and could be extended or improved. During a voluntary siting stage, guided by the principle of voluntarism, criteria for site selection, evaluation, rejection and avoidance would have been established in consultation with the community. These criteria would then aid the host community and the implementing organization in determining the precise lands that would be set aside for the facility.

During the construction stage, the impact management program could include measures to:

i) refine the facility design based on the identification impacts and monitoring of effects to minimize or eliminate them;

ii) change the project schedule to minimize impacts;

iii) maximize the benefits and enhancements; this could include preferential hiring, job training, employment support services, enhancement of business activity, off-site fabrication of components, co-use measures and property management, and community liaison;

iv) implement a monitoring program agreed upon by the community and with community participation;

v) implement public health and safety programs including:
- community health monitoring and research,
- notification of potentially hazardous events, and
- awareness programs for both radiological and non-radiological hazards;

vi) minimize impacts from the workforce, such as long distance commuting, provision of temporary accommodation or new town developments; and

vii) compensate the community, for example, by the use of impact assistance grants, local planning and assistance grants, property value protection, direct financial compensation and in-kind replacement/restoration and community housing development.

5.2.5 Residual Effects

As mentioned in Section 4.6, the residual effects discussed here represent our best judgement on what effects might be left after the application of the impact management measures. This judgement would need to be validated using the affected population and natural environment setting of the chosen site.

It is expected that the construction stage would be the most disruptive for the natural environment. Sound environmental construction practices have been established in other construction projects to minimize effects and these should be followed during construction of the UFDC (Prinoski et al. 1983). The effect of underground excavation on the water table around the site would need to be investigated further, based on site-specific data and mitigation measures taken if necessary. The effect of the construction material traffic on the local transportation network in terms of noise and public safety would also need to be examined.

Other possible residual impacts during the construction stage could be related to demographic and community infrastructure and service changes. These residual impacts, as well as those resulting from measures to enhance local economic benefits, can result in positive social and economic change if managed jointly with the affected communities.

6. ANALYSIS OF UFDC OPERATION

The operation stage, assumed to be 41 years in duration, involves the receipt, packaging and disposal of used fuel in the underground vault. The conceptual design assumes that 10.1 million used-fuel bundles would be handled during this time. This chapter presents an analysis of the environmental, public and occupational safety, and socio-economic implications during the operational period of the Used Fuel Disposal Centre (UFDC).

The following is an overview of UFDC operations, based on more detailed information presented in Chapter 2 and in AECL's primary reference on UFDC engineering (Simmons and Baumgartner 1994):

- Used fuel will be shipped dry in casks from Canadian nuclear generating stations by road, rail or water transport. Water-transported casks containing used fuel will be transferred to the UFDC by road or rail from the nearest barge docking facilities. The major fuel-handling operations at the UFDC will include:

  - receipt of used fuel in transport casks and emptying of the casks,
  - transferring of used fuel into baskets and containers, and void-filling, compacting and sealing of the containers,
  - transferring of the containers to the underground vault, and
  - emplacement of the containers in boreholes within disposal rooms in the vault.

- The used-fuel packaging plant will be the receiving facility for handling casks from both road and rail transport. Casks will be unloaded from the transporters and placed in the cask laydown area. Empty casks will be loaded back on the transporters for the return trip to the nuclear generating stations.

- Once the modules containing used fuel are removed from the cask within a shielded cell, the modules will be transferred directly to the used-fuel packaging cell, or alternatively, into the receiving surge-storage pool. In the used-fuel packaging cell, the used fuel will be transferred from the modules into a basket designed to fit inside the disposal container. The loaded container will then be placed in a shielded transfer cask. Empty modules will be placed back in the transportation cask for the return trip to the generating station.

- Upon leaving the packaging plant, the transfer cask will enter the waste shaft headframe and will be transferred to the cage (vertical conveyance within the shaft). This shaft will be dedicated to the handling of casks containing used-fuel containers. At the bottom of the shaft, the cask will be transferred to the underground transporter, a modified mine truck.

- The transporter will then travel to the appropriate disposal room, a distance of up to 3 km. At the entrance of the disposal room, an overhead crane will transfer the cask from the transport vehicle onto the emplacement platform.

- The container cask will be brought into the room on the emplacement platform and positioned over the appropriate borehole. The container will then be lowered from the cask into the pre-augered borehole and the annulus between the container and the augered borehole will be filled with dry sand. Buffer material will be fed into the borehole in layers and compacted. Once the borehole has been filled and sealed, the container emplacement operation will be complete.

6.1 POTENTIAL RADIOLOGICAL IMPACTS OF THE UFDC ON THE PUBLIC AND THE ENVIRONMENT

This section presents an analysis of the potential radiological impacts on the public and the environment resulting from routine emissions (airborne and waterborne) at the facility. Radiological doses are estimated for members of the critical group, which represent the individuals in the population that are expected to receive the highest radiation dose. Specific exposure scenarios, such as the exposure of Aboriginal people, are discussed in Section 9.2. The health effects that may be associated with radiation exposure are summarized in Appendix E.

6.1.1 Impacts of Normal Operation

6.1.1.1 Analysis Models and Methodology

Details of the analysis presented in this section can be found in Russell (1993a). This analysis involves estimating airborne and waterborne emissions of radionuclides, determining the pathways by which emitted radionuclides might reach a member of the public in the most exposed group, and calculating the radiation dose to a member of this group.

1) Potential Exposure Pathways to the Public

The emission of radionuclides from the UFDC would occur in two ways - through airborne emissions and waterborne emissions. The direct airborne radionuclides emitted from the UFDC are much greater than the indirect airborne emissions from surface water and soil, and therefore, the only source of air emissions considered here. Radionuclides released from the UFDC may lead to a radiation dose to humans via a number of routes or "pathways". There are 10 major exposure pathways to humans from the airborne and waterborne emissions that could contribute significantly to the dose. These are divided into internal and external pathways:

External pathways:

- immersion in air
- groundshine
- exposure to beach sediment
- immersion in water

Internal pathways:

- inhalation
- ingestion of soil
- ingestion of vegetables and fruits*
- ingestion of animal produce
- ingestion of fish
- ingestion of water

* Note that ingestion of grains and cereals has not been included because they are not assumed to be grown for human consumption in the study area, and therefore are assumed to be imported from outside the study area.

The rationale for choosing the exposure pathways is more fully discussed in Russell (1993a, 1993c).

In order to analyze these pathways in a systematic manner, the biosphere has been divided into a number of compartments with specific transfer parameters from one compartment to another (Gorman 1986; CSA 1987; CSA 1991a, Russell 1993b). The radionuclide transfer from compartment i to compartment j is represented by parameter P_{ij}, as illustrated in Figure 6-1. For example, in the model, the UFDC (the source of radionuclide emissions) is designated as compartment 0 and the atmosphere is designated as compartment 1. Thus the transfer of radionuclides from the UFDC to the atmosphere is described by the transfer parameter P_{01}, also known as the atmospheric dispersion factor.

In a site-specific assessment, these parameters would depend on local environmental conditions near the actual UFDC. However, because of the generic nature of the present analysis, only single-valued constants for these parameters are used, and these are generally steady-state or equilibrium values. The generic environmental data are taken from Grondin and Fearn-Duffy (1993a) and are summarized in Chapter 3.

The radiation doses and dose rates in this assessment are expressed as the committed effective dose equivalent (ICRP 1977; CSA 1987), which is the sum of the weighted dose equivalents received by the organs and tissues of the body after 50 years of committed exposure. The "committed effective dose equivalent" is hereafter referred to simply as the "dose" or "dose rate" as appropriate.

2) Emissions to Air and Water

Estimates of emissions to air and water are based on the UFDC design data and the performance of used fuel (Simmons and Baumgartner 1994; Villagran 1993). These emissions are referred to as the 'source term'.

Airborne Source Term

The Used Fuel Packaging Plant has some areas where used fuel is not enclosed in a shielded cask or disposal container. These areas include the Module Handling Cell, the Fuel Packaging Cell and the receiving surge storage pool (see Chapter 2 for a description of these facilities). These are the most important areas when calculating chronic airborne emissions. Contamination in other areas is not expected during routine operations.

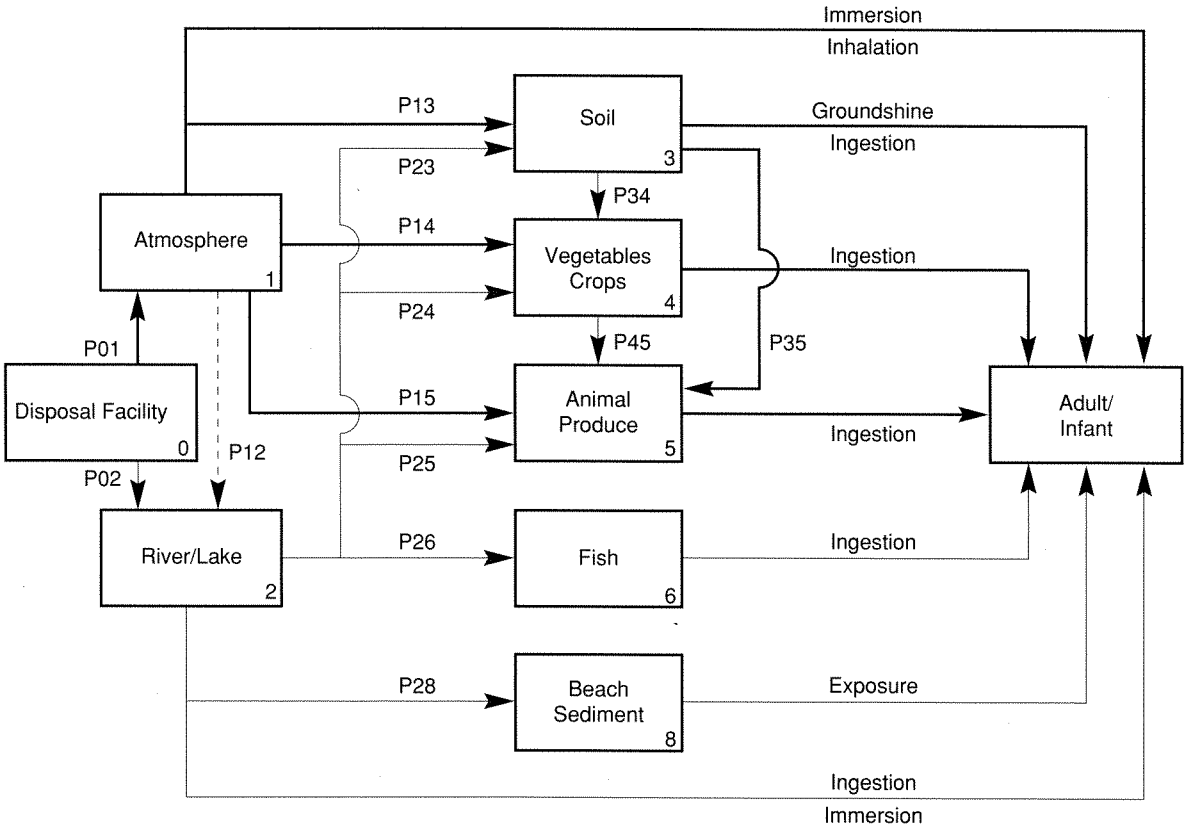
Airborne radionuclides from the Fuel Packaging Cell include:

i) fission products, actinides and activation products escaping from failed fuel elements;

ii) radioactive contaminants in the surface deposits of all fuel bundles; and

iii) neutron activation products generated in the fuel cladding.

At the Fuel Packaging Cell, the major source of airborne emissions is from the assumed failure rate of one fuel element every four weeks of operation (Villagran 1993). Based on a comparison of possible shocks and vibrations during used fuel transportation and handling at the UFDC, with shock and vibration tests on the used fuel, no additional fuel element failures are expected during normal transportation, at the Module Handling Cell or at the UFDC receiving pool.



The environment is assumed to be composed of a number of biological compartments with uniform radionuclide concentration. The movement of radionuclides in the biosphere has been modelled using transfer parameters. For example, the transfer of radionuclides from compartment i to compartment j is characterized by transfer parameter Pij.

FIGURE 6-1: Radiological Pathways Analysis Compartment Model

The rate of transfer of radionuclides from the fuel to the air depends on the temperature and moisture content of the air. In the case of failed fuel, where the uranium oxide matrix is exposed to air (through a crack or damage to the Zircaloy cladding), the irradiation history of the fuel is also important because it strongly affects the fuel oxidation rate (Wasywich and Frost 1986).

The assumed transfer rates of radionuclides contained in the uranium oxide matrix to the surrounding air are based on results of experiments at Whiteshell Laboratories (Wasywich and Frost 1986; 1989).

When the cask lid is removed in the Module Handling Cell, volatile and gaseous radionuclides that have escaped from the fuel bundles during transportation, and are contained in the cask, will become airborne. It is conservatively assumed that the remote handling equipment at the Module Handling Cell is used at full capacity so there would always be two loaded modules continuously exposed to the atmosphere.

Airborne radionuclides from the receiving pool depend on the radionuclide concentrations in the water. These concentrations depend on the quantity of fission products leached out of submersed failed fuel elements. For the purpose of the present assessment, the receiving pool is assumed to be always half-full (the steady state condition during operation).

Waterborne Source Term

Waterborne emissions originate from residual water left in the transportation cask, and from decontamination of transportation casks and disposal containers.

The release of radionuclides from used fuel into the water contained in the transportation cask is derived from Wasywich and Frost (1986; 1989). The disposal container decontamination facility is assumed to receive the radioactive material released from the fuel that is not carried by the ventilation streams. The major contributors to this source are the materials ejected from fuel elements that fail during handling at the Fuel Packaging Cell and the radioactive deposits removed from bundle surfaces at the Fuel Packaging Cell (Villagran 1993).

3) Dispersion Analysis

Radionuclide concentrations in air and water near the UFDC were estimated using data on the reference environment (Grondin and Fearn-Duffy 1993b), potential radionuclide emission rates (Villagran 1993), and transfer models for radionuclides in the environment (Russell 1993c).

4) Dose to the Public and Non-human Biota

The methodology for calculating the dose to the public from exposure to radionuclides released from the UFDC has been adapted from existing standards that are recognized by the Atomic Energy Control Board (Gorman 1986; CSA 1987), the previous interim preclosure assessment (Green and Donnelly 1983), generic environmental transfer models (IAEA 1982; Peterson 1983) and recent improvements in modelling radionuclide transfer in the food-chain for the postclosure assessment (Zach and Sheppard 1992).

The individual and collective doses to members of the public, and the doses to non-human biota, were estimated using calculated radionuclide concentrations, hypothetical exposure scenarios, and dose conversion factors (ICRP 1977; ICRP 1983; Johnson and Dunford 1983; CSA 1987; Holford 1988; 1989). Although calculation of collective doses is not

part of the AECB requirements (AECB 1985; 1987a), it is included so that the methodology may be established for estimating the collective dose during the site selection phase, or to perform ALARA calculations. The collective dose from the operation of the UFDC is one of the factors used to assess differences between one reference environment and another, which may be required during site selection.

5) PREAC Computer Code: Assumptions and Data

The computer code PREAC (Preclosure Radiological Environmental Assessment Code) was developed to calculate the individual and collective doses to members of the public from routine emissions from the UFDC (Russell 1993b, 1993c; Wai 1993a).

The following sections outline the potential radionuclide pathways through the environment, and the calculations performed using PREAC to estimate concentrations of radionuclides.

a) Critical Group Exposures

Calculations of dose to the public are based on exposures to the average member of the "critical group", which represents those individuals that are expected to receive the highest dose (ICRP 1977). For the preclosure assessment, the adult member of the critical group is represented by the "reference man", defined by the International Commission on Radiological Protection (ICRP 1975). The "reference man" is a male/female combination, between 20 and 30 years old, 70 kg in weight and 170 cm tall. The reference man is assumed to be residing on a farm at the UFDC boundary 1500 m from the UFDC emission stack. The location of the farm is assumed to correspond to the wind direction that gives the largest radionuclide concentrations from UFDC airborne emissions.

The infant member of the critical group is assumed to be a one year old infant, as defined by the ICRP (1975). Doses to an infant residing at the UFDC boundary are calculated for several reasons. The Atomic Energy Control Regulations (AECB 1978) specify a thyroid dose limit for persons under the age of 16 years. The AECB will also require the calculation of derived release limits (DRLs) as part of the UFDC's licence to operate. The methodology for calculating DRLs, as specified in the Canadian Standard CSA N288.1 (CSA 1987), requires that dose calculations be performed separately for infants and adults. Ontario Hydro's experience indicates that the release limits for several radionuclides are more restrictive if based on infant doses.

With the exception of cereals and grains for human consumption, the reference adult and infant residing at the UFDC boundary are conservatively assumed to consume only food grown locally on the farm, and to eat fish and drink water from the nearby river or lake which receives the liquid discharge from the UFDC. It is assumed that the infant drinks formula milk made with water from the lake where the effluent from the facility is discharged. It is a more direct pathway than breast milk. The reference individuals are assumed to remain near the facility for their entire lifetime.

No irrigation of crops and pasture grass is assumed in the preclosure assessment, since rainfall is assumed to be adequate for the farm vegetation. However, we assume that backyard vegetables are irrigated, and that farm animals are watered from the contaminated waterbody (river or lake). Variations in the assumptions used in critical group exposure calculations are discussed in the sensitivity analysis (Chapter 9).

b) Radionuclide Concentration in Air

Air contamination from radionuclide emissions from the UFDC were calculated using the Gaussian plume model (Slade 1968; CSA 1987). The calculations were based on the long-term weather frequency data (30 yrs) from representative sites in the Northern, Central and Southern regions of the Canadian Shield in Ontario (Grondin and Fearn-Duffy 1993a).

The annual radionuclide concentration in air for various downwind distances and direction sectors can be calculated using the projected radionuclide emission rate and the average annual atmospheric dispersion factor for the site (Russell 1993a).

c) Radionuclide Concentration in Water

The radionuclides in water near the UFDC were assumed to have two sources: direct liquid effluent from the UFDC and airborne deposition to the water's surface from atmospheric emissions from the UFDC.

The deposition of radionuclides from air to water can be modelled using the air concentration at an average distance from the water, the radionuclide's deposition velocity to water, and the surface area of the water.

The dilution of radionuclides in water will depend on whether the liquid effluent from the UFDC is discharged into a river or a lake. If dilution occurs in a river, it is assumed to occur rapidly and reach equilibrium within a short distance of the discharge location (Russell 1993a). If the liquid effluent discharges into a lake, the radionuclide concentration will vary with time depending on the lake's volume, flow rate and recirculation. Since the source of radionuclides is assumed to remain constant during the operation of the UFDC, the maximum concentration in the lake will occur at the end of the UFDC operating period.

For pathways involving water, the water flow rate and the rate of emission from the UFDC were assumed to be constant over the 41-year duration of the assessment period (i.e. an average value was used in the analysis). Sedimentation was included in the lake scenario but was not considered for the river scenario (Russell 1993a).

The lake and river data used in the analysis are presented in Table 3-6.

d) Pathway Dose Rate Factors

The dose to the critical group at the UFDC boundary and other members of the public within a radius of 100 km of the UFDC can be calculated by considering the radionuclide concentrations in air and water, and the radiological pathways in the environment that lead to exposure to humans.

Calculating the collective dose on a regional basis (0-100 km) should account for most of the population dose for airborne and waterborne emissions since the radionuclides concentration in air falls off approximately as $1/x^2$, where x is the downwind distance from the UFDC, and the population density around the UFDC is assumed to decrease with distance from the facility (Grondin and Fearn-Duffy 1993a).

In order to simplify the analysis, the concept of a "pathway dose rate factor" is introduced (Russell 1993a). Each pathway in the assessment model has a dose rate factor for airborne releases and/or for waterborne releases. Some pathways are affected by both forms of emission. The dose rate factors are given as dose rate per unit of radioactivity

concentration in air (dose rate / $Bq \cdot m^{-3}$) or water (dose rate / $Bq \cdot L^{-1}$). They are based on exposure assumptions, transfer parameters in the environment, and dose conversion factors. Details on the dose rate factor calculations can be found in Russell (1993a, 1993c). Dose conversion factors for human exposure to radionuclides were based on ICRP 26 (ICRP 1977), and are consistent with the current standards set in Canada (CSA 1987). The implication of the recent revisions to the dose conversion factors based on ICRP 60 (ICRP 1991) is discussed in Section 6.1.1.4.

i) Air Pathways

"Air pathways" refer to those exposure pathways that are affected by the airborne emission of radionuclides. The dose rate factors for the air pathways include: immersion in air, inhalation of contaminated air, exposure to contaminated surfaces (groundshine), and ingestion of soil, vegetables and animal produce (milk, beef, pork, eggs and poultry). They are specified in units of $Sv \cdot a^{-1} \cdot Bq^{-1} \cdot m^3$, and can be multiplied by the radionuclide concentration in air to obtain the annual dose rate for each radionuclide and pathway.

Immersion

In the calculation, the exposed group is assumed to be immersed in a semi-infinite cloud of radioactive material. The exposure time fractions are taken to be 20% outdoors and 80% indoors with a shielding factor of 0.9 for the latter due to the building structure (CSA 1987). The immersion dose conversion factors were taken from Holford (1988; 1989) and include a dose factor for skin exposure.

Inhalation

The air inhalation rate, averaged over the year, is assumed to be 8 400 $m^3 \cdot a^{-1}$ for adults and 1 400 $m^3 \cdot a^{-1}$ for infants (CSA 1987). The dose conversion factors for inhalation were taken from Johnson and Dunford (1983).

Groundshine

Radionuclides are deposited on the ground from the air via wet (rain and other precipitation) and dry deposition of gases and particles. They are then assumed to migrate through the soil via water infiltration from precipitation. The rate of transfer through soil depends on the partitioning of radionuclides between the soil particles and the groundwater (Russell 1993c).

The soil compartment in the model is assumed to extend to a depth of 30 cm (in many areas of the Canadian Shield of Ontario, soil depth would be much less). The radionuclide concentration within this compartment is assumed to be uniform. The dose conversion factors used for groundshine assume that the radionuclides in the soil compartment reside on the surface producing a plane source of radionuclides (CSA 1987). Therefore, for the groundshine exposure pathway only, all of the radionuclides in the soil compartment are conservatively assumed to reside on the surface in order to maximize the dose from this pathway. The fractions of exposure time are the same as for immersion and the indoor shielding factor by buildings for groundshine is assumed to

be 0.4 for all forms of radiation (CSA 1987). This is conservative for low energy gamma, and for beta and alpha radiation. The dose conversion factors for exposure to a plane source of radionuclides were taken from Holford (1988; 1989).

Soil Ingestion

Radionuclides are deposited on the ground as described above. The soil ingestion rate for adults and infants from soiled hands is estimated to be 2.4×10^{-2} kg·a^{-1} and 5.8×10^{-2} kg·a^{-1}, respectively (Hawley 1985). The soil ingestion rate from consumption of backyard vegetables is calculated using a soil concentration of 6×10^{-4} kg dry soil per kg of vegetables (fresh weight) that have been washed (Sheppard et al. 1990) and a vegetable ingestion rate of 203 kg·a^{-1} for adults and 84 kg·a^{-1} for infants (CSA 1987). Therefore, the soil ingestion rate via vegetable ingestion is calculated to be 1.2×10^{-1} kg·a^{-1} for adults and 5×10^{-2} kg·a^{-1} for children. The total from both soiled hands and vegetable ingestion becomes 1.5×10^{-1} kg·a^{-1} for adults and 1.1×10^{-1} kg·a^{-1} for infants.

Vegetable and Fruit Ingestion

The radionuclide concentration in vegetables and fruits is assumed to result from two pathways: root uptake via soil and direct deposition from air to vegetation (CSA 1987). The transfer from soil to vegetables and fruits is based on concentration factors compiled by Baes III et al. (1984). The transfer from air to vegetables is based on wet and dry deposition of radionuclides, and a removal constant corresponding to a weathering half-life of 12 days (Zach and Sheppard 1992), which refers to the radionuclide loss from vegetation as a result of wind, rain etc.

For tritium and carbon-14, the transfer from air to vegetation is calculated using the specific activity model (CSA 1987), which assumes that equilibrium has been reached between the specific activity of the radionuclide in air and the specific activity in the plant. The ingestion rate for vegetables and fruits is assumed to be 203 kg·a^{-1} for adults and 84 kg·a^{-1} for infants (CSA 1987). Cereals and grains are not assumed to be grown for human consumption within the region of potential contamination and thus are not included in the assessment model. The dose conversion factors for ingestion were taken from Johnson and Dunford (1983).

Ingestion of Animal Produce

There are three pathways to be considered for the transfer of radionuclides from air to animal produce: inhalation, soil ingestion and pasture grass or feed ingestion (which includes direct deposition and uptake from soil). The transfer parameters from air to animal produce were taken from CSA (1987). The transfer from soil and pasture grass to animal produce were calculated using published transfer coefficients for milk, beef, pork, eggs and poultry (Ng et al. 1977, 1978, 1979a, 1979b, 1982; Ng 1982; Baes III et al. 1984). The transfer of tritium and Carbon-14 are based on the specific activity model (CSA 1987).

The ingestion rates for milk, beef, pork, eggs and poultry are taken to be 220, 14, 10, 5 and 10 $kg \cdot a^{-1}$ for infants, and 174, 40, 31, 14 and 16 $kg \cdot a^{-1}$ for adults, respectively (see Section 9.2 for the ingestion rate of wild animal produce by Aboriginal people and the subsequent calculation of the dose). The values were adapted from CSA (1987) and Statistics Canada (1985a). The dose conversion factors for ingestion were taken from Johnson and Dunford (1983).

(ii) Water Pathways

The dose rate factors for the water pathways include groundshine via irrigation, ingestion of soil, vegetables, animal produce (milk, beef, pork, egg, poultry), fish and water, external exposure to beach sediment, and immersion in water. They are specified in units of $Sv \cdot a^{-1} \cdot Bq^{-1} \cdot L$, and can be multiplied by the radionuclide concentration in water to obtain the annual dose rate for each radionuclide and water pathway.

Groundshine

The soil compartment is assumed to be irrigated (with the water from the waterbody supplying the water to the facility) at an average rate for backyard vegetables of $2.3 \times 10^{-5}\ L \cdot m^{-2} \cdot s^{-1}$ (CSA 1987). As in the case of the air pathway, the radionuclides in the soil compartment down to a depth of 30 cm are conservatively assumed to reside on the surface for external exposure. Also, the increased groundwater flow due to irrigation has been ignored (a larger groundwater flow due to irrigation would decrease the residence time of radionuclides in the soil compartment). The other parameters are the same as those described in the air pathways section.

Soil Ingestion

The ingested soil is conservatively assumed to originate from the irrigated backyard vegetable garden. As in the groundshine pathways, the decrease in radionuclide concentration in soil due to the increased groundwater flow from irrigation has been ignored. The transfer parameters for this pathway were described previously.

Vegetable and Fruit Ingestion

The concentration of radionuclides in vegetables and fruits is due to direct deposition from irrigation and uptake from the soil via roots. The transfer of radionuclides from water to vegetables and fruits is calculated using the annual average irrigation rate, a plant interception fraction of 0.05 (CEC 1979; CSA 1987) and a 12-day weathering half-life. For tritium, the transfer from irrigation water to vegetables is calculated using the specific activity model (CSA 1987). For carbon-14, the transfer from water to vegetables is assumed to be negligible (CSA 1987; Russell 1993c).

Animal Produce Ingestion

The transfer from water to animal produce is based on the daily water intake for each produce group (CSA 1987) and transfer coefficients from feed to animal produce (see the air pathways section).

Fish Ingestion

The transfer of radionuclides from fresh water to the edible portion of fish has been modelled using a bioaccumulation factor (CSA 1987; NCRP 1984; Poston and Klopfer 1986). The transfer of radionuclides from lake sediments to fish was not explicitly modelled, but it is included in the general bioaccumulation factor which is based on measurements in the environment. The rate of fish ingestion is assumed to be 0.55 $kg \cdot a^{-1}$ for infants and 5.5 $kg \cdot a^{-1}$ for adults (Gorman 1986) (see Section 9.2 for fish ingestion rate by Aboriginal people and the corresponding dose calculation). The dose conversion factors for ingestion were taken from Johnson and Dunford (1983).

Beach Sediment Exposure

The beach along the shoreline is assumed to be contaminated by radionuclides in the lake or river through wave action and fluctuating water levels (Russell 1993c). The radionuclide content in the beach sediment compartment has been modelled using the radionuclide distribution coefficient in sediments and a sediment depth of 2.5 cm (CSA 1987). As in the groundshine pathway, the radionuclides in the sediment compartment are conservatively assumed to reside on the beach surface. Since the dose conversion factors are defined for an infinite plane source (Holford 1988, 1989), a shore width factor of 0.3 has been included to account for the finite source geometry (CSA 1987). The critical individual is assumed to be at the beach 1% of the year (CSA 1987).

Water Ingestion

The water ingestion rate is assumed to be 300 $L \cdot a^{-1}$ for infants and 700 $L \cdot a^{-1}$ for adults (CSA 1987). This rate allows for all water ingestion (i.e. drinking water, beverages, etc.). The dose conversion factors for ingestion were taken from Johnson and Dunford (1983).

Water Immersion

The occupancy factor for swimming, bathing and any other water immersion activities such as wind-surfing, is assumed to be 0.01 (CSA 1987). For tritium, the dose rate factor is calculated using the skin absorption rate for water (210 $L \cdot a^{-1}$) and the dose conversion factor for tritium ingestion (CSA 1987). The dose conversion factors for water immersion for the remaining radionuclides were taken from Holford (1988; 1989) and include a weighted skin dose factor.

e) Collective Dose

The calculated collective dose to the population from the operation of the UFDC can be used to compare the radiological impacts in the three regions on the Canadian Shield in Ontario, based on a generic description of the three reference environments (Grondin and Fearn-Duffy 1993a).

The annual collective dose to the population in each region is calculated using airborne and waterborne exposure pathways, and reference adult population and food production data to a distance of 100 km from the UFDC. The assessment methodology uses conservative equilibrium transfer parameters in the environment (Russell 1993c), which tend to overestimate the predicted doses to the public.

(i) Air Pathways

The airborne pathways are assumed to affect the population via direct and indirect exposure pathways. Direct exposure pathways (air immersion, inhalation and groundshine) are calculated based on population data within 100 km of the UFDC since they are the only individuals affected. Indirect exposure pathways (ingestion of vegetables and animal produce) are not based on population but are calculated using food production data because they can affect anyone who consumes the agricultural goods produced in the region.

The population and food production data were taken from Grondin and Fearn-Duffy (1993a). The values are given in terms of 9 radial intervals from the UFDC (1.5-4, 4-8, 8-16, 16-24, 24-32, 32-40, 40-60, 60-80, and 80-100 km). The population and food production within any particular ring is assumed to be uniformly distributed.

The collective dose rate from indirect exposure of airborne radionuclides is based on the food production within 100 km of the UFDC. The number of individuals affected by the food pathways can be estimated by dividing the food production rate in each radial interval by the food ingestion rate per person. This value can then be used with the pathway dose rate factors and the sector-averaged radionuclide concentration in air to estimate the collective dose. The summation is performed over the 9 radial intervals for vegetables and produce.

The effect of variation in population distribution is examined in the sensitivity analysis (Chapter 9).

(ii) Water Pathways

Waterborne radionuclide emissions are assumed to affect the population close to the UFDC. The local community is assumed to derive its water supply from the contaminated river or lake which receives the liquid effluent from the UFDC. The average consumption rate of water for domestic use is 395 $L \cdot day^{-1} \cdot person^{-1}$ (Ministry of Natural Resources 1984). This includes drinking, baths, washing clothes, etc. For collective dose calculations, the radiological pathways are assumed to be water ingestion, water immersion and fish ingestion. The collective dose from the fish ingestion pathway is based on the fish production of the nearby lake or river.

While it is likely that some of the radionuclides will persist at diminishing concentrations in the local environment long after the UFDC has ceased operation, doses will be lower than those estimated in this assessment using equilibrium transfer parameters in the environment. In addition, an environmental monitoring program would be in place to assess any impact of residual radioactivity during the decommissioning of the UFDC.

f) Non-Human Biota Exposure Pathways

The environmental transfer model for radionuclides released to the air and water from the UFDC can be used to calculate the dose impact to non-human biota near the facility. As in the case of human exposure calculations, steady-state or equilibrium transfer parameters are used in the model. It is a general and approximate model, and is considered to be conservative.

Since the environment contains a large number of species of plants and animals, it is difficult to accurately assess the radiation dose and its impact to all living organisms at this generic assessment stage. Instead, a simple model has been developed to assess the dose to a number of generic groups of plants and animals that could be exposed to enhanced levels of radioactivity using published environmental transfer data. At the site-specific stage, an assessment of effects on existing flora and fauna would be carried out.

Four generic organisms were chosen to represent the animals and plants that could be exposed to radionuclides released from the facility during the preclosure and postclosure phases. These generic biota include (Amiro 1992a):

1) Fish; a bony fish typical of the fish that inhabit the lakes on the Canadian Shield. It represents a wide range of free-swimming (pelagic) and bottom-feeding (benthic) species. This would include characteristics of diverse species such as lake trout, walleye, northern pike, lake whitefish and white sucker. The fish is assumed to spend its entire life in the lake or river near the UFDC that has the highest radionuclide concentration.

2) Plant; a plant with nuclide uptake characteristics similar to a broad range of terrestrial vascular plants. This would include many grasses, herbs and trees. The plant can be immersed in contaminated soil, air and water, so it reflects the external exposures received by both terrestrial and aquatic species. To be conservative, these plants are assumed to be irrigated with water from the nearby river or lake which is contaminated with the UFDC liquid discharge.

3) Mammal; a mammal most similar to a herbivore in its eating habits and is assumed to feed on vegetation cultivated by humans near the UFDC. The mammal can be immersed in contaminated air, soil and water, thereby reflecting external exposures received by terrestrial land, soil-burrowing and aquatic mammals. To a large extent, most mammalian predators are also included here. The radionuclide transfer characteristics to mammals are assumed to be similar to those for grazing cattle.

4) Bird; a terrestrial bird that eats seeds and fruit cultivated by humans near the UFDC. Typical species would include the ruffed grouse, song sparrow, and evening grosbeak. The bird can be immersed in air, soil and water, corresponding to a

wide range of terrestrial and acquatic species. Thus, waterfowl would also be included to some extent. The radionuclide transfer characteristics for birds are based on those used for poultry.

Internal Exposure

The annual dose to non-human biota from radionuclides within the organism has been modelled using the estimated radionuclide concentration in the plant or animal. To be conservative, the dose model assumes that all energy from internal radioactive decay is deposited within the organism (Amiro 1992a). While this assumption is reasonable for β-decay, it is very conservative for γ-decay since a significant fraction of the internally emitted γ-radiation will not be absorbed by a small organism (IAEA 1976).

The radionuclide concentration in fish, plants, mammals and birds near the UFDC is based on the environmental transfer model for humans described in earlier sections of this report. The radionuclide concentration in fish is modelled using the bioaccumulation factor for freshwater fish. For plants, the concentration model is based on airborne and waterborne (irrigation) deposition of radionuclides to soil followed by root uptake and direct deposition to plant surfaces. For mammals, the concentration model is based on the transfer parameters for cattle, and considers inhalation and ingestion of soil, crops and water. For birds, the concentration model is based on the transfer parameters for poultry, and considers inhalation and ingestion of soil, crops and water.

While the dose to humans can be expressed in dose equivalent (Sv) which accounts for the biological effectiveness of the various types of radiation and the importance of the dose to the various target organs (ICRP 1991), the dose to non-humans was restricted to the total energy deposited per unit mass of tissue per year ($Gy \cdot a^{-1}$), since a more detailed understanding of the effective dose impact for a broad range of biota was not available. Since the generic dose model depends on radionuclide concentration and assumes total energy absorption from decay, the environmental dose conversion factors for internal exposure are the same for each of the generic species of plants and animals. The internal dose conversion factors for the generic biota were calculated from the average α, β and γ energy per disintegration for each radionuclide (ICRP 1983). The value for ^{129}I has been increased by a factor of 10 to account for the accumulation of iodine in the thyroid. The dose conversion factor units are $Gy \cdot a^{-1} \cdot Bq^{-1} \cdot kg$, where $Gy = J \cdot kg^{-1}$. Since the dose model for non-human biota is restricted to calculating absorbed dose, quality factors or radiation weighting factors for different forms of radiation (α, β and γ) have not been used to convert absorbed dose (Gy) to equivalent dose (Sv). The radiation weighting factor for β and γ radiation is equal to 1 (ICRP 1991). Thus, the dose impact from internal exposure to α radiation may be greater by a factor of 20. Because non-human biota tissue weighting factors are not known, the analysis is limited to estimating absorbed dose (Gy) rather than effective dose (Sv) to non-human biota (see ICRP 1991).

Immersion in Air

The annual dose to non-human biota from immersion in air has been conservatively modelled using a semi-infinite, uniformly contaminated medium with 100% occupancy. The air immersion dose conversion factors were taken from Holford (1989). To estimate the total dose to the organism, the γ-radiation dose at the body surface was added to the β-radiation dose at 70 μm into the body surface of humans. This assumption gives the maximum dose that could be received by the outer portions of the plant or animal. It is assumed that fish are not exposed to air. Since the air immersion dose model does not differentiate between a plant, mammal or bird, the predicted dose is assumed to be the same for each species.

Immersion in Water

The annual dose to non-human biota from immersion in water has been conservatively modelled using a semi-infinite, uniformly contaminated medium with 100% occupancy. The water immersion dose conversion factors were taken from Holford (1989). To estimate the total dose to the organism, the γ-radiation dose at the body surface was added to the β-radiation dose at 70 μm into the body surface of humans. This assumption gives the maximum dose that could be received by the outer portions of the plant or animal. Since the water immersion dose model does not differentiate between a fish, plant, mammal or bird, the estimated dose is conservatively assumed to be the same for each species.

The estimated dose is considered to be very conservative because 100% occupancy in water is unlikely for generic biota other than fish.

Groundshine

The annual dose to non-human biota from living on a contaminated surface (groundshine) has been conservatively modelled with 100% occupancy using an infinite plane source. The groundshine dose conversion factors were taken from Holford (1989). To estimate the total dose to the organism, the γ-radiation dose at the body surface was added to the β-radiation dose derived for humans at 70 μm into the body surface of humans. This assumption gives the maximum dose that could be received by the outer portions of the plant or animal. The estimated dose is assumed to be the same for a plant, mammal or bird, and is zero for fish who are assumed not to be exposed to groundshine.

g) Differences Between Pre- and Postclosure Biosphere Models

The principal differences between the preclosure and postclosure biosphere models are due to the origins and types of radionuclides in each of the analyses. In the preclosure phase, radionuclides enter the surface environment from above the ground surface following airborne and surface water emission of radionuclides from the UFDC. During the postclosure phase, radionuclides are assumed to enter the surface environment from below the ground surface via deep groundwater discharge into a well, lake or terrestrial area. Thus, the ways in which radioactivity reaches the biosphere during the two phases of operation are fundamentally different, and the models describing the behaviour of the radioactivity are also different. In addition, the radionuclides of

concern are not the same during the preclosure and postclosure phases. For example, the important preclosure radionuclides, ^{90}Sr and ^{137}Cs, have half-lives of about 30 years which could be considered long during the preclosure phase, but short during the postclosure phase where the radionuclides are expected to reach the biosphere after hundreds or thousands of years. Further details on the differences between the preclosure and postclosure biosphere models can be found in the postclosure biosphere report (Davis et al. 1993).

6.1.1.2 Analysis Criteria

In order to assess the potential impact of UFDC emissions on public health, the dose from these emissions can be compared with the natural background radiation that would be received by the population around the UFDC. Also, the effects of low-level radiation on human and non-human biota can be examined. Finally, the dose can be compared with radiation exposure regulatory limits.

1) Natural Background Radiation Exposure Levels and Pathways

For most people, natural sources of background radiation in the environment are the principal sources of ionizing radiation (UNSCEAR 1982). The main sources of external radiation are cosmic rays and naturally occurring radionuclides in the earth's crust, building materials and the air. These naturally occurring radionuclides may enter the body via inhalation and ingestion.

Individual exposures to natural forms of radiation, both internal and external, vary widely. The earth's atmosphere acts as a shield against cosmic rays, and the exposure doubles with every 2000 m increase in elevation above sea level (NCRP 1987). Also, cosmic rays vary with latitude since they are affected by the earth's magnetic field. Perhaps the largest source of variability in background radiation is the composition and concentration of terrestrial radionuclides, such as radon, in the ground. These affect external radiation exposures and also internal exposures from the incorporation of terrestrial radionuclides into plants, water and air.

The most significant contributor to internal radiation dose are short-lived radon (^{222}Rn) and thoron (^{220}Rn) progeny which give an average individual dose of about 2×10^{-3} $Sv \cdot a^{-1}$. Radon and thoron are inert gases produced by the decay of ^{226}Ra (from the ^{238}U decay series) and ^{224}Ra (from the ^{232}Th decay series), respectively. They emanate from the ground or building materials, and their concentrations in indoor air depend on the type of underlying soil, building materials, building construction, room size and ventilation rate (UNSCEAR 1982). Typical radon concentrations for inland areas are 50 $Bq \cdot m^{-3}$ (indoors) and 5 $Bq \cdot m^{-3}$ (outdoors) (UNSCEAR 1988).

A survey of radon levels in single-family homes was conducted in 19 cities across Canada (Letourneau et al. 1979; McGregor et al. 1980). The population-weighted average exposures levels were found to be 30 $Bq \cdot m^{-3}$, but the levels varied by several orders of magnitude across the country. In 1988/89, AECL tested the radon levels from natural sources in homes in Pinawa, Manitoba and found the median concentration was 167 $Bq \cdot m^{-3}$ (Friedman 1989). Over 5% of the surveyed homes have radon concentrations exceeding 800 $Bq \cdot m^{-3}$

Contributions of these various sources to natural background radiation exposure levels are summarized in Table 3-7.

2) Natural Radionuclide Concentrations in Water and Soil

Naturally occurring radionuclides, which include ^{3}H, ^{14}C, ^{40}K, ^{222}Rn, ^{226}Ra, ^{234}U and ^{238}U, are either primordial or cosmogenically produced. The main sources of anthropogenic radionuclides are fallout from atmospheric nuclear weapons testing, uranium mine tailings and emissions from nuclear power stations. Longer-lived radionuclides present in water from these sources include ^{3}H, ^{14}C, ^{85}Kr, ^{90}Sr, ^{129}I, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu and ^{241}Am. The background levels of anthropogenic radionuclides in the aquatic environment peaked in the 1960s and are now generally decreasing as a result of radioactive decay, dilution and reduced nuclear weapons testing (UNSCEAR 1982).

The background concentration of ^{3}H in surface waters from natural sources was estimated to lie between 0.1 and 0.9 $Bq \cdot L^{-1}$ (Kaufman and Libby 1954), with an average value of 0.4 $Bq \cdot L^{-1}$ (UNSCEAR 1982). In 1963, the average concentration of ^{3}H in surface water from fallout in the United States was about 150 $Bq \cdot L^{-1}$ (UNSCEAR 1977). In 1981, the concentration of ^{3}H in the Great Lakes varied from 7 to 14 $Bq \cdot L^{-1}$ (Joshi 1991), and the current average ^{3}H concentration in surface waters in Ontario is about 5 $Bq \cdot L^{-1}$ (Christiani 1993).

The concentration of ^{14}C from natural sources in lake water can be estimated from the concentration of carbon in water, and the natural isotopic abundance of ^{14}C (the background specific activity of carbon is 227 $Bq \cdot kg^{-1}$) (UNSCEAR 1982). The concentration of calcium carbonate in the Shield Lakes water ranges from 61 to 120 $mg \cdot L^{-1}$ (Grondin and Fearn-Duffy 1993b). Using the lower value, the carbon content of lake water is 7.3×10^{-6} $kg \cdot L^{-1}$, and the ^{14}C concentration 1.7×10^{-3} $Bq \cdot L^{-1}$.

The ^{90}Sr in surface waters is due primarily to fallout. In 1981, the concentration in the Great Lakes varied from 1.6×10^{-2} to 2.5×10^{-2} $Bq \cdot L^{-1}$ (Joshi 1991), with an average value of approximately 2×10^{-2} $Bq \cdot L^{-1}$. Similarly, the concentration of ^{137}Cs in the Great Lakes varied from 6×10^{-4} to 1.7×10^{-3} $Bq \cdot L^{-1}$ (Joshi 1991), with an average value of approximately 1×10^{-3} $Bq \cdot L^{-1}$. In the absence of future atmospheric testing of nuclear weapons, the concentrations of fallout radionuclides such as ^{90}Sr and ^{137}Cs in surface water are expected to drop by one or two orders of magnitude by the year 2050 (Russell 1991).

Also, the levels of ^{239}Pu and ^{240}Pu in the Great Lakes were found to vary from 1.7×10^{-7} to 4.8×10^{-7} $Bq \cdot L^{-1}$ (Joshi 1991), with an average value of approximately 3×10^{-7} $Bq \cdot L^{-1}$.

The average concentration of ^{238}U in surface waters in Ontario is 1.3×10^{-3} $Bq \cdot L^{-1}$ (NRCC 1983), and this value is assumed for the background levels of ^{234}U and ^{238}U (Amiro 1992b).

The natural concentration of waterborne radionuclides is summarized in Table 6-6.

Natural radionuclide concentrations in soil for some key radionuclides were estimated by Amiro (1992b). These concentrations are shown in Table 6-8.

3) Impacts of Low-Level Radiation

The effect of low-level radiation on living organisms is complex and is usually dealt with in a conservative manner (see Appendix E for a summary of human health effects from exposure to ionizing radiation). In 1982,

the United Nations Scientific Committee on the Biological Effects of Atomic Radiation postulated that the probability of developing a fatal cancer or serious genetic effect (the risk factors) is directly proportional to the dose received, even for low doses and dose rates (UNSCEAR 1982). The risk factor was generally taken to be 2×10^{-2} Sv^{-1} (ICRP 1977), and this has been adopted by the Atomic Energy Control Board (AECB 1987d) for the disposal of radioactive waste.

A recent reassessment of the data from the survivors at Hiroshima and Nagasaki suggests that the risk factor could be as high as 1.1×10^{-1} Sv^{-1} (Doll 1990) for high doses and high dose rate exposures. The U.S. National Research Council's Committee on the Biological Effects of Ionizing Radiation now estimates a risk averaged over all age groups of about 8×10^{-2} Sv^{-1} for an acute exposure (BEIR V 1990). However, this risk could be reduced by a factor of 2 or more if the dose is received over a longer period of time.

The main reason for the increased risk estimates are the additional cases of cancer mortality recorded during the extended follow-up period for the Japanese bomb survivors, a revised risk model, and a downward revision of the dose received by inhabitants of Hiroshima and Nagasaki. Recently, the International Commission on Radiological Protection published their revised recommendations (ICRP 1991). Their estimate of the public's risk of developing a fatal cancer, averaged over all age groups and sexes, was 5×10^{-2} Sv^{-1}. Their estimate of the total radiation detriment (fatal cancers, non-fatal cancers, hereditary effects) was 7.3×10^{-2} Sv^{-1}.

There is concern over the practice of assigning a risk estimate for very low radiation exposures (Health Physics Society 1988). Most of the risk data have been obtained at high doses and high dose rates (UNSCEAR 1986). The risk at lower doses has been extrapolated by assuming a linear response, without threshold, down to zero dose. However, there is no evidence to support this hypothesis; effects at very low doses have not been measured and may not exist. One problem is the large population size required to obtain statistically meaningful data at low doses. It has been estimated that a population of 50 billion people would have to be studied to provide defensible results for exposures as low as 10^{-4} Sv (Health Physics Society 1988). Studies of populations chronically exposed to low level radiation, such as those residing in regions of high background radiation, have not shown conclusive evidence for an associated increase in the risk of cancer (BEIR V 1990).

For low doses and dose rates, the radiation induced effects are difficult to measure and would almost always be masked by the larger carcinogenic effects due to other factors (e.g. smoking). Thus, the health risk at low doses (below 0.1 Sv) and dose rates may be 2 to 10 times lower than calculated from data at high doses and dose rates (UNSCEAR 1988; BEIR V 1990).

Since the precise value of this correction factor is not known, the health risk or total detriment to the public per unit of exposure to ionizing radiation has been assumed to be constant down to zero dose. The ICRP's values of risk from the exposure to ionizing radiation have been adopted for the preclosure assessment.

4) Impacts of Radiation on Non-human Species

The effects of radiation on animal species other than humans are expected to be qualitatively similar to those on humans (BEIR 1972). In general, most animals have a naturally high mortality rate: contrary to humans, they do not live to the full extent of, and do not usually attain, their potential lifespan. Therefore, the main radiation effect of potential

significance on the animal population is impaired fertility (BEIR 1972). The Committee on the Biological Effects of Ionizing Radiation (BEIR III 1980) concluded that probably no other living species are more radiosensitive than humans, so if humans are protected, then it is likely that other organisms would also be protected.

The Atomic Energy Control Board (AECB 1987a) concluded that the level of radiation protection for humans ensures adequate protection of other living species in the environment. A review of the effects of radiation exposure in the environment (Myers 1989) suggested that although the dose to aquatic plants, freshwater fish, and terrestrial plants and animals may be several orders of magnitude greater than the dose to humans (due to bioaccumulation effects), these populations are relatively resistant to deleterious effects of chronic exposure to radiation.

Laratta (1983) examined the effects of radiological emissions from nuclear generating stations on non-human organisms, and found that chronic dose rates of 3.6 $Gy \cdot a^{-1}$ to populations of aquatic organisms had no somatic or reproductive effects. Although individual organisms showed increased chromosomal aberrations at these dose rates, these did not persist or become established in the population at this dose rate. In the terrestrial environment, mammalian embryos showed near complete sterility at dose rates above 1.8 $Gy \cdot a^{-1}$. However, no significant somatic or reproductive effects were detected at dose rates below 1.8 $Gy \cdot a^{-1}$.

The IAEA (1992) has recently examined the implicit assumption of the ICRP that protecting humans will protect the environment in which they live. The IAEA conservatively estimated that representative terrestrial and aquatic biota would receive a dose rate less than 0.36 $Gy.a^{-1}$ if human exposure was kept within 1 x 10^{-3} $Sv \cdot a^{-1}$. They concluded that chronic dose rates of about 0.36 $Gy \cdot a^{-1}$ to terrestrial organisms are unlikely to cause measurable, detrimental effects in populations. For aquatic species, a chronic dose rate of 3.6 $Gy \cdot a^{-1}$ or less was estimated to cause no measurable detrimental effects to the exposed population.

Rose (1992) has conducted a literature review of the sensitivity of non-human organisms to chronic and acute exposure to ionizing radiation. The study examined the lowest dose rates to animals, plants, fungi etc. that could cause adverse effects such as genetic changes, developmental or behavioural changes, and death. For animals, a lethal dose rate of 3.6 $Gy \cdot a^{-1}$ was found for several American rodents, and the lowest dose rate at which any effect was observed was about 3 x 10^{-3} $Gy \cdot a^{-1}$. This experiment involved the foetuses of laboratory rats (reduced body mass and increased brain mass), and the results have been questioned (Rose 1992). For plants, a lethal dose rate of 6.2 $Gy \cdot a^{-1}$ was observed for red pine after 3 years of irradiation and genetic effects in tulip trees were observed at a dose rate of 0.36 $Gy \cdot a^{-1}$. Rose (1992) concludes that the lowest exposure rate that can produce harmful effects to non-human biota is about 1 $Gy \cdot a^{-1}$.

From these results, we conclude that doses around 1 $Gy \cdot a^{-1}$ should have only a minor radiological effect on non-human biota, and doses near 10^{-3} $Gy \cdot a^{-1}$ should have no measurable effects on non-human biota.

For comparison, the background dose to aquatic and terrestrial organisms from natural and fallout sources has been estimated to vary from 2.5 x 10^{-4} to 5 x 10^{-3} $Gy \cdot a^{-1}$ (Laratta 1983).

5) Radiation Exposure Regulations

The allowable exposure to radiation for members of the public in Canada, as specified in the Atomic Energy Control Regulations (AECB 1974), is 5×10^{-3} Sv·a^{-1} above background (excluding medical exposures). This is consistent with the recommendations of the International Commission on Radiological Protection (ICRP 1977). This dose limit is intended to apply to the operation of facilities such as the proposed UFDC, which may release radionuclides into the environment during routine operation. However, the ICRP has recently issued revised recommendations (ICRP 1991), with a public dose limit of 1×10^{-3} Sv·a^{-1} above background. This limit is also being considered by the AECB (AECB 1991a) for the operation of nuclear facilities in Canada. If adopted, it will apply to the UFDC operating phase. The facility will be designed such that the public dose is a small fraction of the proposed regulatory limit.

6.1.1.3 Potential Radionuclides Emissions from the UFDC

The radionuclide source term to air and water from the UFDC during the preclosure phase has been calculated by Villagran (1993). The inventories of important radionuclides in the fuel, selected for inclusion in the analysis, were based on their relative concentrations in the fuel (Tait et al. 1989), the physical data for the reference fuel (Simmons and Baumgartner 1994), and their relative dose to the public (Villagran 1993). The used fuel is assumed to be 10-year old Bruce fuel with a burnup of 685 GJ per kg initial uranium. The primary sources of radionuclides that could be released from the used fuel bundles are expected to be surface deposits of corrosion products, fission products, actinides, and activation products from the primary heat transport system in the reactor. In addition, failed fuel elements are a major source of contamination once they are exposed to air or pool water in the Used Fuel Packaging Plant. These include fuel elements that failed in the reactor and those that would fail during handling at the Used Fuel Packaging Plant.

a) Airborne Emissions

The main source of radionuclide emissions to the atmosphere is expected to be the used fuel packaging plant, where the major handling of radioactive materials will occur (Simmons and Baumgartner 1994). The release rates from failed fuel and surface deposits are based on results of experiments on fuel elements with intentionally failed sheaths (Wasywich and Frost 1986; 1989). The release rate for activation products in the fuel is assumed to be similar to that for release of fission products (Villagran 1993). The release of activation products from the zircalloy sheath is based on the fractional oxidation rate of zircalloy.

The potential airborne emissions of 28 radionuclides during the operation of the UFDC are listed in Table 6-1. An efficiency of 99.97% is assumed for the HEPA airborne particulate filter (Burchsted et al. 1976; Villagran 1993).

b) Waterborne Emissions

The principal waterborne emissions from the UFDC would come from decontamination of the transportation cask and fuel disposal container cask (Villagran 1993). The transportation cask is expected to contain some residual water and have an internal temperature of about 100°C. These conditions are similar to the experimental conditions during which the radionuclide release from fuel elements was measured (Wasywich and Frost 1986; 1989). These experimental results were used to estimate the

transportation cask source term (Villagran 1993). The major source of emissions during decontamination of the fuel disposal cask is the removal of 1% of the surface deposits from the bundles by mechanical means into water. Both the transportation and disposal cask source terms are assumed to be treated by a radioactive liquid waste management system with a particulate removal efficiency of 99.9% by ion exchange (Villagran 1993).

The potential waterborne emissions of 28 radionuclides during the operation of the UFDC are listed in Table 6-2.

TABLE 6-1
Potential Airborne Radionuclide Emissions from the UFDC

Radionuclide	Half-life (years)	Emission Rate ($Bq \cdot s^{-1}$)
^{3}H	1.24×10^{1}	$3.49 \times 10^{+1}$
^{14}C	5.73×10^{3}	4.02×10^{-2}
^{55}Fe	2.70×10^{0}	8.53×10^{-4}
^{60}Co	5.27×10^{0}	3.72×10^{-3}
^{59}Ni	7.50×10^{4}	2.47×10^{-7}
^{63}Ni	9.60×10^{1}	3.25×10^{-5}
^{85}Kr	1.07×10^{1}	$5.41 \times 10^{+2}$
^{90}Sr	2.91×10^{1}	2.59×10^{-3}
^{94}Nb	2.03×10^{4}	5.65×10^{-7}
^{106}Ru	1.09×10^{0}	4.38×10^{-6}
^{125}Sb	2.77×10^{0}	7.34×10^{-4}
^{125m}Te	1.59×10^{-1}	2.02×10^{-3}
^{129}I	1.57×10^{7}	8.24×10^{-4}
^{134}Cs	2.06×10^{0}	2.52×10^{-2}
^{137}Cs	3.00×10^{1}	3.13×10^{-2}
^{144}Ce	7.79×10^{-1}	3.78×10^{-7}
^{147}Pm	2.62×10^{0}	2.67×10^{-5}
^{154}Eu	8.80×10^{0}	2.47×10^{-6}
^{155}Eu	4.96×10^{0}	1.04×10^{-6}
^{234}U	2.45×10^{5}	1.32×10^{-9}
^{238}U	4.47×10^{9}	1.62×10^{-9}
^{238}Pu	8.77×10^{1}	4.04×10^{-7}
^{239}Pu	2.41×10^{4}	8.42×10^{-7}
^{240}Pu	6.54×10^{3}	1.15×10^{-6}
^{241}Pu	1.44×10^{1}	7.13×10^{-5}
^{241}Am	4.32×10^{2}	1.47×10^{-6}
^{242m}Am	4.46×10^{-1}	1.07×10^{-9}
^{244}Cm	1.81×10^{2}	5.94×10^{-8}

c) Emissions from Emplaced Used Fuel

During the operating phase of the UFDC, there is a small probability that some of the disposal containers will be prematurely defected after emplacement in the boreholes of the underground disposal vault. The fraction of defected containers in the vault has been estimated to be 1 in 5 000 (Johnson and LeNeveu 1993). If the fuel element failure fraction is assumed to be 1×10^{-3} elements per bundle (Villagran 1993) and there are 72 fuel bundles per disposal container, then approximately 1 in 14 containers may contain a bundle with a defective fuel element. Since the UFDC is designed to process about 3 471 disposal containers per

year (Simmons and Baumgartner 1994), about 2 containers may be both prematurely defective and contain a failed fuel element over the 41-year operating life of the facility (Johnson and LeNeveu 1993).

The analysis by Johnson and LeNeveu (1993) includes a calculation of the radionuclide emissions into an open panel tunnel in the underground facility from a failed container (sealed within a disposal room) containing a failed fuel element. Once the radionuclides have been discharged into the panel tunnel, they could either remain in solution if the groundwater flow is large, or become suspended via evaporation if the groundwater flow is small. Consequently, two cases have been investigated:

> Case 1: The groundwater flow into the panel tunnel is assumed to be small and the radioactivity becomes airborne. The ventilation exhaust transports the radioactivity to the surface where HEPA filters remove 99.97% of the particulates. Radionuclide losses to the walls and floors of the panel drift and shafts have been neglected. The emissions to the environment are assumed to be from ground level.
>
> Case 2: The groundwater flow into the panel tunnel is assumed to be large enough to require the water to be pumped to the surface and treated using a filter with an efficiency of 99.9%. Radionuclide losses during transport to the surface are neglected. The treated water is then assumed to be discharged into a nearby river or lake.

Using the worst case failure scenario of two failed containers containing defected elements under saturated vault conditions (Johnson and LeNeveu 1993), the maximum release of radionuclides to air or to water from emplaced fuel during the preclosure phase is about an order of magnitude less than the projected emissions to the environment from the surface facilities. They are, therefore, not considered to be significant. These release rates are very conservative and are expected to be lower when more realistic data and more detailed modelling in the vault are available. The potential release rates are listed in Table 6-3.

6.1.1.4 Analysis Results

Radionuclide concentrations in air, water, sediment and soil have been calculated at their maximum value, which occurs at the end of the operating period of the UFDC, that is, at 41 years.

1) Radionuclide Concentrations in Air

The atmospheric dispersion factors at points at the boundary of the UFDC are calculated to determine the direction sector with the largest value. The dispersion in that sector is then used to determine the radionuclide concentrations in air in order to calculate the annual dose to the critical group residing on the farm at the facility boundary. The maximum dispersion factors for the three regions agree to within a factor of 2. These results are not surprising since the frequency distribution of Pasquill stability categories is relatively constant across Canada and does not exhibit a strong site dependence (Gorman 1986).

TABLE 6-2
Potential Waterborne Radionuclide Emissions from the UFDC

Radionuclide	Emission Rate ($Bq \cdot s^{-1}$)
^{3}H	1.84×10^{-1}
^{14}C	7.19×10^{-5}
^{55}Fe	5.08×10^{-3}
^{60}Co	2.25×10^{-2}
^{59}Ni	1.47×10^{-6}
^{63}Ni	1.94×10^{-4}
^{85}Kr	0
^{90}Sr	7.85×10^{-2}
^{94}Nb	3.37×10^{-6}
^{106}Ru	4.06×10^{-5}
^{125}Sb	4.38×10^{-3}
^{125m}Te	1.20×10^{-2}
^{129}I	1.47×10^{-6}
^{134}Cs	2.20×10^{-2}
^{137}Cs	4.04×10^{-2}
^{144}Ce	7.21×10^{-6}
^{147}Pm	5.09×10^{-4}
^{154}Eu	4.70×10^{-5}
^{155}Eu	1.99×10^{-5}
^{234}U	2.51×10^{-8}
^{238}U	3.08×10^{-8}
^{238}Pu	7.70×10^{-6}
^{239}Pu	1.60×10^{-5}
^{240}Pu	2.20×10^{-5}
^{241}Pu	1.36×10^{-3}
^{241}Am	2.80×10^{-5}
^{242m}Am	2.04×10^{-8}
^{244}Cm	1.13×10^{-6}

TABLE 6-3
Potential Emissions from Emplaced Fuel in the Vault

Radionuclide	Emission Rate ($Bq \cdot s^{-1}$)	
	Case 1 Airborne Release	Case 2 Waterborne Release
^{3}H	$2.7 \times 10^{+0}$	$2.7 \times 10^{+0}$
^{14}C	1.5×10^{-3}	1.5×10^{-6}
^{85}Kr	$9.3 \times 10^{+0}$	$9.3 \times 10^{+0}$ *
^{129}I	1.3×10^{-6}	1.3×10^{-9}
^{137}Cs	3.6×10^{-3}	1.2×10^{-2}

* Assumed to be released to the atmosphere.

The radionuclide concentrations in air for the Northern, Central and Southern regions of the Ontario Shield are listed in Table 6-4. The results for the three regions agree to within a factor of 2 because of the similarity in the weather across the regions. The values are within the uncertainty associated with the Gaussian plume model for atmospheric dispersion calculations (Miller and Hively 1987).

2) Radionuclide Concentrations in Water

The concentration of radionuclides in water near the UFDC was calculated for both river and lake discharge scenarios. Of the two, the lake discharge scenario gave the larger radionuclide concentrations and this was used in subsequent dose calculations.

The concentrations in the lake water near the UFDC result from the deposition of airborne radionuclides to the water surface and the waterborne discharge of radionuclides from the UFDC. Except for ^{3}H, ^{14}C and ^{129}I, the airborne deposition to surface water was small compared to the waterborne discharge to the lake.

The estimated total radionuclide concentrations in lake water near the UFDC are listed in Table 6-5 for the Northern, Central and Southern regions of the Ontario Shield. The values for the three regions were similar. The lake volumes and flow rates are similar for the Central and Southern regions, but somewhat smaller for the Northern region.

The radionuclide concentrations in lake water near the UFDC can be compared with the average background values from natural and anthropogenic sources given in Section 6.1.1.2.

A comparison of the waterborne concentration values for some of the key radionuclides is given in Table 6-6. Comparison has also been made between the projected concentrations from the UFDC and the water quality objectives of the Ontario Ministry of the Environment (MOE 1984). Since the radionuclide concentrations in lake water from the UFDC were estimated to be a small fraction of the background concentrations, from natural or anthropogenic sources, the radiological impact of the UFDC on the water quality near the facility is expected to be small.

3) Concentration of Radionuclides in Soil and Sediment

The radionuclide concentration in the soil was calculated using both airborne deposition and irrigation, as described earlier. The total radionuclide concentrations in bulk dry soil are listed in Table 6-7 for the Northern, Southern and Central regions of the shield. The concentrations of ^{3}H and ^{14}C in dry soil are assumed to be zero, since most of the tritium was assumed to be in the form of tritiated water and ^{14}C was assumed to have a negligible distribution coefficient in soil (Russell 1993c). The values for the three regions were similar since the weather patterns, lake volumes and flow rates were similar.

TABLE 6-4
Radionuclide Concentrations in Air at the UFDC Boundary from UFDC Emissions

Radionuclide	Concentration in Air ($Bq \cdot m^{-3}$)		
	Northern	Central	Southern
^{3}H	9.0×10^{-05}	4.8×10^{-05}	5.4×10^{-05}
^{14}C	1.0×10^{-07}	5.5×10^{-08}	6.2×10^{-08}
^{55}Fe	2.2×10^{-09}	1.2×10^{-09}	1.3×10^{-09}
^{60}Co	9.6×10^{-09}	5.1×10^{-09}	5.8×10^{-09}
^{59}Ni	6.4×10^{-13}	3.4×10^{-13}	3.8×10^{-13}
^{63}Ni	8.4×10^{-11}	4.5×10^{-11}	5.0×10^{-11}
^{85}Kr	1.4×10^{-03}	7.5×10^{-04}	8.4×10^{-04}
^{90}Sr	6.7×10^{-09}	3.6×10^{-09}	4.0×10^{-09}
^{94}Nb	1.5×10^{-12}	7.8×10^{-13}	8.7×10^{-13}
^{106}Ru	1.1×10^{-11}	6.0×10^{-12}	6.8×10^{-12}
^{125}Sb	1.9×10^{-09}	1.0×10^{-09}	1.1×10^{-09}
^{125m}Te	5.2×10^{-09}	2.8×10^{-09}	3.1×10^{-09}
^{129}I	2.1×10^{-09}	1.1×10^{-09}	1.3×10^{-09}
^{134}Cs	6.5×10^{-08}	3.5×10^{-08}	3.9×10^{-08}
^{137}Cs	8.1×10^{-08}	4.3×10^{-08}	4.8×10^{-08}
^{144}Ce	9.7×10^{-13}	5.2×10^{-13}	5.9×10^{-13}
^{147}Pm	6.9×10^{-11}	3.7×10^{-11}	4.1×10^{-11}
^{154}Eu	6.4×10^{-12}	3.4×10^{-12}	3.8×10^{-12}
^{155}Eu	2.7×10^{-12}	1.4×10^{-12}	1.6×10^{-12}
^{234}U	3.4×10^{-15}	1.8×10^{-15}	2.0×10^{-15}
^{238}U	4.2×10^{-15}	2.2×10^{-15}	2.5×10^{-15}
^{238}Pu	1.0×10^{-12}	5.6×10^{-13}	6.3×10^{-13}
^{239}Pu	2.2×10^{-12}	1.2×10^{-12}	1.3×10^{-12}
^{240}Pu	3.0×10^{-12}	1.6×10^{-12}	1.8×10^{-12}
^{241}Pu	1.8×10^{-10}	9.8×10^{-11}	1.1×10^{-10}
^{241}Am	3.8×10^{-12}	2.0×10^{-12}	2.3×10^{-12}
^{242m}Am	2.8×10^{-15}	1.5×10^{-15}	1.7×10^{-15}
^{244}Cm	1.5×10^{-13}	8.2×10^{-14}	9.2×10^{-14}

TABLE 6-5
Radionuclide Concentration in Lake Water
Resulting from UFDC Emissions

Radionuclide	Concentration in Water ($Bq \cdot L^{-1}$)		
	Northern	Central	Southern
^{3}H	2.2×10^{-02}	9.3×10^{-03}	1.2×10^{-02}
^{14}C	3.8×10^{-06}	1.6×10^{-06}	2.0×10^{-06}
^{55}Fe	4.0×10^{-05}	2.4×10^{-05}	2.2×10^{-05}
^{60}Co	5.1×10^{-05}	3.8×10^{-05}	3.2×10^{-05}
^{59}Ni	1.1×10^{-08}	6.8×10^{-09}	6.1×10^{-09}
^{63}Ni	1.4×10^{-06}	8.9×10^{-07}	8.0×10^{-07}
^{85}Kr	$0.0 \times 10^{+00}$	$0.0 \times 10^{+00}$	$0.0 \times 10^{+00}$
^{90}Sr	7.9×10^{-04}	4.5×10^{-04}	4.2×10^{-04}
^{94}Nb	4.6×10^{-08}	2.4×10^{-08}	2.3×10^{-08}
^{106}Ru	1.9×10^{-07}	1.3×10^{-07}	1.1×10^{-07}
^{125}Sb	3.0×10^{-05}	1.9×10^{-05}	1.7×10^{-05}
^{125m}Te	7.6×10^{-06}	6.1×10^{-06}	5.0×10^{-06}
^{129}I	2.0×10^{-07}	1.2×10^{-07}	1.4×10^{-07}
^{134}Cs	4.6×10^{-05}	3.4×10^{-05}	2.9×10^{-05}
^{137}Cs	9.4×10^{-05}	7.0×10^{-05}	6.0×10^{-05}
^{144}Ce	2.8×10^{-08}	2.0×10^{-08}	1.7×10^{-08}
^{147}Pm	3.9×10^{-06}	2.4×10^{-06}	2.1×10^{-06}
^{154}Eu	5.0×10^{-07}	2.8×10^{-07}	2.6×10^{-07}
^{155}Eu	1.8×10^{-07}	1.1×10^{-07}	9.9×10^{-08}
^{234}U	1.4×10^{-10}	9.3×10^{-11}	8.2×10^{-11}
^{238}U	1.7×10^{-10}	1.1×10^{-10}	1.0×10^{-10}
^{238}Pu	2.9×10^{-08}	2.1×10^{-08}	1.8×10^{-08}
^{239}Pu	6.1×10^{-08}	4.3×10^{-08}	3.7×10^{-08}
^{240}Pu	8.4×10^{-08}	5.9×10^{-08}	5.1×10^{-08}
^{241}Pu	5.0×10^{-06}	3.6×10^{-06}	3.1×10^{-06}
^{241}Am	1.1×10^{-07}	7.5×10^{-08}	6.5×10^{-08}
^{242m}Am	7.8×10^{-11}	5.5×10^{-11}	4.7×10^{-11}
^{244}Cm	1.1×10^{-08}	6.2×10^{-09}	5.7×10^{-09}

TABLE 6-6
Comparison of Radionuclide Concentrations in Surface Water

Radionuclide	Concentration in Water ($Bq \cdot L^{-1}$)			
	UFDC (Northern)	Natural Background	Recent Levels	MOE Guidelines
^{3}H	2.2×10^{-2}	4.0×10^{-1}	$5 \times 10^{+0}$	$4 \times 10^{+4}$
^{14}C	3.8×10^{-6}	1.7×10^{-3}	-	-
^{90}Sr	7.9×10^{-4}	-	2×10^{-2}	$1 \times 10^{+1}$
^{137}Cs	9.4×10^{-5}	-	1×10^{-3}	$5 \times 10^{+1}$
^{234}U	1.4×10^{-10}	1.3×10^{-3}	-	-
^{238}U	1.7×10^{-10}	1.3×10^{-3}	-	-
^{239}Pu	6.1×10^{-8}	-	3×10^{-7}	-
^{240}Pu	8.4×10^{-8}	-	3×10^{-7}	-

The radionuclide concentrations in soil near the UFDC are compared with background values in the environment for some key radionuclides (see Amiro 1992b). In most cases, the projected radionuclide concentration in soil from operation of the UFDC was small compared to the background level (see Table 6-8). Therefore, the radiological impact of the UFDC on soil quality near the facility is expected to be small.

Although not explicitly calculated in the preclosure model, the concentration of radionuclides in beach sediment can be estimated by multiplying the concentration in water by the transfer parameter from water to sediment and the area density of the sediment. However, since the radionuclide concentrations in both water and soil from operation of the UFDC were estimated to be small, the concentration in the sediment should also be small. For example, in the Northern region, the ^{137}Cs concentration in water was estimated to be 9.4×10^{-5} $Bq \cdot L^{-1}$, the transfer parameter from water to sediment was 280 $L \cdot kg^{-1}$, and the area density was 40 $kg \cdot m^{-2}$ (Russell 1993b). This would give a ^{137}Cs concentration of 1.1 $Bq \cdot m^{-2}$ in sediment. Measured ^{137}Cs concentrations in sediment in the Great Lakes are generally greater than 1000 $Bq \cdot m^{-2}$ (Joshi 1991). Thus, the estimated sediment values from operation of the UFDC are about 3 orders of magnitude less than current measurements in the environment.

4) Individual Dose

As mentioned earlier, the dose to the critical group at the UFDC boundary is calculated by considering the radionuclide concentration in air and water, and the radiological pathways in the environment that account for exposure to humans. This is done using the PREAC code (Russell 1993b; 1993c; Wai 1993a).

As shown in Table 6-9, the estimated annual dose to an adult residing on a farm at the UFDC boundary from the operation of the UFDC was calculated to be about 3×10^{-7} $Sv \cdot a^{-1}$ in the Northern region, and 2×10^{-7} $Sv \cdot a^{-1}$ for both the Central and Southern regions of the Ontario Shield. The infant dose in each region was calculated to be 5×10^{-7} $Sv \cdot a^{-1}$ in the Northern region, and 3×10^{-7} $Sv \cdot a^{-1}$ for both the Central region and Southern regions. In each region, the farm was assumed to be located in the direction sector which gave the largest radionuclide concentration in air at 1500 m from the point of release. The higher dose estimate in the Northern region was due primarily to the smaller lake volume and flow rate assumed for the region. The maximum individual annual dose was significantly less than the proposed limit for the public of 1×10^{-3} $Sv \cdot a^{-1}$ (AECB 1991a). The calculated dose would be only 0.01% of the average background dose from natural sources in Ontario (about 3×10^{-3} $Sv \cdot a^{-1}$) (Neil 1985).

The estimated individual dose rates among the three regions were within a factor of 2 of each other. The uncertainty associated with the dose predictions for the assessment model is probably an order of magnitude (Russell 1993c). Consequently, it is only necessary to examine the dose results from one of the regions in order to obtain further information on the key radionuclides and pathways in the dose predictions. The Northern region was arbitrarily chosen for further analysis.

TABLE 6-7
Radionuclide Concentrations in Dry Soil
from UFDC Emissions

Radionuclide	Concentration in Soil ($Bq \cdot kg^{-1}$)		
	Northern	Central	Southern
^{3}H	0.0	0.0	0.0
^{14}C	0.0	0.0	0.0
^{55}Fe	2.2×10^{-04}	1.4×10^{-04}	1.2×10^{-04}
^{60}Co	6.7×10^{-04}	4.8×10^{-04}	4.3×10^{-04}
^{59}Ni	6.8×10^{-07}	4.2×10^{-07}	3.9×10^{-07}
^{63}Ni	7.8×10^{-05}	4.8×10^{-05}	4.4×10^{-05}
^{85}Kr	0.0	0.0	0.0
^{90}Sr	2.4×10^{-02}	1.4×10^{-02}	1.3×10^{-02}
^{94}Nb	2.9×10^{-06}	1.5×10^{-06}	1.4×10^{-06}
^{106}Ru	4.3×10^{-07}	2.9×10^{-07}	2.6×10^{-07}
^{125}Sb	1.9×10^{-04}	1.2×10^{-04}	1.1×10^{-04}
^{125m}Te	5.2×10^{-06}	3.6×10^{-06}	3.4×10^{-06}
^{129}I	3.8×10^{-04}	2.2×10^{-04}	2.5×10^{-04}
^{134}Cs	5.3×10^{-04}	3.4×10^{-04}	3.4×10^{-04}
^{137}Cs	7.3×10^{-03}	4.9×10^{-03}	4.7×10^{-03}
^{144}Ce	5.0×10^{-08}	3.5×10^{-08}	3.0×10^{-08}
^{147}Pm	2.3×10^{-05}	1.4×10^{-05}	1.3×10^{-05}
^{154}Eu	9.0×10^{-06}	5.0×10^{-06}	4.7×10^{-06}
^{155}Eu	1.9×10^{-06}	1.1×10^{-06}	1.0×10^{-06}
^{234}U	8.9×10^{-09}	5.8×10^{-09}	5.2×10^{-09}
^{238}U	1.1×10^{-08}	7.1×10^{-09}	6.3×10^{-09}
^{238}Pu	1.6×10^{-06}	1.1×10^{-06}	9.8×10^{-07}
^{239}Pu	3.9×10^{-06}	2.8×10^{-06}	2.4×10^{-06}
^{240}Pu	5.4×10^{-06}	3.8×10^{-06}	3.3×10^{-06}
^{241}Pu	1.4×10^{-04}	9.9×10^{-05}	8.6×10^{-05}
^{241}Am	6.7×10^{-06}	4.6×10^{-06}	4.0×10^{-06}
^{242m}Am	4.6×10^{-19}	3.2×10^{-09}	2.8×10^{-09}
^{244}Cm	3.4×10^{-07}	2.0×10^{-07}	1.8×10^{-07}

TABLE 6-8
Comparison of Radionuclide Concentrations in Dry Soil

Radionuclide	Concentration in Soil ($Bq \cdot kg^{-1}$)	
	Northern	Background
^{59}Ni	6.8×10^{-07}	1.7×10^{-04}
^{63}Ni	7.8×10^{-05}	1.7×10^{-05}
^{90}Sr	2.4×10^{-02}	$7.0 \times 10^{+00}$
^{94}Nb	2.9×10^{-06}	4.3×10^{-07}
^{129}I	3.8×10^{-04}	3.0×10^{-05}
^{137}Cs	7.3×10^{-03}	$9.3 \times 10^{+01}$
^{234}U	8.9×10^{-09}	$1.2 \times 10^{+01}$
^{238}U	1.1×10^{-08}	$1.2 \times 10^{+01}$
^{238}Pu	1.6×10^{-06}	6.3×10^{-02}
^{239}Pu	3.9×10^{-06}	$1.7 \times 10^{+00}$
^{240}Pu	5.4×10^{-06}	6.0×10^{-02}
^{241}Pu	1.4×10^{-04}	$1.4 \times 10^{+00}$
^{241}Am	6.7×10^{-06}	5.1×10^{-01}

The annual individual dose to an adult as a function of radionuclide for all pathways is listed in Table 6-10 and illustrated in Figure 6-2. The radionuclide calculated to give the largest dose was ^{90}Sr at 1.7×10^{-7} Sv·a^{-1}, which is about 49% of the total dose. The next largest contributors were ^{137}Cs at 1.0×10^{-7} Sv·a^{-1}, which is approximately 29% of the total, and ^{134}Cs at 5.9×10^{-8} Sv·a^{-1}, which is approximately 17% of the total. Together, these three radionuclides account for 95% of the annual dose from UFDC emissions.

The annual individual dose as a function of pathway for all radionuclides is given in Table 6-11 and illustrated in Figure 6-3. The pathway calculated to give the largest dose rate was emission to water, followed by bioaccumulation in fish and ingestion of fish at 1.4×10^{-7} Sv·a^{-1}, which accounted for about 41% of the total dose. The next most important pathway was emission to water, followed by irrigation of backyard vegetables and soil, and ingestion of vegetables at 1.1×10^{-7} Sv·a^{-1}, which accounted for 32% of the total dose.

The dose was also calculated for each radionuclide and exposure pathway. Detailed pathway analysis results can be found in Russell (1993a). The largest annual individual dose as a function of radionuclide and air pathway was found to be air deposition of ^{137}Cs to soil and groundshine at 1.1×10^{-8} Sv·a^{-1}. The largest annual individual dose as a function of radionuclide and water pathway was calculated to be ^{90}Sr in water followed by irrigation of vegetables and human ingestion of vegetables at 1.1×10^{-7} Sv·a^{-1}.

The annual dose at the UFDC boundary is compared with the natural background radiation dose in Ontario and the proposed AECB dose limit for the public in Figure 6-4. The dose from operation of the UFDC was estimated to be at least three orders of magnitude less than that from either natural background radiation or the proposed dose limit for the public. As seen from Table 6-9, this dose is so low that it would be very difficult to measure it, or distinguish it from the dose received from background radiation.

5) Collective Dose

The annual collective dose to the population is calculated using the sector-averaged atmospheric dispersion for each radial interval out to 100 km, plus the contribution from the water pathways near the facility. The total annual collective dose from all radionuclides and pathways was estimated to be about 1.9×10^{-4}, 1.7×10^{-4} and 2.4×10^{-4} person-Sv per year in the Northern, Central and Southern regions, respectively. Since the collective dose for the three reference environments are similar, the results for the Northern region were arbitrarily chosen to obtain further information on the key radionuclides and exposure pathways (see Table 6-12 for the average atmospheric dispersion factor for each radial interval in the Northern region).

The collective dose from the three regions were similar because the collective dose was dominated by ingestion of water by the local population near the UFDC in each region. The local population was calculated using the availability of water from the lake for domestic use

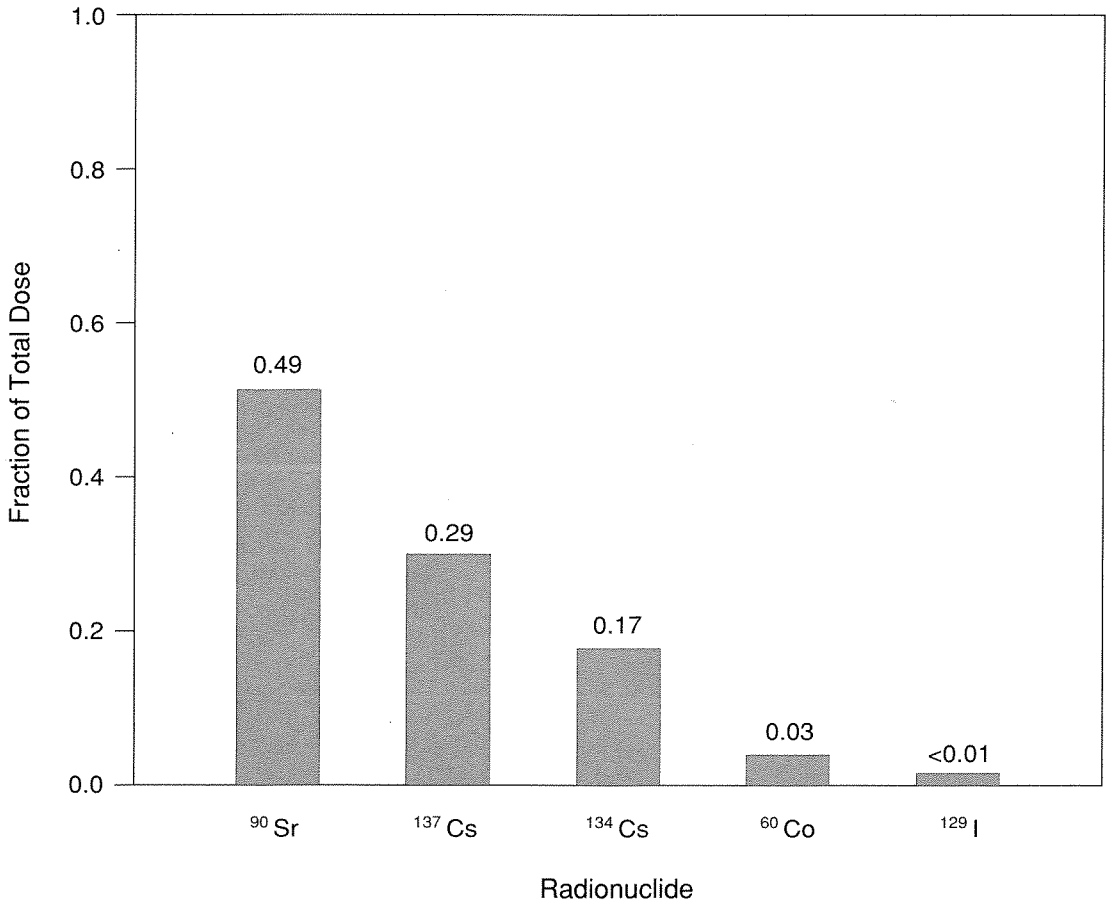


FIGURE 6-2: Individual Dose by Radionuclide in the Northern Region from UFDC Emissions

TABLE 6-9
Estimated Individual Annual Dose at the UFDC Boundary

Region	Annual Dose ($Sv \cdot a^{-1}$)	
	Adult	Infant
Northern	3.4×10^{-7}	5.2×10^{-7}
Central	2.2×10^{-7}	3.1×10^{-7}
Southern	2.0×10^{-7}	2.9×10^{-7}

Average background dose from natural sources in Ontario: 3×10^{-3} $Sv \cdot a^{-1}$

TABLE 6-10
Individual Dose by Radionuclide in the Northern Region From UFDC Emissions

Radionuclide	Annual Dose ($Sv \cdot a^{-1}$)	Fraction
^{3}H	5.5×10^{-10}	1.6×10^{-03}
^{14}C	2.0×10^{-10}	5.9×10^{-04}
^{55}Fe	8.2×10^{-11}	2.4×10^{-04}
^{60}Co	1.1×10^{-08}	3.1×10^{-02}
^{59}Ni	1.8×10^{-15}	5.1×10^{-09}
^{63}Ni	2.9×10^{-13}	8.4×10^{-07}
^{85}Kr	9.2×10^{-12}	2.7×10^{-05}
^{90}Sr	1.7×10^{-07}	4.9×10^{-01}
^{94}Nb	2.4×10^{-11}	6.9×10^{-05}
^{106}Ru	8.4×10^{-12}	2.5×10^{-05}
^{125}Sb	4.6×10^{-10}	1.3×10^{-03}
^{125m}Te	9.1×10^{-11}	2.7×10^{-04}
^{129}I	1.6×10^{-09}	4.8×10^{-03}
^{134}Cs	5.9×10^{-08}	1.7×10^{-01}
^{137}Cs	1.0×10^{-07}	2.9×10^{-01}
^{144}Ce	6.7×10^{-13}	2.0×10^{-06}
^{147}Pm	1.6×10^{-12}	4.6×10^{-06}
^{154}Eu	5.6×10^{-11}	1.7×10^{-04}
^{155}Eu	7.2×10^{-13}	2.1×10^{-06}
^{234}U	1.7×10^{-14}	5.1×10^{-08}
^{238}U	1.9×10^{-14}	5.5×10^{-08}
^{238}Pu	7.1×10^{-11}	2.1×10^{-04}
^{239}Pu	1.8×10^{-10}	5.2×10^{-04}
^{240}Pu	2.5×10^{-10}	7.2×10^{-04}
^{241}Pu	2.6×10^{-10}	7.5×10^{-04}
^{241}Am	2.1×10^{-10}	6.1×10^{-04}
^{242m}Am	7.4×10^{-14}	2.2×10^{-07}
^{244}Cm	9.6×10^{-11}	2.8×10^{-04}

Critical radionuclide = ^{90}Sr

TABLE 6-11
Individual Dose by Pathway in the Northern Region
from UFDC Emissions

Air Pathways	Annual Dose ($Sv \cdot a^{-1}$)
Milk-air	1.5×10^{-09}
Beef-air	7.4×10^{-10}
Pork-air	1.9×10^{-09}
Egg-air	5.1×10^{-10}
Poultry-air	5.6×10^{-10}
Vegetable-air	6.2×10^{-09}
Groundshine-air	1.5×10^{-08}
Inhalation-air	8.5×10^{-11}
Soil ingest-air	1.4×10^{-11}
Immersion-air	9.5×10^{-12}
Water Pathways	
Milk-water	8.7×10^{-10}
Beef-water	1.6×10^{-10}
Pork-water	1.8×10^{-10}
Egg-water	1.0×10^{-09}
Poultry-water	6.7×10^{-11}
Vegetable-water	1.1×10^{-07}
Fish-water	1.4×10^{-07}
Ingestion-water	2.2×10^{-08}
Soil ingest-water	1.3×10^{-10}
Immersion-water	7.6×10^{-12}
Groundshine-water	4.1×10^{-08}
Beach shine-water	1.6×10^{-10}
Total:	3.4×10^{-07}

Critical air pathway = Groundshine-air
Critical water pathway = Fish-water

TABLE 6-12
Sector-averaged Atmospheric Dispersion in Northern Region

Radial Interval (km)	Average Dispersion ($s \cdot m^{-3}$)
(1.5 to 4)	4.1×10^{-07}
(4 to 8)	1.3×10^{-07}
(8 to 16)	4.7×10^{-08}
(16 to 24)	2.3×10^{-08}
(24 to 32)	1.4×10^{-08}
(32 to 40)	9.9×10^{-09}
(40 to 60)	6.4×10^{-09}
(60 to 80)	4.1×10^{-09}
(80 to 100)	2.9×10^{-09}

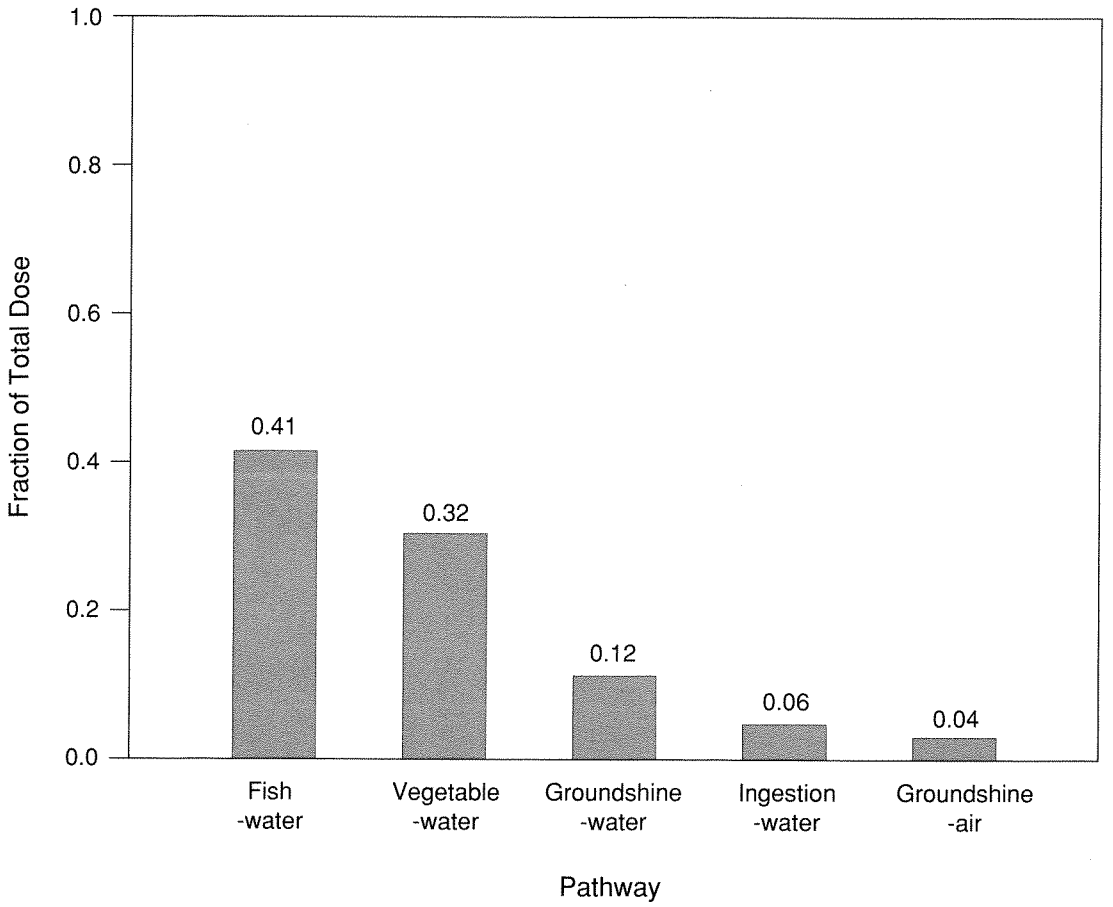


FIGURE 6-3: Individual Dose by Pathway in the Northern Region from UFDC Emissions

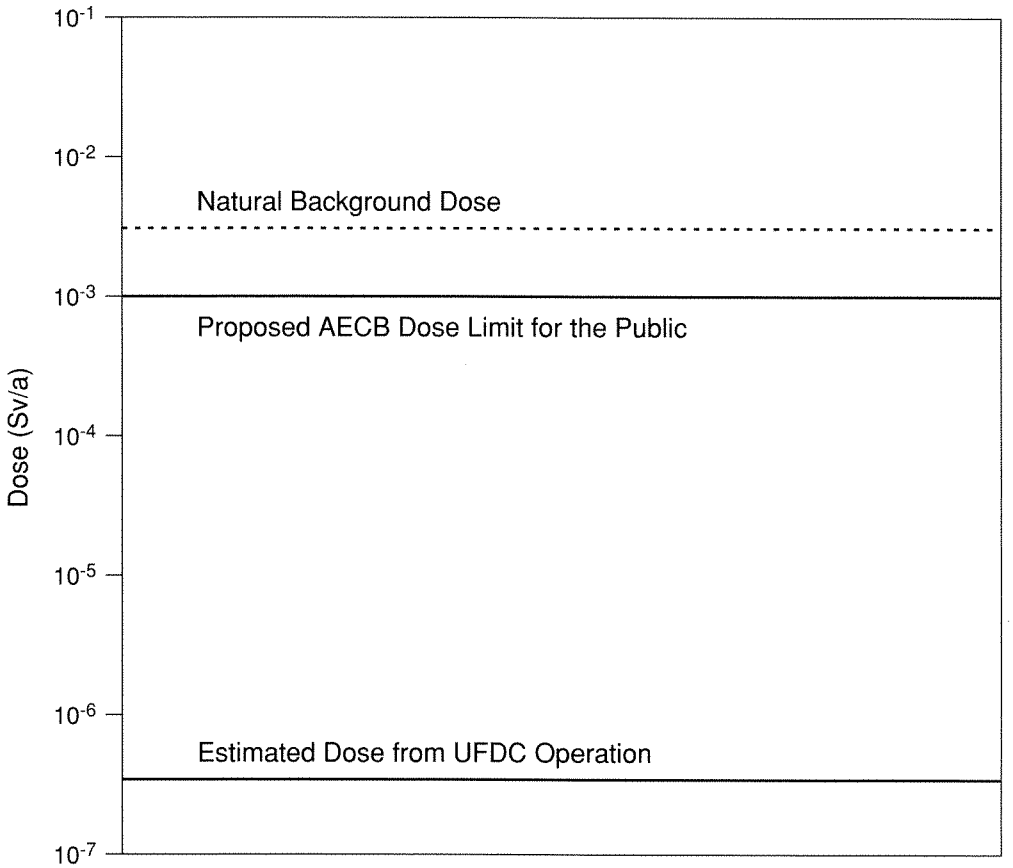


FIGURE 6-4: Comparison of Annual Individual Doses from UFDC Operation, Natural Background Radiation and the Proposed AECB Dose Limit for the Public (AECB 1991a)

(Russell 1993a) and was estimated to be 6 700, 8 200 and 10 000 persons in the Northern, Central and Southern regions, respectively. However, the smaller population in the Northern region was balanced by a smaller average lake size and thus higher radionuclide concentrations in lake water (see Table 6-5). Therefore, while the individual doses were slightly higher in the Northern region, the total collective doses among the three regions were similar.

The annual collective dose for each radionuclide is listed in Table 6-13. The radionuclide that gave the largest contribution to the collective dose was ^{90}Sr.

The annual collective dose as a function of exposure pathway for the Northern region is given in Table 6-14. The pathway that gave the largest collective dose to the population was ingestion of water, followed by groundshine from airborne deposition of radionuclides.

These values can be compared to the expected collective dose from natural background radiation in Ontario using the average dose rate of 3×10^{-3} Sv per year and the population data from the reference environments in the Ontario Shield. The collective dose from natural background exposure is 6.0×10^{2}, 1.7×10^{3} and 1.9×10^{3} person-Sv per year in the Northern, Central and Southern regions, respectively.

6) Implication of Changes to Dose Conversion Factors

The dose conversion factors in this assessment are based primarily on ICRP 26, the 1977 recommendations of the International Commission on Radiological Protection (ICRP 1977), and are consistent with the current standards set in Canada (CSA 1987). In 1991, the Commission issued ICRP 60 containing its revised recommendations on the fundamental principles of radiological protection (ICRP 1991). As a result of these recommendations, the dose conversion factors may change and the calculated doses from the operation of the UFDC may change. However, in most cases, the changes would be small and many are within a factor of 2.

For example, for chronic emissions analyzed in the preclosure assessment, the most important radionuclides for individual and collective dose rates were found to be ^{90}Sr, ^{137}Cs and ^{134}Cs, and the most important exposure pathway was ingestion. These three radionuclides accounted for 95% of the individual dose. Using ICRP 26 and ICRP 60, the adult dose conversion factor for ingestion of ^{90}Sr would change from 3.4×10^{-8} to 3.3×10^{-8} $Sv.Bq^{-1}$, and the value for ^{137}Cs would change from 1.4×10^{-8} to 2×10^{-8} $Sv.Bq^{-1}$. The value for ^{134}Cs would not change. Consequently, the individual and collective dose rate calculations for chronic emissions would increase slightly, but the change would be less than a factor of 2 using the revised dose conversion factors based on ICRP 60.

For acute emissions analyzed in the preclosure assessment, the key radionuclides were ^{241}Am, ^{241}Pu and ^{240}Pu, and the critical exposure pathway was inhalation (see Section 6.1.2.5). Using ICRP 26 and ICRP 60, the adult dose conversion factor for inhalation of ^{241}Am would change from 1.3×10^{-4} to 6.7×10^{-5} $Sv.Bq^{-1}$, and the value for ^{241}Pu would change from 2.3×10^{-6} to 1×10^{-6} $Sv.Bq^{-1}$. The value for ^{240}Pu would change from 1.3×10^{-4} to 6.7×10^{-5} $Sv.Bq^{-1}$. Therefore, the calculated doses for acute emissions would decrease by a factor of 2 using the revised dose conversion factors.

TABLE 6-13
Collective Dose by Radionuclide in the Northern Region from UFDC Emissions

Radionuclide	Annual Collective Dose (person-Sv·a^{-1})
^{3}H	2.2×10^{-06}
^{14}C	4.3×10^{-08}
^{55}Fe	3.8×10^{-08}
^{60}Co	7.7×10^{-06}
^{59}Ni	2.0×10^{-12}
^{63}Ni	7.6×10^{-10}
^{85}Kr	1.7×10^{-08}
^{90}Sr	1.3×10^{-04}
^{94}Nb	5.2×10^{-09}
^{106}Ru	7.2×10^{-09}
^{125}Sb	1.8×10^{-07}
^{125m}Te	1.3×10^{-07}
^{129}I	1.2×10^{-06}
^{134}Cs	1.5×10^{-05}
^{137}Cs	3.4×10^{-05}
^{144}Ce	8.0×10^{-10}
^{147}Pm	5.3×10^{-09}
^{154}Eu	8.0×10^{-09}
^{155}Eu	3.4×10^{-10}
^{234}U	6.0×10^{-11}
^{238}U	6.5×10^{-11}
^{238}Pu	1.4×10^{-07}
^{239}Pu	3.6×10^{-07}
^{240}Pu	5.0×10^{-07}
^{241}Pu	5.2×10^{-07}
^{241}Am	6.2×10^{-07}
^{242m}Am	2.2×10^{-10}
^{244}Cm	3.7×10^{-08}
Total:	1.9×10^{-04}

TABLE 6-14
Collective Dose by Pathway in the Northern Region
from UFDC Emissions

Radionuclide	Annual Collective Dose (person-Sv·a^{-1})
Milk-air	6.8×10^{-09}
Beef-air	4.0×10^{-06}
Pork-air	4.9×10^{-07}
Egg-air	5.8×10^{-08}
Poultry-air	9.1×10^{-09}
Vegetable-air	4.1×10^{-06}
Groundshine-air	2.8×10^{-05}
Inhalation-air	1.6×10^{-07}
Soil ingestion-air	2.7×10^{-08}
Immersion-air	1.8×10^{-08}
Fish-water	9.3×10^{-06}
Ingestion-water	1.4×10^{-04}
Immersion-water	5.1×10^{-08}
Total:	1.9×10^{-04}

7) Dose to Non-Human Biota

The annual dose to four general groups (target organisms) of non-human biota were calculated using steady-state radionuclide concentrations in the environment near the UFDC and a conservative dose assessment methodology.

The dose to non-human biota in the three reference environments were similar because the radionuclide concentrations in the three environments were similar. Thus, the detailed dose analysis was arbitrarily done for the Northern region.

The projected annual dose rate to fish, plants, mammals and birds in the environment near the UFDC was estimated to be 8.6×10^{-6}, 6.5×10^{-6}, 6.4×10^{-6} and 6.4×10^{-6} $Gy \cdot a^{-1}$, respectively. The dose as a function of radionuclide is listed in Table 6-15 and the dose for the four exposure pathways is listed in Table 6-16. For fish, the critical radionuclides were ^{134}Cs and ^{137}Cs, and the critical pathway was internal exposure. For plants, mammals and birds, the critical radionuclide was ^{90}Sr and the critical pathway was groundshine.

The background dose from natural and fallout sources to aquatic and terrestrial organisms has been estimated to be 2.5×10^{-4} to 5×10^{-3} $Gy \cdot a^{-1}$ (Laratta 1983). Therefore, the annual dose rate to non-human organisms is projected to be several orders of magnitude below background levels, and the impact is expected to be very small.

6.1.1.5 Mitigation Measures

Routine measurements of radionuclide concentrations in the environment before and during UFDC operation would allow direct confirmation that emissions are being kept small and that the accumulation of radioactivity in the environment is within estimated ranges. If the emissions need to be reduced, the design and/or operating procedures could be changed to ensure that the radiological impact from the UFDC operation is a small fraction of the proposed AECB regulatory limit.

For example, chronic radionuclide emissions to air and water could be reduced by regular maintenance and replacement of the particulate and ion exchange filters at the UFDC. Also, since most of the emissions have been estimated to occur as a result of fuel failure during handling at the Used Fuel Packaging Plant (Villagran 1993), modifications to the handling procedures would reduce the frequency of failures and the emissions to the environment. Mitigation measures would include:

i) HEPA filter monitoring, regular maintenance and replacement;

ii) ion exchange column monitoring, regular maintenance and replacement;

iii) monitoring at the bulkhead face for early detection of premature failure of a container; and

iv) container retrieval.

TABLE 6-15
Dose to Non-human Biota by Radionuclides in the Northern Region from UFDC Emissions

Radionuclide	Dose ($Gy \cdot a^{-1}$)			
	Fish	Plant	Mammal	Bird
^{3}H	6.3×10^{-10}	5.3×10^{-10}	6.0×10^{-10}	7.3×10^{-10}
^{14}C	1.6×10^{-08}	8.7×10^{-12}	4.4×10^{-11}	2.8×10^{-11}
^{55}Fe	2.4×10^{-09}	3.8×10^{-11}	3.7×10^{-11}	3.7×10^{-11}
^{60}Co	2.2×10^{-07}	4.4×10^{-08}	4.3×10^{-08}	4.3×10^{-08}
^{59}Ni	3.9×10^{-14}	3.3×10^{-13}	3.3×10^{-13}	3.3×10^{-13}
^{63}Ni	1.2×10^{-11}	3.2×10^{-13}	2.0×10^{-14}	1.5×10^{-14}
^{85}Kr	$0.0 \times 10^{+00}$	5.8×10^{-10}	5.8×10^{-10}	5.8×10^{-10}
^{90}Sr	4.5×10^{-07}	5.9×10^{-06}	5.8×10^{-06}	5.8×10^{-06}
^{94}Nb	4.1×10^{-11}	2.0×10^{-10}	2.0×10^{-10}	2.0×10^{-10}
^{106}Ru	1.6×10^{-10}	6.6×10^{-11}	6.4×10^{-11}	6.4×10^{-11}
^{125}Sb	1.6×10^{-08}	4.8×10^{-09}	4.6×10^{-09}	4.6×10^{-09}
^{125m}Te	2.2×10^{-09}	5.3×10^{-11}	4.1×10^{-11}	1.9×10^{-11}
^{129}I	4.4×10^{-12}	7.1×10^{-10}	6.9×10^{-10}	6.8×10^{-10}
^{134}Cs	4.0×10^{-06}	4.2×10^{-08}	4.1×10^{-08}	4.5×10^{-08}
^{137}Cs	3.9×10^{-06}	5.2×10^{-07}	5.2×10^{-07}	5.2×10^{-07}
^{144}Ce	9.5×10^{-11}	7.1×10^{-13}	4.4×10^{-13}	4.3×10^{-13}
^{147}Pm	3.6×10^{-11}	7.2×10^{-11}	7.0×10^{-11}	7.0×10^{-11}
^{154}Eu	1.2×10^{-10}	7.5×10^{-10}	7.4×10^{-10}	7.4×10^{-10}
^{155}Eu	3.5×10^{-12}	5.3×10^{-12}	5.2×10^{-12}	5.2×10^{-12}
^{234}U	1.7×10^{-13}	8.8×10^{-15}	3.4×10^{-15}	5.1×10^{-15}
^{238}U	1.9×10^{-13}	9.3×10^{-15}	3.4×10^{-15}	5.3×10^{-15}
^{238}Pu	2.1×10^{-10}	1.9×10^{-12}	6.3×10^{-13}	6.3×10^{-13}
^{239}Pu	4.1×10^{-10}	3.0×10^{-12}	5.9×10^{-13}	5.9×10^{-13}
^{240}Pu	5.6×10^{-10}	5.4×10^{-12}	2.0×10^{-12}	2.0×10^{-12}
^{241}Pu	3.4×10^{-11}	2.5×10^{-13}	4.3×10^{-14}	4.3×10^{-14}
^{241}Am	3.1×10^{-10}	2.4×10^{-11}	1.9×10^{-11}	1.9×10^{-11}
^{242m}Am	2.1×10^{-13}	7.7×10^{-15}	4.3×10^{-15}	4.2×10^{-15}
^{244}Cm	8.0×10^{-10}	5.4×10^{-13}	1.2×10^{-13}	1.2×10^{-13}
Total:	8.6×10^{-06}	6.5×10^{-06}	6.4×10^{-06}	6.4×10^{-06}

TABLE 6-16
Dose to Non-Human Biota by Pathway in the Northern Region from UFDC Emissions

Pathway	Dose ($Gy \cdot a^{-1}$)			
	Fish	Plant	Mammal	Bird
Internal	8.6×10^{-06}	1.0×10^{-07}	8.8×10^{-09}	1.5×10^{-08}
Air Immersion	0	5.8×10^{-10}	5.8×10^{-10}	5.8×10^{-10}
Water Immersion	3.1×10^{-09}	3.1×10^{-09}	3.1×10^{-09}	3.1×10^{-09}
Groundshine	0	6.4×10^{-06}	6.4×10^{-06}	6.4×10^{-06}
Total:	8.6×10^{-06}	6.5×10^{-06}	6.4×10^{-06}	6.4×10^{-06}

6.1.2 Impacts of Accident Conditions

Given the conceptual nature of the design, the present safety analysis must be considered as a preliminary study that illustrates the methods that could be used in a complete safety analysis of an actual disposal facility. The results demonstrate that the risk associated with a set of postulated abnormal events would be well within the regulatory limits established for fixed nuclear facilities.

6.1.2.1 Analysis Methodology

The public safety assessment methodology used for accident analysis is shown schematically in Figure 6-5 (Russell and Villagran 1993). This methodology is consistent with the methods used in the assessment of public safety for Ontario Hydro's nuclear facilities (Ontario Hydro 1990a).

1) Methodology for Selecting of an Accident Scenario

At the conceptual design stage, the usefulness of the fault-tree analysis technique to identify initiating events and quantify failure frequency is very limited, since the design details necessary to carry out a thorough analysis are not available. Therefore, the selection of reference accident scenarios is based on a systematic review of the concept design and a literature review of safety analyses developed for other repository designs (Jackson et al. 1985).

2) Methodology for Assessment of Consequences

The radioactive releases to the environment in the reference accident scenarios are short-term or acute releases. Following standard practice in the evaluation of the dose to the public from accidents, only the pathways that result in immediate public exposure have been evaluated. It is assumed that any long-term exposures via other pathways would be prevented by corrective actions. A similar criterion is used in the assessment of off-site radiological consequences for Ontario Hydro's existing nuclear facilities (Ontario Hydro 1990a).

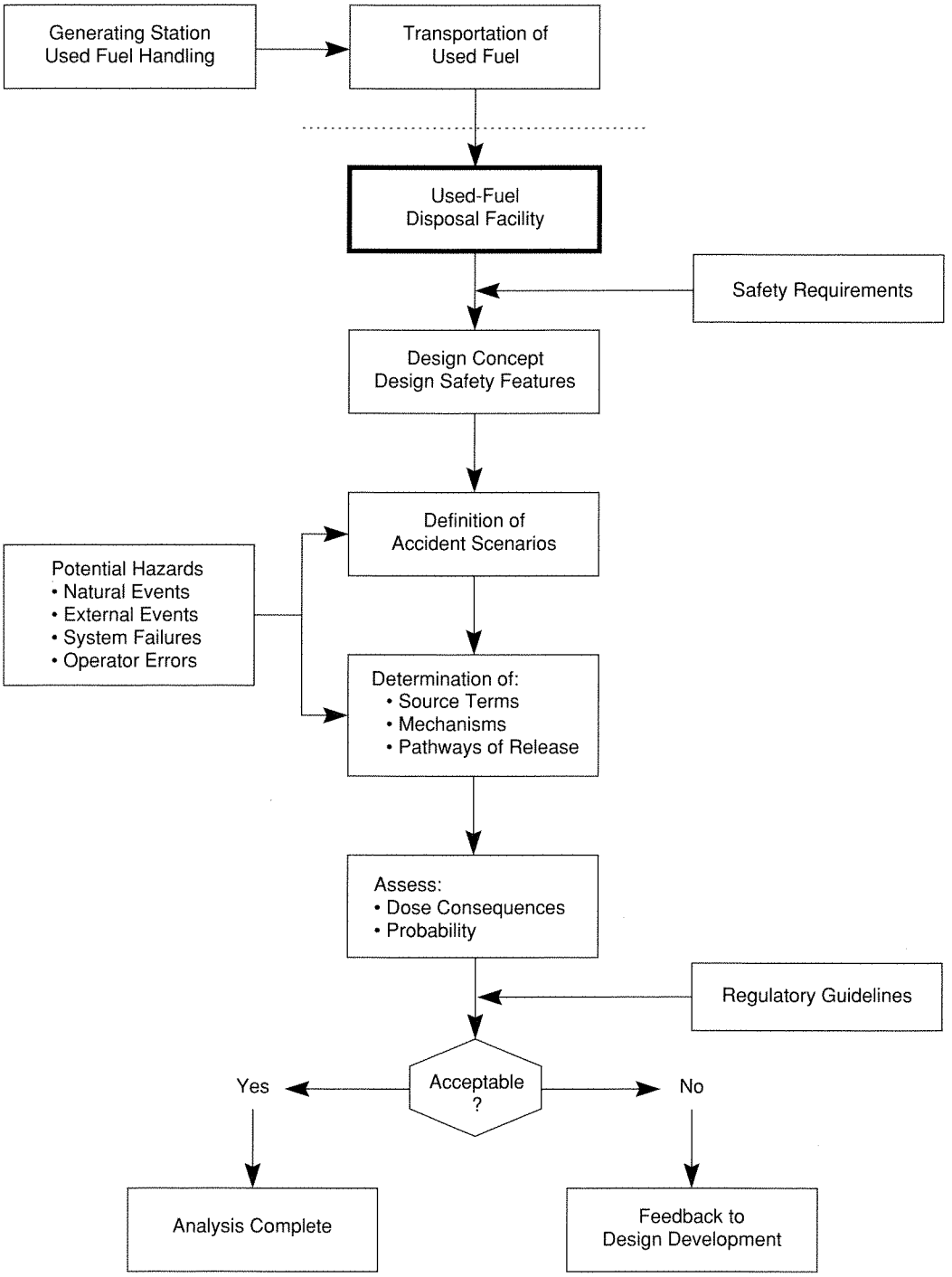


FIGURE 6-5: Public Safety Assessment Methodology for the Preclosure Phase

The dominant pathway for radiation exposure to members of the public from a short-term release of radionuclides is atmospheric transport. The associated pathways that lead to potentially significant doses are: immersion in the radioactive plume (Figure 6-6), inhalation of airborne radionuclides, and groundshine exposure from radionuclides deposited on the ground. A short-term radiological assessment model PSAC (Public Safety Analysis Code) has been developed to calculate the radiological impact from postulated accidents during the operation of the UFDC (Russell 1993d, 1993e; Wai 1993c).

Atmospheric Dispersion

The atmospheric dispersion at the boundary for acute emissions was calculated for various weather scenarios using the Gaussian plume model (Gifford 1968; CSA 1991a). The dispersion parameters that give the largest radionuclide concentration in air were obtained for Pasquill stability class F, which corresponds to stable weather conditions with minimal mixing and dilution of the emission plume. Class F weather was conservatively used for all atmospheric dispersion calculations. The atmospheric dispersion calculation assumed a wind speed of 2 $m \cdot s^{-1}$, an effective height of release of 20 m, and no correction for building wake effects since the geometry of the release point with respect to the surrounding buildings has not been defined at this conceptual stage.

The average radionuclide concentration in the plume and the affected population were used to calculate the collective dose. The adult population surrounding the UFDC was estimated to 100 km from the UFDC by Grondin and Fearn-Duffy (1993a).

Exposure Pathways

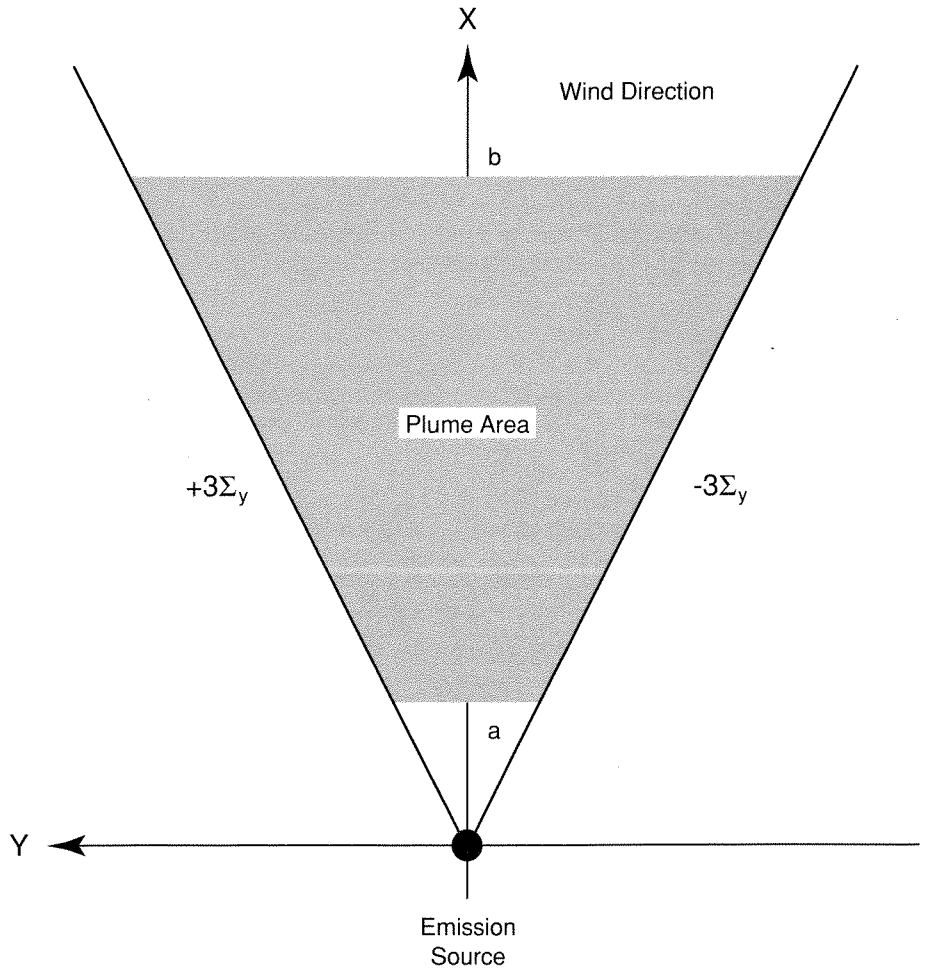
Exposure pathways to the public from the release of radionuclides during an accident at the UFDC include immersion in air, inhalation, exposure to groundshine, ingestion of soil, vegetables and fruit, and ingestion of animal produce. Only those pathways that can lead to an immediate exposure to the public have been evaluated in detail, since it has been assumed that long-term exposure via other pathways can be prevented or restricted by corrective actions. The doses from long-term exposure pathways and food ingestion are discussed in the sensitivity analysis (Section 9.2). Therefore, only the immersion, inhalation and groundshine pathways have been considered when assessing accident doses to adults and infants (defined as one-year old children (CSA 1987)). Infant doses must be calculated since the radiation dose criteria specify a thyroid dose limit, and infants can receive a higher dose than adults when exposed to radionuclides that affect the thyroid.

Ground-level area of radionuclide contamination from a postulated short-term release of radionuclides. The area of the plume is bounded by the downwind radial distances a and b, and the crosswind distances $\pm\Sigma_y$ ($\pm$3 standard deviations of the emission plume to capture at least 99% of the contamination).

Since whole body and thyroid dose limits for the public have been accepted by the AECB for analysis of abnormal events for other nuclear facilities (see Table 6-17), both these doses have been calculated in the UFDC accident analysis.

a) Immersion in Air

The dose to an individual immersed in a plume of radioactive material has been modelled assuming that the plume is a semi-infinite cloud (Holford 1988, 1989). For each radionuclide under consideration and for each



Ground-level area of radionuclide contamination from a postulated short-term release of radionuclides. The area of the plume is bounded by the downwind radial distances a and b, and the crosswind distances $\pm 3\Sigma_y$ (± 3 standard deviations of the emission plume to capture at least 99% of the contamination).

FIGURE 6-6: Plume Area Within Radial Intervals

exposure dose group (adults and infants), the whole body and thyroid doses from immersion in contaminated air depend on the radionuclide concentration in air, the exposure time and the immersion dose conversion factor (Russell and Villagran 1993).

The dose conversion factors for adults for immersion in air (in $Sv \cdot a^{-1} \cdot Bq^{-1} \cdot m^3$) were taken from Holford (1989). The immersion dose conversion factors for infants were conservatively assumed to be 1.5 times the values for adults (CSA 1987), since actual conversion factors for infants are not available. The exposure time was assumed to be the same as the duration of the accident, i.e. 600 seconds (10 minutes). This time was chosen so that the maximum concentration in air would be obtained (the correction factor for increased horizontal dispersion comes into effect when $600 \text{ s} < t \leq 3600 \text{ s}$ (CSA 1991a)).

b) Inhalation

The whole body and thyroid doses to an individual from inhaling radionuclides in air depends on the radionuclide concentration in air, the breathing rate, the exposure time and the inhalation dose conversion factor.

The inhalation rate was assumed to be 2.66×10^{-4} $m^3 \cdot s^{-1}$ for adults and 4.44×10^{-5} $m^3 \cdot s^{-1}$ for infants (CSA 1987). The exposure time was assumed to be 600 s. The dose from exposure to tritium (^3H) was conservatively assumed to come from a tritium oxide (HTO). The inhalation dose from tritium was increased by a factor of 2 to account for the uptake of tritium through the skin.

The whole body dose conversion factors for inhalation were taken from Johnson and Dunford (1983). The thyroid dose conversion factors for inhalation, from Johnson and Dunford (1983), were only given for ^3H, ^{14}C and ^{129}I. The remaining values were calculated using Johnson and Dunford's whole body dose conversion factors and the ratio of the thyroid to whole body dose conversion factors from Killough and Eckerman (1983).

c) Groundshine

The groundshine exposure pathway is based on the deposition to ground (soil and vegetation) of radionuclides from the emission plume following the accident. The process has been modelled using the radionuclide concentration in air and a deposition velocity (CSA 1987; CSA 1991a). For short-term exposures (1 day), the radionuclide removal processes from the ground surface, such as weathering and cleanup, have been ignored. The whole body and thyroid doses to an individual from groundshine exposure assume an infinite plane source of deposited radioactivity. The dose depends on the radionuclide concentration in air, the deposition velocity to the surface, the duration of the accident, the uniformity of the soil, the groundshine exposure time, and the groundshine dose conversion factor (Russell and Villagran 1993).

The total dry deposition velocity to soil and vegetation is used to estimate the radionuclides that are deposited to both vegetation and soil. Dry deposition velocities are usually defined in terms of dry deposition to vegetation and few measurements have been made to both soil and vegetation.

The dose reduction factor accounts for the non-uniformity of the ground surface and is assumed to be 0.7 (CSA 1987). The dose conversion factors from groundshine (in $Sv \cdot a^{-1} \cdot Bq^{-1} \cdot m^2$) were taken from Holford (1989). The dose conversion factors for infants were conservatively assumed to be 1.5 times the values for adults (CSA 1987) since actual conversion factors

for infants are not available. The groundshine exposure time was assumed to be 24 hours or 8.64×10^4 s. Corrective measures were assumed to take place to limit the dose from groundshine exposure.

d) Collective Dose

The collective dose to the population following an accidental release of radionuclides from the UFDC can be calculated by considering the average concentration over the plume area, the immersion, inhalation and groundshine pathways, and the number of people affected by the emission plume.

Grondin and Fearn-Duffy (1993a) have estimated the adult population distribution surrounding the UFDC out to 100 km for each of the three reference environments on the Ontario Shield. The highest population density was found in the Southern region, and this has been conservatively chosen as the population data base for the accident analysis.

3) Methodology for Assessment of Accident Frequencies

It is not possible at this conceptual stage of the design to accurately estimate the frequency of occurrence of the accident scenarios. However, probabilities or frequencies can be derived using experience with similar systems. For example, for the frequency of failure of the crane carrying a loaded fuel module, the known failure rate of similar equipment can be used as an approximation.

The USNRC (1987) assessed the validity of reliability analysis methods by comparing analytically-derived accident probabilities with existing empirical data, for the U.S. High-Level Waste Preclosure Systems Safety Analysis (HLW-PSSA). This assessment supports the methodology used in the present analysis, and it also provided some applicable reliability data for the UFDC systems.

Since the failure frequencies are expected to be infrequent and independent, and since the fault trees for the accident scenarios are not too complex, the rare-events approximation (McCormick 1981) can be used to simplify the accident frequency calculations. The approximation assumes that if two events A and B are independent and rare ($P(A) < 10^{-1}$ and $P(B) < 10^{-1}$), then the probability of A or B can be written as $P(A \cup B) \approx P(A) + P(B)$. This approximation was assumed to be valid for this assessment.

6.1.2.2 Criteria for Safety Evaluation

Based on current safety analysis practices, the safety of the public would be ensured if the following criteria were satisfied:

i) For all abnormal events that might reasonably be postulated to occur during the operating life of the facility, the radiation dose to a member of the public does not exceed the limits set by the Atomic Energy Control Board (AECB 1980).

ii) The risk associated with the operation of the facility should be insignificant compared to the risks to which members of the public are usually exposed.

The AECB has not yet published specific quantitative safety requirements for the preclosure phase of a used fuel disposal facility. However, Regulatory Document R-71 indicates that a deep geological disposal system must, during preclosure, meet the regulations concerning health, safety, environmental protection, safeguards, security and transportation that are applicable to other nuclear facilities and activities (AECB 1985).

In accordance with the above criteria, dose limits were derived directly from the public safety guidelines used in the licensing of the Darlington Nuclear Generating Station (Ontario Hydro 1990a). Classification of events and dose limits similar to the ones used in the Darlington safety assessment are used in the present analysis to determine compliance with the first of the above safety criteria. The dose limits are given in Table 6-17.

Verification of compliance with the second of the safety criteria requires a full probabilistic risk assessment of the UFDC operation. This cannot be done at this conceptual design stage. The present analysis considers only a subset of possible accident scenarios which have been selected by identifying the worst consequence scenario within each accident class. A probabilistic risk assessment can be used to evaluate safety at the site specific stage.

6.1.2.3 Definition of Accident Scenarios

Events that may result in accidental radioactive releases from the UFDC can be classified as internal or external. Internal events originate within the facility and include human error and equipment failures. External events include natural and man-made phenomena occurring outside the facility, such as earthquakes, tornadoes or forest fires.

a) Surface Facilities

i) Transportation Cask Handling Area -- Scenarios S1 and S2

The transportation casks are designed to meet the stringent requirements specified by the AECB for Type B packages, which includes testing under transport accident conditions (Ontario Hydro 1986). The severity of these tests exceeds the severity of possible accidents on the UFDC site, as long as the transportation cask remains sealed. No credible accidents resulting in a significant release of radioactive material from the cask are postulated to occur during transport and handling at the UFDC before the lid bolts are undone.

The only operation that could lead to a release of radioactivity in the cask handling area is when the cask lid bolts are undone and the cask is being lifted towards the Module Handling Cell receiving port.

A failure of the scissors lift, leading to a release of radioactivity in the Cask Handling Area, accident scenario S1, results from the following sequence of events: the scissors lift mechanism fails when coupling the cask to the receiving port of the Module Handling Cell; the cask separates from the port, the lift then tips dropping the open cask on its side onto the floor, thus damaging a fraction of the fuel bundles in it. This results in exposure of failed fuel to air, and the release of radioactive gases and particulates inside the building.

Accident scenario S2 has the same sequence of events as S1, with the added failure of the ventilation system for the cask handling area so that the ventilation exhaust is released unfiltered.

TABLE 6-17
Public Radiation Dose Limits for an Event of Given Frequency *

Event Class	Event Frequency (a^{-1})	Individual Whole Body Dose (Sv)	Individual Thyroid Dose (Sv)
1	$f \geq 10^{-2}$	0.0005	0.005
2	$10^{-2} > f \geq 10^{-3}$	0.005	0.05
3	$10^{-3} > f \geq 10^{-4}$	0.03	0.3
4	$10^{-4} > f \geq 10^{-5}$	0.10	1.0
5	$f < 10^{-5}$	0.25	2.5

* From Darlington NGS Safety Report (Ontario Hydro 1990a). In the original table, the accident frequency is expressed in terms of numbers of expected occurrences per reactor-year.

ii) Module Handling Cell - Scenarios S3 and S4

Dropping used fuel modules as a result of equipment failure during the various handling operations in the Module Handling Cell could lead to extensive fuel bundle damage. The failure of the overhead carriage, accident scenario S3, assumes that one transportation module is dropped on top of another by the robot used to unload the cask. Damage to the modules is assumed to increase with increasing drop height. Maximum damage occurs when the second last module is dropped on top of the last remaining module in the rail cask, when the drop height could be up to 6 m. A large fraction of the radioactive material released from the damaged fuel elements is expected to remain in the cask.

In the current analysis, the radioactive release is assumed to occur in the Module Handling Cell, which is serviced by the active ventilation system. In the S3 scenario, the ventilation system is assumed to operate normally, and 99.97% of the radioactive particulates in the ventilation exhaust would be retained by the High-Efficiency Particulate (HEPA) filters.

Accident scenario S4 assumes an identical sequence of events as S3 with a concurrent failure of the ventilation system of the Module Handling Cell, so that the ventilation effluent is released without filtering.

iii) Receiving Pool

Transfer of used fuel modules in and out of the pool would be done one at a time. Most equipment failures could, therefore, only damage fuel bundles in one module. Dropping of a fuel module in the receiving pool, due to failure of the module handling tool, is not expected to cause as much fuel bundle damage as dropping a fuel module in the Module Handling Cell. Also, the radioactive release would be into the pool water. Therefore, this event is not considered in this assessment.

The temperature of the water in a fully loaded receiving pool (containing 62 400 used fuel bundles) will not exceed 80°C even with a total loss of

cooling of the pool water for a period of two weeks. Since the zirconium alloy sheath that contains the fuel can withstand temperatures of 700°C, loss of cooling in the receiving pool will not result in significant overheating of the fuel bundles. This also applies to the headframe pool. Thus, release of radioactivity due to loss of cooling in either of the pools is not considered.

iv) Fuel Packaging Cell

There is a finite probability of fuel element failures to occur during handling at the Fuel Packaging Cell. Fuel failures involving single fuel bundles are likely to result in small radioactive releases. Since there would be about 5 000 bundle transfers per week, the projected frequency of bundle failure is relatively high. The resulting radioactive releases have been accounted for in the assessment of chronic emissions, assuming a frequency of one failure, on average, every four weeks of operation (Villagran 1993).

Several failure modes are possible during the fuel packaging procedure. For example, a basket or container of used fuel could be dropped. However, the resulting radioactive release and the frequency of occurrence of these events are smaller than those in earlier scenarios. Therefore, they are not included in this analysis.

There are two sets of airlocks in the Fuel Packaging Cell whose failure could create potential pathways for airborne radioactivity to escape from the Cell. Failure of the airlocks connecting the Fuel Packaging Cell to the Module Handling Cell would only allow radioactivity to move from one controlled-access, shielded and actively ventilated area to another, but not to escape the facility. Failure of the airlocks between the Fuel Packaging Cell and the Headframe building would create a potential pathway for airborne activity to escape the facility, but the pressure differential created by the ventilation system would cause air to flow back into the Fuel Packaging Cell, thereby preventing the spread of contamination.

v) Used Fuel Container Transport

The used fuel container is transferred from the Fuel Packaging Plant to the waste shaft using a container cask. The container cask radiation shielding requirements (300 mm of steel) ensure that its mass and structural strength provide adequate physical protection of the disposal containers. Therefore, abnormal conditions that could occur during the transfer of the casks from the Fuel Packaging Cell to the waste shaft are not expected to result in the release of radioactivity. Thus, no accidents that could lead to the release of radioactivity are postulated in the Headframe building.

b) Underground Facilities

i) Shaft and Hoisting Facilities - Scenarios V1 and V2

Two accident scenarios are considered during operations in the vault shaft that could result in the release of radioactivity from the fuel during transfer to the underground vault. In one scenario, a transfer cask is placed into the shaft in absence of the cage; in the other scenario, a failure of the hoisting system results in the loaded cage being dropped down the shaft. The consequences are estimated to be the same in both cases, but the frequency of occurrence is associated with human error in the first case, and with equipment failure in the second case.

Rather than attempting a detailed calculation of the probability associated with each of the above events, the overall probability of dropping the loaded cask down the shaft is estimated on the basis of available statistics from the mining industry, and both scenarios are represented by accident scenario V1, the failure in the shaft and hoisting facilities. All the fuel elements in the disposal container are assumed to fail as a result of the accident.

Accident scenario V2 is similar to V1, but it assumes that the exhaust from vault ventilation system is released to the environment without filtration.

ii) Container Transportation in the Vault

During transfer of the container cask from the waste shaft cage to the storage room using an overhead bridge carriage, the casks are no more than two metres from the floor. Equipment failures are, therefore, not expected to result in radioactive releases from the used fuel containers.

During transfer of the cask to the emplacement room by the underground transporter, safety precautions include restricted access to the transporter route and limiting the maximum speed of the transporter to 8 $km \cdot h^{-1}$. These precautions are considered sufficient to prevent severe accidents that could cause a release of radioactivity from the container.

iii) Container Emplacement

Two potential accidents scenarios during emplacement operations could result in damage to the used-fuel container and bundles. The first scenario is the failure of the container cask grapple, which could result in the used fuel container being dropped approximately six metres from the cask into the borehole. Significant damage to the container would not be expected, but since the container was not designed to provide physical protection to the fuel under such conditions, the integrity of the fuel bundles after the drop could not be guaranteed. The second scenario is initiated by the failure of an interlock system while the container is being lowered into a borehole. This would cause the emplacement platform to move, and the container could be crushed between the platform and the shield ring or between the shield ring and the side of the borehole.

These accident scenarios are expected to have less serious consequences and about the same frequency as the accident scenarios involving the hoisting facilities. They are, therefore, not analyzed further.

iv) Emplacement of a Defective Disposal Container in the Vault

Johnson and LeNeveu (1993) have studied the probability and the radiological consequences of a defective disposal container, containing failed fuel, sealed within an emplacement borehole in the underground vault. The resulting radioactive releases were modelled using conservative assumptions for two different release scenarios: dry conditions and saturated conditions.

Given the high degree of quality control in the container inspection and emplacement operation, the probability of a defective container being emplaced in the vault was conservatively assumed to be one in five thousand, and the probability of any container having one fuel element with a through-wall cladding defect was estimated to be one in fourteen. Therefore, it is estimated that two defective containers carrying defective fuel could be emplaced in the vault during the operating life of the facility (Johnson and LeNeveu 1993).

Assuming dry conditions in the emplacement borehole, the short-term radioactive emissions from a defective container would be limited to the volatile species. The total release is estimated to be several orders of magnitude less than the emissions from the other accident scenarios considered in the preceding sections.

The radiological consequences of the above postulated scenario would be smaller than those of the accident scenarios involving used fuel and container handling, defined previously. Monitoring provisions and appropriate countermeasures during the preclosure period would prevent any significant radiological consequences resulting from defective containers.

The long-term radiological impact of emplacing defective containers, as a result of subsurface radionuclide migration, is analyzed in the postclosure assessment (Goodwin et al. 1994).

v) Internal Fires

Fires and explosions originating from inside the facility (above ground and below ground) could lead to a significant release of radionuclides from unprotected fuel bundles (Eng and Michlewicz 1989). However, a well-planned and implemented fire and explosion protection program at the UFDC could reduce the frequency of such occurrences to a negligible level. For example, the fire protection strategy at Ontario Hydro's nuclear generating stations, which consists of prevention, detection, suppression and minimization of consequences (Ontario Hydro 1990a), could be applied to the UFDC design in accordance with the Ontario Building Code, the Ontario Fire Code, the Ontario Labour Relations Act, and the National Fire Protection Association Codes. The general fire protection requirements for the UFDC, based on current regulations, could include the following provisions:

i) on-site use and storage of combustible materials in areas adjacent to, or containing, equipment that is important to safety shall be controlled and kept to a practicable minimum;

ii) maintenance work involving the use of open flames, soldering, welding and flame-cutting shall be carried out under controlled conditions with fire protection considerations;

iii) appropriate fire extinguishing systems shall be located to ensure that the operation of the UFDC does not significantly impair the capability of equipment important to safety; and

iv) the plant layout shall be designed to isolate items that are important to safety from fire hazards.

c) Ventilation System

All areas of the UFDC surface facilities, where used fuel is handled, would have an active ventilation system. This includes the Module Handling Cell, the Fuel Packaging Cell, the Receiving Pool and interconnecting volumes, such as airlocks. The active ventilation system is designed to limit the consequences of a radioactive release within these areas by filtering the ventilation exhaust (Simmons and Baumgartner

1994). The system would also prevent the spread of radioactive contamination within the facility by maintaining the appropriate pressure differentials between different zones.

The exhaust air from Zones 3 and 4 would be continuously filtered for removal of particulates and discharged through the stack. Two HEPA filters and three fans, each fan providing 50% of the required system capacity, on standby power ensure continuous reliable exhausting (Simmons and Baumgartner 1994). It is assumed for the public safety assessment that the HEPA filters will retain at least 99.97% of the airborne particulate in the effluent (Burchsted et al. 1976).

The emplacement panel upcast ventilation shaft and the waste shaft are equipped with a HEPA filter system that would normally be bypassed. If radioactive contamination is detected in the airflow, automatic control dampers divert exhaust air through the HEPA filter installation and alarms warn personnel. A similar HEPA filter system is also provided on the exhaust from the disposal room in which containers are being emplaced (Simmons and Baumgartner 1994).

Volatile radionuclides such as ^{3}H, ^{85}Kr and ^{14}C (in the form of CO_2) would be carried in the exhaust stream and would be unaffected by the filters. Since the reference design (Simmons and Baumgartner 1994) does not include charcoal filters, all the iodine escaping from the fuel is conservatively assumed to be released to the environment.

Failure of the active ventilation systems resulting in the ventilation exhaust being released unfiltered are considered to have the most serious consequences in terms of immediate dose to the public. For this reason, in this assessment, the most serious failure of the ventilation system is assumed to be loss of filtration. This is the only type of ventilation system failure included in the reference accident scenarios.

d) External Events

Protection against the external events normally considered in the design of nuclear facilities was discussed in Section 2.1.9. In general, the UFDC will be designed to withstand the most severe natural phenomena expected to occur only once in a 100-year period, so that there will be no unacceptable risk to the public. Specific scenarios initiated by external events with potentially serious consequences are discussed below.

i) Criticality due to Flooding

An assessment of the potential of criticality conditions (permitting a sustained chain reaction) occurring as a result of flooding in the vault was carried out by McCamis (1992). The analysis considered all possible arrangements and configurations that the fuel might have in the vault. It was assumed that the vault was flooded and that the containers were full of water. In all conceivable situations, it was concluded that criticality was not possible.

ii) Vault Cave-in

The reference vault design is a conventional, one-level, room-and-pillar type mine excavated at a depth of 500 to 1 000 metres in the plutonic rock of the Canadian Shield. Existing data on hydroelectric powerhouses, oil storage caverns (with a temperature around 100°C), and deep mines in the Canadian Shield indicate that stable underground chambers of comparable depths and sizes can be constructed. However, data on excavated vaults with a similar combination of depth and temperature are

not available. Therefore, thermal rock-mechanics analysis of various vault configurations have been carried out to assess the long-term stability of the reference design.

Near-field Analysis

Tsui and Tsai (1994) carried out a series of three-dimensional thermo-mechanical finite-element analyses of the disposal vault in the area near the container (near-field). These analyses included finite-element thermal transient and stress analyses, to determine the stress distribution in the rock immediately after excavation and at the peak temperature after emplacement. The results indicate that, as a whole, the rockweb between boreholes is relatively stable.

Far-field Analysis

AECL CANDU et al. (1992) reported results of the thermo-mechanical analysis of a room-and-pillar vault concept at a depth of 1 000 m in granite. The thermal analysis showed two temperature peaks, one at about 60 years (70° C) and another at about 4 000 years (67°C). The analysis indicates that surface uplift due to thermal expansion in less than 300 mm at 4 000 years, that no fracture opening would occur at the surface, and that no deep-seated shear movement along fault zones would be induced.

Based on the near-field and far-field vault stability studies, no cave-ins serious enough to result in fuel container damage can reasonably be expected.

iii) Aircraft Crash

Assessing the potential hazard associated with an aircraft crash requires estimates of the probability of a crash for different aircraft types for the specific site, and an estimate of the effective target area. In general, small aircrafts would not be able to penetrate concrete structures of 0.5 m thick reinforced concrete, while most of the larger and faster military aircraft and airliners could penetrate more than twice that thickness (Hall et al. 1985). Although no site has been selected for the UFDC, it is possible to establish an upper limit for the probability of aircraft crashes based on existing data for the province of Ontario (Manning and Aitchinson 1974).

The probability of an aircraft crash on Ontario Hydro's Pickering Nuclear Generating Station, which is close to a large urban centre being served by a major international airport, has been estimated to be less than 1.6×10^{-6} per year. The annual probability of strike on a critical target such as the control room or used fuel bay, based on site-specific data, was estimated to be 1.1×10^{-6} (Manning and Aitchinson 1974).

The Used Fuel Packaging Plant at the UFDC is a concrete structure designed to provide adequate shielding and containment. The concrete walls of the Module Handling Cell and the Fuel Packaging Cell are 1.26 m thick (Simmons and Baumgartner 1994). Light aircraft are, therefore, not expected to be able to penetrate this structure. The only other building above ground at the UFDC that will contain significant amounts of radioactivity is the Headframe building, which is made of structural steel.

Given the small size of the Headframe building (approximately 30 m high by 10 m square), the probability of an aircraft strike is assumed to be an order of magnitude lower than the values for the control room and used

fuel bays at Pickering NGS, which makes it less than 10^{-7}. At this conceptual design stage, detailed assessment of an accident with such a low probability is not considered necessary.

iv) Earthquake

An evaluation of the potential effects of seismic events on an underground used fuel disposal vault during the preclosure phase has been carried out by Ates el al. (1994). A review of available literature shows that most of the Canadian Shield has been seismically stable since the end of the Precambrian period, or approximately 600 million years. Postglacial faulting has occurred and will likely continue. For most parts of the Canadian Shield, peak horizontal particle accelerations are expected to be less than 0.08 g (NRCC 1985) with a probability of exceedance of 10% in 50 years. Existing data on the effect of earthquakes on underground structures was also reviewed to establish a base for assessing the effect of postulated seismic events on the conceptual vault design.

Using published response parameters, basic rock mechanics analyses were used to calculate expected seismic stresses in the vault structure. The results show very low stress levels compared to the strength of the host rock. The report discusses the potential for various modes of structural failure like rock bursts, slab failures and rock "pop-ups". The potential for displacement along faults and the possibility of flooding as a result of seismic activity are also discussed.

The report concludes that correct design coupled with strength characteristics of the present vault design would be sufficient to ensure the integrity of the used fuel disposal vault during an earthquake equivalent to the most intense earthquake ever registered in the Ontario region of the Canadian Shield.

Such an earthquake, if it occurred during the operating stage, might cause flooding of the vault which could potentially trigger radioactive releases from defective fuel under water-saturated conditions, as described by Johnson and LeNeveu (1993). However, the consequences of such an accident could not be worse than those covered by Scenarios V_1 and V_2, and the probability of its occurrence would be very low.

Extensive areas of the Canadian Shield have shown a history of negligible seismic activity, only very minor seismic events with no damage to building structures have been recorded. On that basis, it is assumed that no substantial damage could be caused to the surface facilities from a credible seismic event. Therefore, accident scenarios having an earthquake as the initiating event have not been analyzed further.

v) Forest Fires

Fire statistics in the study area (Southern, Central and Northern regions) have shown the annual frequency of natural and human-induced forest fires to vary from about 250 in the Southern region to 500 in the Central and Northern regions (Grondin and Fearn-Duffy 1993a). The average burned area per fire is between 2 and 4 hectares in the Southern and Central regions, and 102 hectares in the Northern region (Grondin and Fearn-Duffy 1993a). However, the total burned area per year is a small fraction of the total land area in each of the three regions. This reduces the probability of a forest fire affecting the region near the UFDC.

The UFDC design could incorporate features to prevent smoke or heat from external fires from affecting essential plant safety functions. For example, the ventilation system could be isolated from the outside air by dampers so that personnel and equipment are not adversely affected by the conditions outside the facility. The consequences of forest fires can also be mitigated by precautionary measures such as reducing the amount of combustibles (for example, explosives and coniferous vegetation) in the vicinity of the UDFC and near access routes. Forest fire protection/prevention measures are given in Appendix F.

Given that the probability of a forest fire affecting the facility is small, and assuming that effective forest fire protection/prevention steps would be taken to reduce it even further, the effects of a forest fire have not been considered further in this assessment.

e) Summary of Accident Scenarios

The accident scenarios that are examined in further detail in this assessment include the scissors lift failure where either a road or rail cask is dropped before transfer to the Module Handling Cell; failure of the overhead carriage, where a loaded fuel module is dropped onto another module by the Module Handling Cell emptying robot; and a failure in the shaft and hoisting facilities, where a fuel container is dropped down the shaft. The reference accident scenarios are summarized in Table 6-18.

TABLE 6-18
Potential Accident Scenarios used in
the UFDC Safety Analysis

Scenario	Description
S1	**Scissors lift failure:** The open road/rail transportation cask is dropped before transfer of the fuel modules to the Module Handling Cell.
S2	**Scissors lift and ventilation failure:** Same as S1, plus a failure in the ventilation system so that the airborne effluent by-passes the HEPA filters.
S3	**Overhead carriage failure:** A loaded fuel module is dropped on top of another loaded fuel module in the Module Handling Cell.
S4	**Overhead carriage and ventilation failure:** Same as S3, plus a failure in the ventilation system so that the airborne effluent by-passes the HEPA filters.
V1	**Failure in the shaft and hoisting facilities:** A fuel container is dropped down the shaft.
V2	**Failure in the shaft and hoisting facilities plus ventilation failure:** Same as V1, plus a failure in the ventilation system so that the airborne effluent by-passes the HEPA filters.

Note: S represents a surface event
V represents a vault event

6.1.2.4 Impact Analysis

1) Radionuclide Source Term

The quantity of radionuclides released from the fuel as a consequence of each accident scenario was expressed in terms of the fraction of the fuel inventory for each radionuclide and the physical conditions of the accident, including the quantity of damaged fuel elements.

For each radionuclide and accident scenario, the total radioactivity released to the environment following an accident is based on the radionuclide inventory in each used fuel element, the number of failed fuel elements, the release fraction of radionuclides from a failed fuel element, the resuspension factor, the fraction of radionuclides that are resuspended into the air, and the filtration factor or fraction of radionuclides that pass through the HEPA filters (Russell and Villagran 1993).

Radionuclide Inventory and Release Characteristics

The important radionuclides in the fuel selected for inclusion in the analysis were based on the relative radionuclide inventories in the fuel (Tait et al. 1989), the physical data for the reference fuel (Simmons and Baumgartner 1994), and the relative dose impact on the public (Villagran 1993). The used fuel is assumed to be 10-year old Bruce Nuclear Generating Station type fuel with a burnup of 685 $GJ \cdot kg^{-1}$ initial uranium. The radionuclide inventories in each used fuel element are listed in Table 6-19.

The average fuel temperature at the time of the postulated accidents in this assessment is approximately 81°C (Ontario Hydro 1986). Therefore, the only volatile radionuclides are ^{3}H and ^{85}Kr. Tritium (^{3}H) is conservatively assumed to be released in an oxide form. Carbon-14 (^{14}C) released in particulate form after failure of the cladding is assumed to be oxidized and dispersed in the form of $^{14}CO_2$. The remaining radionuclides are assumed to be in solid form and are treated as radioactive particulates in the assessment.

Release fractions for each radionuclide are calculated using the following assumptions:

TABLE 6-19
Radionuclides Considered in the Safety Assessment during Accident Conditions at the UFDC

Radionuclide	Fuel Element Inventory (Bq per fuel element)
^{3}H	1.51×10^{9}
^{14}C	2.18×10^{7}
^{55}Fe	1.07×10^{8}
^{60}Co	1.25×10^{6}
^{59}Ni	3.20×10^{5}
^{63}Ni	4.22×10^{7}
^{85}Kr	2.33×10^{10}
^{90}Sr	2.63×10^{11}
^{94}Nb	2.14×10^{0}
^{106}Ru	4.28×10^{9}
^{125}Sb	4.56×10^{9}
^{125m}Te	1.12×10^{9}
^{129}I	1.50×10^{5}
^{134}Cs	9.93×10^{9}
^{137}Cs	3.91×10^{11}
^{144}Ce	1.46×10^{9}
^{147}Pm	1.03×10^{11}
^{154}Eu	9.52×10^{9}
^{155}Eu	4.03×10^{9}
^{234}U	5.09×10^{6}
^{238}U	6.24×10^{6}
^{238}Pu	1.56×10^{9}
^{239}Pu	3.25×10^{9}
^{240}Pu	4.45×10^{9}
^{241}Pu	2.75×10^{11}
^{241}Am	5.68×10^{9}
^{242m}Am	4.13×10^{6}
^{244}Cm	2.29×10^{8}

(a) Gases and volatile species (^{3}H and ^{85}Kr):

Here, the quantity of each radionuclide available for release is defined as the total free inventory plus 10% of the grain boundary inventory. The free fraction and grain boundary fraction were taken from the safety analysis report for the irradiated fuel transportation cask (Ontario Hydro 1986) (Table 6-20):

TABLE 6-20
Gases and Volatile Species in the Used Fuel Elements

Nuclide	Fuel Element Inventory (Bq)	Free Fraction	Grain-Boundary Fraction	Release Fraction
^{3}H	1.51×10^{9}	0.037	0.121	0.0491
^{85}Kr	2.33×10^{10}	0.037	0.121	0.0491

(b) Radioactive particulates:

The fraction of radioactive particulates released from the failed fuel is described in terms of the total mass of fuel material escaping from the cladding when a fuel element ruptures on impact and the fraction of this material that escapes from the cask or the container holding the fuel.

The quantity of UO_2 fuel ejected from a fuel element following rupture of the cladding has been measured at the Oak Ridge National Laboratory (Lorenz et al. 1980). On average, 50 mg of particulates were found to be ejected from the fuel, following creep rupture of the cladding in light water reactor (LWR) fuel segments. A similar quantity has been assumed to be ejected from CANDU fuel elements following rupture of the cladding during a typical failure caused by mechanical shock (Villagran 1993). This represents about one ten-thousandth (10^{-4}) of the UO_2 mass of a reference CANDU fuel element.

Therefore, the radionuclide release fraction for particulates in fuel failures considered in the present analysis is assumed to be 10^{-4}.

Some particulates have sufficiently low deposition velocity that they remain airborne and are carried in the ventilation exhaust. This fraction should be determined on the basis of particle size distribution, but this information is not available. The fraction is, therefore, assumed to be 1%. In the present analysis, any retention of airborne particulate in the cask cavity is neglected. Therefore, the fraction of particulates that are small enough to remain in suspension in the surrounding air and are carried with the ventilation exhaust is assumed to be 10^{-2}. For the gases and volatile species ^{3}H and ^{85}Kr, plus ^{14}C which is assumed to be present as $^{14}CO_2$, the resuspension factor is taken to be 1.

The HEPA filters are assumed to have an operating efficiency of 99.97% for airborne particulates (Burchsted et al. 1976). Thus, the filtration factor or fraction of radionuclides not retained by the HEPA filters is

3×10^{-4} when the filters are operating. The HEPA filters are assumed to have no effect on the retention of iodine. Therefore, the filtration factor for ^{3}H, ^{14}C, ^{85}Kr and ^{129}I is taken to be 1.

For accident scenarios S2, S4 and V2, where the released radioactivity is assumed to by-pass the HEPA filters, the filtration factor for all radionuclides is taken to be 1.

2) Dispersion

The radioactive material that escaped from the fuel was assumed to be carried out of the facility by the ventilation system and transported in the atmosphere to the closest point accessible to the public. Based on the design of the UFDC site (Simmons and Baumgartner 1994), the minimum distance from the emission point to the exclusion boundary has been taken as 1500 m for all assessments.

3) Analysis of Scenarios S1 and S2

Fuel Damage

For failure scenarios S1 and S2, the open road/rail transportation cask is assumed to be dropped before transfer of the fuel modules to the Module Handling Cell (see Figure 6-7, adapted from Simmons and Baumgartner 1994). The quantity of radioactivity released from the damaged fuel depends on the type of cask being handled.

Each transport module can carry 96 fuel bundles and each bundle has 37 fuel elements (Ontario Hydro 1986), i.e. there are 3 552 fuel elements per module. The road cask has been designed to carry two used fuel modules (i.e. 7 104 fuel elements) and the rail cask to carry six used fuel modules (i.e. 21 312 fuel elements) (Ulster 1993a).

The analysis considered different velocities of impact depending on the various configurations of the falling cask. For example, the scissors lift could collapse without tipping of the cask. In this orientation, the bottom of the road cask was estimated to be about 5.4 m off the ground, and the bottom of the rail cask to be about 2 m off the ground (Simmons and Baumgartner 1994). Also, the scissors lift could fail with the cask tipping over. This could cause the fuel bundles at the top of the cask to fall a greater distance than the bundles at the bottom of the cask.

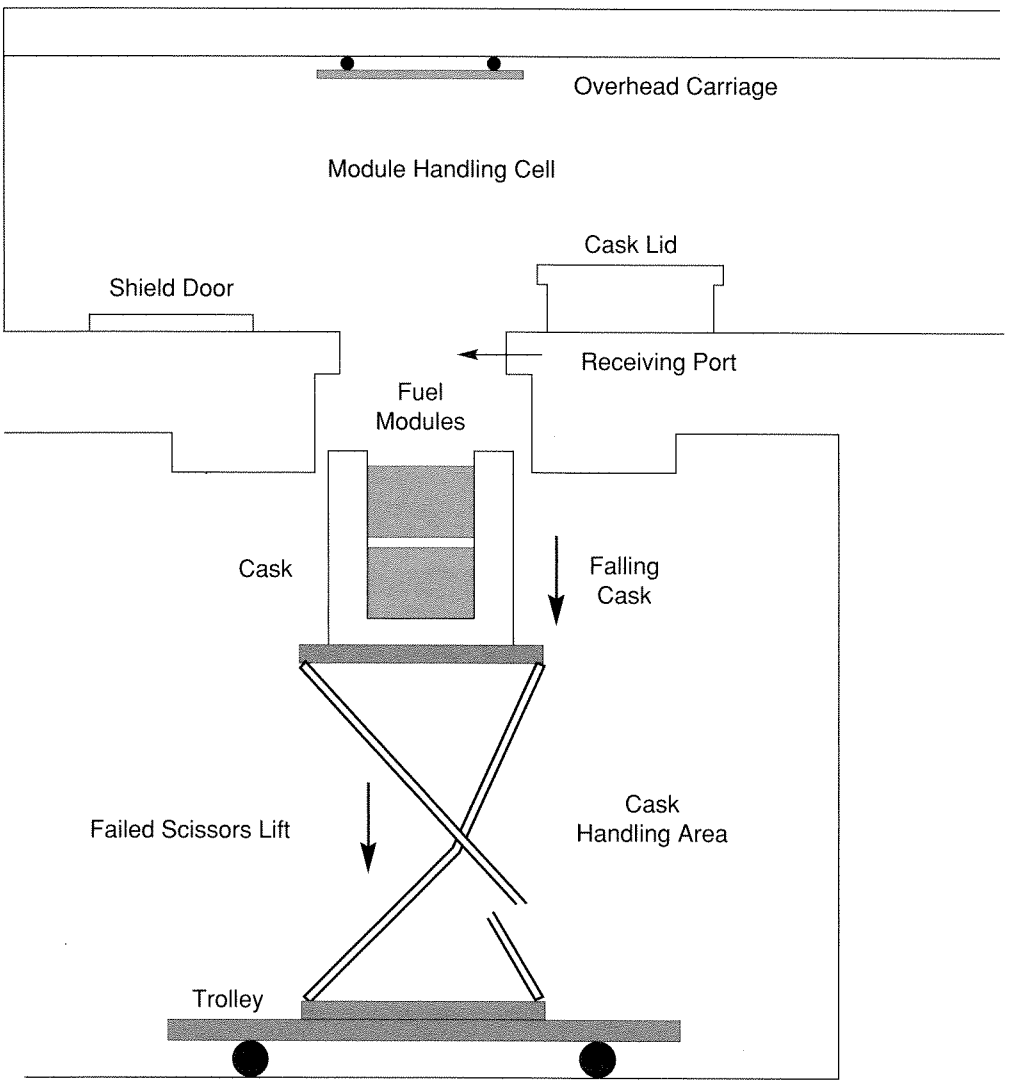


FIGURE 6-7: Scissors Lift Failure in the Cask Handling Area of the Module Handling Cell (Scenario S_1)

The maximum fuel element velocities at impact for the road cask were estimated to be 9.2 to 10.2 $m \cdot s^{-1}$. For the rail cask, the maximum fuel element velocities at cask impact were estimated to be 6.4 to 10.0 $m \cdot s^{-1}$. Thus, for the two transport casks, the fuel impact velocities were of the order of 10 $m \cdot s^{-1}$.

Experimental data on damage to used fuel resulting from mechanical impact is relatively scarce. Nevertheless, some experiments with CANDU fuel have been conducted for impact velocities relevant to the accident scenarios in this assessment. As part of regulatory testing of packages designed for used fuel transport, a package containing unirradiated fuel bundles was dropped 9 m, in tests at the Chalk River Laboratories. The velocity of the package on impact was 13.3 $m \cdot s^{-1}$. Pinhole leaks were found in 9 out of 102 fuel elements, giving a fuel element failure fraction of 0.09 (Taylor 1976). Another series of tests using Bruce-type fuel were conducted by Jackson et al. (1981). In one test, with a velocity on impact of 4 $m \cdot s^{-1}$, no fuel element failures were observed. In two other tests at 13.7 $m \cdot s^{-1}$ impact velocity, the fuel element failure fraction was 0.08. Other bundle drop experiments by Elsayed and Solarski (1982), using impact velocities from 4.6 to 8.3 $m \cdot s^{-1}$, resulted in failure fractions of 0.005.

Few experiments have been conducted on the CANDU fuel of interest; that is, irradiated fuel at low (80-100°C) temperatures. Most of the fuel cladding failure experiments have used unirradiated fuel at ambient temperatures. Analysis of the behaviour of irradiated Zircaloy at 80 to 100°C indicates that its impact strength is about 2.3 to 3.5 times less than unirradiated Zircaloy at 20°C, depending on the hydrogen concentration in the Zircaloy (Sawatzky 1964). Therefore, experiments using unirradiated fuel may underestimate the fuel element failure fraction for irradiated fuel. However, Pon and Archinoff (1983) have concluded that few, if any, fuel cladding failures should occur for impact velocities between 15 and 20 $m \cdot s^{-1}$ for hot irradiated bundles.

Other factors must also be considered when estimating the fraction of fuel failures upon impact, including the orientation of the bundles, the effect of the support structure on the movement of the bundles, and the manner in which energy is dissipated following impact.

The fractional fuel element failure function assumed in the present assessment was based on experimental results and on the above considerations. It is illustrated in Figure 6-8. For impact velocities between 0 and 4 $m \cdot s^{-1}$, the failure fraction was assumed to be 0.01. For velocities between 4 and 13.3 $m \cdot s^{-1}$, the failure fraction was assumed to be 0.10. For velocities greater than 13.3 $m \cdot s^{-1}$, the failure fraction was assumed to be 1, although there is no experimental evidence to assume total fuel failure at speeds just above 13.3 $m \cdot s^{-1}$. A step-wise projection was used for conservatism.

For the scissors lift failure, the estimated fuel element velocities for the modules in the road and rail casks were between 6.4 and 10.2 $m \cdot s^{-1}$. Thus, the fuel element failure fraction for all modules was 0.10. Since there are 7 104 fuel elements in the road cask and 21 312 fuel elements in the rail cask, a rail cask accident would result in the largest emissions. Therefore, the total number of failed elements for the rail cask is 2 131, and this value is used in the assessment for scenarios S1 and S2. (The extreme case where all fuel elements in the rail cask fail is discussed in the sensitivity analysis).

Frequency of Occurrence

The initiating event for scenarios S1 and S2 is a failure of the scissors lift during coupling of the used fuel transportation cask to the receiving port of the Module Handling Cell. The frequency of occurrence of S1 is equal to the frequency of the initiating event, since no other subsystems are involved and no mitigating factors are considered, other than the filtration of the exhaust by the active ventilation HEPA filters.

The frequency of the scissors lift failure was derived from performance data for hydraulic jacks taken from Green and Burne (1972). Assuming continuous duty during two shifts per day, 52 weeks per year, the estimated failure frequency of the scissors lift is 2.1×10^{-3} a^{-1}.

Scenario S2 includes a failure of the active ventilation system so that the ventilation exhaust is released unfiltered. The frequency of occurrence for scenario S2 is estimated to be the product of the frequency of the initiating event multiplied by the median failure probability for the ventilation system reference failure mode.

The packaging plant's active ventilation system has HEPA filters on line. The vault ventilation upcast shafts have HEPA filters on a standby line. When a radioactivity threshold level in the exhaust air is exceeded, the flow is automatically routed through the filters. The probability of failure of the standby filtration system, or of the mechanisms designed to re-route the exhaust through the filters, depends on the safety provisions included in the detailed system design (that is, component redundancy) and on human error (that is, maintenance errors or failure to respond to an alarm indication).

Since a detailed design for the UFDC systems is not available, the probability of loss of filtration is taken from the analysis of a more developed design (USNRC 1987). The assumed value is 7.6×10^{-2}.

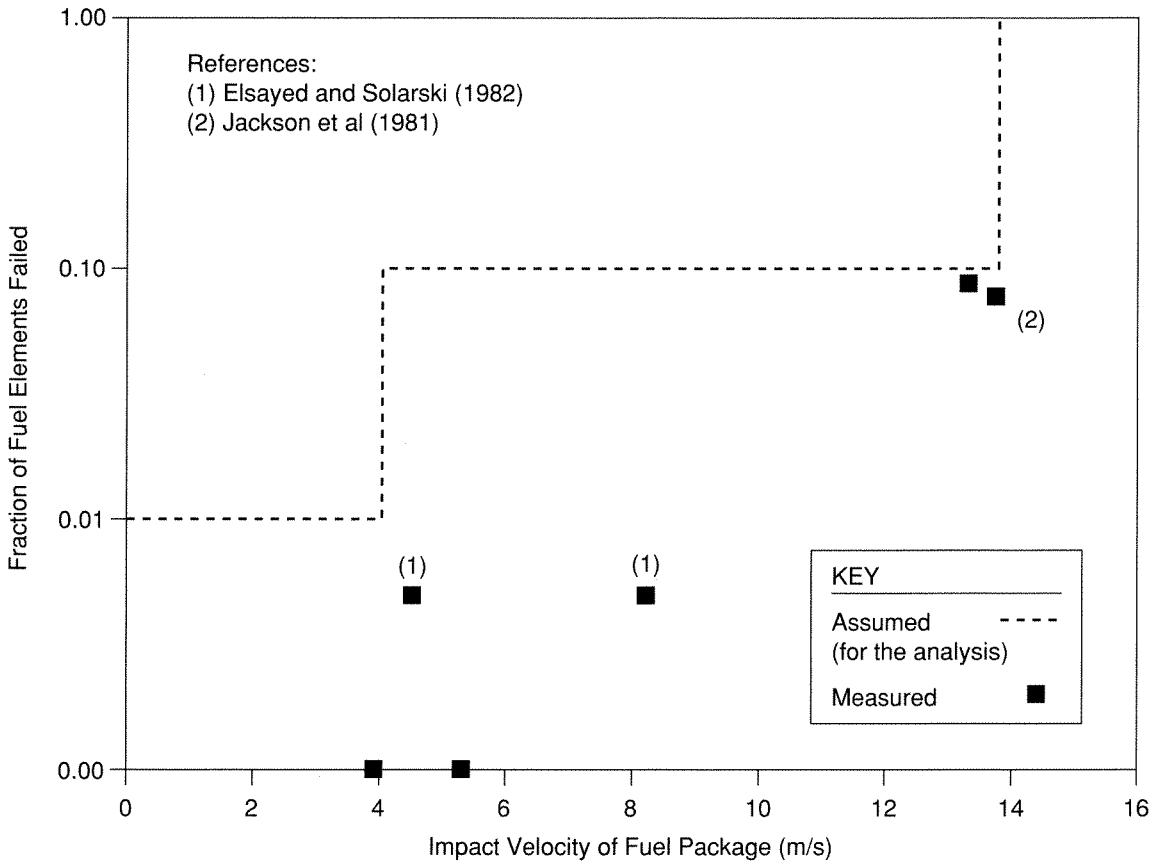


FIGURE 6-8: Fraction of Candu Fuel Elements Failed, as a Fraction of Impact Velocity of a Dropped Fuel Package

4) Analysis of Scenarios S3 and S4

Fuel Damage

For scenarios S3 and S4, a loaded fuel module in the overhead carriage is assumed to drop on top of another loaded fuel module in the Module Handling Cell. The maximum damage to the modules occurs when the secondlast module is dropped on top of the last remaining module in the rail cask (see Figure 6-9). The drop height was estimated to be up to 6 m (Simmons and Baumgartner 1994). Thus, the fuel element velocity upon impact could be up to 10.8 $m \cdot s^{-1}$ and the fuel element failure fraction becomes 0.10. Both the dropped module and the target module were assumed to have this failure fraction. With 3 552 fuel elements per module, the total number of damaged fuel elements for accident scenarios S3 and S4 becomes 710.

Frequency of Occurrence

The frequencies for scenarios S3 and S4 can be estimated as in the previous section. The frequency of S3 is equal to that of the initiating event, which consists of the emptying robot dropping a loaded fuel module. No mitigating factors are considered other than filtration of the ventilation exhaust. In this case, the initiating event can occur either as a result of equipment (overhead carriage) failure or operator error in the Module Handling Cell.

Based on industry statistics, the frequency of an overhead carriage dropping a loaded fuel module is about 3×10^{-6} to 5×10^{-6} per lift (KBS 1978; Heckman and Holdsworth 1979). On average the emptying robot in the Module Handling Cell will handle 2.6×10^{3} modules per year. However, since the module transfer operation will frequently consist of one transfer to the pool and then a second transfer from the pool to the Fuel Packaging Cell, the total number of operations is taken as 5.2×10^{3} per year. Assuming an overhead carriage failure of 5×10^{-6} per lift, the failure frequency for the overhead carriage becomes 2.6×10^{-2} a^{-1}.

The operator error that would result in the release of a fuel module when the handling equipment is in the wrong position is an Error of Commission (ECOM). However, it is reasonable to assume that the design of the Module Handling Cell control panel will include interlocks to prevent this. The failure frequency of the interlock is not known but can be assumed to be less than the mechanical failure per lift. A value of 10^{-6} per lift has been assumed for the assessment. In a simple design, where releasing the module consists of a single operation (e.g. activating a single switch), such an error is assigned a probability of 0.003 (USNRC 1987). Therefore, the frequency of Module Handling Cell operator error becomes 1.6×10^{-5} a^{-1}. Therefore, for accident scenario S3,the probability of equipment failure determines the frequency of occurrence of the initiating event.

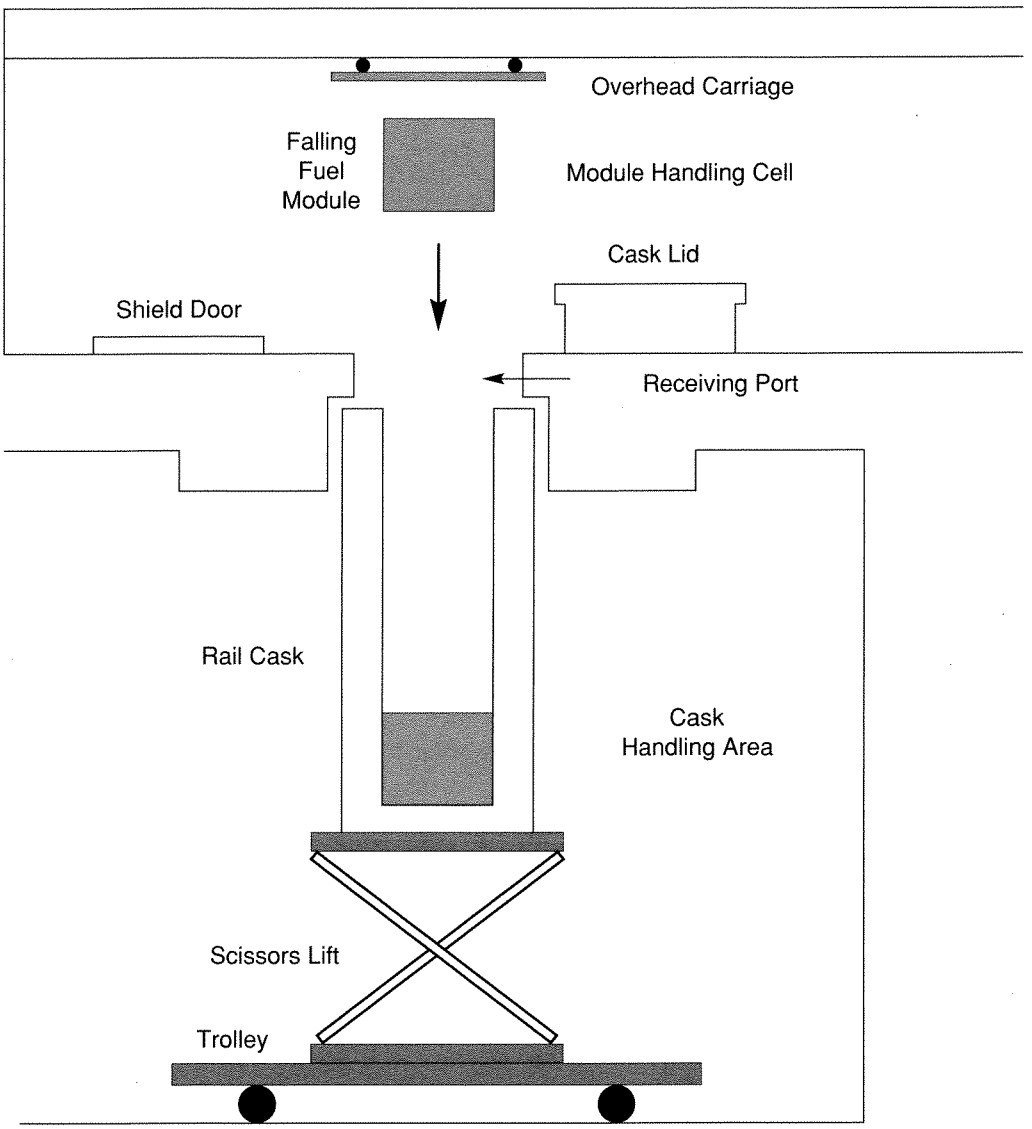


FIGURE 6-9: Overhead Carriage Failure in the Cask Handling Area of the Module Handling Cell – (Scenario S_3)

Accident scenario S4 is the same as S3, but includes a failure of the active ventilation system so that the ventilation exhaust is released unfiltered. This is analogous to the case of Scenario S2 discussed in the previous section. The probability of loss of filtration is 7.6×10^{-2} (USNRC 1987).

5) Failure in the Shaft and Hoisting Facilities, Scenarios V1 and V2

Fuel Damage

For scenarios V1 and V2, failure in the shaft and hoisting facilities is assumed to result in a fuel container being dropped down the shaft. Since the velocity at impact for this accident is not known, all the fuel elements in the disposal container are assumed to fail as a result of the accident, and each disposal container is assumed to contain 72 bundles (Johnson and LeNeveu 1993). Assuming 37 fuel elements per bundle, the total number of failed fuel elements for accident scenarios V1 and V2 becomes 2 664.

A permanent sump filled with water is installed at the bottom of the waste shaft. This should control the release of any fuel particulates if the container cask is dropped. However, the analysis of these accident scenarios has not taken any credit for the mitigating effect of the water in this sump.

The number of fuel element failures for each of the accident scenarios is summarized in Table 6-21.

TABLE 6-21
Number of Fuel Element Failures for the Accident Scenarios

Accident Scenario	Number of Failed Fuel Elements
S1/S2	2 131
S3/S4	710
V1/V2	2 664

Frequency of Occurrence

The initiating event for accident scenarios V1 and V2 is the drop of a fuel disposal container down the shaft. The only event included in V1 is the initiating event. The event sequence for V2 includes a failure of the ventilation system so that the ventilation exhaust is released unfiltered.

An extensive review of shaft hoisting facilities for heavy casks (up to 85 tons) has been done by Hartje et al. (1988). The study included 110 facilities, of which 93 were analyzed in detail. The results show that a shaft hoisting system similar to the one proposed for the UFDC (Simmons and Baumgartner 1994) has no unusual requirements and that the appropriate technology for such a system is fully developed. The proposed design of the UFDC has several advantages with respect to most of the systems surveyed (for example, lower travel velocity, shorter

shaft). A survey of mining data on equipment failures and human error contributions to mining accidents was prepared for the USNRC (1987) for the purpose of developing a data base.

The frequency of an accident involving a transfer cask falling down a mine shaft was determined to be 4×10^{-3} a^{-1}. An evaluation of the same event using analytical methods was carried out by USNRC (1987). The analysis considered initiating events such as human error, electrical and mechanical brake failures, hoist cable failures, and structural failures of the hoist and cage assembly. The results indicated a median occurrence frequency of 4.05×10^{-3} a^{-1}. Therefore, the hoist failure frequency is assumed to be 4×10^{-3} a^{-1}.

Loss of filtration in the waste shaft ventilation exhaust is taken to have the same probability as for the surface facilities (USNRC 1987).

6.1.2.5 Analysis Results

1) Individual Doses

The doses to the critical group, namely an individual adult and infant residing at the UFDC boundary, are listed in Table 6-22 for each potential accident scenarios. The loss of filtration scenarios (S2, S4 and V2) resulted in whole body doses more than 2 orders of magnitude greater than those for the scenarios where filtration is preserved (S1, S3 and V1).

Adult and infant whole body doses were calculated to be between about 10^{-7} and 10^{-4} Sv, depending on the operation of the HEPA filters. Thyroid doses varied between about 10^{-8} and 10^{-7} Sv. The largest individual dose was 2.5×10^{-4} Sv, the whole body dose to an infant from accident scenario V2. For accidents S1, S3 and V1, the critical group, that is the group with the largest predicted dose, was an adult. For accidents S2, S4 and V2, the critical group was an infant.

TABLE 6-22
Individual Doses Calculated for
Potential Accident Scenarios

Accident	Total Whole Body Dose (Sv)		Total Thyroid Dose (Sv)	
Scenario	Adult	Infant	Adult	Infant
S1	2.3×10^{-7}	2.0×10^{-7}	1.7×10^{-7}	1.0×10^{-7}
S2	1.3×10^{-4}	2.0×10^{-4}	3.1×10^{-7}	1.5×10^{-7}
S3	7.7×10^{-8}	6.7×10^{-8}	5.6×10^{-8}	3.4×10^{-8}
S4	4.4×10^{-5}	6.5×10^{-5}	1.0×10^{-7}	5.0×10^{-8}
V1	2.9×10^{-7}	2.5×10^{-7}	2.1×10^{-7}	1.3×10^{-7}
V2	1.6×10^{-4}	2.5×10^{-4}	3.9×10^{-7}	1.9×10^{-7}

Given that the predicted doses to adults and infants were similar for the same accident scenario, and that the predicted doses were similar between accident scenarios S1/S2 and V1/V2, then the adult doses from accident scenarios S1 and S2 can be used to illustrate the key pathways and

radionuclides, and the differences between accidents with and without filtration. The adult whole body doses from accident scenarios S1 and S2 are listed in Tables 6-23 and 6-24, respectively.

The dose results indicate that inhalation is the critical pathway during an accidental release of radionuclides from the UFDC. For accident scenario S1, the critical radionuclide was found to be ^{3}H, which accounted for 62% of the total dose. For accident scenario S2, the critical radionuclides were ^{241}Am, ^{241}Pu, ^{240}Pu and ^{239}Pu, which accounted for 89% of the total dose.

The thyroid dose was relatively insensitive to the presence or absence of particulate filtration since most of the thyroid dose was due to exposure to ^{3}H.

2) Collective Dose

The collective doses to the population surrounding the UFDC from the postulated accident scenarios are listed in Table 6-25. As in the case of the individual doses, the accident scenarios that included the loss of filtration (scenarios S2, S4 and V2) had whole body doses that were more than 2 orders of magnitude greater than the doses from those accidents with filtration (scenarios S1, S3 and V1).

The collective dose within 100 km of the UFDC for the accident scenarios under consideration varied from about 10^{-5} to 10^{-1} person-Sv. The largest collective dose to the population was estimated to be 4.5×10^{-2} person-Sv from accident scenario V2, the dropped fuel container in the vault and ventilation system failure. However, the collective dose from accident scenario S2 was similar in value to scenario V2 and thus either S2 or V2 can be used to illustrate the collective dose in greater detail.

The collective dose and the affected area and population from accident scenario S2 are given in Table 6-26. As for individual doses, the dominant pathway for collective dose was inhalation.

The results from Table 6-26 indicate that about 72% of the collective dose occurs within 16 km of the UFDC based on the distribution of the reference environment population. While the plume area is increasing with radial distance from the UFDC, the radionuclide concentration is decreasing and the population density is assumed to be decreasing with radial distance (Grondin and Fearn-Duffy 1993a). This assumption is conservative since a higher population density close to the facility will expose more people to a higher radionuclide concentration and thus a higher collective dose.

3) Comparison with Regulatory Criteria

The estimated annual frequency and the associated accident Event Class of the six postulated accident scenarios at the UFDC are given in Table 6-27. The accidents were either Class 2 or 3, with the exception of scenario S3 which was Class 1.

Since the thyroid doses were found to be less than the whole body doses, the whole body doses to the critical group (adult and infant at the boundary) can be used to test compliance with the public safety guidelines (see critical group dose criteria listed in Table 6-17). All doses to the critical group were found to be a small fraction of the proposed dose limits.

Long-term exposure doses are discussed in the sensitivity analysis (Chapter 9).

TABLE 6-23
Adult Whole Body Dose from Accident Scenario S1*

Radionuclide	Adult Whole Body Dose (Sv)		
	Immersion	Inhalation	Groundshine
^{3}H	0.0	1.4×10^{-07}	0.0
^{14}C	7.6×10^{-16}	5.5×10^{-13}	3.8×10^{-14}
^{55}Fe	6.8×10^{-21}	1.0×10^{-15}	1.9×10^{-19}
^{60}Co	8.1×10^{-18}	1.3×10^{-15}	7.8×10^{-17}
^{59}Ni	4.5×10^{-23}	9.4×10^{-19}	2.7×10^{-21}
^{63}Ni	0.0	3.2×10^{-16}	0.0
^{85}Kr	4.8×10^{-08}	0.0	0.0
^{90}Sr	1.0×10^{-14}	1.6×10^{-09}	1.3×10^{-12}
^{94}Nb	8.6×10^{-24}	4.1×10^{-21}	9.0×10^{-23}
^{106}Ru	2.4×10^{-15}	9.4×10^{-12}	5.3×10^{-13}
^{125}Sb	4.8×10^{-15}	3.3×10^{-13}	5.4×10^{-14}
^{125m}Te	3.1×10^{-17}	3.4×10^{-14}	1.1×10^{-15}
^{129}I	1.1×10^{-17}	5.7×10^{-13}	7.9×10^{-16}
^{134}Cs	3.9×10^{-14}	1.4×10^{-12}	1.7×10^{-13}
^{137}Cs	5.9×10^{-13}	4.0×10^{-11}	2.7×10^{-12}
^{144}Ce	2.6×10^{-16}	2.6×10^{-12}	8.8×10^{-15}
^{147}Pm	4.1×10^{-17}	2.0×10^{-11}	6.4×10^{-15}
^{154}Eu	3.0×10^{-14}	2.2×10^{-11}	3.1×10^{-13}
^{155}Eu	5.7×10^{-16}	7.1×10^{-13}	7.0×10^{-15}
^{234}U	3.2×10^{-21}	3.2×10^{-12}	1.9×10^{-19}
^{238}U	2.2×10^{-21}	3.5×10^{-12}	1.8×10^{-19}
^{238}Pu	7.6×10^{-19}	2.7×10^{-09}	6.2×10^{-17}
^{239}Pu	1.0×10^{-18}	6.2×10^{-09}	5.3×10^{-17}
^{240}Pu	2.1×10^{-18}	8.5×10^{-09}	1.7×10^{-16}
^{241}Pu	1.1×10^{-18}	9.3×10^{-09}	1.8×10^{-17}
^{241}Am	2.7×10^{-16}	1.1×10^{-08}	5.0×10^{-15}
^{242m}Am	9.5×10^{-21}	8.5×10^{-12}	4.9×10^{-19}
^{244}Cm	1.1×10^{-19}	2.3×10^{-10}	8.7×10^{-18}
Total:	4.8×10^{-08}	1.8×10^{-07}	5.1×10^{-12}

Total Dose from all Pathways: 2.3×10^{-7} Sv

* Accident Scenario S1 - Scissors Lift Failure.

TABLE 6-24
Adult Whole Body Dose from Accident Scenario S2*

Radionuclide	Adult Whole Body Dose (Sv)		
	Immersion	Inhalation	Groundshine
^{3}H	0.0	1.4×10^{-07}	0.0
^{14}C	7.6×10^{-16}	5.5×10^{-13}	3.8×10^{-14}
^{55}Fe	2.3×10^{-17}	3.5×10^{-12}	6.3×10^{-16}
^{60}Co	2.7×10^{-14}	4.3×10^{-12}	2.6×10^{-13}
^{59}Ni	1.5×10^{-19}	3.1×10^{-15}	9.0×10^{-18}
^{63}Ni	0.0	1.1×10^{-12}	0.0
^{85}Kr	4.8×10^{-08}	0.0	0.0
^{90}Sr	3.4×10^{-11}	5.4×10^{-06}	4.3×10^{-09}
^{94}Nb	2.9×10^{-20}	1.4×10^{-17}	3.0×10^{-19}
^{106}Ru	8.1×10^{-12}	3.1×10^{-08}	1.8×10^{-09}
^{125}Sb	1.6×10^{-11}	1.1×10^{-09}	1.8×10^{-10}
^{125m}Te	1.0×10^{-13}	1.1×10^{-10}	3.8×10^{-12}
^{129}I	1.1×10^{-17}	5.7×10^{-13}	7.9×10^{-16}
^{134}Cs	1.3×10^{-10}	4.7×10^{-09}	5.5×10^{-10}
^{137}Cs	2.0×10^{-09}	1.3×10^{-07}	8.9×10^{-09}
^{144}Ce	8.8×10^{-13}	8.6×10^{-09}	2.9×10^{-11}
^{147}Pm	1.4×10^{-13}	6.5×10^{-08}	2.1×10^{-11}
^{154}Eu	1.0×10^{-10}	7.4×10^{-08}	1.0×10^{-09}
^{155}Eu	1.9×10^{-12}	2.4×10^{-09}	2.3×10^{-11}
^{234}U	1.1×10^{-17}	1.1×10^{-08}	6.3×10^{-16}
^{238}U	7.4×10^{-18}	1.2×10^{-08}	6.0×10^{-16}
^{238}Pu	2.5×10^{-15}	9.1×10^{-06}	2.1×10^{-13}
^{239}Pu	3.4×10^{-15}	2.1×10^{-05}	1.8×10^{-13}
^{240}Pu	7.0×10^{-15}	2.8×10^{-05}	5.6×10^{-13}
^{241}Pu	3.8×10^{-15}	3.1×10^{-05}	6.0×10^{-14}
^{241}Am	9.1×10^{-13}	3.6×10^{-05}	1.7×10^{-11}
^{242m}Am	3.2×10^{-17}	2.8×10^{-08}	1.6×10^{-15}
^{244}Cm	3.6×10^{-16}	7.8×10^{-07}	2.9×10^{-14}
Total:	5.0×10^{-08}	1.3×10^{-04}	1.7×10^{-08}

Total Dose from all Pathways: 1.3×10^{-4} Sv

* Accident Scenario S2 - Scissors Lift Failure and Ventilation System Failure.

TABLE 6-25
Collective Dose

Accident Scenario	Collective Dose (person-Sv)
S1	6.4×10^{-5}
S2	3.6×10^{-2}
S3	2.1×10^{-5}
S4	1.2×10^{-2}
V1	8.0×10^{-5}
V2	4.5×10^{-2}

TABLE 6-26
Collective Dose for Accident Scenario S2

No.	Radial Interval (km)	Area (km^2)	Exposed Population (persons)	Collective Dose (person-Sv)
1	1.5 - 4	1.5	350	1.0×10^{-2}
2	4 - 8	4.5	1090	1.2×10^{-2}
3	8 - 16	15	830	4.0×10^{-3}
4	16 - 24	22	690	1.9×10^{-3}
5	24 - 32	28	850	1.6×10^{-3}
6	32 - 40	32	900	1.4×10^{-3}
7	40 - 60	98	2400	2.7×10^{-3}
8	60 - 80	120	1900	1.6×10^{-3}
9	80 - 100	140	1500	1.0×10^{-3}
	Total:	460	10600	3.6×10^{-2}

TABLE 6-27
Accident Frequencies and Event Classes

Accident Scenario	Accident Frequency (a^{-1})	Accident Event Class	Critical Group Dose (Sv)	Fraction of Dose Limit
S1	2.1×10^{-3}	2	2.3×10^{-7}	4.6×10^{-5}
S2	1.6×10^{-4}	3	2.0×10^{-4}	6.7×10^{-3}
S3	2.6×10^{-2}	1	7.7×10^{-8}	1.5×10^{-4}
S4	2.0×10^{-3}	2	6.5×10^{-5}	1.3×10^{-2}
V1	4.0×10^{-3}	2	2.9×10^{-7}	5.8×10^{-5}
V2	3.0×10^{-4}	3	2.5×10^{-4}	8.3×10^{-3}

4) Comparison with Emergency Response Protection Action Levels (PALs)

The estimated doses, for each accident scenario, can be compared with the Protective Action Levels (see Table 2-11) to determine if any protective measures would be required.

The worst possible scenario (V2) has a maximum possible infant whole body dose of 0.25 mSv. The lowest action level, corresponding to a ban on food and water consumption, would be triggered at a dose level above 0.5 mSv. Thus, comparison with the PALs shows that none of the protective measures would be justified.

6.1.2.6 Mitigation Measures

The Province of Ontario has a Nuclear Emergency Plan (Government of Ontario 1986) that has been designed to manage accidents at its nuclear reactor sites. The application of this plan to a nuclear emergency occurring at the UFDC is discussed in Chapter 2.

At the UFDC, it is expected that a Nuclear Emergency Plan would be developed to protect the health and safety of the population surrounding the facility. In the event of an accidental release of radioactivity from the site, the Plan would be activated and the appropriate actions, monitoring and clean-up measures would be implemented.

6.2 POTENTIAL IMPACTS OF THE UFDC ON WORKERS - NORMAL OPERATION

This section presents an analysis of potential impacts of the Used Fuel Disposal Facility (UFDC) during normal operation. Details of the analysis are contained in Zeya (1993a). The analysis is based on the reference conceptual design prepared by AECL (Simmons and Baumgartner 1994; AECL CANDU et al. 1992) and relevant industrial experience. The analysis also assumes that the implementation agency would have an occupational health and safety policy for operation of the facility. An example of such a policy is presented in Appendix H.

Employees may be exposed to low-level releases from ventilation systems and to low radiation fields from arriving transportation casks. However, only employees whose duties require operating, maintaining and servicing equipment related to used fuel disposal would be exposed to radiological hazards.

6.2.1 Analysis Methodology

The first step in the occupational safety assessment was to identify the specific radiological and non-radiological (conventional) hazards to workers during operation of the UFDC. This was accomplished mainly through a detailed analysis of the activities associated with the UFDC operation.

An estimate of the exposure time (person-hours) to the identified hazards is then obtained from work estimates for different labour groups (Section 2.1.1.5) and from comparison with similar experience from other industries. To be conservative, it was assumed that the same workers would be performing the various tasks, every shift for 50 weeks per year. Regulatory requirements, limits, guidelines or procedures for performing the tasks that impact on worker safety were identified.

The identified hazards were quantified where possible, based on the ICRP risk factor for radiological hazard and based on risk factors for both injuries and fatalities per 10^8 person-hours worked, in accordance with standard accident reporting techniques.

6.2.2 Analysis Limitations

Because of the conceptual nature of the design, a full occupational safety analysis could not be carried out. Assumptions on the amount of shielding provided in certain parts of the facility, detailed work routines and labour requirements were made to supplement the reference design data. Estimates of labour requirements associated with equipment inspection and maintenance activities and division of occupational activities into those involving both radiological and non-radiological work versus those involving non-radiological work only, were carried out. In addition, time estimates were made for "hands on" radiological work and activities in the vicinity of radioactive sources (compared to time spent at a desk in a non-radiological environment). Assumptions made for the analysis were mostly based on experience at nuclear power generating stations, and are documented in Petras and Zeya (1989), and Zeya (1993a).

6.2.3 Standards, Targets and Guidelines

Radiological Hazards

Limits on worker exposure to ionizing radiation are established by the Atomic Energy Control Board of Canada (AECB 1978). At present, the AECB requires that no atomic radiation worker (ARW) be exposed to a radiation dose equivalent of more than 50 mSv over a one-year period. This is likely to change in the near future. The AECB has proposed to lower the limit of radiation dose for ARWs to 20 mSv per year (AECB 1991a). The lower limit of 20 mSv per year has been adopted by Ontario Hydro at its nuclear generating stations. To ensure that regulatory dose limits are not exceeded, administrative limits for radiation exposure place restrictions on workers. Doses are checked by using personal radiation dosimeters. It is anticipated that the final UFDC design would incorporate requirements to follow the ALARA Principle for radiation dose optimization. This principle states that radiation exposure to workers are to be kept "as low as reasonably achievable (ALARA)", taking into account social and economic constraints.

Radiation exposures can be reduced by establishing exposure levels which employees may not exceed and by ensuring that every effort is made in support of this objective.

Non-Radiological Hazards

Regulatory requirements on non-radiological hazards are included in the Occupational Health and Safety Act of Ontario (Government of Ontario 1990c). It is assumed that underground activities would be governed by Regulation 854 of the Act. Labour Canada would also have jurisdiction in the health and safety of workers at the facility. Assuming the facility was located in the Ontario portion of the Canadian Shield, an agreement would be required between the various level of governments assigning responsibility for the occupational health and safety of workers at the UFDC. A similar agreement exists at the nuclear generating stations in Ontario by which Labour Canada delegates its jurisdictional rights to the Ontario Ministry of Labour. Ontario Hydro standards and guidelines also provide a wide range of methods that can be used to assess conventional hazards and meet the regulations. Ideally, high standards of safety set by crown corporations such as Ontario Hydro and the Atomic Energy of Canada Limited, should be considered as targets for the level of safety at the UFDC.

The Workers Compensation Board's definition of "loss time injury" was used in the analysis. It applies to work injury or illness that prevents an employee from performing all of the duties connected with his/her regular work on any shift subsequent to the shift on which the injury occurred.

6.2.4 Radiological Impact Analysis

1) Hazard Identification

Chronic radiological hazards associated with UFDC operation can occur from the moment used fuel transportation casks arrive at the disposal facility, during the used fuel immobilization process, and during emplacement of used fuel in underground boreholes. An overview of work activities associated with operation of the UFDC is shown in Figure 6-10. A more detailed chart is available in R-Facility for Figure 6-10. Table 6-28 lists the identified hazards for UFDC activities.

Radiological hazards to workers during operation of the facility are associated with external and internal exposures to radiation. Exposure to external radiation would arise from handling of transportation casks and of used fuel containers, as well as from surface and airborne contamination. Used fuel handling operations at the UFDC make extensive use of robotic or remote handling tools and take place in shielded facilities.

Hazards from airborne radionuclides and loose contamination may be present during the operation stage of the UFDC. Ventilation systems would be designed so that air would flow from zones of lower potential radioactive contamination to zones of higher contamination. The spread of loose contamination can also be minimized by requiring workers to wear protective clothing in certain areas, and by providing hand and foot monitoring equipment at the boundaries of different radiological zones. Personnel contamination monitors would be located throughout the facility at zone boundaries (see Section 2.1.4.8) and other strategic points to detect and prevent the movement of radioactive contamination. The portal monitors, located between zone 1 and zone 2, would sound an alarm in a control room as well as at the monitor. Atomic radiation workers, who are allowed to enter the "property boundary areas", are subjected to special health supervision and individual monitoring for both external and internal exposures.

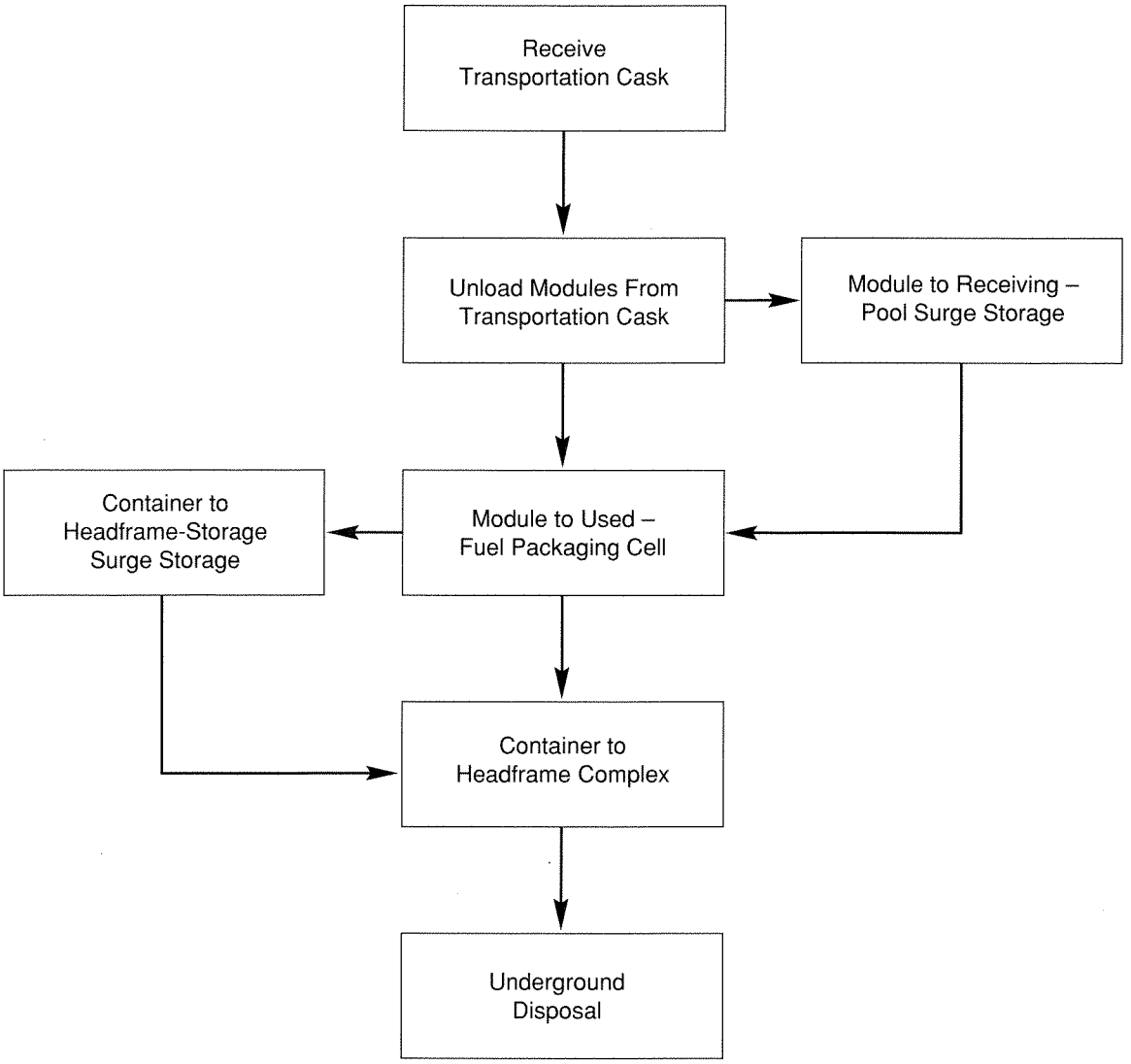


FIGURE 6-10: Work Activities at the UFDC

TABLE 6-28
List of Occupational Radiological Hazards Associated with Normal Operation of the UFDC

A) SURFACE ACTIVITIES
Transport Cask Receiving/Shipping - external radiation dose during handling of road and rail casks in the cask receiving/shipping area - exposure to the ambient radiation field in the cask receiving/shipping area - contact dose during cask inspection activities
Transport Cask Storage - external radiation dose and ambient radiation field dose during cask handling in the full (containing used fuel) cask laydown area
Transport Cask Handling - external dose during activities such as guiding the casks to supporting trolleys, connecting hoses to vent the full casks, linking the overhead crane and impact limiters on full casks - exposure to the ambient radiation field in the cask handling accessible area - external dose during cask decontamination
Used Fuel Handling - no radiological hazard would occur since fuel handling would be done by robot C and remote handling methods
Used Fuel Temporary Storage - exposure to the ambient radiation field (water provides shielding from direct external radiation from the used fuel) - exposure to airborne contamination from drying used fuel modules
Used Fuel Immobilization - no radiological hazard would occur since fuel handling would be done remotely by robot C and remote handling methods (including container repair). Containers would be repaired by similar remote means.
Disposal Container Handling - exposure to ambient radiation field when transporting the containers from the headframe area to either the temporary storage area or the waste shaft.
B) UNDERGROUND ACTIVITIES
Transport of Disposal Containers - exposure to ambient radiation field at the bottom of the waste transport shaft - airborne radiological hazards from the natural background radiation (radon and its daughters) would be negligible since the airborne contamination would be removed by the ventilation system
Emplacement of Disposal Containers - external radiological hazard to workers from shielded casks and groundshine from boreholes containing disposal containers. - airborne contamination in the event of the premature failure of a container
Retrieval of Disposal Containers - external radiological hazard to workers from boreholes containing disposal containers, from shielded casks and from contaminated buffer and backfill material.

During emplacement of a used fuel container in the disposal room, the container handling equipment and the rock and sealing materials provide shielding from external radiation from the container.

Natural radiation from radon gas and its daughters, which are emitted from the rock mass, would be monitored on a continuous basis. The ventilation system would be designed to provide sufficient airflow for the dilution of radon gas and daughter products to acceptable limits. Radon gas emissions from the plutonic rock mass should be much less than for uranium mines and the ventilation flow required for the operation of diesel-powered equipment should be sufficient to keep radon concentrations below acceptable limits (Simmons and Baumgartner 1994). Exposure to radon should, therefore, be negligible and is not included in the dose estimates.

Emissions from disposal containers (in a sealed room) that failed prematurely, as discussed in Sections 6.1.1.3 and 6.1.2.3, can also constitute a hazard to workers during the operation stage. Permeation of radionuclides could occur through the buffer and the backfill material inside the disposal room and could be transported towards the panel tunnels. Dissolved radionuclides could then be resuspended and transferred to other locations via the vault ventilation system. Methods to minimize occupational dose to workers are devised in case such a failure occurs. Fixed area-radiation monitors would be provided in all locations where radioactive materials are handled. Appropriate alarms indicating a high level of radiation or a high rate of increase of radiation level would also be provided. Air and water samples from the underground vault can be monitored to ensure an early warning of a premature failure.

Hazard to workers could arise during retrieval activities (see Chapter 8). Monitoring procedures would be instituted to detect contaminated material, and special procedures and equipment would be developed to segregate and handle this material. Ventilation and other services would be re-established as necessary. A remotely-operated core drill (Simmons and Baumgartner 1994), enclosed within a shielded housing, would be used for container removal from the borehole to minimize occupational dose. Retrieved container handling would be done remotely in a hot cell. The hazards associated with the retrieval operation are, therefore, expected to be similar to hazards during disposal container emplacement.

2) Quantifying Hazards

Doses estimated from receiving the transportation cask at the UFDC were calculated based on road casks handling only. This is a conservative assumption because road casks contain less bundles than rail casks and, therefore, require more handling for the same amount of used fuel transported. The transportation cask is designed to a 0.23 $mSv \cdot h^{-1}$ contact dose on the top and bottom of the cask and for 0.18 $mSv \cdot h^{-1}$ on the sides. Performing these activities on 938 casks per year would result in extremity doses to workers. The proposed regulatory limit for extremity dose is 500 mSv per worker per year. The extremity dose resulting from cask receiving is expected to be lower than 500 mSv per worker.

External radiation is the principal contributor to radiation exposure from used fuel. Surface and airborne contamination only contribute to the ambient radiation field. Internal radionuclide uptake would be kept to a minimum because work areas with projected high levels of airborne radionuclides are inaccessible to workers under normal operating conditions. For example, workers would enter the Used Fuel Packaging Cell (UFPC) only when repairs are planned. In that case, personal air-supplied protective clothing would be worn to prevent individuals from

inhaling airborne particulates and gases. Most of the routine work activities at the UFDC would be carried out by Engineer/Technical (Operators). This will include initial radiation surveys of full transportation casks, rigging and movement of transportation casks into different areas of the UFDC, decontaminating empty transportation casks, operating remote controls for Used Fuel Packaging Plant activities, transporting disposal containers and underground disposal activities. Routine maintenance and repairs would be carried out by Trades (Mechanics), and these activities would include electrical as well as mechanical repairs on equipment such as overhead cranes, inclined elevators and fuel handling/transfer mechanisms. Support staff of the facility would be involved in activities such as radiation control, service maintenance, general decontamination, disposal container fabrication and other support work. Management and Professionals would plan, supervise and audit radiological and non-radiological work at the UFDC. The annual collective dose estimates for routine activities, including service, repair and maintenance activities, are given in Table 6-29 and summarized in Table 6-30 (Zeya 1993a).

Based on the estimated annual collective dose equivalent for UFDC activities given in Table 6-30 and the labour requirements from the reference design (AECL CANDU et al. 1992), the maximum and average individual external doses received by each category of worker at the UFDC is estimated by making a conservative assumption that the same individuals would carry out assigned activities in each area of the UFDC on every shift for 50 weeks a year. Results are shown in Table 6-31 (Zeya 1993a).

The estimates of average radiation doses vary between 0.3 and 9 mSv per year according to the work group. Although very conservative, they are still lower than the regulatory dose limits of 50 mSv per year and proposed 20 mSv per year (AECB 1991b) for atomic radiation workers. Internal radiation dose would be strictly due to airborne radon. The underground ventilation system in the conceptual facility design is based on a requirement to keep radon concentrations well below the threshold values to maintain a safe working environment for all underground personnel (AECL CANDU et al. 1992).

A summary of radiological risks in terms of fatalities is presented in Chapter 11.

6.2.5 Non-radiological Impact Analysis

1) Hazard Identification

The chronic non-radiological hazards from UFDC operation result from activities such as moving heavy objects, light manufacturing activities (basket and container fabrication), and materials handling (rock crushing and particulate transfer).

TABLE 6-29

Used Fuel Disposal Centre Routine Operations
Annual Collective Dose Estimates

Area/Activity	Person-hours	Distance from the cask (m)	Dose Rate ($mSv \cdot h^{-1}$)	Annual Collective Dose (person-$mSv \cdot a^{-1}$)
Transporter Shipping/Receiving Area				
a) Normal Operation	10 800	0.5 to 10 Ambient Field	0.001 to 0.0345	197.4
b) Service and Maintenance	350	Ambient Field	0.02	7.0
c) Repairs	28	Ambient Field	0.02	0.6
Full Cask Laydown Area				
a) Normal Operation	3 680	0.5 to 10 Ambient Field	0.001 to 0.1	337.6
b) Service and Maintenance	42	Ambient Field	0.1	4.2
c) Repairs	28	Ambient Field	0.1	2.8
Decontamination Area				
a) Normal Operation	7 360	0.5 to 10 Ambient Field	0.001 to 0.0345	21.5
b) Service and Maintenance	84	Ambient Field	0.0025	0.2
c) Repairs	28	Ambient Field	0.0025	0.1
Empty Cask Laydown Area				
a) Normal Operation	2 530	Ambient Field	0.0025	6.3
b) Service and Maintenance	84	Ambient Field	0.0025	0.2
c) Repairs	28	Ambient Field	0.0025	0.1
Cask Handling Accessible Area				
a) Normal Operation	7 360	0.5 to 10 Ambient Field	0.001 to 0.0345	170.8
b) Service and Maintenance	42	Ambient Field	0.05	2.1
c) Repairs	28	Ambient Field	0.05	1.4
Module Handling Cell				
a) Repairs	117	Ambient Field	0.25	29.3
Surge Storage Receiving Pool				
a) Normal Operation	5 060	Ambient Field	0.005	25.3
b) Service and Maintenance	175	Ambient Field	0.005	0.9
c) Repairs	14	Ambient Field	0.005	0.1

continued...

TABLE 6-29 (concluded)

Area/Activity	Person-hours	Distance from the cask (m)	Dose Rate ($mSv \cdot h^{-1}$)	Annual Collective Dose (person-$mSv \cdot a^{-1}$)
Control Room				
a) Normal Operation	37 950	Ambient Field	0.0025	94.9
b) Service and Maintenance	100	Ambient Field	0.0025	0.3
c) Repairs	14	Ambient Field	0.0025	0.04
Access and Maintenance Room				
a) Normal Operation	26 284	Ambient Field	0.012	315.4
Basket/Container-Front End*				
a) Normal Operation	3 680	Ambient Field	0.0025	9.2
b) Service and Maintenance	100	Ambient Field	0.0025	0.3
c) Repairs	14	Ambient Field	0.0025	0.04
Basket/Container-Back End**				
a) Normal Operation	1 380	Ambient Field	0.025	34.5
b) Service and Maintenance	100	Ambient Field	0.025	2.5
c) Repairs	14	Ambient Field	0.025	0.4
Headframe Surge Storage Pool				
a) Normal Operation	4 830	Ambient Field	0.012	58.0
b) Service and Maintenance	175	Ambient Field	0.012	2.1
c) Repairs	14	Ambient Field	0.012	0.2
Headframe Area				
a) Normal Operation	9 430	0.3 to 1 Ambient Field	0.01 to 0.02	179.1
b) Service and Maintenance	42	Ambient Field	0.02	0.8
c) Repairs	42	Ambient Field	0.02	0.8
Underground: Transport of Disposal Containers				
a) Normal Operation	4 110	0.3 to 1 Ambient Field	0.0007 to 0.02	222.7
Underground: Emplacement of Disposal Containers				
a) Normal Operation	8 788	0.3 to 1 Ambient Field	0.0007 to 0.02	50.0

* Front-end: assembly line

** Back-end: inspection/storage/retrieval

TABLE 6-30
Summary of Collective Dose to Workers
Routine Activities

Activity	Estimated Annual Collective Dose (person-Sv·a^{-1})
Operation	1.379
Service and Maintenance	0.021
Repairs	0.036

TABLE 6-31
Distribution of Maximum Individual Annual
Dose to Workers

Job Category	Estimated Dose (mSv·a^{-1})	
	Maximum	Average
Management and Professional	10	0.3
Engineer/Technical (Operators)	17	2.0
Trades (Mechanics)	17	9.2
Support Staff (service maintainers, sheet metal workers)	6	0.5

Transporters arriving at the transportation cask receiving area would emit diesel fumes. Most affected areas are: truck bays, truck maintenance areas and inside the truck cab. The workers at risk are the cask handling personnel, drivers and maintenance crew.

Employees working in the basket fabrication area would be subjected to airborne pollutants during the operation stage. Chemical fumes from acid pickling/passivating processes, as well as from welding, could affect them. Handling of the hazardous materials used at the UFDC (see list in Table 2-7) could be a source of hazard if proper handling procedures are not followed.

Dust in the rock crushing plant would be an inherent and chronic hazard for workers in that location. Chronic exposure to dust can result in silicosis.

Noise and vibration from metal stamping machines in the basket and container fabrication area could adversely affect the UFDC workers assigned to this area.

2) Quantifying Hazards

At this conceptual design stage, it is not possible to quantify the non-radiological hazards to which workers would be exposed during normal operation of the UFDC.

The extent of airborne pollution from the chemical fumes from the acid passivating process, as well as from welding, would depend largely upon the efficiency of the ventilation system. Air quality can be controlled (American Industrial Hygiene Association 1982).

Workers involved in the operation of the crushing plant would be required to wear suitable eye, hearing and breathing protection (Simmons and Baumgartner 1994).

Typical levels of noise and vibration from metal stamping machines in the basket and container fabrication area cannot be derived at this conceptual design stage. Normal industrial practice of wearing hearing protection devices can be made mandatory in areas with excessive noise levels.

The quantity of hazardous materials in occupied areas would be restricted to limit the potential exposures received by individual workers to an acceptable minimum based on 2 000 hours of occupancy per year.

6.2.6 Mitigation Measures - Normal Operation

As described in Section 6.1 and in accordance with current practice at the nuclear generating stations (Kabir and Burchartz 1984), a formal occupational radiation management program to minimize occupational dose would be implemented. The radiation management program would establish an occupational radiation exposure target for the design, and a monitoring program would verify that the dose targets are not exceeded during operation. Specific dose reduction programs would be established to reduce personnel doses to "as low as reasonably achievable" (ALARA), with social and economic considerations being taken into account. Both external and internal individual doses would be assessed to check the effectiveness of the radiation control program.

Strict operating procedures would be developed to protect the workers from radiological and non-radiological hazards.

An examination of the collective doses presented in Table 6-29 points to areas where design refinements would contribute the most to a reduction in dose. For example, the collective dose for activities performed in the full cask laydown area is the highest and has the highest average dose rate. Even though these numbers are based on conservative assumptions, additional shielding and a reduction in the time that workers spend in close proximity to the cask would help reduce the dose rate and the total dose. Similar refinements could be applied to transportation of the disposal containers underground, which also leads to high collective doses.

6.3 OCCUPATIONAL SAFETY ANALYSIS - ACCIDENT CONDITIONS

This section presents an analysis of potential impacts of the Used Fuel Disposal Facility (UFDC) on workers during accident conditions. Details of the analysis are contained in (Zeya 1993a).

6.3.1 Analysis Methodology

The approach used in this accident analysis is the same as used for the analysis of normal operation of the UFDC: hazard identification followed by hazard quantification.

The radiological accident scenarios identified and quantified in Section 6.1.2 for the public safety assessment are assumed to apply to workers. Assumptions are made about where workers are located at the time of the accident and about the time required by workers to evacuate the area.

The nature of acute non-radiological hazards is inferred from injury and fatality statistics associated with industries where tasks comparable to the UFDC activities are carried out using similar types of equipment. Forestry, construction, mining and light manufacturing industries are sources of statistical data on worker injuries and fatalities. Slipping and falling, being struck by moving objects, being caught in or between objects, involved in vehicle accidents, explosions and tripping accidents are the most common industrial accidents. Labour requirements specified by AECL (Section 2.1.1.5) were used to estimate conventional risks for UFDC employees.

6.3.2 Radiological Impact Analysis

1) Hazard Identification

System malfunctions leading to radiation incidents may result from equipment failures, operator errors, or external events. It is expected that the design features and the quality of the components would reduce the occurrence of these malfunctions to acceptable levels.

a) Surface Facility Accidents

Malfunctions of the equipment in the surface facilities may lead to release of radioactivity. Radiological accidents can occur during transportation cask handling activities. Examples are: dropping a transportation cask onto the floor of the receiving area; inadvertently removing the lid from a full transportation cask; transportation cask seal failure during inspection; and failure during venting of the transportation cask. The severity of the accident conditions specified in the transport regulations (and for which the cask design has passed the certification test) exceeds the severity of possible transportation cask accidents inside the UFDC site, as long as the transportation cask remained sealed. The accident scenario S1 involving an unsealed cask (described in Section 6.1.2) should have worse consequences on workers

than all the transportation cask handling accidents and, therefore, is the only transportation cask handling accident scenario analyzed in detail.

Radiological accidents can also occur in the Module Handling and Used Fuel Packaging Cells (MHC and UFPC respectively) (scenario S3 in Section 6.1.2), but because they are not accessible to workers during the used fuel immobilization process, workers would not be subjected to the high radiation doses at the accident location. Repairs would be made only after radioactive sources have been removed by remote handling tools. Failure of the airlock seals could, however, result in exposure of workers to radioactive materials released in the cask handling accessible area. Full analysis of such accidents necessitates detailed design data that is not available at this conceptual stage. Consequences are not expected to exceed those for accident scenario S1. The UFDC ventilation design divides the facility into different zones depending on the radiation field present (see Chapter 2), and ensures that air flows from zones of low radiation fields to zones of high radiation fields. In the case of an MHC or UFPC accident, combined with a ventilation system failure in the MHC or UFPC, the contaminated air would not flow to the non-contaminated areas and, therefore, workers there would not be affected. Exposure of workers in the event of such ventilation system failure would be limited by initial evacuation of the contaminated area and subsequent exposure control during clean-up and repair.

b) Underground Accidents

Acute radiological hazards to the UFDC workers during activities underground, may result from airborne radioactivity released following a disposal container failure. A worst case shielded cask handling accident in the underground vault is postulated which involves dropping a shielded cask down the waste shaft onto another cask (scenario V1 in Section 6.1.2). This accident could result in the rupture of shielded casks, damage to the fuel bundles and release of gaseous fission products. The radiological consequences of this for workers were analyzed. The implications of concurrent ventilation system failure are similar to those discussed under Surface Facility Accidents above.

2) Hazard Quantification

a) Accident in Cask Handling Accessible Area

The postulated radiological accident in this area (scenario S1) would be the result of a failure of the scissor lift. The unsealed transportation cask would drop on its side onto the floor damaging used fuel bundles. This results in the release of radioactive gases and particulates. In this accident scenario, two used fuel modules were assumed to be damaged. It is assumed that workers take one minute to evacuate the area. This assumption is conservative, based on a review of operating experience at nuclear stations. The whole body dose and thyroid dose to an individual worker were estimated at 16.5 mSv and 7.5×10^{-3} μSv, respectively, from the inhalation of radionuclides. An external radiation dose is not expected because the used fuel would be contained in the cask which provides appropriate shielding.

b) Underground Accident

The extremely pessimistic scenario for a radiological accident associated with underground activities involves dropping a full shielded cask (or transfer cask) down the waste shaft onto another full cask (scenario V1 in Section 6.1.2). The shielded cask would rupture and the release of radionuclides would follow. It is assumed that the container cask would

have been designed to ensure that no major loss of shielding would result from this type of accident. Here again, workers are assumed to evacuate the work area in one minute. On that basis, the radiation dose that would be received by workers at the bottom of the shaft is estimated to be 20.49 mSv per individual. Thyroid dose is estimated to be 9.3 x 10^{-3} μSv per worker. The pathway for the radiation dose is again through inhalation because workers would be unprotected at that work location. External radiation dose from such an accident would be negligible since it is postulated that only volatile radionuclides and particulates would be released. However, the presence of water in the sump at the bottom of the shaft would act to limit airborne particulate releases.

3) Significance of Dose Estimate

There is no regulatory limit on the occupational radiation dose under accident conditions. Occupational dose and dose rate design criteria for nuclear facilities provide guidance to the levels of radiation dose that would be acceptable under accident conditions. Radiation doses estimated for UFDC workers under accident conditions are below the current quarterly dose limit of 30 mSv per individual, which has been used as a guide to acceptable exposures for any emergency conditions at nuclear generating stations.

6.3.3 Non-Radiological Impact Analysis

The proposed drill-and-blast method is used routinely in mining and civil engineering projects in rocks similar to that proposed for the disposal vault. Ground control would be achieved by standard rock-bolting methods from scissor-lift trucks. It is not expected that massive rock bursts would occur in the underground vault (Simmons and Baumgartner 1994). Accident statistics of the mining industry, including minor rock bursts and rock falls, were used to calculate the risk in underground operations.

Estimated annual acute non-radiological risks to workers are presented in Table 6-32. Based on Ontario Workers Compensation Board and other industrial statistics (Myint 1989; Social Data Research 1986), up to 0.25 fatalities and 60 lost time injuries per year have been estimated for all operation stage activities. This is considered to be a conservative estimate. It is expected that a disposal facility for used nuclear fuel would achieve better than industry average worker safety, more comparable to that of crown corporations. For example, AECL experienced no worker fatality during 1.6 million person-hours worked to construct and operate their Underground Research Laboratory (Zeya 1993a).

6.3.4 Mitigation Measures - Accident Conditions

An alarm system would warn workers of detected hazardous occurrences such as fire, hazardous material releases, radioactive exposure and contamination. Specific detectors (e.g. smoke, heat, radiation monitors, etc.) are strategically located in all work areas to monitor the work place conditions. Audible, visible and/or odour alarms are provided to alert control room operations, physical security and fire protection staff, and radiation and industrial safety staff. A stench gas emergency warning system attached to the ventilation system would be provided as specified in the Ontario Mining Regulations (Government of Ontario 1990c).

TABLE 6-32
Estimated Annual Acute Non-radiological Risks during UFDC Operation Stage

Activity	Labour (person-hours·a^{-1})	Fatality Rate per 10^8 person-hours	Injury Rate per 10^8 person-hours	Annual Fatalities	Annual Injuries
SURFACE OPERATIONS					
Used Fuel Packaging Plant	170 200	20.1	6 540	0.034	11.1
Basket Fabrication	101 200	21.4	6 190	0.022	6.3
Container Fabrication	132 500	21.6	6 000	0.029	8.0
Utility Services	207 000	29.3	5 940	0.061	12.3
Maintenance Services	116 600	12.2	3 080	0.014	3.6
Protective Services	132 000	3.8	3 970	$5x10^{-3}$	5.2
Technical Support	33 100	4.6	4 360	$1x10^{-3}$	1.4
Admin. Services	22 100	3.3	110	$1x10^{-3}$	0**
TOTAL	915 000*	–	–	0.167	47.9
UNDERGROUND OPERATIONS					
EXCAVATION AND BACKFILL					
Shaft Facilities	32 700	30	4 180	0.01	1.4
Underground	7 400	30	4 470	$2x10^{-3}$	0.3
Ancillary Facilities					
EMPLACEMENT OPERATIONS					
Room Borehole Prep.	39 800	30	4 700	0.012	1.9
Borehole Emplacement	28 900	30	4 420	$9x10^{-3}$	1.3
Room Sealing	21 400	30	4 700	$6x10^{-3}$	1.0
Indirect Support	51 900	30	4 470	0.016	2.3
Capital Equipment	700	30	4 470	0**	0**
Project Indirects	104 900	30	4 470	0.031	4.7
TOTAL	287 600*	–	–	0.086	12.9
TOTAL FOR OPERATION		–	–	0.25 fatalities/year	60 injuries/year

* Numbers may not add up exactly because of rounding
** Due to rounding

Radiological Hazards

As mentioned in Section 6.1, emergency response plans would be established at the UFDC. Radiation protection training for workers and periodic drills to improve worker response would minimize radiation dose. Further, designated safe areas where workers can take shelter from hazards and the availability of personal protective equipment would add to worker safety. Some possible accidents have been identified in this study. This information can be incorporated into the design and planning process so that the probability and the consequences of these accidents are reduced, and to provide an initial basic plan to recover from the accidents if they do occur.

Non-radiological Hazards

The establishment and implementation of comprehensive employee training and safety programs, and of a Joint Health and Safety Committee to oversee the overall safety of the facility, would be prerequisites for UFDC operations (Chapter 2). Training programs for workers in conventional safety and the use of safety equipment would be an integral part of the orientation process for all employees. Formal training sessions would be set up and would include the use of specialized safety equipment as well as methods to identify and mitigate occupational hazards (see Appendix H). In addition, arrangements would be made for informal safety meetings where workers can discuss and exchange information and/or address occupational hazards.

The research and development of safety features, to reduce the injury rate (industry average) associated with some activities, is recommended. Application of the ALARA principle to the final design of the facility should help reduce the injury and fatality rates in all operational activities.

6.4 POTENTIAL NON-RADIOLOGICAL EFFECTS OF THE UFDC ON THE PUBLIC AND THE ENVIRONMENT

This section presents an analysis of potential non-radiological effects of the Used Fuel Disposal Facility (UFDC) on the natural environment. Details of the analysis are contained in (Grondin and Fearn-Duffy 1993b) and Russell (1993a) for the toxic chemical emissions (Section 6.4.3). The analysis is based on the reference conceptual design prepared by AECL (Simmons and Baumgartner 1994; AECL CANDU et al. 1992), environment parameters from the region-wide environment characterization presented in Chapter 3 and a review of relevant case studies (Grondin and Fearn-Duffy 1993a). The analysis assumes that the implementation agency would have an environmental protection policy similar to that presented in Appendix C.

6.4.1 Analysis Methodology

The analysis of effects on the natural environment follows the first two objectives of the Preclosure Assessment (see Section 1.1.2) in that it has an impact management focus: it is aimed at identifying possible effects and standard techniques that could be used to mitigate these effects.

TABLE 6-33
Typical Environmental Factors and Attributes

ENVIRONMENTAL FACTOR	ENVIRONMENTAL ATTRIBUTES
Air	Diffusion factor Particulates Sulphur oxides Hydrocarbon Nitrogen oxides Carbon monoxide Photochemical oxidants Hazardous toxicants Odour
Water	Aquifer safe yield Flow variations Oil Radioactivity Suspended solids Thermal pollution pH Biochemical oxygen demand (BOD) Dissolved oxygen (DO) Dissolved solids Nutrients Toxic compounds Aquatic life Fecal coliform
Land	Soil stability Natural hazard Land use patterns
Ecosystem/Flora and Fauna	Large animals Predatory birds Small game Fish, shell fish and water fowl Field crops Endangered species Natural vegetation Aquatic plants
Noise	Ambient level Natural barriers Noise sensitive zones
Non-renewable resources	Fuel resources Non-fuel resources Aesthetics Heritage resources

(Adapted from Jain et al. (1977))

Typically, the first step in a natural environment analysis is to characterize the existing environment, thus establishing baseline environmental conditions. Environmental attributes associated with such environmental factors as air, water, flora and fauna, are identified and characterized. This characterization is done in consultation with public, regulatory and technical stakeholders. An example of the type of environmental attributes and environmental factors included in a natural environment characterization is presented in Table 6-33 (Ontario Hydro 1990b). The second step is to review activities associated with the project and to identify which of the environmental attributes could be affected. Starting with these attributes, the scope of the natural environment analysis is normally determined in consultation with the potentially affected public, regulatory agencies and technical experts in forms such as workshops (see the valued ecosystem component approach outlined in Chapter 10).

The general methodology outlined above could not be used in this non site-specific natural environment analysis. First, the true baseline environmental conditions could not be established given the size of the study area (650 000 km^2). Instead, the environment characterization approach, outlined in Chapter 3, aimed to give as much context as possible to the assessment by describing, in general terms, the natural environment of the study area. This general description was compiled into a region-wide database for the Ontario portion of the Canadian Shield, and is documented in Grondin and Fearn-Duffy (1993a). Secondly, activities associated with the project were reviewed and possible effects identified, but the overall significance of the effects could not be determined without the ecological context and without input from the affected public, regulators and technical experts as would be done in a site-specific situation (see Chapter 10). However, as explained in Section 1.5.1.2, some degree of significance could be derived based on regulatory criteria, on the geographical extent, duration, frequency and reversibility of the change, and on a comparison with background levels.

In addition, case studies of related projects were used to provide some context to the identified potential effects. A list of these case studies is presented in Appendix D.

The analysis approach to be used during implementation is discussed in Chapter 10.

6.4.1.1 Identification of Interactions

Potential changes to the natural environment as a result of UFDC operation can be identified based on the region-wide environment data, the UFDC conceptual design, and a review of case studies of effects from industrial projects (a list of the case studies in the assessment is included in Appendix D). The following generic environmental factors were used in the analysis: ambient noise, air quality, water quality, land use, ecosystem/flora and fauna, and non-renewable resources. Although this choice of environmental factors is somewhat arbitrary, the separation of the natural environment in that fashion facilitates a systematic analysis.

Using a matrix system (Grondin and Fearn-Duffy 1993b), the potential interactions between the generic environmental factors and the activities at the facility during the operation stage are identified. The resulting interaction matrices are shown in Tables 6-34 to 6-41. Details of these interactions are given in (Grondin and Fearn-Duffy 1993b). Only those interactions identified as having a potential for effect on the environment are discussed in the following sections.

6.4.1.2 Criteria for Effect Evaluation

For the purpose of this analysis, an expected change to an environmental attribute was assumed to be an effect. As discussed in Section 1.5.1, the actual significance of the change cannot be determined without a specific site to study, ie. without the proper ecological context and without input from the potentially affected people.

Some degree of significance was nevertheless derived based on:

i) a comparison of the level of change with environmental criteria prescribed by the regulators;

ii) the geographical extent of the change;

iii) the expected duration and frequency of the change; and

iv) the degree to which the change is reversible and a comparison with natural background levels where available.

Table 1-2 presents a summary of the criteria used to indicate the significance of predicted effects.

6.4.2 Analysis of Effects

1) Groundwater Quality

(a) Dissolved Solids

Water samples collected from boreholes in mines and test drill holes in non-mineralised plutons in the Canadian Shield have revealed the presence of saline groundwater at depths as shallow as 300 m. In mines at depths below 1000 m, the salinity of the water is frequently very high, with total dissolved solids (classified as Ca-Na-Cl brine) often exceeding 200 $g \cdot L^{-1}$. These solutions are found in apparently closed pockets and in faults or fractures accessible by boreholes from the mines and are under high pressures. Discharges from boreholes into mines may range from seeps to litres per minute, which may last for days or many years (Frape and Fritz 1981; Frape, Fritz and Pearson 1981). At depths between 500 and 1000 m in non-mineralized plutonic rocks, groundwaters range in salinity from about 5 to 50 $g \cdot L^{-1}$ depending on location in the hydrogeological flow path (Gascoyne et al. 1987, Gascoyne 1988) and vary between Na-Ca-Cl and Ca-Na-Cl in composition.

Table 6-42 summarizes the average groundwater compositional ranges which may be initially encountered during the operation of the facility at 1000 m depth in a plutonic rock environment. Depending on location in the flow path, these salinity levels could be maintained throughout the preclosure period or may decrease because of dilution by fresher groundwater from the near-surface.

TABLE 6-34
Potential Interactions due to Used Fuel Processing Plant

ACTIVITY	ENVIRONMENTAL FACTORS					
	Noise	Air	Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Cask receiving	●	●			●	
Cask decontamination			●		●	
Module drying		●			●	
Surge storage receiving pool operation			●	●		
Fuel packaging		●				●
Diffusion bonding		●				
Helium leak test			●			●
Container rework	●	●	●			
Decontamination			●		●	
Headframe surge storage pool operation			●	●		

TABLE 6-35
Potential Interactions due to Other Surface Facilities

ACTIVITY	ENVIRONMENTAL FACTORS					
	Noise	Air	Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Operation of equipment in the shaft headframes and fan houses	●					
Rock crushing plant operation	●	●	●			
Rock disposal area operation	●	●	●	●		●
Buffer/backfill receiving and storage operations		●	●			
Concrete batching plant operation		●	●		●	
Warehouse/storage yard operation				●	●	
Waste and service shaft/hoisting and ventilation shaft operations	●	●				

TABLE 6-36
Potential Interactions Due to Basket/Container Fabrication

ACTIVITY	ENVIRONMENTAL FACTORS					
	Noise	Air	Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Materials receiving	●	●			●	●
Materials handling	●					
Planing	●	●	●			
Turret lathing	●	●	●			
Bending	●		●			
Drop hammering	●		●			
Drilling	●	●	●			
Rotary shear cutting	●	●	●			
Band sawing	●	●	●			
Vacuum heat treatment		●				
Welding		●	●			
Cleaning		●	●			

TABLE 6-37
Potential Interactions Due to Excavation of the Disposal Vault

ACTIVITY	ENVIRONMENTAL FACTORS						
	Noise	Air	Surface Water Quality	Underground Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Excavation of shafts	●	●	●	●		●	●
Excavation of access tunnels	●	●	●	●		●	●
Excavation of disposal rooms	●	●	●	●		●	●

TABLE 6-38
Potential Interactions Due to Used Fuel Emplacement

ACTIVITY	ENVIRONMENTAL FACTORS						
	Noise	Air	Surface Water Quality	Underground Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Installation of railtrack	●	●	●	●			
Borehole drilling	●	●	●	●			
Initial buffer emplacement	●	●	●	●			●
Augering of initial buffer	●	●	●	●			
Sand/final buffer emplacement		●	●	●			●
Removal of railtrack	●	●	●	●			
Backfilling	●	●	●	●			●
Bulkhead construction	●	●	●	●			●
Grouting of bulkhead			●	●			●

TABLE 6-39
Potential Interactions Due to Disposal Vault Ancillary Activities

ACTIVITY	ENVIRONMENTAL FACTORS						
	Noise	Air	Surface Water Quality	Underground Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Equipment operation for transfer cask handling	●	●					
Equipment maintenance activities	●	●	●				
Diesel fuel storage/filling		●	●				
Buffer/ backfill preparation operations		●	●				
Rock dumping and loading		●	●				
Explosive magazines		●	●				
Pumping facilities			●	●			

TABLE 6-40
Potential Interactions Due to Utility Services Activities

ACTIVITY	ENVIRONMENTAL FACTORS					
	Noise	Air	Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Water supply			●		●	
Compressed air supply	●	●				
Electrical system supply			●		●	
Communications system	●				●	
Control and instrumentation	●					
Heating, ventilation and air conditioning		●				
Waste water treatment			●		●	
Solid waste treatment				●	●	
Sewage treatment		●	●		●	

TABLE 6-41
Potential Interactions Due to Support Services

ACTIVITY	ENVIRONMENTAL FACTORS					
	Noise	Air	Water Quality	Land Use	Ecosystem/ Flora and Fauna	Non-Renewable Resources
Maintenance services		●	●		●	
Technical support laboratories		●	●			

TABLE 6-42
Summary of Compositional Ranges of
Groundwater at 1000 m Depth

Chemical Species	Concentration at 1000 m depth ($mg \cdot L^{-1}$)
Total Dissolved Solids	20 000 - 50 000
Cl	10 000 - 30 000
Na	1 000 - 10 000
Ca	1 000 - 10 000
SO_4	100 - 1 000
HCO_3	0 - 50
F	0 - 5
Br	30 - 200
pH	7 - 8.5

The vault drainage system would pump water from underground excavated areas to a settling pond on the surface. Some saline groundwater may be encountered which could not be discharged directly because its high salinity would affect the surface water quality. The quantity of such water is likely to be small. The total groundwater volume that would flow into an excavation would dilute high salinity water prior to discharge. Some salinity may be seen in the settling pond during excavation, derived from soluble salts and fluid inclusions in the rock matrix opened by blasting and drilling activities. Trace metal content(e.g. U) may also increase in pond water during the operational period due to the changing redox conditions of groundwater inflows. Treatment facilities can be set up to deal with these types of occurrences.

(b) pH Levels

The expected pH range of groundwater is shown in Table 6-42. The pH would tend to decrease, according to the test borehole analyses, as the vault excavations approach 1000 m, because salinity of the groundwater increases and the alkalinity decreases. This groundwater plus percolation of slightly basic runoff from the mined rock disposal area (see Section 5.3.2.3) would tend to neutralize any acidity encountered in surface runoff from the site.

(c) Groundwater

The presence of the underground vault may affect the flow characteristics of the groundwater. As described in Chapter 5, this effect could be mitigated.

2) Surface Water Quality

The main activities producing non-radioactive waste waters are listed in Tables 6-35 to 6-41. Waste waters are classified as either radioactive or non-radioactive, and treated so that discharge into surface waters

does not cause a water quality problem. Waste water treatment methods described in Chapter 2 would ensure that surface water quality would not be affected by operation of the UFDC.

3) Air Quality

Facilities that do not contain significant quantities of hazardous materials, or where hazardous materials present do not have the potential to contaminate the building air, are provided with ventilation systems discharging directly to the environment. Other facilities are equipped with filtration systems as described in Chapter 2.

Rock would be crushed in an enclosed building equipped with a baghouse to collect dust.

Vehicles (see Table 6-45) would use paved roads and should, therefore, be a negligible source of particulate emissions. Grondin and Fearn-Duffy (1993b) show that these particulate emissions and emissions from the vehicles' diesel engines are a small fraction of the regional emissions.

Wind erosion of the waste rock pile could be a source of dust emissions. Erosion potential would vary according to the following characteristics:

i) Moisture content of the granite (erosion is inversely proportional to moisture content);

ii) Extent of crushing of the mined rock (erosion is inversely proportional to particle size);

iii) Height of the pile (doubling the height increases erosion by 1.5); and

iv) Grade of the pile (proportional to steepness of grade, very significant if angle is larger than 10 degrees).

The size of excavated rock particles depends on the type of rock and the excavation method used. The smooth-wall blasting technique to be used for the vault excavation usually results in less than 1% of the waste rock consisting of fine size particles (AECL CANDU et al. 1992). Provided that appropriate dust suppression measures, such as watering, and pile height and grade management, are applied, dust emissions from the rock pile should not affect air quality on and off site.

Since buffer and backfill material would be transferred by enclosed conveyors, and the air stream cleaned using cyclone separators and filters before the air was discharged to the atmosphere, this operation would not affect air quality.

Sewage and solid waste treatment could be sources of odours.

4) Soil and Land Use

(a) Soil Stability and Erosion

Soil stability may be altered as a result of waste rock disposal. This would be especially true if waste rock was placed on moisture-rich soils (e.g. wetlands). The increased pressure on these soils could result in subsidence and compaction of the soils on level surfaces, and slumping and flows of soil on inclined surfaces. These potential effects can be

eliminated by careful siting of the waste rock disposal area on soils with appropriate load bearing capacities or by removing the unstable layers and backfilling with sand and gravel to provide adequate drainage. The Ontario Wetlands Policy (see Appendix B) requires that siting on a wetland be considered very carefully and should be avoided as much as possible. Siting the facility on provincially significant wetlands, as defined by the policy, would be prohibited.

Areas cleared for construction would be landscaped and revegetated to minimize erosion potential. Indigenous species and natural ground cover should be used whenever possible for revegetation.

(b) Land Use

The land committed to the facility would not be available for other uses until after the decommissioning of the facility. The effects of the land use commitment are discussed in Chapter 5.

5) Ecosystems, Flora and Fauna

In addition to the importance of maintaining healthy ecosystems and of preserving flora and fauna, in keeping with the goals and principles of sustainable development, we have to recognize the special relationship that Aboriginal people have with the natural environment. This relationship is examined further in Section 6.5.

(a) Ecosystem Health

It has been recognized that healthy ecosystems have an inherent ability to repair themselves when disturbed, and need minimal external support (Karr et al. 1986). An assessment of effects on ecosystem health should, therefore, start with an assessment of the health of the existing ecosystem (baseline characterization and monitoring) to determine its capacity to adapt to change. It is difficult to assess the effects of UFDC operation on the health of a generic environment. The following considerations on ecosystem health are, therefore, kept at a conceptual level.

The World Conservation Union, the United Nations Environment Program, and the World Wide Fund for Nature (IUCN/UNEP/WWF 1991) emphasized the need to conserve the earth's vitality and diversity. Specifically, they stressed conservation of life support systems, the ecological processes that shape climate, cleanse air and water, and enable ecosystems to renew themselves; conservation of biodiversity, including all species of plants, animals and other organisms, as well as the range of genetic stocks and the variety of ecosystems; and the need for the development of renewable resources to be sustainable. Chapman (1991) recommends that generally applicable measures of ecosystem health include the following:

i) biodiversity;

ii) persistence of habitat; and

iii) continuance of normal succession, while recognizing the fact that change is a normal part of natural community and ecosystem development.

Preservation of ecosystem health would therefore minimize loss of the existing biodiversity, of the existing habitat, and make normal succession possible.

As discussed in Section 6.1.1, the operation of the UFDC would result in a negligible change in the environmental concentrations of radionuclides and a small dose to biota. Loss of biodiversity or habitat are, therefore, not expected as a result of radionuclide emissions during normal operation of the UFDC. Non-radiological effects of the operation of the facility would include noise, changes to air and water quality, and the continued use of the land for purposes other than to support natural communities. These effects although localized would affect ecosystems on the site and could affect ecosystems off-site. Effects on the health of surrounding ecosystems would be minimized, provided that ecologically sensitive sites or those providing habitat for rare or threatened biota are avoided. It is expected that most of the effects could be reversed during decommissioning.

(b) Wildlife

The health of wildlife is a major indicator of ecological health. The most substantial effects of a disposal facility on wildlife would have occurred during the construction of the facility. Operation-related effects may result from noise and vibrations produced by facility operations, road kills from vehicular traffic, possible bird impingement and stack-related mortalities, personnel disturbing wildlife and/or habitat in the vicinity of the surface facilities, and use of settling ponds by waterfowls.

Some of the wildlife displaced from the site during construction activities would return when construction was completed. Those habitats on the site which were not disturbed significantly and which were vacated by species during construction would be utilized by the returning species. Many species which would initially be common to the site are characteristic of park or other altered environments. As landscaped vegetation reaches a more mature natural state, more species can be expected to take up residence on the site. This was observed at the Bruce Nuclear Power Development site which is home to a variety of wildlife species including a healthy deer population. Some species might still avoid the site due to the noise generated by the waste rock disposal operation and other routine operations. For example, transient wildlife populations such as migrating waterfowl, which use the site or the adjacent property, may be disturbed by the noise.

All organic refuse would be collected in covered bins and transported from the site by contractors for disposal or composting. Thus, no refuse "food" would be available to attract nuisance wildlife (such as bears). All other wastes would be collected such that accidental ingestion by wildlife is avoided.

A possible effect of the facility may be bird impingement against any tall structures of the facility, (the reference stack height for the Used Fuel Packaging Plant is 20 m) particularly if the site were located in the path of a major bird migration route. The potential for bird impingement is partly dependent upon the height and type of illumination of the structures. Bird deaths have been reported at thermal generating stations in southern Ontario. Site-specific factors influencing the number of susceptible birds include the amount of forest habitat available and bird migration patterns in the vicinity of the site. The main general factors that appear to affect bird kills are: adverse weather conditions, type and amount of stack lighting, and season of the year. Bird kills occur primarily during the migration period in the fall, with lesser numbers during the spring migration. Experience at Ontario Hydro indicates that the most effective method of minimizing bird impingement is to install strobe (intermittent) lighting on tall structures.

Operating personnel could disturb the wildlife surrounding the site. Operating personnel should be taught strict environmental preservation practices.

Settling ponds are used to reduce the particulate contents of waste water to acceptable levels. Waterfowl might be attracted to these ponds and mitigative measures should be developed to keep these birds away.

(c) Vegetation

Dust emissions from waste rock disposal operations might affect nearby vegetation. Some sensitive species could suffer foliar damage or death as a result of stomata blockage. However, the number of plants affected would likely be small. Dust control measures such as periodic water sprinkling should help minimize impacts. Aesthetic considerations are generally of greater importance than is the actual foliar damage.

Emissions of sulphur dioxide, nitrogen oxides and particulates resulting from vehicular movement, are expected to have minimal effect on vegetation growth. The extent of the potential damage can be calculated at the site-specific stage by estimating the cumulative quantities of these emissions. Minimal amounts of heavy metals released from operation of equipment would be deposited on roadside soils and would enter the foodchain via initial plant uptake. The concentrations of these emissions would be minimized by applying appropriate pollution control measures on all equipment.

(d) Aquatic Life

Operation of the water supply system (i.e. intake, pre- and post-use treatment, and discharge) and site runoff may affect aquatic life such as fish (adult, juvenile and fish eggs), plankton (phytoplankton and zooplankton), benthos and aquatic plants.

Ideally, a water supply intake should be located where the aquatic organism density and water turbidity levels are small in order to minimize the potential for entrainment of aquatic organisms. The impact on a body of water used for a water supply would depend upon the site and the facility characteristics. Site-specific characteristics which influence the effects on aquatic life include location of the intake with respect to fish habitat (e.g. weed beds, shoals, reefs, breeding grounds, migratory routes), fish behaviour, fish movement patterns and densities, water turbidity, currents and surface turbulence. Facility characteristics which influence the effect on aquatic life include volume of water pumped, intake flow velocities and directional characteristics (Ontario Hydro 1981a). The Northern, Central and Southern region reference environments are considered to be inhabited by 35, 41 and 49 common species of fish. Most of these fish species spawn in spring or early summer (Grondin and Fearn-Duffy 1993a).

Studies of water supply intake effects at thermal generating stations can provide some guidance, although generating stations utilize considerably larger volumes of water than a disposal facility would. These studies indicate that the water supply system design, operation, fish behaviourial responses and environmental conditions contribute to entrapment of fish and other organisms in the intake water flow. Findings of these studies (Ontario Hydro 1981a) considered to be generally applicable to a disposal facility water supply intake are as follows:

i) intakes should be sited away from weed beds, shoals and reefs, breeding grounds, nursery grounds and migratory routes;

ii) fish movement patterns are as important as fish densities in choosing the intake location;

iii) water clarity is one of the most important considerations so that turbidity plumes (e.g. creek and river mouths) and turbid zones of lakes should be avoided; and

iv) other factors influencing the frequency of fish contact with an intake flow include current velocity and direction, surface turbulence, water volume pumped, and regional and seasonal differences in fish habitat association, fish activity patterns and fish movement patterns.

Fish which are too large to pass through the water supply intake screens may become impinged upon these screens. Impinged fish die because they may lose protective scales, mucous membranes and suffer other physical injury. Organisms such as plankton, larval fish, fish eggs and other small fish which pass through the intake screens are said to be entrained. All organisms which are entrained would likely be killed by mechanical stresses such as pumping and sand filtration or chemical stresses such as chlorination. Planktonic organisms and early life stages of fish are susceptible to entrainment because their small size and limited swimming ability do not enable them to escape from the entrained water mass (Lawler, Matusky and Skelly Engineers Inc. 1977).

Waste water and site runoff streams which, if not properly treated, may be toxic to aquatic life include effluents, such as phosphates from laundry, saline groundwater from vault drainage, heavy metals from the basket/container fabrication plant and sewage treatment wastes such as biological oxygen demand. Other effluents which may adversely impact aquatic life include suspended sediment in runoff from mined rock and backfill storage/disposal areas, thermal effluent and sediment in vault drainage effluent.

As described in Chapter 2, all waste water streams could be sampled and treated to meet local, provincial and federal water quality standards before being released to the environment. Such water treatment provisions would be sufficient to ensure that the effect on aquatic life, from treated waste water discharged during the operation of the UFDC, would be minimal. Phosphate free laundry detergents should be used at the facility to minimize impact on the receiving water. In addition, water would be recycled whenever possible to minimize the quantity of water used by the facility and subsequently discharged to the surface waters.

6) Ambient Noise

Equipment used in the mined rock handling operations, especially rock crushing and screening operations, would be noisy. The large fans required to push air through the underground ventilation loop deliver as much as 460 $m^3 \cdot s^{-1}$ and are a substantial source of noise at the surface (around 100 dB). The Ontario Ministry of the Environment Noise Control Model Bylaw (Ministry of the Environment 1978) recommends equivalent noise limits of 55 dB(A) during the day and 50 dB(A) at night. Noise level requirements are also included in regulations promulgated under the Occupational Health and Safety Act of Ontario (Government of Ontario 1990c) to protect workers. Generally, noise becomes a source of annoyance to humans in nearby communities when it exceeds 60 dB(A). The

area of controlled access around the facility should provide an adequate buffer so that noise from disposal facility operation would not likely affect surrounding populations. Noise control measures at the source would protect workers. Therefore, noise levels are expected to have a small effect on the ambient noise level outside the facility boundaries.

7) Non-Renewable Resources

For the purpose of the present analysis, non-renewable resources used during operation were divided into three categories: non-fuel resources, fuel resources, and aesthetics, natural and heritage resources. As mentioned in Chapter 5, it is assumed that the UFDC site would not contain any mineral resources. Therefore, operation of the UFDC at that site would not take away future mineral extraction possibilities.

(a) Non-Fuel Resources

Table 6-43 lists the major non-fuel non-renewable resources which would be consumed during the operation of the facility. Other materials which would be consumed during the life of the facility include: resins, acids, bases, chlorine and other treatment chemicals. The quantities used are not expected to be large enough to affect their availability.

TABLE 6-43
Total Non-fuel Resources Committed during UFDC Operation

Resource	Mass (Mg)
Titanium	20 400
Carbon Steel	62 000
Silica Glass Beads	79 000
Crushed Granite*	6 800 000
Silica Sand	2 358 000
Bentonite Clay	2 057 200
Glacial Lake Clay	1 800 000
Cement	42 000

* assumed to be provided by excavation of the vault.

Titanium

Only about 5% of the world's annual production of titanium minerals is used to make titanium metal; the rest is used primarily in paint to produce white titanium pigment.

The required amount of titanium metal for the fabrication of disposal containers is about 20 400 Mg over the life of the facility, at an average annual consumption of about 510 Mg (Grover 1991). Currently identified, proven world titanium ore reserves are estimated to be about 260 million Mg (titanium content) (Grover 1990). The UFDC requirements are, therefore, a minute fraction of these reserves.

Although there are no production plants for titanium metal in Canada, significant quantities of titanium minerals are available. Quebec Iron and Titanium generates more than 1 million $Mg \cdot a^{-1}$ of an 80% TiO_2 slag (Grover 1990). The UFDC yearly requirements would be a small fraction of that production.

It is anticipated that the average world demand for titanium metal around the year 2000 would be about 170 000 $Mg \cdot a^{-1}$. The known mineral reserves and expected titanium metal manufacturing capacity are more than sufficient to meet this demand. Demand projections for titanium metal beyond the year 2000 are not available.

The average world demand for titanium minerals is expected to be around 2 million $Mg \cdot a^{-1}$ (titanium content) by the year 2000. Demand projections beyond the year 2000 are not available. Two demand scenarios for titanium minerals beyond the year 2000 were considered in the present analysis. First, assuming that the average demand remains at the 2 million $Mg \cdot a^{-1}$, with no new reserve discoveries and no new mineral being used to produce titanium, the titanium reserves would last until the year 2110 (Grover 1990). On the other hand, if one assumes a continuous 3% growth with everything else remaining the same, the titanium reserves would last until around the year 2040 (Monenco Ontario Limited 1990). This is somewhat conservative since there was zero growth in demand between 1980 and 1988. It was assumed that the actual growth would lie between these two estimates and an average growth was used in the analysis. Based on this average growth, the current reserves of titanium would ensure availability of titanium minerals up to the year 2075, which is long enough to enable the UFDC operation to carry on from 2025 to 2065.

In addition to the proven reserves, there are uneconomic (to-date) titanium mineral resources throughout the world. These are estimated to contain about 430 million Mg (titanium content). Extraction of these resources would help extend titanium supply even longer.

Carbon Steel

If carbon steel were used to manufacture the baskets for the stabilization of the fuel bundles within each container, the amount required per container is 444 kg for an annual usage of 1 550 Mg and a total requirement over the life of the facility of 62 000 Mg. Judging by the quantities of carbon steel being manufactured in Canada at present (see Chapter 5) and the known quantities of iron ore and coal reserves (raw components of carbon steel), the basket fabrication requirements are not expected to strain these resources.

Bentonite Clay

Bentonite clay would be used as a constituent in the borehole buffer, vault backfill and sealing materials. With an average of 51 430 Mg of bentonite used per year, approximately 2 057 200 Mg of bentonite would be required for the borehole buffer material around the containers, for the upper backfill material throughout the vault and for sealing of the shafts and any exploratory or monitoring boreholes.

Bentonite is a clay of varied chemical composition, consisting primarily of the mineral montmorillonite. There are two types of bentonite: swelling or non-swelling.

Total production and known reserves of bentonite clays in Canada are presented in Grover (1990) and are reproduced in Table 6-44. The amount of known reserves in Canada is estimated to be 2.5 million Mg, while the UFDC requirements are just over 2 million Mg. Requirements would, therefore, constitute 80% of the currently known reserves of this resource and the average annual requirements would almost meet the production capability of the only swelling bentonite site in the country. However, 80% of the bentonite used in Canada is imported, mostly from the United States (Monenco Ontario Limited 1990). The annual UFDC

requirements would constitute about 18% of the total yearly Canadian imports and 23% of the yearly Canadian imports from the U.S. (Monenco Ontario Limited 1990).

The bentonite requirements could also be supplied by imports, and therefore, should not affect the current availability of the resource. The new requirements could also be seen more as an economic incentive to develop new Canadian bentonite extraction projects rather than a negative effect on a non-renewable resource.

TABLE 6-44
Annual Canadian Production Versus Estimated Reserves

Material	Canadian Production (Mg)	Estimated Reserves (Mg)
Bentonite		
Non-Swelling	20 000	Extensive
Swelling	60 000	2 500 000
Glacial Lake Clay		
Lake Agassiz	282 000	Extensive
Lake Barlow-Ojibway	-	Extensive
Lake Algonguin	18 000	Extensive

(Grover 1990)

Glacial Lake Clay

Glacial lake clay is a generic name which describes a family of clays with different composition and properties. It would be used for vault backfilling purposes. The requirements of glacial lake clay are estimated at 44 060 $Mg \cdot a^{-1}$ (AECL CANDU et al. 1992), approximately 1 800 000 Mg over the lifetime of the facility.

The three most common types present in Canada are:

i) Lake Agassiz (southern Manitoba, northwestern Ontario) (280 000 Mg yearly production, with extensive reserves);

ii) Lake Barlow-Ojibway (central northern Ontario) (no commercial operation); and

iii) Lake Algonquin (Lake Superior shoreline) (18 000 Mg yearly production, with extensive reserves).

Due to the lack of data on reserves of Glacial lake clay within Canada, it is not possible at this time to determine the effect that the use of the quantities estimated for the disposal facility would have on the reserves. The average annual requirements do, however, amount to a large percentage of the present annual commercial production rate (19%). This could have some effect on the supply and demand for this resource.

Sand and Gravel

Silica sand would be used with the Bentonite clay (50/50 mixture by weight) for the buffer material, and gravel would be used during the construction stage. As shown in Table 6-43 approximately 2 358 000 Mg of sand or 59 000 $Mg \cdot a^{-1}$ would be used for this purpose, an average annual consumption equal to that of the Bentonite clay.

The production rate of sand and gravel in Canada in 1985 was about 240 million Mg and about 60 million Mg in Ontario alone (Ministry of Northern Development and Mines 1987). During the operation of the facility, the disposal facility's sand requirement would be 0.10% of the annual Ontario production. The peak annual sand requirement for the facility, therefore, represents a very small portion of the supply.

The only major limitation on the supply of sand is the distance to markets (i.e. transportation costs). The one-way haulage distance is not expected to be greater than 100 km and it is, therefore, unlikely that there would be any difficulty in meeting the requirements for sand and gravel.

Glass

The immobilization material proposed for the filler material inside each container is glass beads. Approximately 566 kg per container is required. This translates to a total quantity of 78 583 Mg and an average annual consumption rate of 1 965 Mg. The composition of the glass beads would be as follows:

SiO_2	76 wt %
Na_2O	12 wt %
CaO	12 wt %

The worldwide abundance of all of these materials is such that the quantities of glass beads required for the facility are not expected to have a significant effect on the reserves of raw materials.

(b) Fuel Resources

i) Natural Gas and Crude Oil

The underground vault would be heated by a gas heating system with a capacity of 24 600 kW (AECL CANDU et al. 1992). The average annual fuel consumption would be approximately 3.1 million m^3 of natural gas. Therefore approximately 127 000 000 m^3 of natural would be required over the 41 year life of the UFDC. The production rate of natural gas in Canada in 1986 was 76 384 000 m^3, natural gas by-products were 18 906 m^3 and crude petroleum was 84 964 m^3 (Ministry of Northern Development and Mines 1987). Most of the production is centred in Alberta. Although the fuel requirements of the disposal facility have not been estimated, it is not expected to be more than 1% of the production rate.

ii) Electricity

It is assumed that during the operation stage, power requirements at the UFDC would be supplied by electricity from the provincial electrical grid. The reference design (Simmons and Baumgartner 1994) specifies a total load of around 22 MW, with 7 MW required by underground operations and 15 MW required by the surface facilities. Over the 41 years of operation of the facility, the total electrical resource required would be about 900 MW·a.

c) Aesthetics, Natural and Heritage Resources

Aesthetics

The portions of the facility that may be visible off site are the rock disposal and backfill storage piles, the stack and other tall structures. The visibility of these structures will be influenced by the topography

of the site, the layout of the surface facilities in relation to the site topography, and the type and amount of screening afforded by vegetation. The aesthetics of site structures can often be improved by landscaping the site. Preservation of vegetation windbreaks and specimen trees near cleared land, the creation of buffers and revegetation of cleared land with native species would help create a natural appearance and blend surface facilities into the existing topography.

The tree species that characterize the forests in each region of the Shield are discussed in Grondin and Fearn-Duffy (1993a). The average height of the trees in the three regions (Hosie 1969), in a surrounding mature forest should provide adequate screening for the rock disposal and backfill storage piles (assumed to be up to 10 m high). Should the facility be located in an area with a large amount of black spruce, attention should be given to preserving as many as possible for wind breaks and screening, since this is a relatively slow growing species.

The upper portions of the tall structures and stack would be visible off the site. The Service Shaft Headframe would be approximately 70 m high and the Waste Shaft Headframe 30 m high. An undesirable visual effect of these structures may be minimized through:

i) architectural design;

ii) landscaping;

iii) proper positioning with respect to viewpoints; and

iv) a 1.5 km (minimum) land use control zone around the UFDC structures.

Natural and Heritage Features

Much of the effect of a disposal facility on natural and historical features would occur during the construction stage. Development of the disposal facility would have provided improved access to any features on or near the site. Operation of the UFDC may affect these features as a result of:

i) continuing access and potential vandalism by site personnel;

ii) having a large industrial facility near scenic or wilderness features; and

iii) noise, dust and vibrations from disposal facility operation which may disturb ecological sites.

In addition to avoidance measures at the siting and construction stages, protective measures which may be taken or continued during operations include:

i) restricting access of site personnel by fencing, regulations or similar measures;

ii) establishing and maintaining buffers between sensitive natural and heritage features, and activities at the site (e.g. a land exclusion zone between the two);

iii) proper site maintenance (e.g. control of litter); and

iv) establishing and maintaining effective protective devices.

TABLE 6-45
Maximum Road or Rail Traffic to Deliver Each of the Non-renewable Resource Materials to the Site

Material	Number of Dump Truck* Trips	Number of Flat Bed Truck** Trips	Number of Semi-trailer Trips	Number of Rail Box-Car* Trips	Number of Flat-Bed** Railcar Trips
Titanium	3 040	680	550	630	760
Carbon Steel	20 460	4 570	3 720	4 270	5 120
Glass Beads	8 270	1 850	1 500	1 730	2 070
Sand	163 570	36 560	29 740	34 150	40 930
Bentonite Clay	217 170	48 520	39 480	45 350	54 350
Glacial Lake Clay	208 140	46 520	37 840	43 460	52 090
Cement	5 010	1 120	910	1 050	1 250
Total	625 660	139 830	113 760	130 650	156 570

Average number of vehicles (road and rail): 233 300 vehicle trips***
Expected daily increase in road traffic (in-full, out-empty): about 50 vehicles/day

Average number of vehicles (road only): 293 100 vehicle trips***
Expected daily increase in road traffic: about 60 vehicles/day

Average number of vehicles due to operation (rail only): 143 600 vehicle trips***
Expected daily increase in rail traffic (in-full, out-empty): about 30 vehicles/day

Traffic is based on a 230 day working year over a 41 year period

* or trucks of an equivalent capacity for metal products
** or trucks of an equivalent capacity for sand, bentonite and lake clay, and cement
*** a trip constitutes a carrier going to the site full, and coming out empty

8) Transportation of Construction Materials during Operation Stage

Like construction, operation of the facility would affect local road and/or rail traffic. The transportation effects of the used fuel to the site have been evaluated and documented in a separate Ontario Hydro study, the Used Fuel Transportation Assessment (Grondin et al. 1993). This does not, however, include the increased traffic transporting other materials used in operation. Table 6-45 summarizes the material and subsequent vehicle requirements for each of the non-renewable resources which would be transported to the site during operations.

The vehicle traffic would be substantial over the 41 years of operation. If all deliveries are made via dump truck, the total could be about as high as 130 trucks per day (in and out). The smallest traffic increase would result from materials transportation by semi-trucks (about 24 per day) or rail box cars (about 28 per day).

Most of the transported material would be buffer and backfill. The significance of the effect would depend on the distance that these materials are transported. Since almost all of the bentonite and glacial lake clays are mined outside of Ontario, transportation may be a very significant factor in facility siting.

Given that it is difficult to predict where each of the non-renewable resources would come from, the fuel requirements for the transportation operation could not be estimated.

6.4.3 Potential Impacts of Toxic Emissions from the Used Fuel

The impact from the airborne and waterborne emission of chemically toxic contaminants from the UFDC was assessed using the same methodology as for the dose impact from the chronic emission of radionuclides from the UFDC which have been described in this report and elsewhere (Russell 1993a, 1993f). While the emission of toxic chemicals from routine operation of the UFDC is expected to be small, it is worth considering the impact of these postulated emissions on the environment near the UFDC. One measure of the impact of toxic contaminants in the environment is to estimate their concentrations in the basic biosphere compartments of air, water and soil, and to compare these concentrations with natural or background levels where possible. If the projected concentrations of toxic contaminants are a small fraction of the background levels, then it can be argued that the environmental impact of these toxics will also be small.

Therefore, the scope of the assessment has been limited to determining the concentration of chemically toxic contaminants released from the UFDC and to compare these concentrations with background levels (Russell 1993f).

6.4.3.1 Potential Toxic Chemical Emissions from the UFDC

A large number of potentially toxic contaminants have been identified in the used UO_2 fuel and in the Zircaloy fuel sheath found in CANDU nuclear reactors. A total of 85 elements were screened in the postclosure assessment of the concept for disposal of Canada's nuclear fuel waste to yield eight chemically toxic elements of concern, plus one element (technetium) which has no stable isotope but is potentially toxic (Goodwin et al. 1987; Goodwin and Mehta 1994). The list includes chromium, selenium, bromine, molybdenum, technetium, cadmium, antimony, cesium and samarium (Cr, Se, Br, Mo, Tc, Cd, Sb, Cs and Sm, respectively). Uranium (U) was also added to the list because of its abundance in nuclear fuel and its potential for emission to the

environment. Technetium is different from the other toxic contaminants in the list because it does not occur naturally in the environment. The only known isotope, ^{99}Tc, is radioactive and is present as a result of nuclear weapons testing and nuclear power production.

The emission of chemically toxic contaminants to air and water from the UFDC was based on the prediction for the emission of radionuclides from the facility (Villagran 1993). Data concerning the release of toxic contaminants from used fuel during handling are not generally collected and estimates of emission rates need to be postulated from other measured data. Since the data for estimating the preclosure emission of ^{134}Cs and ^{137}Cs from used CANDU fuel are available (Villagran 1993), the emission data for ^{134}Cs were conservatively used to calculate the toxic contaminant release fractions for all nuclides except U. Uranium release fractions were based on ^{238}U emission rates during the preclosure phase (Villagran 1993).

The fraction release data are given in Table 6-46.

Using the fraction release rates and the mass inventory of toxic contaminants in CANDU fuel (Goodwin and Mehta 1994), the toxic chemical emission rate from the UFDC are calculated (Russell 1993a).

The toxic chemical release rates are listed in Table 6-47.

6.4.3.2 Environmental Concentration of Chemically Toxic Contaminants

The concentration of chemically toxic contaminants in air, water and soil near the UFDC was assessed using the same methodology as for the chronic emission of radionuclides from the UFDC, which have been described in this report and elsewhere (Russell 1993a,c).

The annual average toxic chemical concentration in air from airborne emissions was calculated using the Gaussian plume model. The calculations were based on the long-term weather frequency data from representative sites in the Northern, Central and Southern regions of the Canadian Shield in Ontario (Grondin and Fearn-Duffy 1993a).

The concentrations were evaluated at the UFDC boundary (1500 m) for the direction sector with the largest nuclide concentration.

The maximum toxic chemical concentration in water occurs at the end of the UFDC operating period and for the lake discharge scenario. The concentration depends on the lake's volume, flow rate, mixing and sedimentation (Russell 1993f).

The toxic chemical concentration in soil includes airborne deposition and irrigation of lake water. The environmental concentrations near the UFDC of chemically toxic contaminants were evaluated for the three reference environments on the Canadian Shield (Grondin and Fearn-Duffy 1993a). The results for the Northern region are given in Table 6-48 (contaminant concentrations in the other two regions were similar to the values in the Northern region).

The environmental concentrations of toxic contaminants in the basic compartments of air, water, sediment, and soil near the UFDC were calculated to be very small (the airborne concentrations are so small that they do not require further analysis). The toxic chemical concentrations in lake water and soil can be compared with the regulatory and background concentrations compiled by Amiro (1992b) and Goodwin and Mehta (1994). The regulatory criteria were taken from Environment Canada

TABLE 6-46
Toxic Chemical Fractional Release Factors to Air and Water

Nuclide	Inventory ($Bq \cdot element^{-1}$)*	Q_a ($Bq \cdot s^{-1}$)	Q_w ($Bq \cdot s^{-1}$)	RF_a ($element \cdot s^{-1}$)*	RF_w ($element \cdot s^{-1}$)*
^{134}Cs	9.93×10^{9}	2.52×10^{-2}	2.20×10^{-2}	2.54×10^{-12}	2.22×10^{-12}
^{238}U	6.24×10^{6}	1.62×10^{-9}	3.08×10^{-8}	2.60×10^{-16}	4.94×10^{-15}

*Note: "element" refers to a used-fuel element. Thus the inventory is given in Bq per used fuel element, and the release factors are given in fraction of a used-fuel element per second.

TABLE 6-47
Toxic Chemical Emissions to Air and Water from the UFDC

Nuclide	Airborne Emission Rate Qm_a ($mg \cdot s^{-1}$)	Waterborne Emission Rate Qm_w ($mg \cdot s^{-1}$)
Cr	2.34×10^{-09}	2.05×10^{-09}
Se	1.64×10^{-10}	1.43×10^{-10}
Br	8.40×10^{-11}	7.34×10^{-11}
Mo	1.06×10^{-08}	9.25×10^{-09}
Tc	2.70×10^{-09}	2.36×10^{-09}
Cd	1.81×10^{-10}	1.58×10^{-10}
Sb	3.73×10^{-11}	3.26×10^{-11}
Cs	7.25×10^{-09}	6.33×10^{-09}
Sm	2.92×10^{-09}	2.56×10^{-09}
U	1.30×10^{-10}	2.46×10^{-09}

TABLE 6-48
Toxic Chemical Concentrations in Air, Water, Sediment and Soil in the Northern Region

Nuclide	Toxic Chemical Concentrations			
	Air (C_a) ($mg \cdot m^{-3}$)	Water (C_{wl}) ($mg \cdot L^{-1}$)	Sediment (C_{sed}) ($mg \cdot kg^{-1}$)	Soil (C_s) ($mg \cdot kg^{-1}$)
Cr	6.0×10^{-15}	4.6×10^{-12}	3.2×10^{-10}	8.0×10^{-10}
Se	4.2×10^{-16}	2.2×10^{-13}	3.2×10^{-11}	4.9×10^{-11}
Br	2.2×10^{-16}	6.8×10^{-13}	1.0×10^{-11}	1.9×10^{-11}
Mo	2.7×10^{-14}	3.5×10^{-11}	3.5×10^{-10}	2.7×10^{-09}
Tc	7.0×10^{-15}	6.0×10^{-12}	6.0×10^{-13}	7.0×10^{-11}
Cd	4.7×10^{-16}	6.0×10^{-13}	4.8×10^{-11}	2.1×10^{-11}
Sb	9.6×10^{-17}	3.7×10^{-13}	1.7×10^{-11}	2.4×10^{-11}
Cs	1.9×10^{-14}	1.5×10^{-11}	4.3×10^{-09}	2.2×10^{-09}
Sm	7.5×10^{-15}	1.0×10^{-11}	2.6×10^{-09}	1.3×10^{-09}
U	3.3×10^{-16}	1.4×10^{-11}	4.9×10^{-10}	8.7×10^{-10}

TABLE 6-49
Comparison of Toxic Chemical Concentrations in Lake Water

Nuclide	Concentration in Water (C_{wl}) ($mg \cdot L^{-1}$)		
	UFDC Soil (Northern)	Background Levels	Regulatory Limits
Cr	4.6×10^{-12}	-	2×10^{-3}
Se	2.2×10^{-13}	-	1×10^{-3}
Br	6.8×10^{-13}	1.4×10^{-2}	-
Mo	3.5×10^{-11}	1.0×10^{-3}	5×10^{-3}
Tc	6.0×10^{-12}	2.4×10^{-14}	-
Cd	6.0×10^{-13}	-	2×10^{-4}
Sb	3.7×10^{-13}	1.0×10^{-1}	-
Cs	1.5×10^{-11}	2.0×10^{-4}	-
Sm	1.0×10^{-11}	1.0×10^{-4}	-
U	1.4×10^{-11}	1.0×10^{-4}	-

TABLE 6-50
Comparison of Toxic Chemical Concentrations in Soil

Nuclide	Concentration in Soil (C_s) ($mg \cdot kg^{-1}$)		
	UFDC Soil (Northern)	Background Levels	Regulatory Limits
Cr	8.0×10^{-10}	$2.2 \times 10^{+1}$	100
Se	4.9×10^{-11}	3.7×10^{-1}	1
Br	1.9×10^{-11}	$1.0 \times 10^{+1}$	-
Mo	2.7×10^{-09}	$1.6 \times 10^{+0}$	4
Tc	7.0×10^{-11}	1.0×10^{-8}	-
Cd	2.1×10^{-11}	6.0×10^{-1}	1
Sb	2.4×10^{-11}	2.0×10^{-1}	20
Cs	2.2×10^{-09}	$2.0 \times 10^{+0}$	-
Sm	1.3×10^{-09}	$5.0 \times 10^{+0}$	-
U	8.7×10^{-10}	9.5×10^{-1}	-

(1987b), Angus Environment Limited (1991), the Canadian Council of Ministers of the Environment (1991).

The results are given in Tables 6-49 and 6-50. The projected toxic chemical concentrations were an insignificant fraction of regulatory or background concentrations, except for Tc in lake water. Since Tc does not exist naturally in the environment, it is not surprising that its projected concentration may exceed background concentrations from weapons testing fallout and nuclear power production. Nevertheless, the environmental impact from Tc is expected to be very small. Note that the estimated Tc concentration in lake water from UFDC operation is about 6×10^{-12} $mg \cdot L^{-1}$, which in absolute terms is very small.

6.4.4 Summary of Analysis Results

Air Quality

Storage of sand, gravel, bentonite clay, and the mined rock crushing and transfer operations would be in enclosed spaces, thus reducing the potential for dust emissions. Dust suppression measures would likely be necessary to minimize dust emissions from the waste rock pile. Air concentrations of toxic chemicals from UFDC operation were estimated to be negligible.

Water Quality

Effects on the water quality would be associated with operation of the water supply system, site runoff and discharge of waste waters. The water treatment provisions and run-off control would prevent degrading of water quality. Water would be recycled to minimize effects on the aquatic environment of both the water withdrawal and water discharge reservoirs.

The projected concentration of Technetium (does not occur naturally) in water was estimated to be higher than background concentrations in lake water. Nevertheless, the concentration of Tc is very small in absolute terms and is expected to have a negligible impact on the environment.

Land Use

Provided that land cleared during construction is landscaped and planted with new vegetation to minimize erosion, soil stability may be altered only in the operation stage by waste rock disposal activities.

Concentration of toxic chemicals in soil from UFDC operation was estimated to be negligible.

Ecosystem/Flora and Fauna

Effects would be similar but much smaller than those during construction.

Ambient Noise

Noise from vehicles travelling to and from the site is expected to cause the greatest impact beyond the site boundary. Controls, such as muffling devices, would be employed as necessary to minimize excessive noise from these vehicles. Noise from rock crushing and screening and the operation of the vault ventilation system would also need to be mitigated. However, the distance between UFDC facilities and the site boundary (1.5 km for the rock crushing plant, possibly less for the rock storage area and the ventilation shafts) would help to mitigate noise effects.

Non-Renewable Resources

Non-renewable resources, such as titanium, carbon steel, bentonite clay, glacial lake clay, silica sand, propane and glass would be used during operation of the facility. Except for bentonite and glacial lake clay, none of these materials are currently in short supply, and there are substantial reserves for future use. If more deposits of bentonite and glacial lake clay are not established, the facility operation would depend on the importation of these resources.

Traffic

A small increase in traffic would result from transportation of material during the operation stage. The effect on the local area would depend on the level of use of the existing road and rail networks.

Aesthetics, Natural and Historical Features

Adverse aesthetic effects can be mitigated with appropriate landscaping provisions. Much of the effect of a disposal facility on natural and historical features would have occurred during the construction stage. Additional measures could be used during the operating stage to minimize effects.

6.4.5 Summary of Mitigation Measures

Since, for the most part, operation of the facility uses available technologies, proven environmental protection measures can be included in the design to minimize risk to the environment.

As part of the facility design, systems would be planned to control and manage the waterborne, airborne, solid and liquid wastes that would be generated during the operation of the UFDC. The philosophy is to minimize waste production, reuse and recycle as much as possible, and for radioactive waste, to manage wastes through concentration and long-term storage, or by decontamination and release to the environment. All

emissions would be monitored, documented and reported to the appropriate public and regulatory authorities. Details of the environmental protection provisions of the facility are given in Section 6.1.

Predicted ecological effects and displacement of land use capability would largely be reversed following closure and rehabilitation of the site. Healthy ecosystems have an inherent ability to repair themselves when disturbed and are expected to recover. The productive capability of the land permanently relinquished as a result of disposal facility construction would be minimized by siting in an area that has little potential for use. Sensitive environmental areas would be avoided through careful siting of the facility. Some of the requirements for non-renewable resources will need to be examined again due to possible reserve shortages in the next century.

A summary of the specific existing or recommended mitigation measures for protecting the environment is given in Table 6-51.

6.4.6 Analysis of Accident Conditions

A wide variety of hazardous materials would be used and produced during operation of a disposal facility and could be potentially hazardous to human health and the environment. Table 2-7 presents a list of the non-radioactive hazardous materials likely to be present. With strict adherence to handling procedures for hazardous material, proper training of the facility personnel in these procedures, and adequate emergency response provisions for accidental spills, the release of these materials should be controlled to have minimal effect on the environment.

6.5 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENT

6.5.1 Introduction

This section presents an analysis of potential impacts that the siting, construction, operation, decommissioning and closure of a used nuclear fuel disposal facility could have upon the social and cultural vitality, economic viability and political efficacy of communities and regions. It includes a description of the methodology used in the analysis, a review of potential impacts from normal and abnormal activities at the facility, and a discussion of potential social and community impact management measures.

The potential impacts during siting, construction and decommissioning discussed here are summarized in Chapters 4, 5 and 8 respectively. The socio-economic impact assessment of transporting used fuel to the disposal centre is included in Chapter 7.

Study Objectives:

The objectives of the socio-economic impact assessment (SEIA), as part of the generic concept assessment, are:

i) to identify potential socio-economic impacts that could result from the disposal facility;

ii) to highlight interrelationships among potential socio-economic impacts;

iii) to set out for public review, impact management measures that could be implemented in site specific assessments; and

TABLE 6-51
Summary of Existing or Recommended Mitigation Measures

ENVIRONMENTAL FACTOR	MITIGATION MEASURE
Water Quality	Should important quantities of saline groundwater occur in the vault excavation, measures would have to be taken to ensure that these waters do not reach surface waters before treatment. Waste water treatment would ensure that surface water quality is not affected by operation of the UFDC. Effluents would be monitored for radioactivity to provide assurance that if there were releases, they would be inconsequential.
Air Quality	Facilities which contain significant quantities of hazardous materials, or where the materials present have the potential to contaminate the building air, are provided with air filtration systems. Appropriate dust suppression measures, such as watering, and pile height and grade management, should be applied to the waste rock pile. Air streams from buffer and backfill material conveyors are cleaned using cyclone separators and filters before the air is discharged to the atmosphere. Appropriate pollution control measures should be applied to all equipment. Emissions would be monitored for radioactivity to provide assurance that if there are releases, they are inconsequential.
Soil and Land Use	The waste rock disposal area should be located on soils with appropriate load bearing capacities or the unstable soil layers should be removed and backfilled with sand and gravel, providing adequate drainage. Locating the waste rock pile on wetlands should be avoided as much as possible. Land which has been cleared during the construction stage should be landscaped and revegetated to minimize any erosion potential.
Ambient Noise	The controlled access zone around the facility should provide an adequate buffer. Noise control measures at the source would be taken to protect workers.
Non-Renewable Resources	The aesthetic effect of site structures can be improved by landscaping. Preserving vegetation windbreaks and specimen trees near cleared land, creating buffers and revegetating cleared land with native species would help create a natural appearance and would blend surface facilities into the existing topography. The adverse visual effects of site structures may be minimized through: 1. architectural design; 2. landscaping of the site; 3. proper positioning with respect to viewpoints; and 4. providing of a 1.5 km exclusion zone around the perimeter of the site. Solid wastes would be stored in refuse containers and removed from the site by a contractor. Natural and heritage features would be protected by: 1. restricting access of site personnel by fencing, regulation or similar measures; 2. providing and maintaining buffers; 3. proper site maintenance (e.g. control of litter, etc.); and 4. providing and maintaining suitable, effective protective devices.

continued...

TABLE 6-51 (concluded)

ENVIRONMENTAL FACTOR	MITIGATION MEASURE
Ecosystem/ Flora & Fauna	Ecologically sensitive sites or those providing habitat for rare or threatened biota should be avoided. All waste would be collected in covered bins and transported from the site by disposal contractors or appropriately disposed of on site. Stack lighting should be designed to minimize bird impingement. Operating personnel should be trained in preservation practices for wildlife and the environment. Mitigative measures should be developed to keep birds away from the settling ponds. Dust control measures should be used to prevent dust from the waste rock pile settling on the surrounding vegetation in sufficient quantities to affect it. Effect of water supply intakes can be minimized by including the following considerations when locating the intake: 1. siting away from weed beds, shoals and reefs, breeding grounds, nursery grounds and migratory routes. 2. taking into account fish movement patterns, fish densities, current velocity and direction, surface turbulence, size of the intake capture field (i.e. water volume pumped), and regional and seasonal differences in fish habitat. 3. avoiding turbidity plumes (e.g. creek and river mouths) and turbid zones of lakes. For the preservation of aquatic life, all waste water streams would be sampled and treated to meet local, provincial and federal water quality standards before being released to the environment. Water should be recycled as much as possible to minimize the quantity of water used by the facility and subsequently discharged.

iv) to set out for public review, the principles and processes that could be followed in developing a community based impact assessment and management strategy.

Assumptions:

The following fundamental ethical assumption guides the socio-economic impact assessment:

The socio-economic impact assessment of the disposal facility will reflect the basic principle that those who are to bear the risks of the disposal of nuclear used fuel, i.e. the public in general and specifically the local communities, have the right to fully participate in the decision-making process related to impact assessment and management, facility planning, licensing, operations and monitoring.

This ethical assumption has an important bearing for this non site-specific assessment: determination of the significance of impacts and risks needs to take into account the valuations of the people who may be affected. The introduction into a community of a new project, such as a disposal facility, results in changes or effects in that community. Whether or not these changes have a significant impact on community, either negative or positive, is determined through the assessment and evaluation of significance which includes the consideration of local community values and beliefs (See Section 1.5).

This assumption also has a significant bearing for the site-specific SEIA methodology to be used at the implementing stage: if it is an ethical imperative to facilitate the participation of the public and local communities in the decision-making process, then it will be necessary to use methods of social analysis that incorporate the evaluating criteria, moral and otherwise, of that public and/or community as components of the measures of significance.

Throughout the history of human societies, technology has had far reaching consequences not only in terms of the production and use of materials and tools, but also in the socio-economic, cultural and political organization of societies. Technologies have intended and unintended consequences that challenge the values that underlie social organization (Ellul 1964; Mumford 1963; Polanyi 1957; Gehlen 1980; Postman 1993; Franklin 1990). Decisions about technologies are value-laden: they have implications about the type of life and society that is desired by people and communities. Therefore, social values need to be integrated in the planning process for the development and implementation of new technologies. The assessment of public values is a crucial part of socio-economic impact assessments (Torgerson 1980; Vedung 1978; Schrader-Frechette 1991; Douglas and Wildavsky 1982; Otway and Thomas 1982; Kasperson et al. 1988; Bromley and Segerson 1992; Sagoff 1992).

This implies that, whenever possible, analyst judgement or professional judgement must not take precedence over, nor be a substitution for, the valuations of the public or communities involved. Furthermore, every effort must be made to engage in a process that allows public discussion of risks and the assessment of public and local community opinions, concerns and values. The methodology of this present SEIA reflects this goal.

The present document also attempts, within its generic confines, to analyze, when pertinent, the potential social, economic and cultural impacts to northern and Aboriginal communities in recognition of their distinctive circumstances. Although impacts to northern and Aboriginal

communities are taken into account, it does not imply any intention to, nor implied knowledge that, the disposal facility will indeed be placed in or near these communities.

6.5.2 Methodology

Impact assessments are commonly conducted in the content of site selection and/or site characterization. These studies typically involve the evaluation of alternative sites to identify a preferred location where impacts might reasonably be expected to be minimal, or the identification and assessment of the most probable set of impacts on a host community.

For concept assessment, this study of the socio-economic and cultural changes necessitates a departure from conventional practice in that the assessment remains at a theoretical level. Unlike other types of socio-economic impact assessments, no specific communities are identified, constraining the specific prediction, assessment and evaluation of potential effects.

Therefore, this SEIA presents an assessment of the kinds of changes possible with disposal facility implementation. Without a specific site, it is impossible to eliminate from consideration any of the range of potential effects that can happen in a community as a result of the introduction of this project. As has been stated previously, (see the Preface), many of the assumptions made for this concept assessment are conservative, that is, they would tend to overestimate adverse effects. At the evaluation stage, after the selection of one or more candidate sites, a complete SEIA will be undertaken; at which time it will be possible, working with the community(ies), to identify, assess and evaluate the specific impacts and related impact management measures that would be appropriate and acceptable in each case.

The analysis is based, generally, upon socio-economic impact theory and research, and specifically on:

i) the literature review of studies of comparable large-scale projects and their socio-economic impacts;

ii) studies of public opinion regarding large scale projects and nuclear facilities in particular; and

iii) community dynamics and the social processes which determine the nature and significance of impacts at any location.

Details of the socio-economic impact assessment research (Paez-Victor 1993) that are used extensively in the preparation of the present analysis can be found in the supporting documents. A list of the major case studies used in the analysis is included in Appendix D. The present SEIA is based on a reference design for the disposal facility (Simmons and Baumgartner 1994). Three distinguishing features of this SEIA are its use of social science research and case studies, its community-centred focus and impact management focus.

6.5.2.1 Research and Case Study Focus

This SEIA has an historical approach. The impact analysis is based upon a literature review and case studies of large scale projects that have been built throughout Canada (and elsewhere, principally in the United States) and the documented impacts they have had upon human communities. The projects examined include those in both northern and southern Canada, as well as those in urban and rural areas. SEIA normally takes place

The projects examined include those in both northern and southern Canada, as well as those in urban and rural areas. SEIA normally takes place within a particular locality with identified human groups. The present SEIA, lacking a facility, a site and a community, is based upon the analytical discussion of a broad range of impacts that have occurred in the past with other projects, with the intention of anticipating those that may occur in the future if a disposal facility were to be accepted and implemented in some hitherto unknown locality.

Much of the research analyzed in this assessment deals with projects that involved the influx of a large, young workforce into small rural communities. In addition, case studies dealing with abnormal operating conditions at facilities, actual hazardous events, or attitude and behavioral studies are used to illustrate the potential impacts associated with projects that have risks which, regardless of their probabilities, represent significant consequences to people and communities (Wlodarczyk 1993).

In order for the present analysis to be useful, it is necessary that it be relevant to the Canadian experience, and the Ontario context in particular, in view of the Joint Statements made by the Governments of Canada and Ontario (1978, 1981) in establishing the Canadian Nuclear Fuel Waste Management Program. In order to accomplish this goal, use has been made, whenever possible, of Canadian case studies and research literature. Because there are particular sensitivities to Aboriginal communities and their needs, additional attention has been made to examine case studies which affect Aboriginal communities and lands throughout Canada, particularly in Northern and remotely located areas. Small, remote and Aboriginal communities, can be more vulnerable. In fact, the attention to these communities provides a sensitivity factor for the discussion of socio-economic impacts and their management. Their consideration is not meant to undermine the open and public siting process nor does their consideration imply any bias towards the siting of the disposal facility in any particular locale.

6.5.2.2 Community Centred Focus

The types of impacts relevant to SEIA are those that have a social character: i.e. felt not just by an individual or series of individuals, but by individuals as part of a social grouping defined as a community. Four levels of social analysis are usually addressed in socio-economic impact studies (individual, group/organization, community/region and society). These will be incorporated into the study with a major emphasis on community throughout the analysis (Paez-Victor 1993).

Communities are formed by real, living persons, whose individuality is not in doubt, either legally or philosophically. However, individuals are part of a social world that, by means of culture, enables them to have opinions, uphold values, maintain attitudes and generally, perceive reality around them. Such things as language, family, education, socio-economic status, roles, age, gender, religious, philosophical or political affiliation, ethnic groupings, media and political orientation all act upon people helping to form their world view (Weber 1946; Timasheff 1967).

The assessment of the natural environment, and the public and occupational health and safety assessment used a reference environment assessment by averaging the data from three Ontario geographical regions: Southern, Central and Northern (see Chapter 3). The socio-economic assessment does not use this reference environment method because the criteria used to distinguish geographical areas would not adequately reflect the social environment criteria that are critical for

unidentified "reference communities" that included a county, a town, a township and an unorganized area (as a possible new town site). However, this approach was criticized through external peer review as looking at social impacts through the eyes of municipal officials, and not of those perceived by residents, as downplaying impacts on individuals, and overlooking the larger society where wider social implications of the concept could be felt (Lang, Armour 1984).

(As will be seen in Section 7.5, the SEIA of the transportation component of the disposal system used three settlement patterns, urban, cottage/recreational, and rural/agricultural, to represent affected populations along potential transportation routes. The use of settlement patterns and related methodology was criticized as causing the SEIA to focus too heavily on impacts to the individual. The spatial boundaries (i.e. the transportation corridor) were also criticized as being too restricted. It was recommended that interprovincial and international implications also be considered (Lang, Armour 1984). Temporal boundaries also needed to be expanded to examine impacts to future generations.)

In the present SEIA, local impacts refer to those occurring within an affected community, while regional impacts are those shared by many communities over a larger geographical area.

Socio-economic impacts vary geographically and occur on a local, regional, provincial and even national scale. These impacts are defined and understood according to fundamental analytical social concepts and processes. It is these concepts and processes which shed understanding on the difference the introduction of a project, such as a disposal facility, can make to people as they interrelate with each other and with their natural environment in the day to day tasks of solving the problems of collective living. The SEIA is grounded not on a geographical units, but on the social unit of community (Lockhart 1987; Blishen et al. 1979; Bowles 1981). Socio-economic impacts are analyzed according to a fundamental social consideration: what are the changes that a project such as the disposal facility will bring to people as they interrelate with each other and with their natural environment?

1) Definition of Community

A community is a group or groups of people linked to each other to some degree, by the ties of history, and/or environment, organizational life, common social challenges, economic interest, political articulation and, most importantly, face to face personal interaction.

Any socio-economic impact assessment requires a clear understanding of the social world that could be potentially affected by a project. There are several social levels potentially affected by the disposal facility: the local community, a region (of several communities), the provincial and national levels and, ultimately, the international level. In this section, community and its characteristics are defined. The community is considered the fundamental social world, from which impacts ripple into the other social levels (Paez-Victor 1993).

The definition of community is a key conceptual tool, because whether or not there is a social impact will depend upon:

i) the existence of a community (not simply isolated individuals); and

ii) the characteristics of the community or communities.

2) The Role of the Individual within the Community

Undoubtedly, communities are formed by real persons whose individuality is a tenet of Canadian society, politics and culture. Notwithstanding, when dealing with environmental and social impacts, it is the person, not in isolation but in relationship to others, that is the unit of analysis.

Human socio-cultural environment, while having a necessary but not sufficient basis in the physical world, is fundamentally a symbolic universe. By this it is meant that the quality that distinguishes humans from non-humans, culture, is a system of symbolic communication that starts from the acquisition of language and embodies customs, beliefs, attitudes and behaviour in all human activities.

The distinguishing characteristic of culture is that it is not an inherited trait, but a learned one. The process of learning culture is not just education; it is broader than that. It is part of adult as well as childhood life. Every social role and status brings with it a learning process whereby a person acquires the knowledge of the social expectations attached to each social role and situation.

The main social institutions of a society include the family, the educational system, religious, political and economic organizations, and the media. They are composed of varied and by no means homogeneous groups with differing interests and outlooks. All, however, are factors that exert influence upon the formation of the attitudes, systems of beliefs and patterns of behaviour in individuals. This is referred to as the process of socialization.

The agents of socialization which have the most important influences over a person's attitudes and behaviour are the configuration of people to whom the individual has or has had a meaningful personal relationship. This includes first of all those with whom the individual has substantial face-to-face interaction, such as the family, friendship network, work colleagues, etc.

Reference groups are also important. These are people whom the individual may not know personally, but who enjoy their esteem, such as public figures, well known community members, people who belong to the same groups or have the same economic or political interests or beliefs. These can even be those who are only known through their writings.

This does not mean that basic individual human rights and freedom, nor the creativity of the human psyche are being denied. It does mean that for purposes of analysis, this SEIA assumes that the products of individual expression, including attitude towards risk, take place within a social context, specifically that of the groups that form the community; and it is within such a context that these attitudes and behaviours make sense.

6.5.2.3 Impact Management Focus

The purpose of predicting potential impacts is to seek to avoid or reduce negative effects and to enhance positive effects through the development and implementation of impact management measures. Therefore the focus of this analysis is to recommend a community-based impact management process, and to identify various impact management measures that could be implemented, working with the affected community, to manage the effects of change resulting from this project within that community.

The process of impact assessment and impact management are interconnected. The assessment of impacts leads to the identification of impact management measures which, in turn, may lead to other effects which require assessment and management. For example, the preferred facility design might be altered to manage an identified socio-economic impact; that design change will have to be factored into the assessment of impacts. These processes are also interconnected with public involvement activities. As described in Chapter 1, it is essential to work with affected communities through joint problem-solving and planning, to identify and assess potential effects and to develop possible impact management measures. Although the methodologies for impact assessment, impact management, and public involvement are discreet, these processes must support and facilitate their mutual success. The siting process, which would be initiated prior to a site specific SEIA, will set the stage for the public involvement activities supporting the assessment of project effects. A successful siting process will develop the partnership between the implementing organization and the community which will then enhance, in particular, the identification and negotiation of impact management measures consistent with community values and goals.

Within the constraints associated with a non site-specific assessment, it is necessary to identify and take into account the range of possible impacts occurring in a diversity of communities including rural, urban, remote, or Aboriginal. This does not imply that the disposal facility will be sited in any one of these places. It is assumed that the siting of the disposal facility will be a result of a siting process, based on the principles of openness, fairness, shared decision-making and voluntarism, the outcome of which cannot be estimated.

Socio-economic impact management programs can be prepared to respond to any unanticipated impacts. The key elements of success in managing any unanticipated impacts are:

i) a flexible impact management program,

ii) early detection of socio-economic impacts through a structured monitoring program and contingency planning implemented by the community;

iii) shared decision making with the community in a joint impact management program; and

iv) periodic review of impact management strategies.

It should not be assumed that those potentially affected will experience the full range, the same kinds of impacts, or even impacts to the same degree. This can only determined with a site-specific socio-economic impact assessment.

6.5.2.4 Characteristics of Socio-Economic Impacts

Theoretically, there are many potential impacts associated with an undertaking such as a disposal facility. This generic assessment, however, examines impacts in the absence of potentially affected communities and the absence of a fully detailed project. Therefore, it relies on social science theory and research (See Appendix D).

1) Definition of Socio-Economic Impacts

Socio-economic impacts have two dimensions:

a) Socio-economic environment impacts are assessed essentially at the social level, rather than the individual level.

The impacts and risks associated with many economic development activities, while experienced by individuals, are created by the activities of others which have consequences for one or more persons. The implementation, avoidance, control, abatement or eradication of these impacts requires action through political, economic and/or managerial decision-making channels.

If environmental and socio-economic impacts were merely a question of impacts upon individuals, impact management would be simplified to mere bargaining with or compensating each person. While impact management does include this type of measure, it is not exclusively, or even fundamentally, about individual compensation.

Socio-economic impact management is a series of measures ultimately designed to allow individuals to continue their interrelated and vital living activities without hindrance, with minimal risk to their environment and/or their health and safety, and, if possible, with benefit to their community.

The socio-economic variables discussed in this section pertain to the characteristics of communities. These are to be distinguished from the characteristics related to the disposal facility discussed under Section 6.5.2.6. The means by which potential impacts might be managed is discussed in Section 6.5.5.

b) Impacts on the social environment are determined by the relationship between project requirements and the characteristics of the host community.

Socio-economic impacts express a relationship between project and community. There are two types of fundamental characteristics important to any SEIA: those pertaining to the project characteristics (source of change) and those pertaining to the community and the natural environment (receptor of impact). A facility may have, for example, the particular requirement for a construction workforce of two thousand people. This by itself does not constitute an impact. The degree of significance, therefore the impact, would depend on location, i.e. the circumstances of the host community. A requirement of 2000 construction workers in a small community that did not have a locally available workforce could result in the potential for the new workers to either commute to, or move into the host community for a portion, or for all of the construction period. Inmoving workers, especially with families, would place a strain on local housing, other community infrastructure and services. The extent of the strain, or impact, would depend on the planning and coping capacity of the community. Alternatively, a requirement of 2000 construction workers nearby a larger urban centre with a developed infrastructure and an available labour force could result in no significant adverse community impact. Thus the project requirement does not by itself create the impact, but only in relationship to the specific characteristic of the host community.

Every major large scale project, such as the proposed disposal facility, has a discrete set of project characteristics which initiate environmental, as well as, socio-economic impacts. Project characteristics, with their resource and labour requirements, generate

effects, such as noise or workforce influx, for example. Whether these project characteristics constitute an impact depends upon the interaction with and response of individuals and their communities, which make up the socio-economic environment, and the natural environment.

This generic assessment provides a framework for describing community characteristics. In a site-specific assessment, a comprehensive description of the community(ies) would be prepared before the project is implemented to obtain socio-economic baseline data with which to assess changes resulting from project implementation (Paez-Victor, 1993).

6.5.2.5 Community Characteristics

The first essential step in an SEIA is the comprehensive description of the community or communities. Since this is an assessment without a site, community or particular environment, it is not possible to describe the characteristics of an actual community. The generic assessment is, therefore, based on the social theory that identifies main community characteristics in general and proposes a framework for their description based on the work of various social researchers (Bowles 1979, 1981; Blishen et al. 1979; Sinclair and Westhues 1974). This generic description will be used together with a description of the project characteristics (Section 6.5.2.6) and research studies to identify the kinds of impacts that could result from the implementation a disposal facility.

Communities vary according to three main characteristics, which will determine community capacity for evaluating and managing socio-economic and environmental impacts:

i) Social and Cultural Vitality;

ii) Economic Viability; and

iii) Political Efficacy.

These three dimensions, taken together, provide a conceptual framework to help understand community structures and processes. At the site specific stage, indicators can be developed which will facilitate the detailed socio-economic impact assessment of the candidate communities. Socially and culturally vital communities with viable economies and with a high degree of political efficacy will be more able to manage effectively any potential project-related impacts, to maintain these capabilities and to achieve long-term benefits (Bowles 1981).

At the site-specific stage, the indicators of change for each of these three characteristics should include both direct and indirect data:

> Direct data information obtained from individual community members which express beliefs, values and viewpoints (Lockhart 1987);
>
> Indirect data information obtained from secondary sources (other than individuals) such as historical records, statistical and demographic data, economic indices and social research.

Socio-economic impact assessments that do not consider both types of data may be challenged for their lack of sensitivity to local values and public opinion. By including both types of data it is possible to systematically identify social processes in such a way that include experience reliability and the validity of everyday experience.

Examples of indicators which might be used in a site-specific assessment and monitoring program, to identify changes in the socio-economic environment, are listed in Appendix G (Table G-2).

The three main community characteristics are described in the following section. Because these are characteristics of a whole entity, a community, they are intrinsically linked even though they are analytically distinguished. It may be helpful to think of these characteristics as intertwining circles (See Figure 6-10A).

1) Social and Cultural Vitality

Social and cultural vitality is the degree to which individuals become mutually bonded in reciprocal relationships of trust and obligation in order to share knowledge, obtain resources and resolve mutual problems.

The degree of social and cultural vitality is reflected in the description of community culture and heritage, settlement patterns, interaction patterns and networks, mutual support, conflict resolution, prevailing social norms and values, and attitudes towards risks.

Social interaction and social integration take place within the bounds of culture. Sociologists define culture as the symbolic and learned aspects of human society, including language, customs and convention. It is possible to distinguish:

i) the main or dominant culture (for example: Canadian culture);

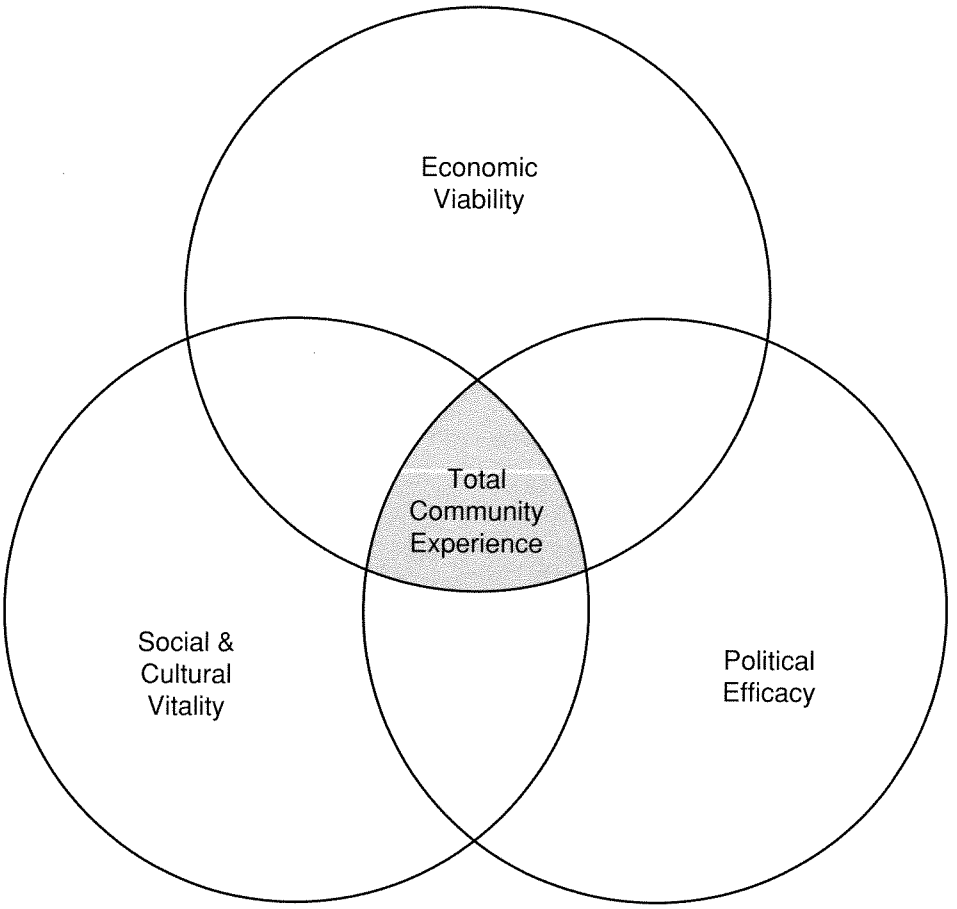
ii) its variations within different social groups expressed as either traditions or lifestyles (for example: the differences between rural and urban communities; and

iii) sub-cultures which co-exist with the dominant culture but have distinguishing features from it (e.g. Ojibwa culture).

Indicators of social and culture vitality will necessarily distinguish cultural patterns of interaction of the dominant culture and the sub-cultures which exist in Canada. These indicators will include both material culture (heritage area features or buildings, for example) and non-material culture (such as beliefs and customs).

An important consideration in appraising social and cultural vitality is how the natural environment affects the way individuals relate to each other in a community. In common usage, the word "community" generally identifies groups of people with a particular locality or environment. Indeed, when the relationship of a group with the land and environment are inescapable, the natural environment then becomes an essential part of the self definition of those communities. In particular, references will be made throughout the discussion with regard to Northerners and Aboriginal people.

Approximately 65% of Ontario is geographically considered northern (Statistics Canada 1988; Bone 1992). Canada as a whole is a northern country, however, people living in the northern sections of the provinces have a special identification with the northern environment (see Section 6.5.2.1).



Note: Refer to text Section 6.5.2.5 for explanation

FIGURE 6-10A: Illustration of Methodological Approach to SEIA for Concept Assessment: Characterization of Community Dynamics

In Canada, the distinction between north and south, in terms of human meaning and interaction, is not simply made. Northerner's self-identification may be considered as a regional consciousness expressed through the appreciation of local natural features, cultural traits and economic issues. Hamelin (1979) attempted to measure the degree of Northerness by combining both human and physical factors. Northerness then, is to be understood not simply as a matter of geography or locality, but also as a psychological identification and social commitment to the locality (Bone 1992).

> "For those Canadians born and raised in the North, regional consciousness is based on the concept of homeland. By living, working and playing in a Northern environment, they have developed a deep and lasting attachment to their surroundings" (Bone 1992).

Thus, in Ontario, to be a northerner is partly a spacial location and partly attitudinal. People who live outside and to the north of the densely populated southern settled areas of Ontario generally consider themselves "northerners". This identification includes those who live in cities, towns, hamlets or in wilderness areas. A distinguishing feature of this northern state of mind is a strong attachment to the northern land and environment.

This northern concern for the environment was reflected in a Province-wide public opinion poll sponsored by Ontario Hydro in 1987 which found that those who expressed the greatest concern about the handling and storage of used fuel were residents of northeast Ontario (Hardy Stevenson and Associates 1992a).

Aboriginal people and their communities, while of varying cultures, do share in common a spiritual relationship with the land that transcends economic interests. The land, its flora and fauna form part of their system of beliefs concerning the how and why of Creation and their role within it. More so, the land is linked to their self-identity as a people.

> "The Native people believe that this land was given to them by their Creator and that they were given this land to live off and to pass it on to future generations in pretty well the same condition that they got it...The Nishnawbe Aski, our name alone, refers to the people and the land is the interpretation of Nishnawbe Aski" (Chief Charles Fox, Nishnawbe Aski Nation, FEARO Scoping Session) (Dowell 1991a).

2) Economic Viability

Economic viability is the ability of a community to create and maintain some measure of local control of material security through its economic activities and to maintain a satisfactory balance between local and external economic factors.

At the site specific stage, socio-economic impact assessment will include indirect data on factors such as wage and traditional economy, labour force features, structure and diversity of local economic activities, economic function of larger urban centres, local facilities and services, resource and environmental base of the economy. Direct data will include information on the attitudes, beliefs and values of the community with respect to the environment, resources, the job market, economic security, opportunity and equity.

It will be necessary to adequately describe the relationship between the economic activities of a community and its natural environment: i.e. the interchange of resources and energy that forms the basis of its economic well being.

In Ontario, there are important north-south economic and political issues related to the distribution of goods, services and political power. Specifically pertinent is the exploitation of natural resources and the distribution of their profits and jobs, and benefits in general. These concerns have implications for the socio-economic impacts of the used fuel disposal facility as they raise the issue of regional equity and the unequal distribution of risks and benefits (see Section 1.5). This point was explicitly made in the FEARO scoping sessions in 1991:

> "Is nuclear waste disposal in the north really a fair distribution of social burdens and benefits when more than 95 percent of the consumers of nuclear power live in southern Ontario?" (Mr. John Stradiotto, Atikokan Citizens for Nuclear Responsibility, FEARO Scoping Session) (Dowell 1991a).

3) Political Efficacy

Political efficacy is the ability of the community, through local processes, to reach relevant collective decisions, maintain order, and mobilize and control the use of its resources. Political efficacy depends not merely on formal political institutions and processes, but also on the community's ability to legitimately, formally or informally, resolve its own social and economic decisions and conflicts (internal efficacy), and to effectively negotiate with outside parties, such as other levels of government, and large industries and business project management (external efficacy). The key indicators of political efficacy are the level of community participation in decision-making and the style of leadership in the community.

At the site specific stage, indirect data for political efficacy would include information on local expertise in planning, management and obtaining government funds, and general local government administration; formal and informal political structure and dynamics, record of past public issues resolved or not resolved, methods and processes of decision making. Direct data would include community values and attitudes of the community's political successes or failures, political decision making process and challenges. Ultimately, indicators of political efficacy should measure the ability and the difficulties that communities may have in making decisions about their resources and impacts upon their environment.

Social theory and observation points to a consistent pattern of socio-economic impacts due to large scale industrial projects and development (Toennies 1957; Durkheim 1985; Polanyi 1957, 1968). In Canadian northern communities, research reveals that the more the internal vital processes of a community displayed features of social bonding, robustness and political efficacy, the better able communities are to manage and resist negative impacts (Lockhart 1987; Bone 1992). A model of socio-economic impact assessment that is sensitive to community processes and culture can best predict and manage impacts resulting from large scale projects such as the disposal facility.

It is possible that no definable community or that several different communities across a broad region may experience impacts from the disposal facility. Their significance will depend on how the project

changes social and economic realities and how the members of those communities evaluate and interpret the changes that the project has had on their lives.

6.5.2.6 Project Characteristics

As impacts on the social environment are determined by the relationship between project requirements and the characteristic of the host community, it is necessary to identify the project characteristics.

The occurrence and type of socio-economic impacts can vary according to:

1) the stage of the undertaking: (i.e. siting, construction, operations and decommissioning); (see Chapter 2), and

2) according to operating conditions; both normal and abnormal.

A review of relevant research literature, the disposal facility conceptual design and the environmental effects analysis indicated that the following project characteristics have been considered major sources of impacts: risk to health and safety; facility design; workforce; off site services and land requirements; resource use, emissions and wastes; material and services procurement expenditures; and safety, security and environmental protection requirements (Wlodarczyk 1993).

RISK

As discussed in Section 1.5.3.2, risk is evaluated here in a social context. There are other approaches taken in other parts of the EIS, notably technological and psychological paradigms are presented. The social approach is used here to be consistent with the SEIA method, and to be able to suggest suitable approaches for impact management. Also discussed in Section 1.5.3, the term "risk" can be broadly defined as "the existence of a threat to life and health" (Advisory Committee on Nuclear Safety 1986).

It has been common in the past for risk researchers to describe the problems of risk as one in which experts and their "objective facts" are pitted against lay persons and their "subjective values". However, recent risk research reflects that this approach shows a poor understanding of the nature and practice of science, as well as an erroneous and patronizing view of the general public (Kasperson et al. 1988; Schrader-Frechette 1991; Lopes 1992; Fischhoff 1989).

Certainly no scientific assessments or evaluations are empirically confirmed independent of values, assumptions and normative criticism. Objectivity in science means the deliberate attempt to avoid misinterpreting or omitting data to suit personal preferences or interests. In that sense it is value free. Values that stem from the personal, cultural or philosophical context or methodological values are more difficult to avoid in science and risk assessment, if at all (Schrader-Frechette 1991).

On the other hand, lay persons do not evaluate risks exclusively in terms of values, independent of experience, and certain types and degrees of knowledge. The perceptions, observations and facts that individuals have of the world around them, of risks in particular, are a result of both values and the action of the external world (physical and social) upon them. Community dynamics, psycho-social dynamics, moral and ethical values, political and economic values and distributions, education and information dissemination - all have a role to play in the lay persons process of risk appraisal.

The defining characteristic of the disposal facility and its transportation system is the fact that it deals with hazardous radiological material. The technology of the disposal facility has been developed in order to reduce the risks of radiological wastes by means of their permanent isolation. However, the risks associated with the nuclear materials and the disposal technology in turn, have the potential to affect public and occupational health and safety as discussed in Section 1.5.3.

The environmental and safety analyses presented in Sections 6.1, 6.2 and 6.3 of this chapter conclude that the level of exposure to radiation is well below the regulatory limits and that consequently the risk to human health is very small. Whether such risk is acceptable or not is a decision of value pertaining to people and/or their legitimate representatives. Thus, social dynamics, moral and ethical values, political and economic considerations, education and information dissemination all have a role to play in the way people appraise the risks of the disposal facility (Slovic et al. 1978, 1980, 1982; Covello and Allen 1988; Leiss 1989; Burns and Slovic 1990; Lichtenstein et al. 1987).

There are certain patterns in the social context within which individuals become aware of and appraise technological risks (Slovic et al. 1978, 1982; Sandman 1985; Sandman and Miller 1991)). Risks are less acceptable to individuals and communities when the risks are:

i) unfamiliar;

ii) involuntary;

iii) dramatic, memorable;

iv) uncertain;

v) dreaded;

vi) controlled by others, or control uncertain;

vii) difficult to detect or undetectable;

viii) seen as unfair, risk distribution skewed; and

ix) not amenable to individual protective action.

These characteristics have been directly correlated with nuclear risks (Slovic et al. 1978, 1985, 1991; Williams 1988; Vedung 1978; van der Pligt et al. 1984; Leiss 1989; Burns and Slovic 1990; Kunreuther et al. 1990). People are deeply concerned with potential radiological impacts of nuclear installations. These installations are associated with high "dread risk factor": lack of control, catastrophic potential, fatal consequences, and inequality of risks and benefits (Slovic et al. 1982; Lopes 1992).

These risks also have the potential to be the most important sources of socio-economic impacts and can also determine the level of intensity for many other impacts (Williams and Olshansky 1987; Burns and Slovic 1990; Williams 1988; Nieves et al. 1992; Leiss 1989). Therefore, it is the aim of socio-economic impact assessment to disclose the underlying social context of the risks that are intrinsic to any project:

> "So, most risk analysts, regardless of their disciplines, would probably agree that risk assessment is not an objective, scientific process; that facts and values frequently merge when we deal with issues of high uncertainty; that cultural factors affect the way people assess risk; that experts perceive risk differently from other members of the public; and that risk communication is more effective when it is structured as a dialogue than as a one-way transfer of facts from experts to the public" (Jasanoff 1993).

FACILITY DESIGN

The scale and physical design of a large scale project can have potential effect upon the natural and human environment. The sheer size of large-scale projects may alter local and regional social life, economy and environment. For example, in the early 1970s, after the commencement of the Bruce Nuclear Power Development, the large inmoving workforce and the workers' families placed a tremendous strain on the infrastructure of the small rural communities in the vicinity of the construction project. The additional project-related construction activities further affected local roads and services. Both local and regional adverse impacts resulted. These events led Ontario Hydro to commence community impact payments to these communities in 1975.

The disposal facility was designed initially to package and dispose of approximately 250,000 used-fuel bundles per year, for an estimated 41 years (Simmons and Baumgartner 1994). While this capacity may be reduced due to changing circumstances and decisions, the initial design capacity has been assumed throughout this analysis. The disposal facility is expected to operate 230 days per year, five days per week with two eight hour shifts per day. The reference design specifies that the manufacturing, packaging and handling operations would be automated to the extent possible as an occupational safety measure. Details on the disposal facility reference design are presented in Chapter 2.

Potential physical, biological, environmental quality and resource effects of the disposal facility are addressed in other sections of this report. These effects can potentially have socio-economic implications.

From a socio-economic point of view, the four most important features of this facility design, are:

i) it is a nuclear facility;

ii) it is a large scale, complex technological project;

iii) considering its pre-and post-closure period, it is of planned, unusually long duration; and

iv) it is a waste management facility.

WORKFORCE REQUIREMENTS

Murdock et al. (1983b) note that "the nature of the projects workforce is one of the most critical factors determining its socio-economic impacts". The size of the workforce, the relationship between construction and permanent employment, the mix of skills, and the project payroll are all factors that can affect the community(ies). When labour is brought into a project, this can affect dramatic demographic changes, not just in the project community, but also in surrounding areas (section 6.6.3.2 for

detailed analysis of workforce - originated impacts to a community's economic viability).

As discussed in Section 2.1.1.5, the reference disposal facility design specifies project stages that extend over approximately 89 years requiring a relatively stable workforce population.

Stage	Approximate Duration Years	Estimated Workforce Peaks
Siting	23	470
Construction	7	1315
Operation	41	1025
Decommissioning	16	495
Closure	2	75
TOTAL	89	

During each of the stages in the facility life-cycle there would be both trade groups and scientific/technical jobs required. In some large scale projects, construction related jobs offer the greatest opportunities for local and regional employment. However, the unique characteristics of this project provide continuing, stable opportunities for highly skilled jobs.

Depending on the location of the disposal facility and its proximity to a local community, and on the character of that community, the workforce requirements associated with this project would have an effect. Whether the workforce commutes, or moves into the community, or establishes a separate community could result in a range of impacts in that community, affecting local employment, infrastructure, services and community life.

OFF-SITE SERVICES AND LAND REQUIREMENTS

The need for off-site services such as water, sewers, waste disposal and utilities may have an impact on community facilities and services, and land use. The water supply for disposal facility processes, fire fighting and domestic uses is assumed to be drawn from either a river or a lake, although the possibility exists of using municipal water supplies. The facility is to be self-contained in terms of waste water and sewage systems, and therefore, reliance on community services will be minimized. Non-radioactive liquid and solid waste could be either disposed of on-site or at suitable off-site facilities. Overall, demands on off-site services are limited to electrical power and possibly supplementary water, liquid and solid waste disposal services.

No specific site has been considered or selected for construction of the disposal facility. A detailed description of the site layout and its facilities is provided in Chapter 2. As mentioned in Chapter 5, the disposal facility would require 15.6 km^2 of dedicated land to provide space for all surface facilities and excavated rock. At the site specific stage, there is the potential to optimize service design, working with the local community.

RESOURCE USE, EMISSIONS AND WASTES

The inputs that a facility obtains from its surrounding environment (land, air, water, resources) and the outputs that it puts forth into it (emissions, wastes) can have impacts on the ecological balance and quality of that environment. Resource use, emissions and waste management can affect the environment and through it, the activities of the community or region (see Section 6.4). Effects upon environmental quality can affect business, municipal services, land use, employment and population, property values, community facilities and services (see Section 6.6.3.2). These changes have the potential to impact the social viability and economic vitality of communities that inhabit that environment. However, the analysis of the natural environment effects (Section 6.4) concludes that these effects are likely to be minimal or manageable.

SAFETY, SECURITY AND ENVIRONMENTAL PROTECTION REQUIREMENTS

Large projects such as the disposal facility require services and facilities related to occupational and public health which include: police, fire, emergency planning and health facilities. The disposal facility is to be self-sufficient in terms of fire-fighting personnel.

Specific approvals from various levels of governments and their agencies would be required (see Appendix B). Obtaining these approvals will require joint planning and thorough involvement of the local community. In addition, some facilities, particularly those which handle nuclear or other hazardous materials, have special safety or security requirements which necessitate the involvement of local fire fighting, police and medical officials in their planning and administration. These requirements have financial implications for affected communities and other levels of government.

MATERIAL AND SERVICES PROCUREMENT EXPENDITURES

Project expenditures such as the purchase of supplies and services could be a source of positive impact to the economic viability of communities. The expenditures could affect both positively and negatively the markets, businesses in general, price and sales levels, housing and other social services (see Section 6.6.3.2 for a full discussion of project economic impacts).

6.5.3 Potential Impacts from Normal Disposal Facility Activities

This section presents the full range of socio-economic impacts that could occur in a community resulting from the implementation of this disposal facility concept. As discussed elsewhere, many of the assumptions made for this concept assessment are conservative, that is, they would tend to overestimate any potential adverse impact. At the site-specific stage, a socio-economic impact assessment would be able to determine the actual potential effects and, working with the local community, be able to determine their significance, i.e. their impact, based on compatibility with the community's goals and values.

Some of the impacts identified in this concept assessment may affect more than one of the characteristics of community life: social and cultural vitality, economic viability and political efficacy; some impacts may affect all characteristics. These potential impacts have been identified in research literature from other experiences in actual communities and regions.

A full range of impact management measures is discussed in detail in Section 6.5.5, while only some suggested approaches are referred to here.

6.5.3.1 Potential Impacts to the Social and Cultural Vitality of Communities

Impacts that have the potential for affecting particularly the social and cultural vitality of communities are identified based upon literature review and research. Impacts upon the socio-cultural vitality of a community are those impacts that have the capacity to affect the way people interact with each other in their everyday lives. This would include changes in group self-definition and identification, mutual assistance and labour sharing activities, and the relationships of kinship and social networks.

Given that the three community characteristics are integrated and that socio-economic impacts are cumulative, the sources of impacts on social and cultural vitality might also affect the other community characteristics of economic viability and political efficacy.

PUBLIC AND OCCUPATIONAL HEALTH AND SAFETY IMPACTS

Definition of health and health impacts:

The World Health Organization (1967, 1986), and Health and Welfare Canada (1986a) redefined health, not in a narrow sense based upon epidemiological data of mortality and morbidity, nor on toxicological effects of substances on the human body, but in broader terms which include environment and lifestyle. A holistic view considers health as:

i) a state of complete physical, mental and social well-being, not just the absence of disease and disability; and

ii) a condition that allows people to lead socially and economically productive lives enabling their groups or communities to satisfy their needs and aspirations, and to change or cope with their natural environment.

Hence, human health is now widely understood as a function of the quality of the environment - water, air, land, flora, fauna and resources - and social conditions - poverty, employment and socio-economic inequality. Social well-being, mental health or psycho-social stress thus become serious considerations in the determination of health impacts (Health and Welfare Canada 1986a, 1986b; Kitchen et al. 1991).

> "Health is defined as the extent to which an individual or group is able, on one hand, to realize aspirations and satisfy needs; and on the other hand, to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, a dimension of our "quality of life", and not the object of living; it is a positive concept emphasizing social and personal resources, as well as physical capabilities" (World Health Organization 1986).

The activities at a disposal facility for used nuclear fuel would bear some similarities with construction, mining, industrial and waste management projects and facilities. A review of these types of projects showed that they pose public and occupational health risks and can consequently, affect the social vitality of communities (Viscusi 1992).

The analysis elsewhere in this Preclosure Assessment shows that radiological impacts of the disposal facility on members of the public would normally be orders of magnitude below the proposed new regulatory limit. More specifically, the analysis concludes that:

- Radiation exposure of members of the public resulting from normal operation of the disposal facility would be less than 1 percent of the proposed new AECB limit. It would amount to an even smaller fraction of the average exposure from natural background radiation.

- Public radiation exposure in the event of an accident at the disposal facility would still be below limits which the AECB has accepted for existing nuclear facilities. Based on analysis of a range of accident scenarios, the maximum exposure level would be less than 10 percent of the annual exposure from natural background radiation. None of these accident scenarios would require public evacuation based on action levels under the Nuclear Emergency Response Plan in Ontario.

- Radiation exposure of workers at the disposal facility, even with the conservative analysis used in conjunction with the current non-optimized conceptual design, would be expected to be well below the AECB limit for Atomic Radiation Workers.

- Human health effects from exposure to radiation, based on well known international studies, are summarized in Appendix E.

Nevertheless, public health concerns associated with nuclear facilities centre on the potential of induced cancer and genetic alterations in nuclear workers, their families, and/or the local communities (Schrader-Frechette 1980; Fischhoff 1985; Williams 1988; Lambert 1990; Nieves et al. 1992; Yassi et al. 1990; Lenssen 1991).

The potential impact to public and occupational health and safety associated to any new facility is a major concern with regard the social and cultural vitality of a community. The probability and the consequences of health impacts associated with nuclear materials and technology can be the most important source of all the socio-economic impacts of a disposal project and they can affect the nature and significance of a wider variety of socio-economic impacts (Thomas et al. 1983; Murdock et al. 1983a, 1983b).

As emphasized earlier, the environmental and safety analysis presented in Sections 6.1, 6.2 and 6.3 of this chapter concludes that the level of exposure to radiation would be well below the regulatory limits, and that the level of risk to human health would be small. However, whether such risks are acceptable or not is a decision of value pertaining to people and/or their legitimate representatives. Thus, social dynamics, moral and ethical values, political and economic considerations, education and information dissemination all have a role to play in the way people appraise the possible health impacts of the disposal facility.

Given the potential significance of this impact on the social and cultural vitality of a community, it is essential that this issue be addressed and managed in conjunction with the community. Impact management measures could be developed, including joint planning, information management, monitoring and contingency planning, which would ensure the preservation of community standards for a healthy environment and lifestyle. These measures would be based on the practices established during the siting process.

Well-Being and Stress

From a holistic point of view, health impacts have two ways of affecting mental and physical well-being of people: firstly, by the incidence of illness or accidents (low probability in this case) and, secondly, by the level of concern over the probability or consequences of illnesses and accidents. Concern over the health and safety of family, friends, community and environment, can affect health and also interfere with the normal day-to-day interactions of people (Otway and Thomas 1982; Slovic et al. 1982, 1991; van der Pligt 1984; Williams and Olshansky 1987; Williams 1988; Kunreuther et al. 1990). Since the most important concerns with hazardous waste management facilities are those pertaining to public health and safety, this will also be the case for nuclear fuel disposal.

> "Research results suggests that the most prevalent concern about nuclear waste, regardless of whether it is high or low level, is the potential risk of radiation to public health and safety" (Greber, 1990).

Stress is, therefore, a relevant health impact. Although some causes can be traced to a biological route (an infection or illness, for example), other causes are identified with environmental and social conditions. Some people may experience increased levels of stress as a result of the concerns about risks of nuclear-related work and changes in their lifestyle and community (Williams and Olshansky 1987; Slovic et al. 1991; Leiss 1992; Schrader-Frechette 1991). Psychological responses to stress often involve feelings of concern and increased anxiety or tension, accompanied by feelings of a loss of control. More extreme responses could involve feelings of resentment, apathy or depressed mental states. Direct physiological responses to stress are likely.

Although different people can experience varying degrees of stress in relation to the same situation, stress is cumulative in the individual and may lead to longer-term problems such as alcoholism, chemical dependency, and mental illness (Sorensen et al 1987). Prolonged experiences with high levels of stress or repeated episodes of acute stress can lead to physiological problems (Folkman and Lazarus 1980).

Stress can also be cumulative in a social sense. For example, there is collective stress associated with rapid population growth and the consequent social and cultural change in a community. Often the number of crimes and incidence of problems increase more rapidly than the rate of population growth (Berry 1992).

Rapid population growth and change, such as that experienced in communities that have a large project workforce in-migration, can be associated with increased crime, delinquency and other social problems which threaten people's safety and feelings of security (Finsterbusch 1980; Shklinyk 1984; Waldram 1983, 1986). Adequate project coordinating with municipal planning and joint impact management can alleviate or avoid such impacts.

In general terms, Ontario residents are deeply concerned about nuclear materials, and the disposal and transportation of used fuel in particular. Focus group research and public opinion surveys regarding used fuel in Ontario confirm that the most frequently cited concerns are health and safety related (Greber 1986, 1985, 1983a, 1983b, 1982; Pieroni 1984; Decima Research Ltd. 1985; Goldfarb Consultants 1987, 1992). A report from the Institute of Concern for Public Health (1985) carried out for Ontario Hydro concluded that health and safety concerns will be raised by communities near the disposal site and along the transportation corridors.

Used nuclear fuel and a facility such as a disposal facility have many of the features which may lead to high levels of concern over risk (see Section 6.5.2.6). Radiation is invisible and imperceptible to the human senses, and consequently some people will consider it as an "unfamiliar, insidious and even unfair" threat (Siting Process Task Force on Low Level Radioactive Waste Disposal 1987). Risk studies in which rating scales are used show that nuclear risks score at or near the extreme high-concern end (Lowrence 1976; Slovic et al. 1978).

The degree of public concern regarding health impacts related to nuclear materials disposal is evidenced by the geographic distance residents felt would be desirable to separate them from a nuclear waste management facility. For both low and high level radioactive waste facilities, the minimal acceptable distance was said to be approximately 30 km (Decima Research Ltd. 1985).

One of the most emphasized variables relating to the public assessment of any risk is whether or not it is seen to be controllable. In a survey, a large majority (87 percent) felt that communities should have the right to decide whether or not a high-level waste disposal facility should be located near them. In fact, 27 percent of these respondents considered community control the most important condition under which the siting of a nuclear waste facility would be acceptable to the public. Thirty-eight percent of the respondents stated that independent monitoring would also enhance the acceptability of a siting decision (Decima Research Ltd. 1985). For these reasons, the proposed cooperative siting process would tend to decrease the social and psychological impacts related to risk because they allow greater public control.

As previously noted, according to the environmental and safety analysis elsewhere in this assessment, the levels of risk to human health associated with the disposal facility are expected to be low. However, considering the risks that do exist with respect to radioactive materials and disposal technology, and that there are high levels of concern over them, these and any associated stigma can be regarded as a potentially significant source of impact on well-being and stress to people, communities and regions. The social and cultural vitality, economic viability and political efficacy of communities may all be affected. In tandem with efforts to manage adverse impacts on health and safety, impacts related to well-being and stress can be addressed through joint planning, full access to information, joint monitoring and contingency planning, and other measures which build on the community control developed during the siting process.

Aboriginal Health

The health of Aboriginal people is directly linked to the health of the environment within which not only their traditional economic activities occur, but to which intrinsic meaning for their life is attributed. A large portion of the diet of Aboriginal people comes directly - without intervening processing - from the land. This was taken into account in

the radiological pathways analysis (Section 9.2.1.5). Even if an allowance is made for the Aboriginal diet including 10-20 times more fish than the average diet for the hypothetical "critical group" assumed to be living at the disposal site boundary, the resulting radiation exposure to individuals would still be less than one percent of the regulatory limit.

Medical anthropology recognizes that most Aboriginal peoples across Canada experience health in a multi-dimensional way:

> "Health in Aboriginal society cannot be understood from within the classical, medical illness model. It is as much a community and family issue as an individual issue. It is intimately tied to the health of the land, and to the Aboriginal link with the land. And it is as much a psychological, social, cultural and spiritual concern, as a physical concern. Non-physical illness can and frequently does have catastrophic effects" (O'Neil and Solway 1990).

Health statistics identify a considerable gap between the health levels of Aboriginal people and the general Canadian population including mortality, infant mortality and morbidity (Indian and Northern Affairs Canada 1989a, 1989b; Grescoe 1987; Kue 1987; Frideres 1988; Posti and Moffatt 1988). This already vulnerable situation of Aboriginal health requires the prevention of any further possible health impacts to Aboriginal communities (Berry 1992; Mao et al 1986; Posti and Moffatt 1988; Singh Bolaria and Dickinson 1988; O'Neil & Solway 1990).

It is essential to carefully manage any new development, particularly in a remote area, in order to account for the sensitivity of the traditional Aboriginal land use activities and the potential consequences to health and to community vitality. At the site specific stage, all planning activities could be jointly managed with Aboriginal communities, including the socio-economic impact assessment. Impact management activities would also be jointly developed to be culturally appropriate and acceptable to the Aboriginal community.

Safety and Security

Much of the public concern over disposal facility development will be related to the possibility of a nuclear accident. The analysis presented in this report concludes that none of the accident scenarios postulated for a disposal facility would warrant an evacuation of areas beyond the site boundary. On the basis of the public and occupational safety analyses, risks associated with the disposal facility are estimated to be limited to those related to the socio-economic impacts associated with conventional industrial accidents. This does not, however, mean that there are no risks, that they will not be publicly recognized, that their associated social and psychological impacts will not occur, nor that people will not consider leaving an area voluntarily if the disposal facility is sited near them (Burns and Slovic 1990; Kasperson et al. 1988).

Chapter 1 and Appendix B present the various legislative and regulatory requirements associated with the disposal facility. A number of local approvals and the involvement of community officials will also be required. For example, there is an official Ontario Nuclear Emergency Plan that has as a goal "the safeguarding of the health, safety and well-being of the inhabitants of the Province and to protect their property". Chapter 2 contains a discussion on emergency response in Ontario.

Impact management measures for the disposal facility will include a detailed emergency plan that will require commitment of time and resources on the part of federal and provincial government ministries, the facility operator, and local communities. Plan development and practice emergencies will involve local officials, Aboriginal authorities and emergency response authorities. A broader involvement of workers, unions, and local and Aboriginal public in the development of safety and emergency plans and the periodical testing of the emergency system, as well as the monitoring system, will be needed in order to mitigate risk and the stress it represents.

In summary, in order to prevent public and occupational health and safety impacts, it is assumed that the disposal project would have an impact management program with the following characteristics:

i) impact management will be based upon socially acceptable and generally agreed upon criteria and guidelines obtained through the public process;

ii) impact management will be jointly planned and implemented with the community;

iii) community impact monitoring will be central to the program; and

iv) specific public and occupational health monitoring systems and research would be implemented.

RESIDENT DISPLACEMENT

Resident displacement refers to the forced relocation of residents due to the acquisition of property required for a facility. Experience in past similar projects shows that displacement is one of the most significant socio-economic impacts since it involves the loss of land, property, and the uprooting of individuals and families from neighbourhoods or communities.

As presented in Chapter 5, and assuming a voluntary siting process that follows publicly agreed upon criteria and principles, the displacement impacts resulting from disposal facility land requirements could be minor. In addition, the long duration of the siting stage would allow sufficient time for planning any needed mitigation measures to avoid displacement impacts. However, depending upon location, some displacement could occur as a result of land requirements for a construction camp, possibly a new town and other utilities, services and infrastructure to accommodate the project and its workforce. The following is a discussion of the kinds of impacts related to the displacement of residents in general.

The potential impacts of forced relocation include: the physical and psychological strains of moving, the disruption to kinship networks, friendship and other personal relationships. The psychological stress from the loss or interruption of contact with familiar surroundings, family and friends is also related to health impacts. Displaced residents will need to be compensated for the hardships associated with the time, energy and finances devoted to finding adequate or comparable housing.

Similar impacts may be experienced by individuals who were not part of the forced displacement, but who choose to move into or out of a community. It is also necessary to take into account the impacts upon

those who, residing on the margins of the disposal facility will not be relocated, yet nevertheless may wish to move out and are unable to do so for economic reasons.

Socio-economic impacts rarely have an even distribution, affecting segments of the population within communities, cities and societies in different ways. Impacts vary in terms of their degree of severity according to distributional patterns linked to gender, age, socio-economic status, ethnic groups, or health conditions. For example, the severity of impacts associated with displacement is greatest among the elderly or disabled, long-time residents and low income persons. Such individuals are often less mobile or feel a high degree of attachment to a place and consequently are less able to adapt to relocation.

The displacement for Aboriginal people may be in terms of their seasonal residency and traditional economic activities. Both spiritual and cultural values may be affected: land and wildlife represent not only an important economic resource for Aboriginal communities, but as well, cultural and spiritual symbols of Aboriginal identity. Construction activities that curtail or impede their traditional land use can negatively affect them. Aboriginal people have a culture-sustaining tradition of hunting. It is not easy, nor perhaps possible, to give up hunting for a time nor to relocate their hunting territory as these are culturally determined by long-standing customs and rights (Bone 1992; Wolfe 1988). In Ontario, given the geographical extent of land claims and traditional lands of Aboriginal people, it is necessary to be aware of the possible impacts of the disposal facility to Aboriginal land use.

An impact management program, jointly planned and implemented with the community, should be able to prevent and/or mitigate any potential resident displacement impacts associated with this project.

FAMILY IMPACTS

Families are fundamental to the survival of, and consequently, to the social and cultural vitality of communities. Impacts that affect the physical and mental health of family members are, therefore, of fundamental importance not only to the family but to the community at large.

The main potential positive impacts to the family are those that increase the family income by providing employment to parents. The increase of family income is one of the most important indicators of socio-economic disparity, of social well-being in general and, in particular, of the degree of children's health and well being.

The provision of steady income for the families that constitute the backbone of communities, is a benefit not only in terms of the present but also has important implications for the future of the family and the communities: by means of their access to wealth and income, families endow their children with advantages that have biological, material and psychological consequences which in turn largely determine their life chances. The potential of the children of any community, to be productive, responsible, and contributing citizens lies in the level of material and cultural endowments which their families are able to provide. Thus, parental advantages to their children have to be understood as having a social investment content. The relatively stable, long-term, highly skilled employment opportunities associated with the disposal facility is therefore a potentially beneficial impact for communities and regions.

However, the type of work undertaken at the facility, the length and irregularity of shift work, and the length of travel to and from work may increase stress among all members of the family (Alsands Project Group 1979).

A study of the psycho-social impacts combining natural and technological hazards research (Sorensen et al. 1987) suggests that in a situation characterized by the presence of a risk, such as an operating nuclear facility, increased tension among family members may occur.

The literature suggests that increased family tension and conflict may occur in communities experiencing rapid demographic growth, manifesting itself in greater family tension, conflict and potentially a higher divorce rate (Finsterbuch 1980; Alsands Project Group 1979). These social problems may be more pronounced for segments of the population currently experiencing major social problems, particularly low-income families. However, the long lead time of this project permits planning to mitigate these effects.

Special support services may be needed for the spouses of workers who have re-located to the local community. Women who re-locate to northern communities have experienced particular stresses in the process of adaptation to a colder climate, fewer employment opportunities, fewer amenities and social services, lack of family network, and social isolation (Gill 1984).

Family relations in communities experiencing a period of decline from the closure of a facility may become more strained. Fewer marriages and births in the years following closure have been observed in certain cases (Buss and Redburn 1983). Again, the long duration of this project and the planning mechanisms established through an impact agreement would facilitate appropriate measures to mitigate any closure related effects.

An impact management program should be able to mitigate negative family impacts, and should seek to enhance positive benefits.

DEMOGRAPHIC CHANGES

The in-migration of workers and their families is a major project characteristic that can cause rapid social changes within communities. Social change is not in itself positive or negative; it is the context within which it occurs and the direction that it is given that can contribute to beneficial or detrimental value to the health and well being of people and their communities (Lindheim and Syme 1983).

The influx of disposal facility workers can be expected to create and induce changes in some communities and regions which will have long-term implications for their adaptability, or conversely, vulnerability to future change. These demographic impacts are considered to be cumulative in nature, resulting from a complex interaction of all of the disposal facility socio-economic impacts.

Disposal facility development could have an immediate impact on the social structure of a community by changing its socio-demographic composition (i.e. population, ethnicity, income and age structures). Communities which attract and retain the greatest share of project-related population growth would likely experience the greatest change in social structure. An increase in socio-cultural, political and economic diversity can be expected if a community grows (Branch et al. 1982). Evidence from other large-scale developments indicates that new residents tend to be younger, better educated, more highly skilled, have generally

higher incomes, different lifestyles, and prefer different social and leisure activities than the local population. Typically, a decrease in the median age of the population occurs.

The actual influx of operations staff and their families (i.e., the workforce) will tend to have strong and lasting impacts on the community. These impacts would also be most pronounced in areas of distinctive ethnic or cultural heritage (e.g. Aboriginal or french-speaking communities) where they would represent the challenge, as well as the opportunity, of cross-cultural communications.

A community may also change as a result of changing roles and relationships between communities, and between the community and larger society. These changes emerge as new values, ideas, attitudes and practices are brought into the community. New residents and individuals who leave the community may create new social and economic ties between communities. Furthermore, existing community groups, new groups which form in response to the disposal facility, and organizations involved in project development may also establish extra-local ties to provincial or national organizations. These ties form the basis for an exchange of knowledge, skills, values and beliefs between the community and the larger society (Williams and Payne 1986). New emergent groups may become a permanent component of its social structure. Again, these impacts could also be pronounced in areas of distinctive ethnic or cultural heritage (e.g. Aboriginal or french-speaking communities), and in remote and more isolated communities. These changes are very dependent on location and community characteristics. For example, the significance of these changes could be greater in a remote community compared to an urban centre.

Disposal facility development may result in basic changes to the roles people play within their community groups, organizations and institutions resulting in more formal interaction patterns and changes in "community norms". These include: creation of new roles, more positions in old roles, differentiation of roles, redefinition of old roles, replacement in existing roles and the elimination of old roles (Cortese and Jones 1979).

Permanent changes in the socio-cultural structure, however, are most likely to occur if a major change occurs in the occupational base of a community. This occurs in communities that obtain the largest share of the project-related economic benefits, have a larger proportion of population growth, and show greater diversification in their economies over time (Mountain West Research Inc. 1980).

Rapid social change, such as that spurred by demographic changes, has contributed to salient social disruption of the status and roles within Aboriginal communities and associated psycho-social health problems (Shklinyk 1984; Waldram 1983, 1986; Wolfe 1988; Berry 1992).

An impact management program jointly planned and implemented with the community, following criteria and guidelines determined through broad social consensus, that is continuously informed by socio-economic impact assessment and community impact monitoring activities, should be able to prevent and/or mitigate negative demographic impacts.

HOUSING IMPACTS

Impact on the Availability of Housing

The availability of housing in most communities is a function of the demand and supply of residential units. In-migrant project workers, their families and others will increase the demand for housing.

The greatest demand for housing can be expected during the peak construction period. Construction workers are often reluctant to relocate with their families, consequently, their housing demands are usually concentrated on the rental market. The development of mobile home parks along with conversions of single family dwellings and seasonal accommodations to multiple unit and year-round residences often occurs as the demand for rental accommodation increases. Operations phase employees tend to prefer owner-occupied housing. Thus, increases in the demand for single family housing can be expected during this phase.

During periods of high demand, vacant and particularly resale housing will likely be rapidly absorbed. Local residents who may decide to leave the community at these times are not likely to experience trouble selling their property.

Out-migration from a community after the peak construction period and during later project stages may result in an oversupply of housing. Typically, a glut of rental accommodation occurs after the construction phase, and more permanent housing after operations.

While increased demand for housing may stimulate new construction or housing conversions, some "local builders may not be able to handle the increased demand and may face substantial competition from housing construction companies from outside the community, although it may take several years for outside developers to come in" (Halstead et al. 1982). Adequate prevention of this situation can be carried out through joint impact management related to housing.

Overall, these changes tend to result in a greater variety of housing types available in a community. The beneficiaries of increased housing demand will likely be local businesses, landlords and housing contractors. However, if housing shortages occur, those most likely to suffer would tend to be in-migrant workers and their families, low income families/households or those on fixed income currently living in rental units. With proper planning on the part of the project administration and in coordination with local municipal planning offices, such housing shortages should be predictable and thus manageable.

Concerns regarding the availability of housing and the associated impacts on local communities has led to varying approaches in impact management among different large scale projects. These are discussed in detail in Section 6.5.5. Camps have been developed to accommodate usually single construction workers. Fly-in arrangements have also been used. New town development ensures the project is self-sufficient, eliminating any adverse impacts on local communities. Although these efforts reduce adverse effects, they also reduce opportunities for project-related benefits. The long lead-time in the reference implementation schedule, prior to the initiation of siting activities and during early site screening activities, would allow planning to mitigate any anticipated housing availability impacts. The long duration of this project, in particular the operating stage, does afford the opportunity to jointly plan for project needs and community improvements, where appropriate.

Impacts on the Adequacy of Housing

The adequacy of the current housing stock can be assessed according to the needs of the existing social groups within the community (low, medium, high income groups, elderly and single-parent families and Aboriginal people).

Large scale projects in rural areas have been accompanied by the development of mobile home parks, and the conversion of single family dwellings and seasonal accommodations to multiple and year-round rental units. Although these changes are usually limited to the pre-peak construction period, their effects on the housing market can be more long-lasting.

Cluett et al. (1979) notes that the rent from several project workers usually exceeds the rent which a permanent resident family can afford. In-migrant workers earning higher wages than local residents are usually more willing to pay higher rents for small and simple accommodation. The result is usually strong competition for new accommodations among in-movers, and a struggle on the part of local residents to retain their housing. Low and moderate income families within the community, those on fixed incomes and those in substandard housing are often most severely affected.

Massey (1977) reports that approximately eighty percent of residents in temporary or mobile units would prefer other forms of housing such as a conventional home or an apartment. However, research regarding the adequacy of such housing is inconclusive to date.

The transition from the construction to the operations phase of the project may be accompanied by a deterioration of the temporary units as owners find it increasingly difficult to find and retain tenants.

An impact management program jointly planned and implemented with the community, following criteria and guidelines determined through broad social consensus, that is continuously informed by socio-economic impact assessment and community impact monitoring activities, should be able to prevent and/or mitigate negative housing impacts.

NUISANCE IMPACTS

Nuisance effects generally include disturbance due to noise, dust, vibration, night lighting, odours, traffic and visual intrusion. Residents' day-to-day activities and their use and enjoyment of property may change as a result of nuisance effects associated with facility-related activities. The most often noted changes in resident behaviour as a consequence of nuisance effects include closing of windows and/or doors; reduced outdoor activities; trouble sleeping; increased difficulties in learning, communicating and other tasks; increased stress; more frequent and time consuming cleaning of property; and, feelings of lost privacy. The significance of nuisance effects will depend upon the extent of the effects and upon how they are evaluated by those affected.

As discussed in Chapter 5, there would be truck traffic associated with the facility, in addition to the transportation of the used fuel. Increased congestion on local roads and changes to the transportation infrastructure coupled with safety concerns would have the potential to change the accessibility to some properties, reduce or interfere with the use of roadways by residents, and disrupt visiting patterns which are the basis for social networks. This impact can be addressed through planning and impact management.

Aesthetic impacts could be caused by the piles of excavated rock, backfill storage piles, stacks and other tall disposal facility structures. Appropriate landscaping and distance separation should mitigate this effect.

Impacts are expected to be greatest during the construction stage of the project. The magnitude of nuisance impacts tends to decrease with distance from its source. The distance separation from the facility construction area to the nearest property boundaries should reduce most nuisance effects. The natural environment analysis (Grondin and Fearn-Duffy 1993b) concluded that nuisance effects can be largely avoided or reduced to minimal levels through siting, effective control technology and proper environmental policy and procedures. Continuing impact management activities, including monitoring, can address the social impact of nuisance effects.

IMPACTS TO COMMUNITY SATISFACTION

Satisfaction with a community is an indicator of social and cultural vitality. If the very nature of the human interactions that keep a people bound with ties of common cause, lifestyle, and values are being affected, then the community could feel threatened and dissatisfied. The salient sign of the breakdown in community social vitality is the migration of its members. Other indicators include greater stress, loss of commitment to the community, and withdrawal from community activities.

The literature suggests that residents may experience a change in the level of satisfaction with their community as a result of the introduction of large projects in their area. Disposal facility development may produce changes in some community features and attributes which, combined and accumulated, make the community a less attractive place to live.

Research suggests that community satisfaction decreases with increasing size. This may be exacerbated by project-related growth as the number and scale of individual changes in a community increases (Finsterbusch 1980).

The potential for community dissatisfaction exists throughout each stage of project development depending upon the significance of the community characteristic affected. Dissatisfaction levels are highest in regards to housing and recreation; during the construction and early operations project phases, dissatisfaction with local services is usually greatest (Murdock et al. 1986). However, its persistence over time is variable from community to community and dependent on impact management measures taken. Dissatisfaction will likely be high if residents perceive an overall negative change in their way or quality of life.

Some residents may decide to leave the community as a result of high degrees of concern over risk. However, this is an option open only to those who have the resources to be mobile and the abilities to relocate elsewhere. Usually this is not an option for people of low income or low education and training. It is not generally an option for Aboriginal peoples who have a special attachment to their locality.

The proposed cooperative siting process and a joint impact management program with the community are more likely to affect positively the degree of community satisfaction because these two processes are the venue for a real measure of community control. In addition, the impact management program provides the opportunity to enhance satisfaction throughout the lifetime of the facility.

IMPACTS TO COMMUNITY COHESION AND CONFLICT

The literature review identified impacts that affect the degree of cohesion and conflict within a community. Whether a community responds with conflict or cohesion to external pressures upon it such as those of the disposal facility will be largely a function of its political efficacy, particularly the ability of its social, economic and political leadership. Impacts to the community, however, will be felt first of all in terms of social and cultural vitality.

The introduction of a disposal facility can be a source of either cohesion or conflict for the social and cultural vitality of a community. Individuals and groups within the community may be divided as to their support for or opposition to the facility or they may disagree over specific aspects of the development proposal. The cohesiveness of a community may, however, be enhanced as residents unite to oppose the facility or to negotiate a community agreement with the proponent. This will be a function of the degree of political efficacy within the community.

Project related in-migration may also affect cohesion as conflicts arise between new and long-term residents, and those who benefit and those who may not or cannot benefit from the project-related growth (Bowles 1981; Peele 1976). Such conflicts will vary from community to community, but may be more pronounced with Aboriginal peoples and minority groups with a distinctive lifestyle and culture to protect.

Loss of cohesion would be most pronounced during the pre-peak construction period and should progressively dissipate as integration and adjustment to a community usually occurs within the first two years after in-migration (Cluett et al. 1979).

Voluntary out-migration may result in a loss of kinship and friendship ties for those remaining in the community. Local residents may become less satisfied with the community as a place to live and choose to withdraw from community activities which promote cohesion. This can have important consequences for its social and cultural vitality.

Similarly, impacts on local features which contribute to the interaction of the community may result in decreased levels of interaction among residents. New development (for example, roads) may limit the interaction among residents, isolate segments of the population or create a redistribution of population within a community.

The disposal facility could test a community's ability to absorb or adjust to substantial change without serious social disruption. This will be a function of the strength of the community's social vitality, economic viability and political efficacy. Community integration can be affected by the disruption of an established pattern of population change or as a result of a permanent or long-term change in the community's population. Even a small change in population in areas with distinctive ethnic or cultural heritages could be destabilizing to the community.

In tourist and cottage/recreational areas, unique patterns of population change are usually established which often contribute to the long-term stability of the community and region, and if altered could result in serious social disruption (Ontario Hydro 1982). Some communities which have experience with sudden changes in population are more resilient to the changes likely to accompany the development of a major project. The length of time required for communities to adapt will vary, however, the adaptability of some Aboriginal communities may be longer than for non-Aboriginal ones.

Community dynamics can also be affected by a loss of long-term residents, and home owners, or where there would be a loss of historical continuity provided by residents whose ancestors lived in, and helped build the community.

Communities which have dealt effectively with large-scale project changes will be more prepared and resilient to the impacts of decline during decommissioning and closure, and other non-project related changes affecting the community.

The siting process assumed for this facility development is based on cooperative planning and community voluntarism. Successful siting is premised on community support. The success of this approach should help to mitigate any potential community conflicts and improve cohesion. The joint planning process established in a negotiated community impact agreement would provide a continuing mechanism to strengthen community cohesion and to resolve conflicts. Also, throughout the lifetime of the disposal facility, depending on the location of the site, the people who work at the facility could become integral members of the social life of the community.

EDUCATIONAL IMPACTS

Population changes as a result of the in-migration of project workers and their families for the construction and operation of a disposal facility will affect the demand for all educational facilities that serve the area. Typically, fewer adverse impacts on community colleges and universities occur than at elementary and secondary school levels.

The transmission of skills, knowledge and values is of fundamental importance to the social vitality of community life. Potential education-related impacts include the disruption of educational facilities and services; increased need for new curriculum and/or programs; and change in school boards' financial resources.

The significance of potential impacts will depend on the number of inmoving workers and their families, the capacity in existing facilities, and on the ability of existing facilities to adjust to changing enrolment. At educational facilities currently operating at physical capacity, increased enrolment may require that facilities be enlarged and/or improved, benefiting both existing and new students. Facilities with excess capacity during periods of growth may become more effective.

Increased enrolment during periods of growth may result in increased class sizes, possibly larger staff requirements, or increased workload for existing staff potentially decreasing the quality of education provided. A high turnover rate among teachers and difficulties in attracting new staff may intensify these impacts. The short-term residency of construction workers and their families may cause additional problems for teaching staff.

Loss of enrolment associated with a decline in project-related workforce may require reductions in staff and closure of non-viable programs and facilities. The impact of declining enrolment will depend upon the manner in which growth-related changes were managed.

Changes in the number of pupils, teachers, administrative staff and facilities will have implications for school finances, local taxpayers and funding agencies. An increased tax base would allow better facilities. During growth periods, per student provincial grants for

operating costs will respond directly to enrolment levels. During periods of decline, reduced provincial grants will have to be accommodated.

In cases where school boards are unable to adjust expenditures, local taxes will likely increase. Assistance with capital construction costs is determined by a review of priorities carried out by the Ministry of Education. The identification of local need does not guarantee assistance with capital costs.

Disposal facility development may also result in a need for new curriculum, vocational or adult education courses or programmes. For example, a major barrier to Aboriginal employment is limited education which does not allow the Aboriginal worker to compete with the non-Aboriginal. Government and private sector job training programs and on-the-job-training opportunities are important responses to this social situation. However, it is through finishing high school that young Aboriginal students would increase their employment chances. The proportion of Canadians of Native ancestry that have graduated from high school is well below the national average. "Such levels of schooling effectively prevent many Natives from entering the wage economy" (Bone 1992). Long term operations jobs at this disposal facility will permit needed preparation to ensure job opportunities are realized.

Job opportunities generated by the project may stimulate demands for related vocational and skills training programs at the high school, community college and university levels. The unique character of the disposal facility would require highly skilled jobs in science and technology. This need over such an extended period creates the opportunity for new courses, research chairs, and specialized studies. These might require new facilities and specialized settings, which might represent a benefit to the community. The nature of training and education required will shift with project stages. The nuclear aspect of the disposal facility will probably stimulate interest in environmental education programs. During construction and operation, the unique nature of the facility may result in an increased demand for such information.

Educational strategies that result from vibrant community participation in a joint impact management program could help meet and enhance educational opportunities and challenges, and mitigate negative educational impacts.

IMPACTS TO RECREATIONAL ACTIVITIES

Recreational activities are an important aspect of interaction for the members of any community, influencing the community's degree of social and cultural vitality. Recreational activities may be organized or unorganized, service-based or environmentally-based. The disposal facility may change the recreational facilities and also affect the economic viability of community. For example, there may be disruptions to wilderness types of recreation, also linked to tourism economic activities. Another example would be the pressure on the capacity of existing recreational facilities in a community created by the influx of the project workforce. The participation of residents in related activities may also change as a result of the effects on the natural environment, or changes in the use and enjoyment of these facilities and amenities. The ability of particular communities to absorb changes can only be ultimately identified once specific sites have been identified. Hence, the development of a disposal facility could potentially affect recreational and community activities, and their related facilities, services and amenities.

Additional demands on these features due to population growth may reduce their availability to some residents, their attractiveness and/or operational effectiveness. If excess facility capacity exists or if the area can absorb the increased demand, adverse impacts may not occur.

The expansion or provision of new community and recreational features may benefit existing residents in addition to serving new ones. The nature of activities and types of facilities in a community may change. New and younger residents may demand a higher quality or a wider range of recreational opportunities. In some cases, particularly in smaller communities, informal activities may become more formal or organized, and more elaborate facilities may become economically feasible.

Careful planning and an impact management program jointly planned and implemented with the community, should be able to mitigate negative impacts and enhance positive effects to recreational activities and services.

IMPACTS UPON ABORIGINAL COMMUNITIES

Impacts to Spiritual Values Related to Land and the Environment

The centre of the traditional lifestyle and culture, or way of life for Aboriginal peoples is the land (see Section 6.5.2.5 for a discussion of the relationship between environment and the Aboriginal community's social and cultural vitality). The identification Aboriginal people have with the land is different from that of the dominant culture as noted by Berger (1977):

> "...they regard themselves as inseparable from the land, the waters and the animals with which they share the world. They regard themselves as custodians of the land, which is for their use during their lifetime, and which they must pass on to their children and their children's children after them".

For Aboriginal peoples, reverence for the land, seen as the total environment, has a deep spiritual quality, indistinguishable from mysticism (Wolfe 1988). At the FEARO scoping meetings, April 1991, the following statements were made by participant Aboriginal people about their identification with the environment:

> "There may be psychological and spiritual impacts on a non-Aboriginal community but I don't believe that they can possibly compare to the effects on Aboriginal people with their unique relationship to the land" (Mr. Chris Reid, Ontario Metis and Aboriginal Association; Dowell 1991a).

> "The communities of Nishnawbe Aski have a unique relationship with the land. That must be understood at this hearing. This is our land. We have survived here for many years, but the land and the First Nations that have long lived on this land continue to be threatened by the actions that many private companies and government agencies wish to carry out. It seems that they consider this land to be merely empty space to be exploited" (Deputy Grand Chief Charles Fox, Nishnawbe Aski Nation, 18, 32; Dowell 1991a).

In light of this unique relationship with the land, a nuclear fuel waste management facility, such as the disposal facility, may be regarded by some Aboriginal people as being at odds with some Aboriginal social and spiritual values. One such example is their reverence for "the cycle of

life" by which they mean that there is a oneness of people and the land in all its elemental forms, a oneness of things animate and inanimate (Edmond 1986; Wolfe and Strachan 1987; Wolfe 1988):

> "There is probably no amount of favourable environmental assessment findings that will convince the leadership and the people and the membership of UCCM (United Chiefs and Councils of Manitoulin) that a violation of a cycle of life should be considered or even indeed taken, which is the position that we have ..." (Mr. Tim McGregor, speaking for United Chiefs and Councils of Manitoulin, March 6, 1991, 120-130: Dowell 1991a).

Increased training and employment opportunities, and the increased presence of non-Aboriginal people may change the value Aboriginal people, particularly the youth, place on maintaining their language and practising other cultural activities. This may inhibit communication among Aboriginal people, particularly with elders, and diminish the ability of the community to pass on their culture to subsequent generations. A loss of cultural knowledge and environmental knowledge can thus ensue:

> "Of great concern to the people I talked to is a destruction of traditional lifestyles. There are still quite extensive traditional activities taking place in northern Saskatchewan. Even though there is very few people that actually make a living at hunting, fishing and trapping, there is a lot of people who do, to a certain extent, use traditional activities." (Lorna LaPlante, Saskatchewan Native Corporation and the Metis society of Saskatchewan, FEARO Scoping Meeting, April 1991, 16, 21: Dowell 1991a).

Impacts to Cultural Values of Aboriginal Economy

The introduction or enhancement of a wage economy may provide sufficient income to raise the standard of living for some Aboriginal families and their communities. Whether this would allow for the provision of better services for the community is a function of the degree of control that the community could have in directing the impacts upon it.

Some Aboriginal people may want the economic opportunities represented by the disposal facility:

> "We have a special relationship with the land. We have a spiritual relationship with the land and exploitation of natural resources is something that we abhor, we don't agree with. But with new concepts, non-Native concepts being introduced to a Native community, concepts for employment, concepts for economic development, those views are slowly changing" (Chief Charles Fox, Nishnawbe Aski Nation, FEARO Scoping Meeting, April 1991, 18, 48: Dowell 1991a).

> "The northerner must benefit from northern development. But not as gifts, not as handouts, and not as a do-gooder type of approach. Because that will surely destroy them. I am all for getting native people to work. I am all in favour of that. But what I disagree with is simply putting them on the job for the sake of political, social or economic or other factors. It has never helped the native at any time in their history and it is not going to help them tomorrow or in the future. I disagree with the creation of an atmosphere of false perception and conception that the world owes anyone a

rate and process of change do not exceed its capacity for managing change. Moreover, if the local communities desire sustainable development for their economies, rather than the common boom and bust cycle, then a regional outlook is necessary in the implementation of economic impact management measures.

During the seven year construction period, the procurement of materials and services and workforce requirements would create the potential for increased business activity, employment opportunities and increases in personal incomes. Typically, the construction stage represents the best opportunity for local residents and businesses to share the economic benefits of the project. However, the unusually long duration of the operating stage of the project, provides unique planning opportunities to optimize local benefits.

Generally, communities that provide a substantial share of the project's employees, experience population growth (as a result of an influx of workers and their families) and generate secondary employment opportunities (as a result of the expansion of housing and community services) are likely to benefit most from the economic expansion. These benefits could also be shared by the surrounding communities and region. There could also be impacts on housing and property values, local taxes, and Aboriginal businesses and activities. The economic changes resulting from increased population and employment could result in positive change if the ensuing development meets community and regional needs, and reflects community and regional goals.

REGIONAL IMPACTS

The economic impacts of major projects are often seen to be the most positive, benefiting particularly businesses and individuals who gain employment or income in the market or wage economy. The size of the workforce required and the estimated levels of expenditures for materials and equipment have the potential to create substantial employment opportunities and income benefits, as well as substantial stress to a community's economic viability. Attention to the socio-economic context within which projects operate (i.e. the relationship between project effects and the location and character of the community), however, will determine its benefits and its costs:

> " ... available evidence suggests that the local economic impacts of large-scale developments are neither inherently positive nor negative, but rather are heavily dependent on the nature of the site area and of the project" (Murdock et al. 1986).

The economy of northern communities, because of their strong reliance on resource extraction and because of their lack of diversity, are likely to be more sensitive to the economic consequences of the disposal facility. For this reason, they are considered specifically in this assessment. Typically, major resource projects in the north, usually industrial resource extraction undertakings, foster economic activities in areas directly linked to the projects' activities.

The most desired result of such activities is the strengthening of the local and regional economies, the local community(ies) being the most salient recipients of this activity. For the reasons, particular care must be taken in the planning of planning local participation.

Historically, large projects have not succeeded in diversifying the northern Canadian economy (Bone 1992). It is possible that the reason for this has been their single resource focus and the fact that they have

been driven by the interests of the market and out of region owners and economic interests. While large projects have helped to develop its resources, compared to the southern regions of Canada:

> "the Canadian North as a whole received relatively few benefits from resource projects, and there is little evidence to suggest that the northern resource economy will evolve into a more diversified and stable economy" (Bone 1992).

Whenever economic development occurs, uneven distributions accentuate social and economic inequalities between individuals and communities. The distribution of income and employment, not usually central for economic impact analysis, is certainly important to social impact analysis because the patterns of income and employment within the community are often the source of social change (Craig-Davis 1984). Individual and family incomes rise sharply in communities where people are employed by a project. The income and employment differences between Aboriginal and non-Aboriginal are also sharply differentiated, linked to different levels of education, therefore employability.

Part of the reason for these inequalities is that the Ontario economy, reflecting the Canadian economy, is a dual economy: consisting of a resources or wage economy, and an economy characterized by traditional, land-based economic activities such as hunting, fishing and gathering generally carried out in northern regions of the province. It is sometimes referred to as the Aboriginal economy, however, these activities are also carried out by Non-Aboriginal northeners. There are nearly 100,000 trappers in the Canadian north and only about half are Aboriginal people (Schellenberger and MacDougall 1986). The traditional land-based economy is evolving, however, since it is unable to completely meet the needs of Aboriginal communities. Therefore, Aboriginal people have an increasing participation in the wage economy.

The economic impacts of a large project upon regional development is expected through three avenues:

i) the influx of taxes to municipalities enabling them to provide new and better socio-cultural services and programs (such as medical and educational facilities);

ii) the influx of new money being spent by workers stimulating the local economy; and

iii) new needs in the markets, increasing opportunities for businesses and workers.

The off-site project requirements are one of the main concerns of local community municipalities. It has been the attitude of most private companies and Crown corporations to consider their contribution to regional development solely in terms of their investment in resource exploration and project investment. Off site matters by and large, have been left to the local communities, in a scale of priorities whereby the company comes first, then the shareholders and lastly the local or regional interests. These attitudes are changing, even in the private sector. For example, uranium mining companies in Saskatoon have started scholarship programs for northern students (Bone 1992). A used fuel disposal facility, which will necessarily have regional impact, can only offset negative ones, by conscious commitment to regional development.

Impact management that could successfully address potential workforce regional impacts would necessarily depend upon: (1) coordination between the project management and the planning authorities at the local, regional, and provincial levels; and (2) an effective joint impact planning and monitoring with the potentially affected communities that assured a certain measure of community control. Careful planning is required to enhance benefits on a regional scale.

WORKFORCE IMPACTS

This section analyzes workforce-related impacts with respect to: workforce size and type, impacts on employment and labour supply, and impacts on secondary employment.

a) Impacts on Employment and Labour Supply

Levels of employment and labour supply are directly influenced by the amount of available work, the number of employed and unemployed, the skills available and sectoral competition.

Disposal facility development will provide a large amount of employment opportunities throughout its life cycle. These opportunities will be governed not only by the skills required but also by the size of the available labour pool. Murdock et al. (1986) conclude that the percentage of local hiring is directly related to the size of the labour pool. Projects in more rural areas tend to generate large commuter fields. In such cases, project employment opportunities are likely to be distributed over a wider region. Another means of spreading the employment benefits to other communities is the use of a rotational workforce. The Norman Wells project, for example, obtained 55% of its labour force in the peak construction period in 1984 in this manner (Stewart and Bone 1986).

The reference design specifies that the disposal facility construction stage would take place over a period of 7 years and the operations phase would continue for 41 years. The actual length of employment for any individual could be less, as the mix of skills required for different stages of construction encourages workforce turnover. However, as discussed in Section 2.1.1.5, the workforce requirements are fairly stable over the duration, with some of the construction jobs carrying over into the operating stage.

Experience with large Canadian projects shows that labour supply problems were confined to highly skilled trades. A similar situation is reasonable to expect with disposal facility development. For some trades, workers may be drawn from across the province or country. Construction trades workers are identified by the union local having jurisdiction over the construction site according to "out-of-work" lists. As a result, non-local union workers may have an advantage over local workers.

Generally, most of the non-scientific/professional employment opportunities will be in unionized skilled trades. This condition may limit opportunities for some Aboriginal people, to the extent that they may not qualify in a skilled trade, or may not be a member of an appropriate union. To enhance these employment opportunities for Aboriginal communities, impact management measures will need to be developed in conjunction with Aboriginal communities to assist in training and qualifications. Other measures can also be used to enhance opportunities for Aboriginal employment. For example, practices could be more open to Aboriginal peoples by air-commuting to their communities, such as many resource companies now do in the Northwest Territories,

Saskatchewan and Ontario. Air commuting offers Aboriginal workers access to the work place but allows their families to remain in their settlements. This was the case at the Normal Wells project (Bone 1992). This is a welcomed change, and one that is meaningful to the disposal facility, because the activities of resource companies in the Canadian north have been marred by a failure to involve the local Aboriginal people in the economic activity and development (Tough 1972). In the North, especially in Aboriginal communities, there is considerable hidden unemployment, i.e. people wanting to work but not actively seeking a job.

Although local unemployment rates can be expected to decline during project development, project employment may attract people in search of work to the local area. Speculation about employment opportunities and raised expectations may result in inmovers, some of whom may not gain employment as they are not qualified, or because the openings are filled. This may lead to higher overall unemployment levels on a temporarily basis. This impact, however, would be most likely to occur during the siting and pre-peak construction period.

Operating employees often prefer to live closer to work than construction workers. There will be a tendency for disposal facility operations management and technical staff to move into local communities from elsewhere, while the majority of the maintenance and clerical staff will likely be hired from local communities in the region. The relative stability of employment during the operation stage in the technical and scientific fields will create a continuing demand for these skills in the local and regional areas.

In smaller communities, disposal facility employment could change the occupational base of an area. A major shift will influence its development potential, by either attracting or averting different types of activities from an area. Certain types of work can be displaced by a project, such as occurred in the agricultural and small manufacturing sector in the region near the Bruce Nuclear Power Development (Schwass 1980). At the completion of the construction phase or after decommissioning, alternative employment opportunities within a community or region may help to retain disposal facility workers in the area.

Impact management measures, such as preferential hiring policies, can be implemented as part of a joint impact management program with the local communities, coordinated with local, regional and provincial planning authorities in order to mitigate negative impacts on employment and labour supply and to enhance beneficial impacts.

b) Workforce Size and Type

The size and the type of workforce is estimated to be two of the most critical sources of impact to any community's economic viability.

As discussed under Project Characteristics, and in Section 2.1.1.5, the size of the workforce over most of the facility's life-cycle is stable and the types of jobs tend to be highly skilled technical/scientific. The peak labour requirement over the seven year duration of the construction stage is estimated as 1300 persons, while the peak requirement over the forty-one year duration of the operating stage is approximately 1000. The size of the workforce over the operating stage is relatively stable. Also, the transition from the construction to the operating stage could be more easily managed than experienced at other major projects as the overall numbers do not change significantly and there is some continuity of the actual work.

Northern Ontario communities are characterized by the co-existence of both a traditional and a wage economy, and have been very sensitive to impacts of large-scale projects, usually based on non-renewable resource extraction. Since population densities in the north are dramatically less than that of southern regions, workforce impacts have been significant. Hence, the social impact of a used fuel disposal workforce influx can be expected to affect all community characteristics in northern Ontario. However, due to the long-term nature of the disposal facility, some of the worst effects of development projects in the north, i.e. their short-term, boom-bust characteristics, may be avoided.

The demand for labour associated with large scale construction projects may represent a serious problem for economic development in the North.

> "The demand quickly outstrips the capacity of the local labour market to supply workers, thereby shifting recruitment to Southern labour sources. Added to this problem is the limited number of skilled workers in the Northern labour force. For these two reasons, many jobs are filled by workers from Southern Canada" (Bone 1992).

Concerns over expected large influx of workers from the south is one of the major social concerns in northern communities, particularly for Aboriginal communities. During construction, communities are affected by the introduction of transient people who place demands on community life and services and who, not having their customary home base, may be under stress.

In order to offset negative social impacts from the increase of the workforce needed, the Norman Wells Pipeline Project in the Northwest Territories, for example, had all its major contractors fly-in workers on a temporary basis, for periods of two weeks to a month. Further, temporary workers were lodged in self-contained work camps. Fly-in arrangements can also provide employment for disadvantaged workers available outside the project area. In this way, the local community did not suffer from a large numbers of in-migration during the pipeline construction period (Bone 1992). When workers are hired on temporary basis, but with frequent return to their homes, social and psychological stability is maintained, as most workers families remain either in the north or the south where they are based, thus reducing many negative social and psychological impacts.

The disadvantages of air commuting temporary workers, however, is economic since the jobs are held by people from out of the area and, furthermore, their wages are not spent in the local economy. In addition, workers could be flown in from the south to jobs located in the north. In the Norman Wells Project, the Federal government intervened to insist that every effort was made by Esso to employ northerners. Two air commuting systems were established, one from the south and one from the Northwest Territories (Bone 1992).

This project will require a large permanent workforce during the operating stage. This may require the building of new towns or expanding existing ones. Social vitality can be thus affected, as well as economic viability and the ability to politically control these demographic changes. Furthermore, the sharp rise in population size of surrounding towns can create economic inequalities between communities in a region. Fly-in commuting is an example of an impact management measure to reduce economic inequalities.

The full implications of these socio-economic impacts will ultimately depend upon site-specific considerations such as size and location of the

community or communities, the character of the local labour force and, most importantly, the dynamics occurring within the main community characteristics, as discussed in Section 6.5.2.5. Workforce changes will affect all three basic community characteristics, but, in particular, economic viability.

Joint impact management programs with the local communities, coordinated with local, regional and provincial planning authorities, will be necessary in order to prevent negative impacts due to workforce type and size, and to enhance beneficial impacts.

c) Impacts on Secondary Employment

Changes in the business climate may have a positive impact on secondary employment opportunities in the construction, retail and service sectors. As mentioned previously, funds injected to the economy are spent and re-spent by individuals and businesses making purchases and paying employees. During the siting and construction phases of project development, secondary employment tends to be generated in the local or regional retail and services sectors, if the project is obtaining materials and services locally.

Generally, secondary employment opportunities will be greater for the operating stage, stimulated by expansion of community infrastructure and the injection of new wages into the economy. Most of these jobs may be taken by the spouses of project workers or local residents (Gilmore et al. 1982). In some cases, increased productivity in local businesses and extensive commuting by project workers could reduce the anticipated economic development.

Declines in project employment during the decommissioning stage may also adversely affect secondary employment levels. If the disposal facility becomes the dominant employer, the adverse impacts of a decline in disposal facility employment would be severe. For example, recent deliberation over the future of the Bruce A Nuclear Plant highlights these potential impacts. The Bruce Nuclear Power Development employs overall 5,000 employees with about 3000 employees at the Bruce A Plant. The plant is by far the largest employer in the Bruce area. It is estimated that every primary job created by Ontario Hydro, produces 0.87 of secondary jobs in the Bruce area. It is further estimated that 2,200 spinoff jobs in nearby communities would be lost if the Bruce A Plant is closed. However, declines in secondary employment are often not as widespread as expected due to the use of personal savings for household expenses, reliance on a second income and a greater willingness to go into debt (Ontario Hydro 1984c). The degree of this decline is sensitive to local conditions and to the success of impact management, for example, inducing retiring staff to remain in the community.

Joint impact management planning will be necessary in order to prevent negative impacts due to secondary employment and to enhance related beneficial impacts.

ENVIRONMENTAL QUALITY IMPACTS

There is now a growing concern among the Canadian public, north and south, as well as the regulating authorities, that economic benefits do not necessarily outweigh environmental effects, and development projects should ensure the continued well-being of the environment.

Environmental effects have a particular capacity to affect Aboriginal people's lifestyles and cultures due to the nature of their land use. Past experience in Canada's north shows that the burden of pollution and

environmental damage caused by pulp and paper companies, oil, gas and hydro-electric development, forest industry, and mining, has been acutely felt by Aboriginal people who rely heavily on the land and water for their survival. The most salient example is the mercury poisoning at Grassy Narrows (Shklinyk 1984; Bone 1992; Wolfe 1988; Geisler et al. 1982; Waldram 1986; Berry 1992). While these negative environmental impacts may have been perceived by mainstream Canadian society as the price of progress, to Northerners it may be viewed as the hidden price of progress, i.e. environmental and social costs (Bone 1992).

A critical social factor to the well being of members of a community is the quality of life which is linked to the natural environment. This is particularly true in northern communities and Aboriginal communities. It is possible that changes in environmental quality could influence the nature and significance of socio-economic impacts. The environmental analyses presented in Chapter 4, 5, Section 6.4 and Chapter 8 conclude that the technology exists to mitigate the identified environmental effects. On this basis, the socio-economic impacts resulting from effects on the natural environment are expected to be limited.

The analysis of natural environmental and land use factors assumes that the following areas would be avoided: permafrost areas, native reserves, prime agricultural lands, areas of high timber capability, areas of outstanding recreational use, and wetland areas. In addition, the AECB has recommended that there be little likelihood that the host rock will be exploited as a natural resource, i.e. siting should avoid areas containing minerals or other materials of commercial value or strategic importance (AECB 1987b). The avoidance of these and other locally significant features would help in reducing the potential for socio-economic impacts, particularly if there is consensus, over these and any other avoidance criteria, reached through open and broad public discussion which later form the basis of the agreed siting process.

Given the extensive area of the Canadian Shield region affected by Aboriginal land claims, lands which are under treaty, used for subsistence purposes or regarded as homeland by the Aboriginal people, it is very likely that impacts on the Aboriginal peoples and communities would occur.

An impact management program jointly planned, implemented and monitored with the communities, and in coordination with local and provincial environmental authorities, can help avoid estimated negative impacts and help to deal quickly with unanticipated impacts.

IMPACTS ON BUSINESS ACTIVITY

The disposal facility will change the volume of business sales, will introduce new customers, diversify local and regional markets, and change the competitive structure in an area. These impacts result from the purchases of project supplies and services; changes in community facilities and services; changes in the activity of the retail and service sector.

Increased business activity can be expected in response to population growth and the levels of direct and secondary employment generated by the project in a community or region. Those gaining employment or increased income will generate further business activity. Funds injected to the economy are spent and re-spent by individuals (e.g. food and housing) and businesses making purchases and paying employees. The supply of goods and services in the construction and operational stages represent a

business opportunity. Increased competition for project contracts may result in lower per unit profit margins and diversification in the supply of products and service.

However, for this chain of economic spinoffs to be enhanced, it would be necessary for the project to make efforts to obtain labour and materials needed for the construction and operation from local and regional sources. If not, these benefits could be lost through leakage to southern economies (Ironside and Mellor 1978; Ironside and Fieguth 1990).

Research indicates that most of project spending for specialized equipment during construction, particularly for large facility components, goes to major manufacturers and suppliers concentrated in existing industrial centres (Murdock et al. 1983a). Ontario Hydro experience indicates that the best opportunities for local construction contracts lie in the area of site preparation work, provision of transportation services and sub-contracting to larger firms. Depending on location, the expansion of community facilities and services often stimulates business activity and economic development during the operating phase (Cluett et al. 1979).

The disposal facility will also use large quantities of materials in the fabrication of disposal containers and buffer and backfill stimulating business activity in the transportation and potentially the manufacturing sectors.

Benefits would be distributed across specific types of businesses. During construction, real estate firms, hotels and restaurants may benefit more than other businesses (The DPA Group Inc. 1986). Rapid growth in a community may attract larger chain stores (Murdock et al. 1986).

Many single industry towns have experienced vulnerability to changes in the business cycle due to market or price fluctuations. These changes do lead to losses of purchasing power, which in turn affect business. The workforce declines associated with later project stages could trigger some loss or turnover of local businesses depending on the success of economic diversification efforts through an impact management program. This project is not sensitive to business cycles. Therefore, the demand for local labour and services would be relatively stable over a 70 year period, (to the end of the operating stage).

a) Impacts on Business Development Plans and Potential

The disposal facility development may positively change the operational effectiveness and viability of businesses, i.e. the opportunities for and level of investment which influence long-term economic development potential.

Business operations could experience changes as a result of disruption to routine operations, changes in business climate, and responses of employees and the community to the nuclear risks of the facility. These impacts could affect business activities near the disposal facility site itself or in a broad geographic area.

Site acquisition can be expected to disrupt or displace any existing on-site activities such as agriculture, forestry, trapping or recreation. New high paying project jobs may cause wage and labour competition, altering the cost structures of existing businesses. Marginal business operations are considered to be most vulnerable to these kinds of impacts. In most cases, wages in local businesses increase at a rate only slightly greater than inflation.

The disposal facility could provide the potential for economic diversification planning. Studies (Van Zele 1976; Schwass 1980) have concluded that energy projects generate business in the retail and service sector rather than stimulate new industrial growth. Therefore, a deliberate effort must be made to encourage new industrial development.

It is possible that new or existing businesses could be discouraged from locating or expanding in a community near a disposal facility or throughout a broader region. However, in Ontario there are a number of businesses located in the vicinity of the Pickering, Darlington and Bruce Nuclear Generating Stations.

b) Impacts on Tourism

Public involvement activities and attitude research regarding the disposal concept indicate that communities or regions relying on tourism as a source of income are concerned that the disposal facility may disrupt tourist related activities or change tourism development plans and potential (Pieroni 1986).

One of the issues relating to tourism is the question of the potential for economic impacts resulting from negative imagery or stigma. In the State of Nevada this is an issue under examination due to the concern that the siting of a disposal facility there could adversely affect local tourism. A negative perception among potential tourists may result in decreased visitation levels and expenditures, adversely affecting local business revenues, future investment and employment. To date, social research has not been able to verify that this concern has resulted in any adverse impact. In the extreme case associated with an accident, subsequent research at Three Mile Island has determined that the decline in tourism immediately following the accident may be attributed, in part, to other factors, i.e. the gasoline crisis and inclement weather, and that this decline did not extend past the 1979 tourist season (Himmelberger et al. 1993).

Case studies indicate that the potential for adverse impacts tends to dissipate as operating experience at the facility is established (Sorensen et al. 1987; Allison et al. 1993). This evidence is consistent with the experience at AECL's Whiteshell Laboratories, located in Manitoba's busiest tourist region, and with the Bruce nuclear site, located in Ontario's Bruce Peninsula tourist area.

Improved access to previously isolated areas will increase the opportunity for tourism-related development and may stimulate new investment. However, improved access associated with the construction of roads, site servicing, and the influx of the project workforce may result in increased local angling and hunting pressures. A reduction in other hunters' or fishermen's success rate may result in a shorter stay or discourage return visits. New access roads and increased hunting or fishing can have a detrimental impact upon the Aboriginal traditional economy that is heavily based upon these activities. This issue has been addressed in a number of other development situations and local negotiations have determined a resolution.

Construction activities and the presence/operation of a facility in some environments has the potential to displace or disrupt local wildlife, disrupt tourists and affect the enjoyment of their activities, influencing visitation levels over the long-term. The disposal facility's land requirements, and project-related population growth may also affect the tourism development potential of the area by changing the availability or use of land.

The in-migration of project workers may provide an important economic benefit for existing operators during the construction period. Increased business may serve to stimulate investment in the provision of accommodation and other services. In more extreme cases, the disruption or loss of long-term traditional business may adversely affect future development plans and potential.

An impact management program jointly planned, implemented and monitored with the communities, and in coordination with business representatives, as well as local and provincial economic development agencies, can help avoid negative impacts to tourism businesses and enhance benefits.

c) Impacts on Local Income and Price Structure

New jobs and new people in a community may increase the average personal income, benefiting both individuals, their families and community.

During construction and operations, project wages are generally higher than prevailing local wages, especially in rural areas. Higher project wages may trigger wage competition and higher prices for land, housing and locally purchased goods and services (Cluett et al. 1979). In this way, increased income may induce local inflation.

An increase in the cost of living will adversely affect those on fixed incomes and those not benefitting from the project. Inequities in the sharing of costs and benefits can lead to resentment and tensions within the community (Halstead et al. 1982).

Because of the large labour force during the operating stage relative to the construction stage, and because many of the construction jobs carry forward into operations, the decline following construction usually observed in large-scale construction projects (Cluett et al. 1979) is not anticipated in this project. The impact of the decline associated with the decommissioning will be influenced by the scale and diversity of the local economy and the success of earlier planning efforts to diversify the economy.

Possible effects on tourism, housing prices, and other development opportunities which are discussed in this section could contribute to changes in local prices. An impact management program jointly planned, implemented and monitored with the communities, and in coordination with business representatives, as well as local and provincial economic development agencies, can help avoid negative impacts to income and price structures.

IMPACTS ON HOUSING AND PROPERTY VALUES

The relationship of housing impacts to economic viability centres upon changes in property values. Studies of property value impacts around industrial facilities indicate that property values may either increase or decrease. Decreased property values during the construction stage are most commonly related to nuisance effects. Declines caused by nuisance effects tend to recover close to pre-impact levels regardless of whether or not the nuisance is eliminated (Clayton Research Associates Ltd. 1985). Declines due to nuisance impacts are usually restricted to the area surrounding a site or the source of an identified interference (e.g. access route). The proposed land belt (for security purposes) around the disposal facility will serve to minimize the potential for nuisance effects. No consistent relationship has been established between decreased property values and distance from a an industrial facility.

Increase in property values could occur as a result of increased employment generated by the facility, greater accessibility brought about by new or improved transportation features, or land speculation in the community during the planning and early construction stages of the project. If population increases significantly, declines in land values may not occur. Property value impacts induced by these changes are more likely to occur on a regional scale.

Residential properties appear to be more susceptible to property value changes, than farm, commercial or industrial properties (Clayton Research Associates Ltd. 1985). Middle to upper income housing tended to increase in value even during the workforce decline period, as permanent operational staff enter the housing market (Ontario Hydro 1985). Overall, property value impacts appear to be site and project-specific, in part determined by buyers' responses to the risks and impacts associated with proximity to a particular type of facility.

This has been one of the more sensitive issues related to development. There are now several examples of impact management measures relating to property value protection. In Ontario, the Ontario Waste Management Corporation has developed a program for a hazardous waste treatment and disposal centre. Ontario Hydro developed one of the first protection programs in 1974 related to the Bruce Nuclear Power Development. During the site evaluation for a disposal facility, the socio-economic impact assessment would determine the extent of any potential property value impact, and, working with the local community, the proponent would negotiate the appropriate measures to manage it. Part of any successful impact management program is monitoring and contingency planning jointly carried out between the proponent and the affected community.

IMPACTS ON LOCAL TAXES

To a resident, the residential tax, plus the cost of all local services, are considered to be the best measures of the cost of living in a community (Ministry of Municipal Affairs 1985). The exact effect on household taxes will be largely determined by local expectations, and the decisions of local governments and service boards, and the location of the disposal facility relative to municipalities that will serve as residential locations for in-migrants.

If population growth occurs to a degree that requires the addition of new services, changes to the level of service or financial character of the community may result. Long time residents will likely experience real increases in tax levels (Wlodarczyk 1993).

Under existing apportionment systems, the location of the disposal facility in a small jurisdiction can attract a disproportionately large share of county, regional or district costs (e.g. new roads or increase in road maintenance). In some instances, the increase in its share of these costs as a result of the added assessment could be greater than the total revenue gained from the facility. Changes to the apportionment system may be necessary. A proponent can provide direct impact payments to communities, usually to a local government, in order to enable the community to carry out specific mitigation measures. The amount of the payment is usually negotiated with the community and is directly related to an identified impact. Often these payments are directly associated with an impact agreement which includes monitoring and compensation provisions.

During the period of decline following the operational life of the facility, local tax levels will be responsive to spending levels, provincial grants and other revenues. The key determinant in tax levels

will be the adjustments that affected jurisdictions make regarding expenditure levels. Slower capital expenditures will reflect a mature service level. However, there may be increasing pressure for some jurisdictions to utilize reserves to cover operating expenses. In addition, the user rates for some services may increase. Appropriate planning measures could offset transition effects.

A jointly developed impact management program could ensure no unacceptable adverse impact on the community's finances or levels of service.

IMPACTS TO ABORIGINAL BUSINESS AND ECONOMY

Aboriginal economy and business cannot be analyzed without reference to the context of land use, environmental concerns and culture. The disposal facility to some extent shares some features with large-scale hard rock mining. In northern areas, environmental conditions, such as slower biological regeneration and permafrost, can exacerbate any land and water pollution creating significant socio-economic impacts for residents. Aboriginal people suffer the most from industrial pollution because they rely on local sources of food (Bone 1992). Therefore it is important to mitigate any such impacts on the environment through careful siting and impact management measures as proposed for this disposed facility.

The Aboriginal economy in the past was entirely land based. Today it is a mixed economy, blending land-harvesting activities with that of the market/wage economy of the settlement, urban type. There are Aboriginal individuals and corporations operating a variety of businesses from stores to construction firms. However, values and attitudes are still traditionally governed. It is these Aboriginal cultural values that maintain the land based economic system and allow it to survive today within the market/wage economy. The importance of land claims for Aboriginal people can, therefore, be understood as their means to ensure that their culture, communities and their economy survive in modern times with sufficient, undamaged land, capital and control:

> "The whole issue of land claims and Aboriginal rights impacts or imposes itself on this particular concept that AECL is putting forward" (Mr. Alan Roy, Union of Ontario Indians, March 6, 1991, FEARO Scoping Meeting, 65-66: Dowell 1991a).

A siting process implemented with criteria of fairness, openness and voluntarism, shared decision-making and safety and environmental protection that have been defined through a legitimate public process and broad social consensus, and subsequently, an impact management program planned and implemented with a significant degree of Aboriginal participation, thus ensuring a real measure of community control, would be the most effective way to avoid major negative impacts to Aboriginal business and economy, and would enable the communities derive an optimum of benefits from the disposal facility.

Impact on Traditional Food Harvesting and Land Use

The Aboriginal economy is characterized by its close ties to the land, both in terms of traditional activities and current ones. Food harvesting is still an important activity, representing substantial economic value.

Traditional food harvesting and its consumption by Aboriginal people themselves is a communal effort which reduces their need to purchase and store food, provides nutrition, as well as income through sales in the

market, and binds the communities culturally. For example, in the Norman Wells Project, Dene employees did not alter their habits of harvesting and eating "country food", reaffirming their culture and commitment to a land-based economy (Bone 1988). Also, in the Northwest Territories it is estimated that country food contributed $55 million per year to the Aboriginal economy (Usher and Wenzel 1989).

The radiological analysis elsewhere in this document includes analysis of human exposure to radiation through consumption of local fish or locally grown foods. The analysis examined local food consumption typical of Aboriginal lifestyles, concluding that the radiation exposure to individuals, assumed to live at the boundary of the facility site, would be less than one percent of the regulatory limit. Therefore disposal facility operation is not expected to be a significant risk to Aboriginal food harvesting, whether for their own consumption or for commercial sale.

During site selection, the implementing organization would work with any potentially affected local Aboriginal community to ensure that the activities associated with the siting activities and subsequent site development are undertaken in ways that will avoid or minimize any disruption of traditional harvesting activities.

The disposal facility development may represent a threat to the manner in which Aboriginal people use and manage both their legal and traditional land base and its resources. Traditional land is the area used by Aboriginal Bands since time "immemorial". The land and the manner in which it is used is an important component of Aboriginal peoples' culture. Aboriginal communities heavily rely on their land base as a source of livelihood:

> "The Nishnawbe Aski communities also engage in Aboriginal activities across a very large portion of Ontario. In fact, our treaty area, Treaty No. 9 territory, covers approximately two thirds of Ontario's land mass and Aboriginal activities are carried out on a large percentage of that land" (Chief Charles Fox, Nishnawbe Aski Nation, FEARO: Dowell 1991a).

Increased access to an area may enable non-Aboriginal people to hunt, trap, and fish in an area that previously may have been used solely by Aboriginal people. A loss of land, increased competition and decreased hunting, fishing, trapping and gathering success in one area may cause the over-exploitation of resources in another, and create difficulties in maintaining traditional hunting law. On the other hand, new access to areas previously difficult to reach could prove to be beneficial, if the ability to conduct subsistence activities is enhanced.

The main impact management strategy to address negative impacts to Aboriginal people is their prevention through measures such as:

i) fair, open and voluntary siting process that follows principles and criteria that have been broadly approved through a legitimate social process;

ii) direct financial compensation; replacement or restitution; and

iii) Aboriginal representation in impact assessment, management and monitoring decision-making.

6.5.3.3 Potential Impacts to the Political Efficacy of Communities

Due to an absence of a real community, this conceptual assessment of political efficacy must rely less on the particular dynamics of legitimate decision-making, informal political processes, leadership style or participation, than on the formal political structure, particularly those of the municipalities, regions, province and Aboriginal communities.

A host community, particularly from the outset of the siting process, but also throughout the different stages of the project, could undergo a range of political events and challenges. These would be a consequence of the community's role as a recipient of project-related socio-economic impacts and also of the community's role in the impact management program. Some of the likely political developments would include:

i) internal competition for leadership positions reflecting varied opinions, interests or values within the community;

ii) the need at various times for different purposes, to legitimize community decisions through representative and systematic public participation; and,

iii) the implementation at the community political level of policies to redress any economic and social imbalances likely to be caused by the project's economic impacts.

There would be public opinion reactions resulting from the announcement and implementation of public hearings and siting activities. These include the responses of the media, including specialized professional and academic publications and journals. Groups and organizations that have a special interest in energy and environmental issues might become involved first in the hearings and public discussion process, and subsequently during the siting process. Aboriginal groups and professional organizations would follow the siting process closely and might choose to become involved.

The criteria, process and potential results of the siting process, as well as the risk implications of nuclear waste technology, would all be reviewed in the public opinion arena and formal public hearing venues. This in turn, means that the political efficacy of communities might be affected as the political and municipal leadership tries to control and manage the outside influences upon it and, at the same time, tries to maintain their political positions and good standing within their communities.

There are significant differences between communities in their ability to manage change and to derive long-term benefit for their members. Past experience with developers and with public participation mechanisms will influence a community's attitudes to change and will have developed certain capabilities and competence to respond to change. The consultation process undertaken to initiate the proposed siting process will be critical in establishing effective relations between the implementing organization and potentially involved communities. Initial contact will affect community perceptions about the veracity of the siting process and of the proponent, thereby influencing the internal dynamics among various community groups and organizations. It is

important that the implementing organization work in partnership with the communities in order to support the development of positive political efficacy or competence throughout the lifetime of the disposal facility.

Lacking an actual site or community, the present analysis of potential impacts to the political efficacy of communities will focus, among others, on potential impacts to municipal services, facilities and finances.

IMPACTS TO MUNICIPAL FACILITIES AND SERVICES

An influx of the project workforce may cause changes in the physical condition of facilities, their quality and the level of service in a community. Population growth in any community will place an extra burden on existing municipal environmental facilities and services. Utilities and municipal services (water, storm and sanitary sewage, solid waste systems) will need to be provided to new residential, commercial or industrial development. The disposal facility could also add to the demand for municipal services such as domestic waste disposal. This might result in the extension of existing services or require development to be directed to serviced, but unutilized, areas.

In communities where facilities and services are inadequate, an expansion or upgrading of these features may be necessary as a result of demographic changes. Dissatisfaction with current services, coupled with concerns for environmental, and public health and safety may increase demands for new types of facilities and services, particularly new water supplies. The implementing organization will have the responsibility to ensure that any nearby community is not adversely affected by the project, such that it experiences an unnecessary burden on municipal facilities and services. These impacts can be addressed through a negotiated impact management program.

Changes in demand for services may also create an administrative burden. Planning, design and construction will require specialized engineering and project management skills. In the operating stage, larger systems may require additional service, maintenance and supervisory staff. If these changes cannot be accommodated, the quality and level of service will likely diminish. However, the greatest potential for disruption of these services exists during the early construction stage of the disposal facility because of the initial influx of workers.

The impacts on the dynamic of political life during siting, could also affect municipal facilities and services, as their future plans might be put on hold until the siting issues are resolved.

Population decline at the end of construction or during decommissioning may not seriously affect the quality and levels of service where they are operating at capacity. A significant decline in population, however, may result in increased user fees if the system carries high fixed costs. Physical deterioration of an expanded infrastructure and subsequent changes in the level of service may occur over the long term if the remaining population base is not able to maintain the system. A properly implemented impact management program should be able to avoid these effects.

An impact management program jointly planned, implemented and monitored with the communities, and in coordination with municipal representatives can help avoid negative impacts relating to local municipal facilities and services and enhance positive ones.

a) Impacts to Health and Safety Facilities and Services

Potential impacts on health and safety services and facilities include disruption of existing health care and fire and emergency facilities and services, and the potential need for new facilities, services and activities, such as health monitoring and research.

The influx of the disposal facility workforce may change the adequacy and physical condition of facilities, and the level and quality of service. To a large degree, the magnitude of the potential disruption will depend on project-related population changes and the condition of the existing facilities and services. Disruption of facilities and services with excess capacity will tend to be minimal. However, if social problems (e.g. alcohol or drug abuse) occur, the level of disruption may be greater than anticipated strictly by population growth rates. In Ontario Hydro's the experience with the Atikokan impact management program, impact payments were made to the Atikokan clinic, and, in response to community concerns, Ontario Hydro paid for the assistance of the Addiction Research Foundation to monitor alcohol and drug use over the construction period. This monitoring program determined that no significant increase in use developed in that time.

Some residents may need or expect a different range of services and facilities than are currently available. In such instances, these services and facilities may be seen as inadequate. Increased demand may also cause the more efficient use of these features or the provision of a more diverse range of services, benefiting users (Halstead et al. 1982). The disposal facility will require the development and maintenance of an emergency plan. This will require the involvement of local police, fire and medical authorities.

It is expected that any increase in population related to the disposal facility would see an increase in hospital use. Furthermore, major construction projects, and mining and manufacturing operations typically experience higher than average rates of occupational accidents creating greater demands for emergency services. However, it is anticipated that these rates will not occur with this project development. For example, the experience at AECL's Underground Research Laboratory in Manitoba includes significantly less than the industry average rate of occupational accidents associated with mining activity. Therefore increased use of local hospital facilities should not be greater than what would be anticipated resulting from demographic changes.

Increased stress among residents may result in an increase in demand for health services. There is some concern that established residents may experience stress related to community growth and change and that the families of inmoving workers, particularly women, may experience stress related to living in a more remote location, particularly if they are isolated and unable to find work. These potential impacts should be short-term in duration and addressed through joint planning and impact management.

Some hospitals may not be equipped to provide all forms of treatment and may need to transfer patients to regional treatment centres. Developments in remote areas or smaller communities may not be able to attract new health care professionals. During periods of population decline, changing demographic characteristics may shift the focus of care needs, and the types of facilities and services affected. Decreases in quality and level of service may result in such instances.

The disposal facility may generate demands for new equipment and services not currently available in a community if it is under-serviced or if the community expects greater levels of health, police and fire protection. New forms of development, scattered residences, and cottage conversions may introduce a new demand for a particular type of fire equipment and greater inspection. These infrastructure and service impacts can be mitigated through impact management planning. Any improvements will represent long-term benefit for the community.

When the disposal facility begins to handle nuclear materials during the operating stage, some hospitals will need to be prepared to receive site employees in the event of occupational accidents involving radiation and other hazardous materials. Some local and regional health care professionals will have to become knowledgeable about the potential health effects of radiation. Knowledgable health care professionals can participate in the health monitoring programs and can also help advise community members regarding potential hazards of radiation. Decommissioning may change the need for some types of services due to a decrease in disposal facility activities. However, residual health and safety and concerns will have to be evaluated and appropriate responsibilities taken.

b) Impacts to Social Services

The in-migration of the disposal facility workforce would affect local social services. Increased population may change the demand for the quality and level of services and/or the physical condition of related facilities due to changes in their use. Changes in demands for various social services may be experienced across a broad region if services are inadequate or shared among communities. The provision of these services may benefit both existing and new users in a community.

Non-urban communities, be they southern or northern, generally have a network of social services that run on non-contractual, voluntary labour. Communities with strong social vitality have members that are engaged in diverse activities of mutual self help such as town councillors and hospital auxiliaries. In urban centres, these services would necessarily be part of salaried, contractual labour. It is not that formal services are not important or do not exist, but the voluntary services constitute the backbone of the community's vitality and interaction. This is a community characteristic that may be affected by the rapid influx of new population, of temporary workers and of commuters. These changes bring about an increase in the demand for social services, at the same time that they do not increase the non-contractual labour force that had provided the services on a voluntary basis. Therefore, the character of the small community is changed dramatically as it becomes, like the urban centres, dependent not on the mutual help of community members but on formal services, which could mean an increase in the taxes (Paez-Victor 1993).

Unlike some other growth-related changes, the potential impacts on social services do not necessarily diminish over the operational lifetime of the facility. Instead, the service demands and the types of services may change over time, depending upon the needs that individuals and communities experience due to different activities and stages of the disposal facility. Service demands during periods of rapid growth or decline often increase at a rate greater than that expected solely on the basis of population change because of the changes in lifestyle among residents in the community. The long-term social service needs will tend to emerge during the operating stage. These demands tend to relate to

family needs such as child care, family, drug and alcohol abuse counselling services. Changing associated with the end of construction and operating stages may increase demands on services.

Impacts on service agencies may be significant if they are understaffed, underfunded, lacking in program flexibility and experience with growth, or have limited capacity in their facilities. Alternatively, if local service agencies have some excess capacity and experience, population growth may result in more efficiency (Halstead et al. 1982).

The ability of service agencies to recruit and retain staff will be affected by the location of the disposal facility, particularly if in a remote area. High staff turnover will tend to exacerbate service disruption.

An impact management program jointly planned, implemented and monitored with the communities, and in coordination with municipal representatives, can help avoid negative impacts relating to local social services and enhance the provision of services to benefit the community.

c) Impacts to Police and Fire Services

The presence of radioactive material at the disposal facility would impose special security requirements on police (see Section 6.7 on security).

Demand for police services will change relative to population changes. In growth areas, an increased need for traffic supervision would likely be the most noticeable potential impact. During construction, increased disturbance in hotels/motels and in communities around the site may be a problem with increases in alcohol and drug-related crimes, traffic offences, theft, vandalism, and Fish and Game Act violations.

Local and provincial police will need to be prepared to respond to disposal facility requests for assistance. Police forces will need to familiarize themselves with the site and key facilities in order to be able to assist. There will be added need for off-site local community services.

The need for fire services and equipment is also expected to increase in response to an increased numbers of dwellings and businesses.

The reference design comprises self-contained services at the site. There will be regulated/legislated requirements for basic fire protection and emergency services. However, it may be possible to work with a nearby community to contract back-up support services, which would provide opportunities for longer-term community benefit. An impact management program would seek any enhancement opportunities and mitigate any adverse impacts resulting from in-moving workers and their families.

IMPACTS TO MUNICIPAL FINANCES AND ADMINISTRATION

This section deals with impacts to municipal finance and administration in non-Aboriginal communities. The efficient use of municipal funds to suit a community's needs is a function of political skill and the community's over-all political efficacy.

a) Impacts Upon Municipal Planning and Administration

Ultimately, all community changes and municipal service impacts have planning and administrative implications. Depending on location, a disposal facility may contribute to the need to institute new forms of

municipal government; a greater federal, provincial or First Nations role in the management of an area; and to changes in the division of responsibilities and interrelationships among various levels of government, including First Nations.

Changes to the political, administrative and financial structures of local and regional governments may also occur. At the political level, the creation or changing of municipal boundaries may be required. The creation of new committees, changes to the roles of existing committees, and more formalized procedures may develop. At the administrative level, more sophisticated structural arrangements and procedures may be introduced.

During the disposal facility siting stage there will be a need for affected and host municipalities to participate in planning, assessments, hearings and other public participatory events. The negotiation of impact management agreements and impact monitoring programs will also increase staff workload.

During the construction stage, more emphasis on the processing of private development applications and the associated public capital works can be expected. Increases in inquiries, complaints and requests to which council and administrative staff must respond may occur. Legal actions deemed necessary will increase both staff workload and costs. These changes may decrease the quality and level of service provided, and necessitate a greater reliance on external specialists and advisors.

The manner in which municipalities respond politically and administratively to a development could influence the public's reaction to the quality, costs, and accessibility of local government. Impact management planning will bring a new administrative focus on economic diversification efforts.

There will tend to be sharper focus and demands on the roles and responsibilities of the levels of government, and that of the different working committees that have negotiating, monitoring or any other kind of link with the activities of the disposal facility.

There will also be a greater demand for public participation, responsibility and accountability through joint planning, impact management and monitoring. Therefore, regulating agencies and levels of government will see an increase in and a change in the quality in their relationships with the host community.

Though impact management programs there will be opportunities, working with the communities and in coordination with municipal representatives, to help avoid negative impacts relating to municipal planning and administration and to provide planning assistance. Ontario Hydro has provided this assistance through impact agreements for the Atikokan, Bruce and Darlington projects.

b) Impacts upon Municipal Land Use Policies

Population growth and new or expanded urban centres will change existing land use patterns and may preclude future uses. Often a change occurs from open space, wilderness or agricultural uses to more urban uses. If growth occurs within existing communities, higher population densities and more intensive land uses may result. If local transportation routes are upgraded or new access routes constructed, some growth along these corridors may result (e.g. strip development).

Land use changes can result from the redistribution of population or activity patterns away from the disposal facility site area or its transportation routes if development is nearby. The concerns raised regarding possible resident out-migration due to radiological risk are subject to much investigation, however the issue of population voluntary out-migration has not been confirmed in the literature. Some research indicates population increases around nuclear facilities (Knox and Burnison 1992). Long-term planning and development patterns may need to change in response to changing population, the site location or transportation routes (Payne and Williams 1986).

The project and the changes that result from it could potentially require changes in existing land use policies, resource or other management agreements and programs of various jurisdictions. Special land use policies and resource management agreements may be required in the vicinity of the repository or along access routes to preclude incompatible uses.

Governments may need to change by-laws or policies to manage and control disposal facility and related development or activities. Special by-laws and resolutions may be promulgated in support, or opposition to, the disposal facility. Policy changes may be required to facilitate economic development and the provision of alternate forms of housing. These potential impacts, along with potential changes in property values, may also affect the overall stability and continuity of land use, increase development speculation, land assembly and absentee land ownership.

It will be important to ascertain whether the disposal facility land use plans have implications for local Aboriginal land claims and their land use activities (see Section 6.5.3.1).

An impact management program, jointly planned, implemented and monitored with the communities and in coordination with municipal representatives, can help avoid negative impacts relating to municipal land use policies and provide land use planning assistance. For example, Ontario Hydro provided funds to assist Bruce Township develop official plan documents.

c) Impacts to Municipal Capital and Operating Costs

Changes to services provided by a municipality or other level of government will have financial implications in terms of capital and operating costs.

Capital costs will be incurred by the municipality in the project planning and construction stages. These expenditures are necessary in order to place the community in a position where it can manage the expected growth. These costs will include those associated with the planning, financing, approval, and installation of capital projects. Costs associated with planning for expanded service delivery capabilities will also be incurred early on.

Costs associated with participation in disposal facility related studies and approvals will also be incurred in the siting and construction stages. Those costs were identified as the single greatest capital costs associated with the proposed Ontario Waste Management Corporation facility (Future Urban Research 1987).

The costs associated with the provision of services are often incurred before growth related municipal revenues can be generated. In addition, costs associated with the project may not be restricted to areas or jurisdictions nearest the facility. Historically, impact management measures have been designed to mitigate this impact.

During periods of population decline, associated with disposal facility decommissioning, there will be opportunities to reduce municipal expenditures, especially debt charges incurred during expansion and operating costs of local facilities due to the long planning horizon. The ability to avoid carrying substantial fixed debt charges during a period of decline will provide some flexibility.

It is anticipated that disposal facility development will have financial benefits in terms of municipal revenues for local municipalities depending on location. Certain changes in municipal revenues will also reflect changes in costs to provincial and federal governments responsible for the delivery of various services.

Current provincial grants are responsive to the needs of changing populations. During periods of decline, the general support grants now reflect any change in municipal levies; in Ontario the Resource Equalization Grant helps compensate for any loss in tax base. It is difficult to speculate about the future structure of municipal finance as this is an area of active change in many parts of Canada.

A siting process based on principles of fairness, openness and voluntarism, and on criteria arrived at through a process of broad social consensus, would include the principle that the project proponent would be responsible to manage the effects of change. Furthermore, an impact management program jointly planned, implemented and monitored with the communities, and in coordination with municipal representatives, can help avoid negative impacts relating to any further or unanticipated municipal capital and operating costs, and enhance positive ones.

d) Impacts to the Municipal Tax Base

Local municipalities may experience growth in their tax base if an expansion of housing stock and business establishments occurs. Residential and farm assessments will tend to increase as more permanent residents enter the community. Commercial and industrial assessment will change in response to changes in local business operations.

Revenues from licenses and permits will vary with population levels and development activities. Building permit revenue will be associated with expansion to accommodate disposal facility related growth. The disposal facility, if located within municipal boundaries, would likely generate substantial building permit revenue.

During the decommissioning stage, residential and farm assessments will likely not decline unless housing units are actually removed. Commercial, industrial and business assessments are more sensitive to changes in the local economy. Business failures may result in the loss of business assessments and the revisions of commercial assessments to lower valued residential assessments. Residential assessments will tend to increase as a percentage of total assessments during periods of decline in the commercial and industrial tax base.

Since a junior level of government cannot levy a tax on provincial or federal government property, the Government of Ontario, the Government of Canada and their agencies voluntarily contribute "payments-in-lieu of property taxes". The disposal facility would contribute such payments to affected municipalities. The amount of the payment-in-lieu would be established at the outset of the siting stage following principles and criteria agreed upon as a result of public hearings.

Capital costs associated with development are sometimes recovered through municipal agreements with developers or through lot levy charges. These contributions will be an important revenue source during the disposal facility related growth period. The success of the municipality in establishing an appropriate lot levy or obtaining contributions will influence the longer term operating costs of the municipality.

An impact management program jointly planned, implemented and monitored with the communities, and in coordination with municipal representatives, can help avoid negative impacts to the municipal tax base and enhance positive ones.

e) Impacts to Transportation and Communication

Project development is commonly accompanied by changes in the use of passenger and freight transportation facilities and services available in an area. These facilities and services are important to economic viability, social and cultural/vitality and political efficacy. In this section, our attention is focused on political efficacy.

The type of transportation feature potentially affected by the disposal facility development would depend upon the mode selected for the transportation of used fuel and other freight to the disposal site. Grondin et al. (1993) conclude that an increase in use of existing features is not likely to cause increases in traffic densities or a safety risk of a magnitude that would cause major disruption. The environmental assessment did not analyze the impacts on transportation related to population growth.

A remote disposal facility location will likely require the expansion of road and/or rail facilities. Increased demand for air passenger travel service and some additional demand for freight service could also occur, particularly if a fly-in type construction project is undertaken. Decreased use of these facilities from peak levels can be expected during the operating stage. Special medical emergency services, if required would affect existing or new airport facilities. The addition of new services or the expansion/upgrading of existing transportation features will benefit users by increasing the quality and levels of service.

Increased use of local roads will be proportional to the number of commuters and the extent of in-migration to a community. The use of, or demand for public transit will change relative to population levels. The need to introduce or expand public transit will tend to be greatest once a more permanent operational workforce is established.

Increased demand for maintenance services will likely occur during periods of growth. An expanded infrastructure and used fuel transportation activities will tend to sustain these service demands throughout later project stages.

There is also the potential for changes in the communications infrastructure and services. The nuclear nature of the project along with changes in population may result in changes in demand for local media, changing the quality and levels of service provided. New types of services may become available in a community. Local media may gain prominence on a regional, provincial or national level.

At the site specific stage, a socio-economic impact assessment would determine the extent of potential impacts resulting from population changes and from disposal facility activities. Impacts can be mitigated using transportation alternatives for workers, e.g. busing, and scheduling for project-related traffic. Compensation can be used to

address the need for road upgrades and continuing maintenance. These are issues within local government jurisdiction, requiring timely, cooperative planning. A jointly planned and managed impact management program would mitigate potential adverse impacts, provide monitoring and contingency planning, and seek opportunities for longer-term community benefit.

IMPACTS TO POLITICAL ACTIVITY

Changes in community leadership may occur as a result of disposal facility development activities. It will be necessary for community leadership to be able to manage the social changes that the disposal facility will bring to their constituency. Political ability will be needed to champion the needs of the community vis-a-vis the demands of the project.

Residents who become dissatisfied with the community may blame the incumbent officials and choose to replace them. A turnover of leadership may also occur if the incumbent officials adopt a different position than the community with respect to their support or opposition to disposal facility development, or if their leadership efforts are seen as inadequate.

Increased involvement and membership in public interest or citizen organizations can be expected. As the saliency of local issues increases, new organizations are apt to form, both supporting and opposing disposal facility-related decisions. Civic and social organizations may find it necessary or desirable to adopt stands or positions on disposal facility-related issues. National or international public interest groups may take on a greater role in local affairs. Local governments may pass by-laws intended to influence siting or to direct disposal facility activities, and may adopt resolutions in support or opposition to the project.

The proposed siting process for the disposal facility is based on principles of fairness, shared decision making, openness and voluntarism;, thus the possibility exists that the political activity in the eventual local site area may not become acrimonious. However, considering the highly controversial nature of nuclear-related projects, the possibility exists for social unrest and acts of opposition such as lobbying and protest. Intense opposition could emerge if local, municipal top-down siting lacks involvement or if there is a lack of community involvement in monitoring and mitigation processes. The adoption of acts of violence and sabotage could be conceivable in such cases. This, in turn, may induce institutional responses such as the implementation of intensive security measures. With the proposed siting process based on criteria obtained through the public process and which enjoys broad social consensus, these circumstances could be avoided.

IMPACTS TO LABOUR UNIONS

One of the more important segments within a community, and one that would be directly involved with this development proposal, is the labour unions. An important aspect of political efficacy is the ability of a community as a collective to manage local resources. Labour unions can play an important role in bargaining with outside agencies for changes that can benefit the whole community. Labour can have the ability to work with other segments in the community to enhance local collective interest. In the process of this involvement, labour unions themselves will be affected by the disposal facility project.

During the early project stages, there will be a need for affected labour organizations to participate in negotiations (formulation and administration of collective labour agreements) and planning efforts (local area definition, hiring sequences). These activities will likely increase the workloads, and change the responsibilities of union officials and administrative staff. Depending upon the location, labour unions may also be required to establish or expand facilities and services for its membership in the local area, potentially straining their budgets and operating costs.

Jurisdictional disputes over work assignments may occur between some unions as a result of the temporary nature of the construction workforce, the tendency for unions to try and expand or retain opportunities for their members, and new types of work involved. Labour agreements may need to be negotiated prior to construction.

It will be necessary to arrive at agreements with labour unions to allow for Aboriginal people to either be employed as non-union members or for special arrangements for their incorporation into unions.

An impact management program jointly planned, implemented and monitored jointly with the communities, and in coordination with labour representatives, can help avoid negative impacts and enhance positive ones.

IMPACTS TO THE POLITICAL LIFE OF ABORIGINAL PEOPLE

Aboriginal issues are also discussed in R-Public (Greber et al. 1994). The following discussion is presented in the context of socio-economic impact assessment.

Aboriginal people across Canada are asserting their rights as nations:

> "First Nations are not an interest group in Canada, they are not a user group, they are the original people of the country and that is why in the wisdom of the federal government, they saw fit to have a section to the Constitution which enshrines Aboriginal rights" (Mr. Alan Roy, Union of Ontario Indians, March 1991, FEARO Scoping Meeting, 08: Dowell 1991a).

They have a unique legal and cultural status in Canadian society. This is largely due to the treaties and agreements that were signed, prior to, and since Confederation. It also stems from the guarantees provided in the Canadian Constitution, from court decisions and from their distinct cultural identity, heritage and lifestyle.

The Government of Ontario in signing The Statement of Political Relationship (Government of Ontario 1991) with the Chiefs of First Nations in Ontario recognizes the inherent right to self-government and is committed to its implementation:

> "Ontario recognizes that under the Constitution of Canada, the First Nations have an inherent right to self-government within the Canadian constitutional framework and that the relationship between Ontario and the First Nations must be based upon respect for this right".

The potential impacts of a disposal facility on Aboriginal people include the impacts on individuals, families, households and communities as discussed in previous sections. However, some potential impacts on Aboriginal people will differ from the impacts on non-Aboriginal people

in the same geographic area, due to their unique situation. Therefore, this section deals specifically with Aboriginal rights and governance, their use of land and their traditional lifestyle and culture.

Aboriginal people possessed distinct land and cultural rights when this continent was settled. The legal existence of these distinct rights, called "Aboriginal title", has been confirmed in several decisions of the Supreme Court of Canada. These rights are supplemented and supported by treaty rights arising of pre- and post-Confederation treaties. While many of these rights remain undefined, recent Supreme Court decisions have indicated the pre-eminence of Aboriginal rights under certain circumstances.

The development of a disposal facility has the potential to infringe upon Aboriginal use of land traditionally used for subsistence purposes. This issue would have to be taken into account in negotiations involving the potentially affected communities, including Aboriginal communities, and the implementing organization. The response of Aboriginal communities and/or political organizations in such instances may be governmental, legal or political action, including use of existing policies and agreements in the form of a land claim, negotiation, litigation or political lobbying. This issue would have to be addressed at the commencement of siting activities.

Aboriginal leaders in Canada recognize the need for a broad land base for their communities to promote self-sufficiency by initiating economic development ventures on the land. Disposal facility development may result in a change in the status of land claim negotiations. Lengthy land claims, slow court or political action related to disposal facility development on Crown land, particularly if it is traditional land, may lead to frustration on the part of some individuals and groups, resulting in outright rejection of the proposal or the pursuit of more non-traditional forms of opposition. It is also possible that disposal facility development could provide the economic development opportunity to enable political self-sufficiency.

Disposal facility development may also strain or change relationships among Aboriginal communities, and between Aboriginal communities and government agencies. This could occur initially during the deliberations within communities over the decision whether or not to host the site. Some site evaluation activities such as access road construction, cutting grids of survey lines, and survey of flora and fauna may affect Aboriginal land use and rights. For example, with new access routes there could be increased hunting by local residents and exploration crews. Also, local wildlife would likely be temporarily disturbed by construction and survey activities. These in turn, can affect the degree of conflict and cohesion within and between communities.

In addition, the desire for economic development may serve to heighten competition among Aboriginal groups for project-related, publicly available revenues.

Aboriginal self-government at the present time, is being discussed in various jurisdictions including Ontario. It may mean a new level of government centred on the issues of land, land use, and resource development. The self-government discussions are in the preliminary stage of negotiations; it is premature to speculate on their full implications.

For Aboriginal communities (and other groups dependent on the land), the social consequences of natural environment impacts need to be carefully assessed. The main impact management strategy is to work with Aboriginal people to develop measures such as:

i) direct financial compensation; replacement or restitution;

ii) Aboriginal representation in impact assessment, management and monitoring decision-making; and

iii) Partnership arrangements for cooperative enhancement.

SUMMARY

This section has presented a broad range of the kinds of socio-economic impacts that could result from the development of this disposal facility. Because this is a concept assessment, the approach has been a conservative one, that is, tending to overestimate the scope of adverse impacts. At the site specific stage, a socio-economic assessment would determine the actual potential impacts dependent on the characteristics of the local community, including its values and attitudes. Based on such an assessment, the implementing organization would work together with the community to develop a comprehensive program to manage the effects of change.

6.5.4 Potential Impacts from Abnormal Disposal Facility Activities

The public radiological safety analysis concluded that none of the postulated accident scenarios would exceed regulatory criteria or warrant an evacuation of areas beyond the site boundary. This does not, however, suggest that there will be no risks nor that concern over them will not occur. In extreme instances, spontaneous or voluntary evacuation could occur as a result of a minor incident at the facility. However, to date, there have been no examples of this occurrence following reported incidents at Ontario Hydro's nuclear stations.

6.5.4.1 Impacts to the Social and Cultural Vitality of the Community

Any negative impacts to the physical well being of workers and other members of a community can have severe consequences to the vitality of that community. Furthermore, the existence of the possibility that such impacts could take place, regardless of whether they have occurred or not, can create real concern and anxiety in a community. For example, even though the Chernobyl incident occurred in the former USSR, shortly after this nuclear accident, Health and Welfare Canada reported the following:

> "The Chernobyl incident raised more information requests than any other single topic in health protection over the last 20 years. The lines were blocked and more than 5,000 phone calls logged" (Sommers 1989).

The safety analysis of the used fuel disposal facility, based on a range of postulated accident scenarios, shows that public exposure to radiation in the event of such accidents (however unlikely) would be small and well below limits which the AECB has proposed for existing nuclear facilities. The maximum exposure would be expected to be less than 10 percent of the annual exposure from natural background radiation. Furthermore, the exposure of disposal facility workers in such accident scenarios was analyzed and found to be well below the level considered acceptable for

nuclear generating stations. No evacuation of local public would be required in any of these accident scenarios, based on Protective Action Levels under the Nuclear Emergency Plan for Ontario.

If abnormal events and conditions were to occur at the disposal facility causing harm to humans and the environment, these could result in significant social and cultural changes.

In addition to safety by design, the main impact management measures would be:

i) the avoidance of accidents and abnormal activities through a financial (equipment) and organizational (regulations, surveillance) commitment to safety on the part of the disposal facility management; and

ii) joint impact management and monitoring with those who potentially face the risks: the community.

6.5.4.2 Impacts to the Economic Viability of the Community

Abnormal operating conditions at the disposal facility have the potential to result in significant economic impacts. A single serious incident or even a series of small events could serve to increase health and safety concerns among local residents. These concerns could lead to a departure of residents. However, the significance and likelihood of such departures is not determined. Some research results indicate no measurable effect on housing market activity in the vicinity of the Three Mile Island plant following the 1979 accident, suggesting residents did not fear living near the plant (Knox and Burnison 1992).

A serious event or the concern about a serious event can disrupt directly-affected business operations, for example, local tourism. These businesses could suffer production and sales losses. Dependent businesses and other operations affected by the possible closure of key transportation routes could also suffer. Local residents could suffer losses in income associated with declines of business activity. Declines in prices of local products would be possible if a stigma were attributed to the local area or a particular product. Abnormal conditions could cause decreased tourist visitation and expenditures in the short term. Potential long-term impacts on business, especially on tourism plans, would be related largely to risk concerns and any associated stigma.

In addition to safety by design, the main impact management measures would be:

i) the avoidance of accidents and abnormal activities through a financial (equipment) and organizational (regulations, surveillance) commitment to safety on the part of the disposal facility management; and

ii) joint impact management, monitoring and contingency planning with the host community.

6.5.4.3 Impacts to the Political Efficacy of the Community

In the event of abnormal conditions or the occurrence of an accident at the disposal facility, a community's ability to manage its affairs would be challenged. Groups and organizations, including the media, would be involved, local leadership would be critical, local facilities and

services could be affected and the partnership with the implementing organization would be tested. The intensity of political activity could increase, and local community cohesion and stability in the short-term could be affected. Any impacts on local municipal finance, planning and administration would depend on the degree of disruption of routine activities, and the extent of costs associated with any emergency planning and response.

An impact management program would include contingency and emergency response planning, with provisions to compensate a local municipality for any additional financial costs related to emergency response activities.

The experience at operating nuclear plants suggests that it is important to disclose reportable incidents to the local community and to openly discuss all operating conditions of the facility. This measure could be a feature of an impact management program, in order to effectively manage all changes associated with the facility, and to enable the host community to establish and maintain the political efficacy necessary to cope with the challenge presented by abnormal conditions.

SUMMARY

In summary, based on a range of postulated disposal facility accident scenarios, the safety analysis elsewhere in this document shows that the maximum radiation exposure of the public would be small, well below levels proposed by the AECB for existing nuclear facilities, and less than 10 percent of the annual exposure from natural radiation. No evacuation of local public would be required in any of these accident scenarios. Nevertheless, public concerns about the potential consequences of abnormal operation or accidents are understandable, as the impacts to a community could potentially be very negative.

In addition to safety by design, it is therefore important that an overall impact management program include provisions for monitoring and contingency planning.

6.5.5 Social and Community Impact Management

Impact management is a strategy for impact prevention, mitigation, enhancement, compensation and monitoring, which has been jointly developed with the community. The role of the community in decision making is crucial in order to assure that the programs are compatible with community values and interests. A joint impact management program is designed to allow communities themselves to take part in the protection and enhancement of their natural and social environment.

The aims of joint impact management programs are to protect people and their community from adverse impacts, enhance the capacity of local systems to cope with change, enhance those impacts deemed beneficial, and increase the implementing organization's accountability to the community. As a consequence, such programs may foster good working relationships between the implementing organization, the community and others involved in the disposal facility. Community monitoring measures are a good example:

> "People want to be informed about what is being done. They want the results of testing made public, and they want some type of community input into radiation monitoring and rad-waste decisions" (Bord and O'Connor 1989).

Joint management of impacts related to facilities that handle hazardous materials, such as the disposal facility, can be a very successful strategy in not only allaying unwarranted fears, but in preventing risks and impacts to the host community and potentially affected communities:

> "I believe that once built and operating, a new waste facility will only remain safe if there has been continuous and comprehensive community oversight and monitoring during the facility's entire construction, operating and maintenance phases" (Sandman 1986).

The implementation of such a program would be initially agreed to at the siting stage with the host community, with further modifications and provisions over time, as impact management is necessarily site specific.

While no implementing organization has yet been identified for the disposal facility, it is reasonable to assume that an impact management program would be based on the following principles:

i) the people and communities that host the project and/or are potentially affected by it have a legitimate right to participate fully in decisions regarding the mitigation, compensation, monitoring, contingency planning and enhancement related to impacts;

ii) efforts to avoid or reduce the severity of adverse socio-economic impacts should take precedence over attempts to offset such impacts;

iii) affected communities will be compensated for unavoidable adverse impacts; and

iv) efforts to optimize local benefits will be consistently carried out to the greatest extent possible.

The following subsections identify a range of possible measures that may be used as part of an impact management program with the community.

6.5.5.1 The Process of Impact Management

The process of an impact management strategy or program, to be further developed during the siting stage, could include the following broad goals:

i) ensuring a high level of disclosure and scrutiny to demonstrate the integrity of the facility;

ii) optimizing any social and economic benefits of the project to the local community;

iii) preventing and/or mitigating potential negative impacts;

iv) alert detection and response to potential and unanticipated impacts through a community monitoring system and contingency planning;

v) compensating negative impacts that cannot be mitigated or otherwise managed;

vi) establishing effective and continuous communication between the implementing organization, the community and its diverse groups or stakeholders in order to facilitate joint problem solving; and

vii) establishing a dispute and conflict resolution process to ensure that goals are met and community concerns are addressed.

In order to achieve these goals, an impact management program would have to carry out the following activities:

i) the establishment of policies;

ii) the development of institutional arrangements;

iii) impact management implementation and community monitoring; and

iv) periodic review and revision of the program.

All these activities are carried out through a consensus building process that would involve joint planning with regulatory, governmental agencies and affected communities. As indicated in Chapter 4 and R-Public (Greber et al. 1994), it is necessary to establish early in the siting stage, the role that the community would have in the identification, monitoring, mitigating and enhancement of impacts.

A special set of guidelines or policies may also be required for a particular aspect of the project (e.g. human health monitoring) or to address broader social policy issues in a more comprehensive manner. For example, specific guidelines and agreements will likely be required with Aboriginal communities, such as the Memorandum of Understanding between the Nishnawabe Aski Nation, and the Ontario Government. It is necessary to underline that the advent of Aboriginal self-government and the implementation of self-government institutions may have a significant impact on the siting and operations of the disposal facility, as well as in the implementation of social impact assessment studies and in any type of socio-economic impact management program.

1) Institutional Arrangements

An institutional arrangement is a formal or informal understanding between two or more parties regarding their roles and responsibilities in the overall impact management program. Some arrangements may require new legislation to facilitate the implementation of impact management measures and the administration of the program. In some cases, disposal facility specific arrangements will need to be consistent with or included in other existing agreements or arrangements.

Institutional arrangements will most likely be required during the siting stage in order to facilitate joint fact finding and other planning activities with the host community (see Chapter 4 and R-Public (Greber et al. 1994)).

The framework, principles and process of impact management are a product of broad social consensus obtained through input from government, regulatory bodies and especially, the public hearings and other processes or public participation prior to siting. Community impact agreements must confirm to this broadly accepted framework. However, the details of

community impact agreements are negotiated between the implementing organization and the host community. Some of the features that can be included in a community impact agreements are:

i) statements describing project characteristics, community characteristics and the full range of possible impacts or concerns;

ii) a description of the rights and responsibilities of each party to the agreement;

iii) agreements to provide necessary project information such as construction schedules, employment levels and projections for the number of in-migrants;

iv) provisions for joint monitoring with the community including the identification of variables to monitor, the type of participation and/or verification by the community of monitoring results;

v) provisions for the determination of impacts and the selection of appropriate management measures;

vi) provisions for the adequate organization and implementation of an effective working relationship with the community;

vii) a financial agreement that includes mechanisms for compensation;

viii) a description of audit procedures;

ix) a process for dispute resolution (e.g. arbitration); and

x) allowances for extensions to the agreement for future negotiation and settlement of impacts that may arise after the term of the original agreement.

In addition to formal impact agreements, effective liaison measures can provide the means for continued participation of the community in decision-making regarding the project's development. A number of precedents and models exist for the establishment of liaison committees (Wlodarczyk 1993).

The liaison committee could become the vehicle for continuous impact management over the life-cycle of the facility. The committee, with specific terms of reference agreed to by the parties, would most probably be created in a negotiated impact agreement. An effective committee would meet regularly, and would have formal arrangements, including minute keeping, agendas, voting procedures, and rules of order. Membership and size would be established by the terms of reference. A dispute resolution process also would be jointly agreed to. The roles and responsibilities, especially its relationship to the local municipality and the implementing organization, should be clearly identified. An effective committee will reflect a positive relationship between the host community and the facility operator and be a key component in the effective management of change associated with the facility.

2) From SEIA to Community Planning

The main purpose of SEIA is to identify impacts and recommend measures for their prevention or management. SEIA cannot be a limited one-time study because of the significant time lag between the time of the initial project study and project construction. During that time many changes can occur with the project and the community. These changes will influence the nature of the resultant socio-economic impacts. There will be a need to assess impacts at different stages in the siting process.

The establishment of continuing community planning within the framework of an impact management program is recommended. Planning studies can be a joint community-proponent undertaking or a study independently commissioned by the community itself. The success of community planning (e.g. planning with Aboriginal communities) is dependent upon the access to and cooperation of community members and the degree to which study techniques are culturally appropriate. The scope of community planning for the disposal facility will vary depending upon the needs and expectations of the communities affected and the socio-economic conditions encountered.

Communities and development programs are not static, but change over time. The full scope of an impact management program should also be reviewed and revised periodically to suit the changing socio-economic conditions in the community and such things as political changes (e.g. changes in government leaders, and progress in the move towards Aboriginal self-government), resolution of Aboriginal land claims, changes in the project (e.g. project stages and schedule changes) and unanticipated changes.

6.5.5.2 Potential Impact Management Measures for a Disposal Facility

Considering the generic nature of this assessment, a range of measures has been identified, based on a thorough review of the research literature including case studies (see Appendix D: Table D-4, D-5 and D-6 plus SEIA References), that may be considered for a comprehensive impact management program with the community. The specific measures that may need to be implemented in the future will depend upon detailed impact studies, impact monitoring and agreements with the host community. The measures presented here represent a range of measures that should be considered during disposal facility design optimization studies, site-specific impact assessments and plans and strategies agreed upon with the host community and that reflect broad social consensus.

Minimizing Adverse Impacts

The following are some measures which past projects have shown could minimize impacts:

a) Facility Design Optimization

Estimates of the workforce required for the disposal facility indicate that the peak workforce is small, while the operations workforce is large relative to some other major Canadian projects. The large number of operating stage jobs enhances local employment opportunities. Furthermore, project activities could be rescheduled to manage the employment transition between project stages.

The proposed land use control zone, and any additional controls on the site will minimize local land use conflicts, the visual intrusion of the facility, most site related nuisance effects, and will add to the physical separation of the facility from people and communities.

In siting, it is assumed that the disposal facility will be self-sufficient in terms of environmental and safety-related facilities and services ensuring that the facility does not place additional burdens on a local community's municipal facilities, services or compromise its fiscal integrity. The design options should be discussed with the community; the provision of non-safety related services provides an opportunity for joint planning and enhancement.

b) Extended Monitoring

Extended environmental and performance monitoring stages may be implemented after the operating stage in order to undertake additional work and public consultation to authorize facility decommissioning or closure. Although the disposal facility has been technically designed so that its safety is not reliant on institutional controls, this does not mean that there will not be institutional controls if the regulators, the public and the local communities decide to implement these controls. An extended monitoring stage may serve to diminish the adverse impacts of workforce decline. The community may consider extended monitoring as a necessary measure for dealing with the risk of radiological contamination. In any case, with a jointly planned impact management program, the community would be assured of the ability to participate in key decisions during the life cycle of the facility.

c) Avoidance

From a socio-economic perspective, the proposed siting process is premised on broad public consensus building. This is not only the best way to obtain social approval, but also enhances the identification, evaluation and management of socio-economic and cultural impacts. Once sited, the location of the disposal facility within a suitable area can be adjusted locally to conform to the avoidance criteria such as to maximize the geographic distance from a community, or from a unique local feature, resource, or tourism area. For example, the natural environmental analysis (Grondin and Fearn-Duffy 1993b) recommends the avoidance of permafrost areas, areas of natural or historical significance, Aboriginal lands, agricultural lands, areas of high timber capability, outstanding recreational use and wetlands. Similarly, the location of a new town, construction camps or villages can be adjusted locally. However, these and all avoidance and siting criteria must be socially deliberated and approved through the public participation process.

d) Long Distance Commuting

It may be jointly agreed by the community and the implementing organization that measures could be taken to encourage commuting, such as: the provision of bus and/or van pool transportation to the facility or fly-in services from communities supplying portions of the workforce. Travel allowances may be provided to offset commuting expenses. On-site measures such as the provision of preferred parking or a rider exchange service are also possible.

Workforce scheduling and rotation systems can be established whereby workers spend a specified period of time at the project site and a leave period at home. Such a scheme is an alternative to the new town and community expansion settlement options. Depending upon facility location, new transportation facilities such as airstrips may need to be provided.

Air commuting can be of importance to Aboriginal communities. In the case of the Norman Wells Project in the Northwest Territories, there were 1700 rotational workers, of which 540 were Aboriginal from diverse scattered communities. The air commuting system played a key role in spreading the job benefits to communities beyond the local project area (Bone 1992).

e) Provision of Temporary Accommodation

Temporary accommodation can be provided by means of construction work camps or worker dormitories and mobile home parks. Clear policies with respect to eligibility for such accommodation need to be established. Construction work camps and dormitories are typically restricted to single status accommodations in order to discourage the in-migration of families for the siting and construction stages. Some proportion of the mobile homes can be reserved for workers and their families. Temporary accommodation may need to be provided in conjunction with long distance commuting measures and new town development.

f) New Town Development

A new town is a special type of impact management measure, as it involves the establishment of a new community in order to avoid adverse impacts on existing communities. This option is considered to be a complex measure. Generally, the creation of a new town to service project workers, their families and other in-migrants will require a high amount of financing and providing an adequate mix of housing, a full range of services and facilities, a transportation infrastructure and a mix of retail services in a regular self-sufficient central business district. New towns can vary in size, ownership, government and lifespan.

g) Nuisance Effects Management

In general, the distance separation of the facility is the best management measure for nuisance effects. Measures to control nuisance effects at source can include: the use of quieter equipment or the installation of muffling devices, imposition of vehicle speed restrictions, restriction of hours of operation, the substitution of construction/operation processes, careful location of equipment and facilities, use of dust suppressants or road watering, careful site design and layout to maximize distance setback, exploitation and preservation of natural topographic features and vegetation, the erection of barriers (berms, walls etc.), perimeter planting, and architectural treatment of the facility.

Measures to control nuisance effects off-site include: roadside planting, woodlot protection/management, dwelling area treatment, provision of air-conditioning for households, improvements of glass/window type, washing of windows/dust clearing, and cautionary notes on titles.

Joint planning of these measures with the community could involve the staging of various construction activities, the establishment of a complaints procedure, development of larger buffer zones, and/or industrial influence areas.

h) Access Route Modifications and Restrictions

Access route modifications would involve the construction and/or improvement of roadways in order to ensure adherence to recognized standards and criteria. Such improvements could include changes to lane widths, shoulder widths, road surface types, creation of additional lanes

or by-passes, and the installation of traffic safety features such as signal lights and appropriate signalization. The need for these modifications would be based upon detailed impact studies and joint impact management decisions and agreements with the host community. Additional measures could include the prudent location and design of site entrances.

Access route restrictions would involve the designation of specific routes for disposal facility related traffic or segments of traffic. In addition, vehicle speed restrictions could be imposed. Furthermore, access to certain roadways may be entirely restricted. These restrictions could be implemented through the enactment of municipal by-laws or by means of joint impact management agreements. Penalties or fines could be imposed on those not adhering to designated routes or speed restrictions.

Public Health and Safety Programs

a) Health Monitoring and Research Program

While the safety analysis indicates that there should be no threat to public health, it is acknowledged that public concern may require the implementation of a comprehensive public health monitoring system and research program that would be designed in cooperation with the community. Such a program could be overseen by an independent research institute.

It should be noted that workers in the nuclear industry have been and will continue to be monitored as a matter of routine; these records are stored and maintained by the Radiation Protection Branch of Health and Welfare, Canada. Non-radiological health programs can also be implemented, as there could be health impacts resulting from conventional disposal facility activities, for example, those related to occupational hazards such as mining.

b) Notification of Hazardous Events

The provision of an extensive emergency preparedness program is an important impact management measure. It would include radiological risks as well as non-radiological, such as mining accidents.

In addition to the emergency preparedness program, the public should be notified of any reportable incident as part of monitoring, in order to demonstrate open communications and responsible safety management. Notification would also relieve community concerns and stress regarding risk, as community members become fully informed of facility operations and involved in contingency planning. Any notification procedure could include local media, government, emergency response health and safety agencies, and Aboriginal representatives.

c) Awareness Programs

A general health and safety information program can be established ensuring that the information is culturally appropriate and socially approved. The aim is to ensure that residents, community groups and people using an area are aware and knowledgeable of the risks and safety procedures associated with the disposal facility, emergency response procedures and impact management efforts. Media programs can also be undertaken.

Managing Community Change and Compensation

a) Payments-in-Lieu of Taxes

At the present time, payments are based on the valuation of property and the taxing authority's mill rate. Payment or payments-in-lieu of taxes is not discretionary. The actual payment amount is dependent upon the type and size of the property along with the type, number and size of buildings on the property. Assessment is usually based upon the value of a comparable privately owned taxable property or building.

Payments in lieu are generally not made until buildings are constructed and assembled; however, they may continue even after decommissioning. The settlement of payments with local governments are usually made within the fiscal year of the taxing authority. In some jurisdictions, interim payments of as much as 95 percent of the anticipated payment can be arranged.

b) Impact Assistance Grants

Impact assistance grants take the form of direct service subsidies to a local government or relevant authority to undertake the necessary measures within their jurisdiction. Service subsidies usually take the form of cash payments to support the necessary mitigative measures.

The specific nature and amount of assistance provided by the proponent will vary according to specific community needs as identified through impact studies and joint impact management programs. Impact assistance may be offered as a one-time payment, regular on-going payments, or funds could be released as the need for additional assistance is detected through the continuing impact management program.

c) Local Planning and Technical Assistance

Planning and technical assistance may be provided through direct involvement of the proponent's staff in the local activities, or through the provision of funds to offset their costs of hiring experts and consultants. Special liaison or joint planning committees may also be established for these purposes. The provision of assistance to the local host community may be agreed upon as part of the initial siting agreements and joint impact management arrangements.

d) Property Value Protection

The need for a property value protection program would be identified during the site-specific SEIA. The features of any program would respond to local conditions. A property value protection program can be composed of a guaranteed purchase or compensation provision, a buy-out option and provisions for "hardship cases". In each of these provisions, specific conditions would determine application.

Guaranteed purchase or compensation would involve the purchase by the proponent of individual properties from owners who wish to sell, after an attempt has been made to sell the property on the open market. The owner would obtain a fair market value for the property. As an alternative, property owners may be compensated for the difference between the market price of the property and the owner's actual selling price.

A buy-out provision would allow owners who wish to sell their property to approach the proponent directly without first attempting to sell the property in the marketplace. Fair market value for the properties would be provided by the proponent.

Hardship case provisions within the program would compensate owners who do not wish to sell their property but are likely to suffer financial hardship due to their diminished ability to borrow using property as collateral. Other hardship cases could relate to compensation to individuals who have difficulties in selling their property due to job transfer, illness or to elderly, disabled or retired individuals whose property has been on the market before site announcement and affected by the site announcement.

e) Community Housing Development

Community housing development activities can include proponent-sponsored construction of permanent housing subdivisions within a community, assistance for housing revitalization or conversion, and the provision of assistance to local housing developers. Housing revitalization or conversion involves the identification of under-utilized buildings and providing funding or other assistance/incentives for their renovation or conversion to housing units. Assistance may be also be provided to in-migrants and local developers in terms of subsidized rental and mortgage rates, guaranteeing occupancy, or in obtaining appropriate zoning and other by-law changes.

f) Direct Financial Compensation and In-Kind Replacement/Restoration

Compensation or replacement/restoration measures can be undertaken as a result of a demonstrated or expected impact (e.g. contamination of water supply, loss of trap lines, logging and mineral rights, impairment of commercial fisheries etc.). Direct compensation can also take the form of payments to the host community which are tied to the volume or activity level of the waste being handled. Typically, the dollar amount of this form of compensation is capped to avoid an excessive financial burden being placed on the proponent, and in order that the host community does not experience an unjustifiable windfall.

g) Community Liaison Measures

The most important link which the disposal facility can have with the community during the construction, operating and decommissioning stages may be that which is forged through a liaison committee, as it would be the vehicle to administer the community impact agreement. An effective liaison committee becomes the forum for issue management, co-planning and problem solving throughout the lifetime of the facility. The community agreement would specify conflict resolution procedures for dealing with impact discrepancies, complaints and disagreements. Participation of the community on an equal basis in the issues that matter most to them, would be the basis of a continuing working relationship between the facility and the community.

As previously discussed, a liaison committee, with specific terms of reference agreed to by the parties, could be created in a negotiated impact agreement. An effective committee would meet regularly, and would have formal arrangements, for example, minute keeping, agendas, and formal procedures, including voting rules. Committee membership and size would be established by the terms of reference. A formal dispute resolution process, specified in the community impact agreement, would deal with any disagreements between the parties. However, informal dispute resolution could include voluntarily using third party opinion, or investigative studies. The roles and responsibilities of the liaison committee, especially its relationship to the local community and the implementing organization, would need to be clearly identified. The committee could receive and review all relevant information and reports,

could develop and manage impact monitoring programs and develop appropriate responses to manage unanticipated effects. The committee could manage all impact management programs.

Community liaison is not restricted to formal liaison committees. At various stages of the project, the implementing organization should employ regular informal liaison measures to support community involvement. Throughout the siting process regular information exchange and liaison activities would be critical to the success of the process. In addition, at various stages, an information hot-line can be established which would provide interested individuals with up-to-date information regarding the facility, the status of operations, major milestones achieved at the facility, status of any negotiations between the implementing organization and host community interests, and progress regarding impact management efforts etc. An information hot-line may be used to provide accurate information to residents in the event of an on-site or off-site accident or provide local residents or interested individuals with access to responsible facility officials.

Particularly if new towns are created, neighbourhood aid programs might be considered to help organize residents. Community integration coordinators may be hired to be responsible for introducing newcomers to other people and the neighbourhood, making them aware of the range of services and facilities available in the new community, and promoting involvement. The aid program could also operate an information and distress line.

Other measures include the establishment of community field offices, information centres, translation services, task forces, facility tours and demonstrations.

h) Development of Disposal Facility Closure Plan

The disposal facility closure plan should be jointly developed and implemented with the host community. The procedures and measures to minimize potential employee effects which can be included in a closure plan are: attrition, transfers, skills upgrading, job redesign, associate placement, under-utilization of human resources, early retirement, provision of separation benefits, counselling for external placement or training.

A plan aimed at community needs could include strategies for economic growth, revitalization and long-term diversification. Such a plan should follow three basic principles. First, the community is in the best position to judge what efforts are likely to succeed, therefore, the facility management involvement should be in the form of support for local initiatives. Second, the success of these efforts requires a commitment of time and money from the proponent, the community and relevant government agencies. Finally, efforts should focus on areas of sustainable development that "fit" the local and regional economic, natural and social environment.

Basically, the plans for closure amount to strategies for fostering sustainable development. It is impossible to successfully implement sustainable development when the facility is getting towards its close if local and regional economic diversification and re-vitalization have not been an integral part of the facility objectives from the start. Therefore, plans for sustainable development of the local and regional economy should be an integral part of the disposal facility. Due to the high technology nature of the project, the economic diversification may take the form of activities related to it through scientific and

technological research, education, teaching and communications. These plans can be revised periodically as a contingency for unexpected closure and potential extended monitoring periods.

Benefits and Enhancements

a) Preferential Hiring

A preferential hiring program could require the negotiation or re-negotiation of collective agreements with appropriate labour unions prior to project commitment. In addition, a firm commitment by the proponent to hire local workers would also be required. Other institutional arrangements may also be required between the proponent, the unions, the First Nations, and provincial and federal levels of government to delineate their interests and responsibilities in addressing the employment needs arising from the project.

b) Occupational Training and Education

The implementing organization should ensure appropriate training and education to optimize local job opportunities.

Three forms of occupational training can be undertaken: simulation, community-based and institutional training. Simulation training would involve the establishment of simulated employment conditions in order to conduct 'hands-on' training for specific project-related work. Community-based training would allow community members to develop skills that will help them acquire jobs. Institutional training and education involves the establishment of a variety of degree, diploma, apprenticeship and skills development courses at local and regional educational institutions.

The provision of occupational training services may require training allowances, accommodation, qualified instructors, and entrance guidelines that do not necessarily depend upon previous educational levels. Attention will need to be given to culturally appropriate training methods and special requirements of the participants.

Institutionalized training and education is the responsibility of governments, colleges and universities. The implementing organization and these authorities should cooperatively plan and develop appropriate programs. New opportunities will exist in science and technology due to the nature and the extended life-cycle of this facility. Programs should be designed to ensure that local employment is optimized, that long-term benefits accrue to the community from educated and skilled workers, which will, in turn, support the longer-term operating staff needs at the facility.

c) Employment Support Services

Employment support services can include a wide variety of possible activities. These can include placement/referral services, on-site counselling and community employment support. Placement and referral services would provide interested and eligible individuals with increased access to hiring offices by establishing temporary hiring centres in remote and non-serviced communities, the provision of travel and accommodation support, and assistance with union membership costs.

Counselling services can be offered on-site or in the community which could deal with vocational, financial, substance abuse, and stress-related problems. Community employment support would involve advising local residents as soon as possible after project commitment of

the jobs, goods and services required, union requirements, training programs and skill requirements. Spouses of re-located workers may need special employment support services, including child care. Attention will need to be given to the provision of services in a culturally appropriate manner.

After the specific need for support services is identified, the implementing organization and the host community would determine the nature and extent of support required.

d) Business Activity Enhancement

Provisions for local procurement or other enhancement measures can stipulate dollar values or percentages of local goods and services to be purchased. Such provisions may include qualifiers to ensure that local purchases are competitive with those outside the target area. Businesses involved in the project may also be encouraged to relocate or establish satellite operations in the local area. Large contracts can be split to make them more accessible. Local shops could also be prequalified prior to tendering to ensure quality standards are understood and met.

Other local business activity enhancement measures can include communication strategies to inform local businesses and the proponents' own contractors of project requirements, schedules and local business opportunities. Assistance can be provided to local firms and organizations in interpreting contract requirements, and obtaining legal, financial, planning or management advice or training.

e) Off-Site Fabrication of Components

This option could involve the establishment of an independent and dedicated facility or the awarding of contracts to businesses with existing equipment to manufacture the required components away from the disposal facility site.

f) Co-Use Measures and Property Management

Co-use would involve improving public access to, and facilitating the use of, disposal facility-owned equipment (e.g. graders, utility trucks, construction lift trucks and service vehicles). A formal registry system can be established to provide qualified and interested individuals with the access and use of this equipment or they can be provided on a case-specific basis. The facility proponent may also participate in a mutual aid agreement with neighbouring municipalities, in the event of a local emergency, through the provision of equipment and trained personnel.

Property management practices involve the maintenance of structures and the continuity of land use on acquired properties. In addition, if land use controls surrounding the site are implemented, the proponent may need to negotiate co-use or co-management agreements for activities compatible with the security and operation of the facility.

6.5.6 Conclusions

The conclusions of the assessment of potential impacts on the social, cultural and economic environment are as follows:

1) The present analysis has been limited by the absence of a site and, consequently, the absence of a context of actual people and communities in which to carry out a socio-economic impact assessment. Therefore, after an extensive literature review, a generic analysis has been done that identifies the types of impacts

types of impacts that may occur if a disposal facility were to be sited. Without an actual site, or a natural and social environment, it is not possible to predict the probabilities of specific impact occurrence. Neither is it possible to evaluate the full significance of impacts without knowledge of the values, opinions and concerns of the people who would be subject to potential impacts.

2) It is noted that the environmental and safety analyses elsewhere in this document shows that radiological impacts on members of the public assumed to live around the disposal facility would normally be extremely small. Even under abnormal or postulated accident conditions, potential impacts on the public are expected to be well below limits applied to existing nuclear facilities. Nevertheless, the potential for radiological impacts to human health and the environment would likely be of concern to people who live around the disposal site. These concerns and associated stress and stigma remain a potential source of social, cultural and economic impacts which would need to be addressed.

3) The most positive impacts of the disposal facility would likely be those positive economic impacts associated with large-scale projects: employment and stimulation of the local and regional economy. Due to the particularly long time span of disposal facility activities, there is the potential of long-term employment and associated sustainable economic development if the disposal facility impact management program includes regional outlook and policies. This is an advantage over most resource-based large-scale projects which are more vulnerable to resource depletion and market fluctuations. There are, however, possible negative economic impacts which would have to be avoided or mitigated.

4) Northern communities and Aboriginal communities have particular dimensions that make them more susceptible to change. Therefore, it is particularly important these communities be involved in every stage of project implementation in order to sensitively plan for their needs.

5) The successful management of expected and unexpected social, economic, cultural, health and/or environmental impacts is contingent on a system of vigorous and creative joint impact management with the community throughout the lifetime of the facility.

6.6 ECONOMIC IMPACTS

6.6.1 Objective and Scope

This section presents the analysis of the economic impacts in Ontario and the Rest of Canada (ROC) resulting from expenditures undertaken in Ontario for all stages of the UFDC life-cycle. It is an economy-wide evaluation which looks at the impacts on the regional economy. Potential socio-economic impacts on the local community are analyzed in Section 6.5. Details of the analysis can be found in (Cheng 1993a). The analysis assumes that the UFDC would be located in the Ontario portion of the Canadian Shield.

6.6.2 Evaluation Methodology

6.6.2.1 Methodology Description

The economic impacts can be expressed in terms of a number of key indicators of economic performance, for example: Gross Domestic Product (GDP), employment, wage rates, inflation, interest rates, and foreign exchange rates. In the ensuing analysis, two such indicators are used: GDP expressed in millions of dollars, and employment expressed in number of person-years*. These indicators have been selected because they are the best measures of economic performance to identify the impacts associated with designing, constructing, operating, and decommissioning a UFDC based on the conceptual design developed by AECL and the used fuel transportation system developed by Ontario Hydro. In general, the provincial GDP is interpreted as an approximation to the provincial income. Employment is a useful indicator for policy makers as it provides information for ranking projects which generate the same level of GDP impact.

GDP and employment impacts are estimated using Ontario Hydro's interprovincial input-output model. Data for the model are provided by Statistics Canada Input-Output Division, from their 1984 interprovincial input-output data bank. Impacts are expressed in constant dollar (real) terms by transforming the Statistics Canada 1984 data to 1991 values as appropriate. Provincial GDP and employment impacts were estimated for a change in the level of aggregate demand (via consumer spending), purchases of a particular commodity, or production in an industry. For example, the construction of buildings and structures stimulates production in the construction industry, while design and engineering services for the UFDC stimulates the service sector of the economy.

In summary, Ontario Hydro's I/O model estimates economic impacts in Ontario and the Rest of Canada. The model distinguishes between the direct, indirect and induced effects. The direct effects on GDP and employment are the labour employed and capital cost incurred as a result of the production considered. Indirect effects are examined via the network of inter-industry linkages. Induced effects describe the re-spending of household, corporate and government income.

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*A person-year is defined as one person working full-time for one year, or any other combination thereof; for example, two people working full-time for half a year each, etc.

The actual procedure used to estimate GDP and employment impacts is as follows:

i) expenditure data on the UFDC design and construction, operation and decommissioning from the reference UFDC design (Simmons and Baumgartner 1994) are allocated by the I/O model using a matrix of GDP multipliers in Ontario for each particular expenditure category;

ii) employment impacts are the products of the expenditures and the employment multipliers. The employment multipliers are based on a matrix of jobs-to-shipments ratios for provincial industries in 1984 and labour requirement information (Simmons and Baumgartner 1994). The conversion from 1984 to 1991 employment impacts is based on an index of average improvement of labour productivity over the same period;

iii) the numbers generated represent the GDP and employment impacts of designing, constructing, operating, and decommissioning a disposal facility in Ontario based on the conceptual design developed by AECL. The same applies to the analysis of transportation impacts; and

iv) a similar methodology is used to estimate GDP and employment impacts for the Rest of Canada.

In this study, impacts are directly proportional to the proposed expenditures on the UFDC development (design, construction, operation, and decommissioning) and used fuel transportation. No impact is expected on Hydro's electricity price or borrowing since it is the utilities' (Ontario Hydro, New Brunswick Power and Hydro Quebec) policy that the future costs for the disposal and storage of used fuel be paid for by current customers. For example, Ontario Hydro's current provisions for future used fuel management costs (not including storage costs which are part of the NGSs operating costs), through surcharges on nuclear energy, amount to less than one percent of revenues coming from electricity consumers in Ontario. The revenues from the surcharge are being placed into a sinking fund (see Section 6.6.2.3) expected to fully finance the transportation and disposal of used fuel.

6.6.2.2 Analysis Assumptions and Limitations

The results generated by the I/O analysis are subject to the following assumptions, some of which relate to the limitations of the I/O model itself:

i) I/O analysis assumes that the inputs and outputs of industries are linked on the basis of simple proportional relationships;

ii) no constraint is assumed on the supply of inputs into production. Labour, materials and energy are available in unlimited supply to all producing industries;

iii) there are no price or technology-induced changes in the production structure from 1984 through to the end of the study period;

iv) all industries contribute to the output values of all commodities according to their 1984 market shares;

v) since the UFDC is to be located in Ontario, it was assumed for this generic analysis that impacts on the Rest of Canada stem from initial spending undertaken in Ontario. That is, there are no direct impacts on the Rest of Canada. Indirect impacts on the Rest of Canada are, however, included;

vi) the I/O model accounts for personal and corporate income taxes, as well as government re-spending of revenues from taxation. However, the estimates of revenues are based on the tax structure prevailing is the model's base year (1984 in the year on which the Statistics Canada data are based);

vii) the employment impacts are assumed at the 1991 productivity level. The employment impacts estimated here should be smaller if the impacts are adjusted for productivity gains over the 1991-2079 period; and

viii) I/O analysis measures the gross impacts of an activity, without accounting for the efficiency of resource allocation. Unless the inputs are drawn completely from an unemployed pool of labour and capital, these resources would have an opportunity cost or a value of alternative use. Consequently, the net economic impacts of these expenditures would require valuing each input on an incremental basis to its opportunity cost. This is the realm of social cost-benefit analysis and is not attempted here.

6.6.2.3 Terms and Definitions

(a) Gross Domestic Product and Employment

"Real value-added" is defined here as the constant dollar amount that Ontario producers contribute towards the final value of goods manufactured, processed or sold in the province. GDP is measured as real value-added plus depreciation and interest (on net assets) and is expressed in millions of real (constant) 1991 dollars.

Employment is derived from real value-added using job-to-shipments ratios, and may vary depending on the capital intensity and local content of the activity. Employment is measured in number of person-years of work at 1991 productivity levels. The GDP and employment impact results differ since the depreciation and interest on net assets (net cash flow) components of the GDP vary between options.

(b) Direct Impact

The "direct economic impact" of investment and operation is derived from the "first-round" expenditures on equipment, labour, and all other inputs used in designing, constructing, operating and decommissioning the conceptual UFDC.

(c) Indirect Impacts

"Indirect economic impacts" are those associated with the subsequent inter-industry production linkages, as successive rounds of supplier and sub-supplier industries participate in the economic activity. For example, the indirect impact of constructing various buildings and structures in a conceptual UFDC would include the stimulus to the cement industry, the metal fabricating industry, and the construction industry. "Leakages" of economic activity out of Ontario, as well as the effect of

activity originating outside Ontario and flowing back into the province, are also taken into account. For example, if some of the cranes and other special equipment needed to construct buildings and structures were manufactured in another province, then the imports of the special equipment represents a leakage of economic activity; in the model, this is accounted for by the economic impacts in the Rest of Canada. In turn, importing equipment may create activity in Ontario if, for example, the manufacture of cranes uses steel from Ontario.

(d) Induced Impacts

"Induced impacts" result from the re-spending of labour and corporate incomes, as well as any government spending which is incremental to economic activity. For example, the induced effects through labour include the "ripple effect" resulting from the initial spending of wages and salaries by construction workers, engineers, etc. Corporate income is re-spent out of the net cash flow to materials and service-supplying firms. Government spending derives from the collection of personal and corporate income tax and other tax revenues. Leakages of economic activity are accounted for, to the extent that income is spent on goods and services from outside of Ontario, by the economic impacts on the Rest of Canada. The re-spending amount of income in Ontario is determined via a matrix of "average propensities to spend" with respect to goods and services*.

(e) Economic Impact

Evaluation of the direct, indirect, and induced effects allows for a full economy-wide assessment of the economic impact of the facility. That is, the economy-wide economic impact is the sum of the direct, indirect and induced impacts. Results presented in this report are at the economy-wide level of aggregation.

(f) GDP and Employment Multipliers

Multipliers are defined to be the ratio of the economy-wide impact to the expenditures. The GDP multiplier measures the extent to which an initial injection of spending is amplified through the economy, as the initial outlay stimulates further spending and income. The GDP multipliers are expressed in 1991 dollars of value-added per dollar spent. Similarly, employment multipliers are expressed in number of person-years at 1991 productivity levels per million dollars spent.

(g) Net Present Value

The results in this report have been net present valued (NPV) or discounted. Discounting provides a summary of a stream of impacts by valuing them at a particular point in time. In this report, the impacts are valued as of 1991. The factor by which future impacts are discounted is the time-related value of money. The Ontario Hydro Corporate Discount Rate is used for this purpose (4.5% at the time of analysis).

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*Average propensities to spend take the form of shares of income that are spent on consumer durables, consumer services, non-residential consumption, etc. A portion of the income is assumed to be saved rather than spent.

(h) Sinking Fund

A sinking fund refers to the funds set aside on a regular basis for the purpose of repaying debt, or for the depreciation of capital equipment. The method ensures that the full capital invested in a project is recovered at the end of a project's life.

6.6.3 Impact Analysis of UFDC Development

The economic impacts in Ontario and the Rest of Canada stemming from the UFDC expenditures over a period of 89 years are analyzed. Three major expenditure categories are examined: design and construction, operating and decommissioning.

6.6.3.1 Cost Data

Data on each expenditure category associated with the conceptual UFDC are from AECL's concept engineering study (Section 2.1.1.5), and are in real (1991) dollars. The data are separated by expenditure categories; therefore, operating expenditures are separated from design and construction expenditures, and so on. Table 6-52 presents a summary of the input cost data used by this study for the 89 years. These estimates include a contingency of 17%.

TABLE 6-52
Summary of Input Cost Data

Activity[1]	Expenditures (1991 Million$)	Per Cent of Total
Siting	2 110	16
Construction	1 810	14
Operation	8 080	60
Decommissioning	1 320	10
Total	13 320	100

[1]Costs of transportation are presented in Chapter 7.

6.6.3.2 Potential Economic Impacts of a Used Fuel Disposal Facility

Tables 6-53 and 6-54 present the GDP and employment impact multipliers for the expenditure categories in Ontario and the Rest of Canada from the I/O model. For example, the direct employment multiplier for construction material in Ontario is 5.66. This means that for every million dollars spent on construction material in Ontario, 5.66 person-years of employment are generated in Ontario.

1) Impacts in Ontario

Duration of the UFDC implementation stages specified in the reference design are shown in Figure 2-6. The following paragraphs, (a) to (e), present the estimates of economic impacts in Ontario for each of these implementation stages plus the total impacts in Ontario. Figures 6-11 and 6-12 and Table 6-55 summarize the estimated impacts in Ontario.

TABLE 6-53
GDP and Employment Multipliers[1] for Ontario
per 1991 Million Dollars of Expenditures

Activity	Direct GDP	Economy-wide GDP	Direct Employment	Economy-Wide Employment
Management	0.985	2.11	7.76	26.73
Admin.	0.982	2.11	13.11	32.10
Engineering	0.991	2.12	10.44	29.38
Trades	0.977	2.10	11.45	30.46
Material	0.378	1.18	5.66	21.00

TABLE 6-54
GDP and Employment Multipliers[1] for the
Rest of Canada per 1991 Millions Dollars of Expenditures

Activity	Direct GDP	Economy-Wide GDP	Direct Employment	Economy-wide Employment
Management	0	0.375	0	7.31
Admin.	0	0.375	0	7.30
Engineering	0	0.375	0	7.32
Trades	0	0.374	0	7.30
Material	0	0.333	0	6.38

[1]Note: GDP values are in millions of dollars. Employment values are in person-years.

NOTE: Regarding Figures 6-11, 6-12, and 6-13, it should be noted that no specific assumption was made for economic impact analysis purposes as to when implementation of the disposal project would begin. The default date was 1991, the time of the analysis. Therefore, any detailed interpretation of the graphs in these figures should take into account the time shift between 1991 and the year in which implementation actually begins (not expected until 1996 at the earliest). Given the analysis assumptions in Section 6.6.2.2, the shape of the graphs would not be affected by this time shift.

(a) Siting (23 years)

The direct and economy-wide employment impacts would be about 15 500 and 52 600 person-years respectively. The direct and economy-wide net present value GDP impacts would be about $961 and $2 219 million, respectively. Percentage-wise, the net present value GDP and employment impacts represent about 50% and 15% of the total net present value GDP and employment impacts, respectively.

(b) Construction (7 years)

This is the period where the annual economic impact of the project would be at its peak. The direct impact on GDP would be about $356 million (NPV), and the direct employment impact would be about 13 400 person-years. The economy-wide impacts from these expenditures almost triple the direct impacts on the provincial economy. The NPV of the GDP impact would be about $869 million, and the employment impact would be about 44 800 person-years.

(c) Operation (41 years)

The direct NPV of the GDP impact is $672 million, and the direct employment impact would be about 61 200 person-years. The economy-wide impacts are in direct proportion to operation expenditures. The economy-wide NPV of the GDP impact is $1.63 billion, and the employment impact would be about 198 800 person-years of employment over the operating life of the centre. The GDP impacts of the operation of the UFDC are heavily discounted as they would happen at least 30 years from now.

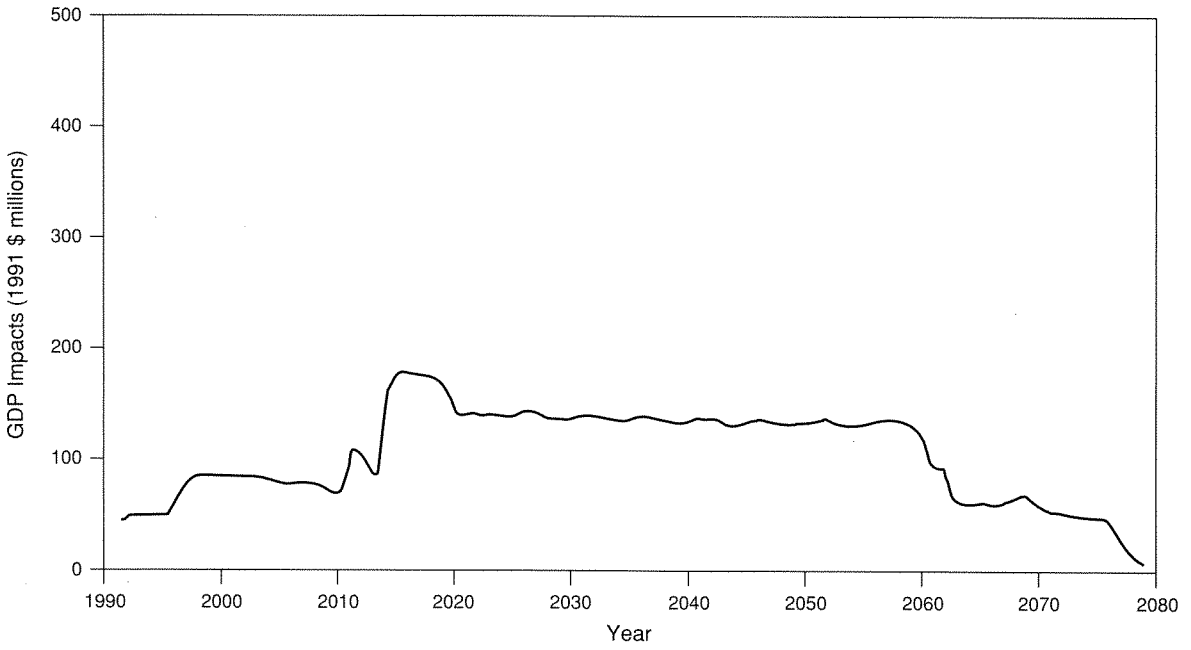
(d) Decommissioning and Closure (18 years)

The decommissioning impacts would be small relative to the other stages. The direct GDP impact would be $30 million on a net present value basis, and the employment impact would be about 10 200 person-years (see Figures 6-11 and 6-12). The economy-wide impacts would also be small: the NPV of the GDP impact would be about $71 million, and the employment impact would be about 33 000 person-years.

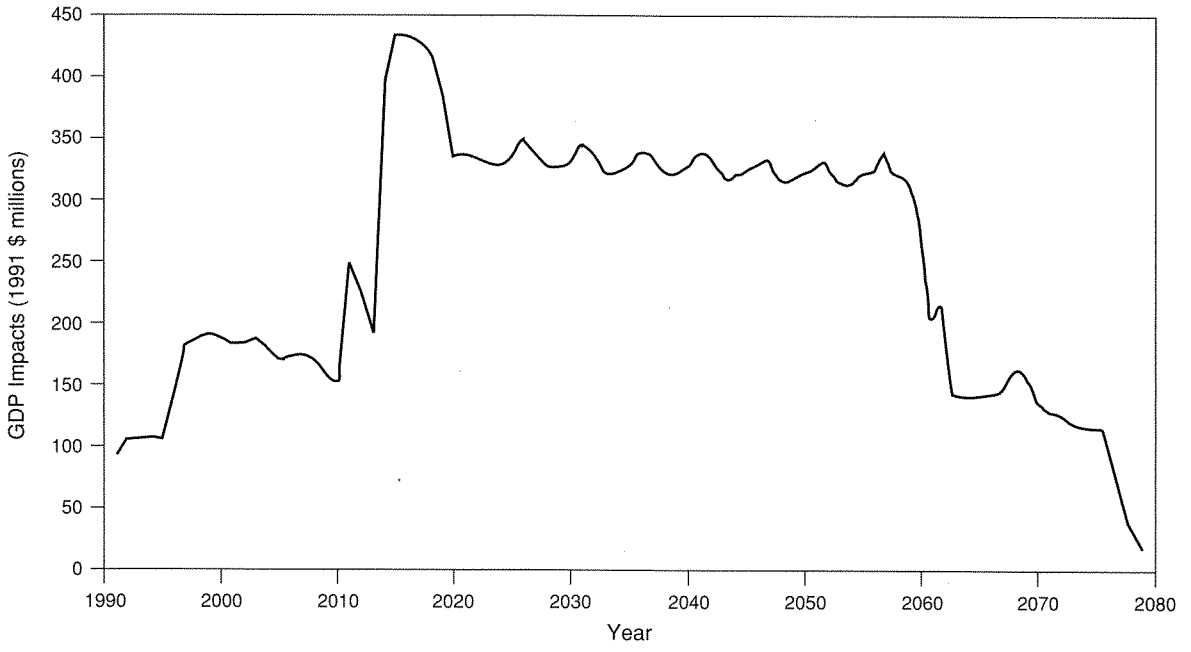
(e) Total Impacts in Ontario

The total direct and economy-wide impacts that would result from siting, constructing, operating and decommissioning a conceptual UFDC cover 89 years. The direct impact on Ontario GDP would be about $2.0 billion on a net present value basis, and a direct employment impact of approximately 100 000 person-years. The economy-wide impacts in Ontario almost triple the direct impacts. The NPV of GDP would be about $4.8 billion, and the employment impact would be approximately 329 000 person-years. These impacts represent less than 0.1% of the average annual provincial GDP and labour force. Table 6-55 summarizes the direct and economy-wide impacts in Ontario.

Direct Impacts



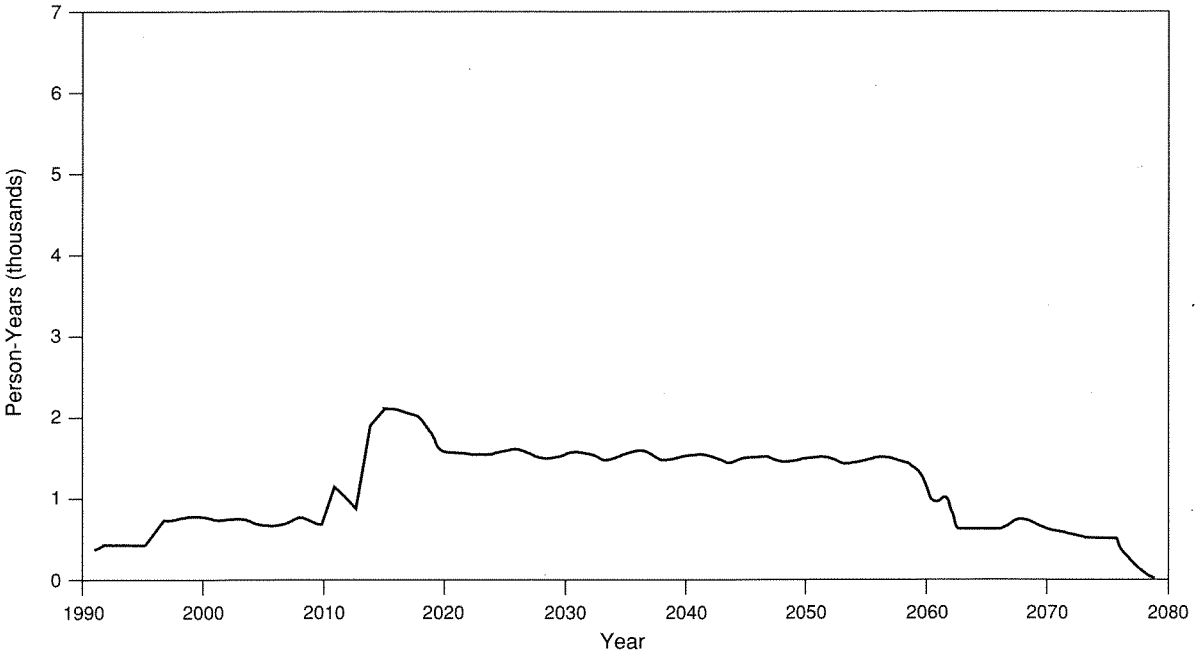
Economy-Wide Impacts



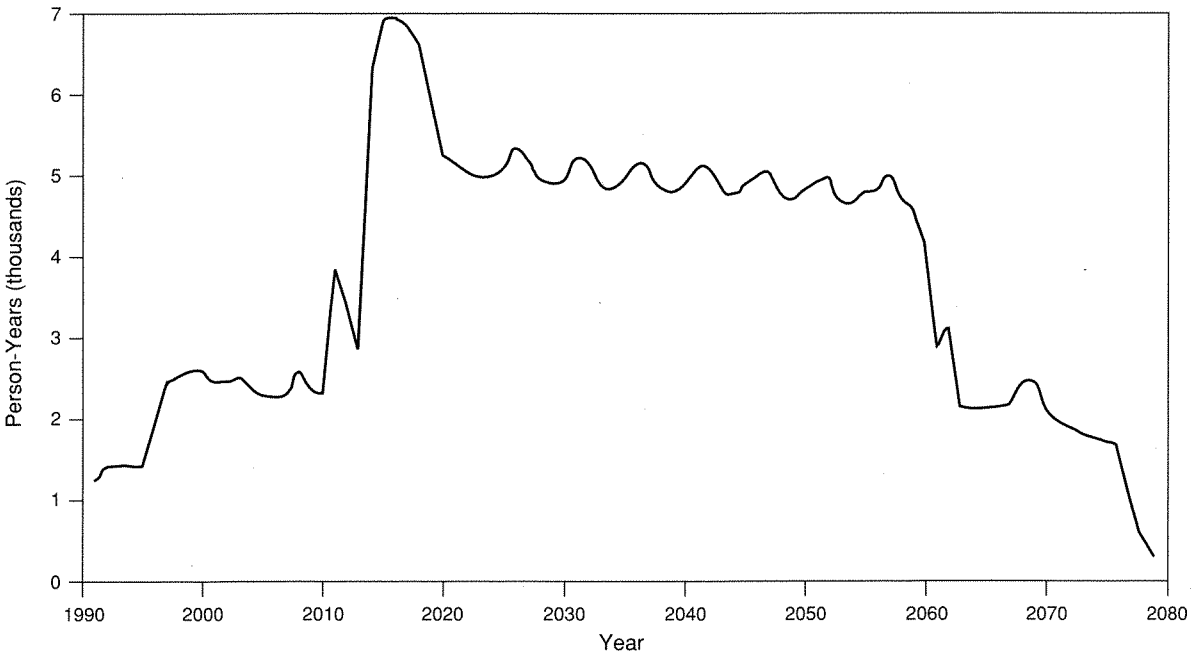
*See explanatory note in text (6.6.3.2) regarding interpretation of dates shown in these graphs.

FIGURE 6-11: Impacts of Construction and Operation of the UFDC on the GDP of Ontario*

Direct Impacts



Economy-Wide Impacts



*See explanatory note in text (6.6.3.2) regarding interpretation of dates shown in these graphs.

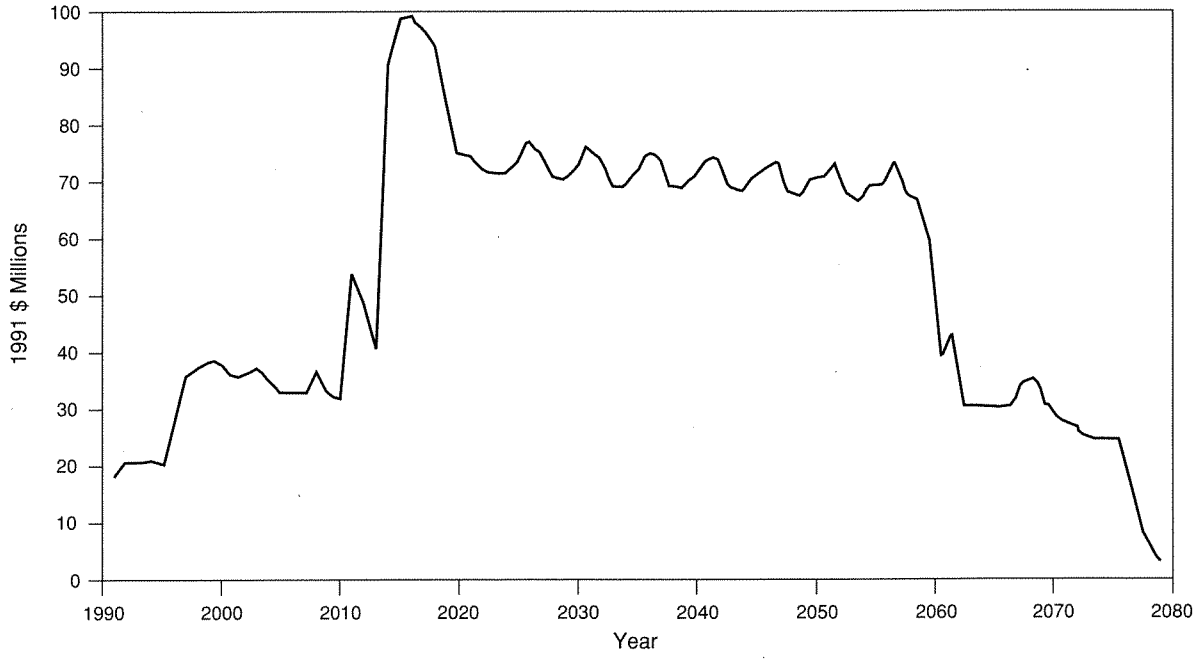
FIGURE 6-12: Impacts of Construction and Operation of the UFDC on Employment in Ontario*

TABLE 6-55
Direct and Economy-wide Impacts in Ontario

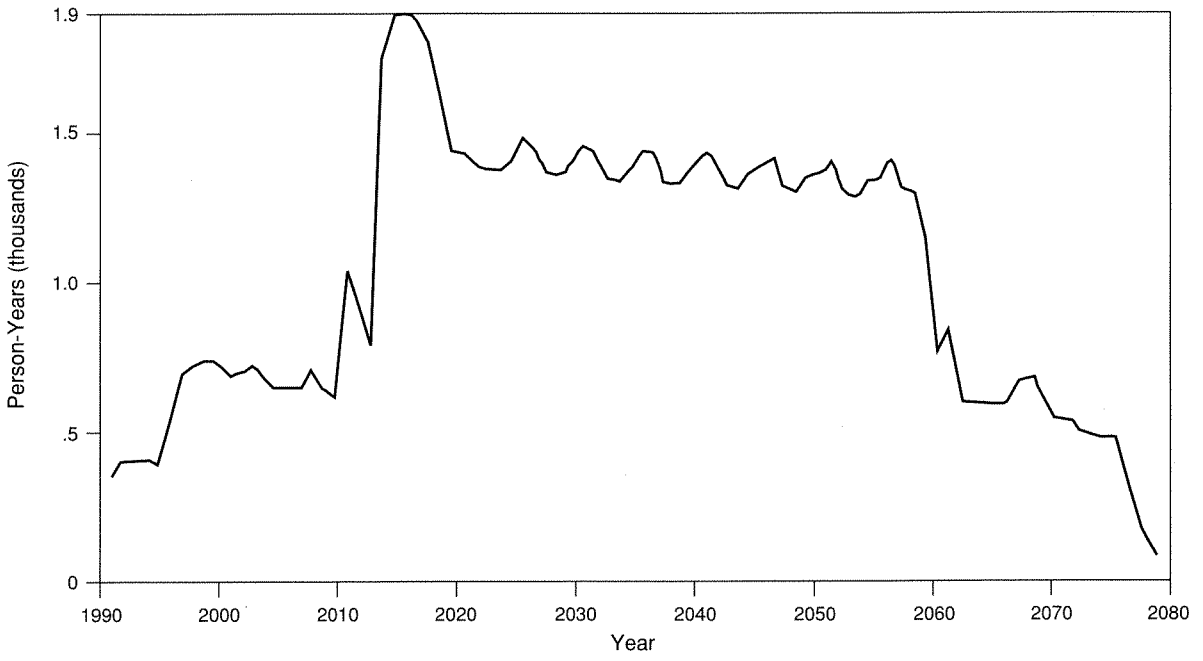
DIRECT IMPACTS		
Activity	**Net Present Value of GDP (1991$ million)**	**Employment Person-years**
Siting	961	15 500
Construction	356	13 400
Operation	672	61 200
Decommissioning	30	10 200
Total	2 019	100 300
ECONOMY-WIDE IMPACTS		
Activity	**Net Present Value of GDP (1991$ million)**	**Employment Person-years**
Siting	2 219	52 600
Construction	869	44 800
Operation	1 629	198 800
Decommissioning	71	33 000
Total	4 789	329 200

*Numbers may not add up due to rounding.

GDP Impacts



Employment Impacts



*See explanatory note in text (6.6.3.2) regarding interpretation of dates shown in these graphs.

FIGURE 6-13: Impacts of Construction and Operation of the UFDC in the Rest of Canada*

2) Impacts for the Rest of Canada

There would be no direct impacts for the Rest of Canada resulting from expenditures on a reference UFDC in Ontario. In other words, direct multipliers for the Rest of Canada for all spending categories are assumed to be zero. Therefore, the results presented below are economy-wide impacts for the Rest of Canada.

The total economy-wide impact for the Rest of Canada due to spending in Ontario on a conceptual UFDC, as illustrated in Figure 6-13, would be approximately one-half of the direct impact in Ontario. The NPV of the GDP impact would be $1.0 billion, and the employment impact would be 91 400 person-years. Table 6-56 summarizes the economy-wide impacts for the Rest of Canada.

6.6.4 Conclusion

The preceding analysis shows the economic impacts associated with the various stages of the conceptual UFDC over the period (year 1 to 89) in Ontario as well as in the Rest of Canada. These impacts would peak during the construction period (year 24 to 31). The economy-wide NPV GDP and employment impacts in Ontario would be about $4 789 million and 329 000 person-years. On average, these impacts represent less than 0.1% of the annual provincial GDP and labour force.

For the Canadian economy as a whole (including Ontario), the expenditures on the reference UFDC are expected to contribute some 420 500 person-years of employment and $5 791 million (NPV) on GDP.

TABLE 6-56
Economy-wide Impacts, Rest of Canada

Activity	Net Present Value of the GDP (1991 Million $)	Employment Person-years
Siting	440	14 700
Construction	195	12 200
Operation	352	55 300
Decommissioning	15	9 100
Total	1 002	91 400

*Numbers may not add up due to rounding.

The employment impacts estimated here assume the productivity would remain at the 1991 level. The employment impacts would be much smaller if they are adjusted for potential future productivity gains. Furthermore, these impacts should not be treated as benefits. Rather, the jobs created may be drawn from other sectors of the economy. Consequently, the net benefits flowing from the UFDC would be some fraction of the economy-wide impacts estimated in this assessment.

6.7 SECURITY AND SAFEGUARDS

6.7.1 Methodology

This section a) describes the nuclear safeguards and security design requirements for the conceptual used fuel disposal facility (UFDC) and used fuel transportation system, and (b) evaluates the possible safeguards and security provisions of the UFDC and reference used fuel transportation system (Simmons and Baumgartner 1994; Ulster 1993a,b), against the design requirements. Details of the analysis can be found in Frost (1993a).

6.7.1.1 Safeguards

1) Background

Canada, having signed an agreement in 1972 (IAEA 1972a) with the International Atomic Energy Agency (IAEA) on nuclear safeguards, has an obligation to fulfil IAEA safeguards requirements for substances containing nuclear materials. The objective of these safeguards requirements is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons and other nuclear explosive devices, or for purposes unknown, and the consequent deterrence of such diversion by the risk of early detection. The IAEA defines a significant quantity of nuclear material as the approximate quantity for which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive device cannot be excluded. In the case of plutonium, this amounts to 8 kg of elemental plutonium (IAEA 1987). The reference road and rail casks would carry an approximate plutonium content of 14 and 40 kg, respectively. The conceptual UFDC, at full capacity, would therefore have on its site many times this plutonium quantity. It is important to note that the plutonium in used fuel is not in a form that would be directly usable for nuclear weapons. In order to be used in nuclear weapons, the plutonium would have to be separated from the used fuel, a process that requires specialized expertise and facilities.

2) Applicable Regulations

There are no AECB or IAEA safeguard regulations specific to the geological disposal of used fuel. However, the basis for safeguards that applies to any nuclear facility is described in IAEA documents (IAEA 1972a; IAEA 1972b). In addition, the IAEA recently issued two documents in connection with an IAEA consultants meeting on safeguards for final disposal of spent fuel in geological repositories (1991a, 1991b).

Canada has among the most stringent safeguards policies in the world to minimize the risk that exported uranium and/or CANDU technology may be used to acquire nuclear weapons (Department of External Affairs 1985). The Federal government safeguards commitment under the Nuclear Non-proliferation Treaty (NPT) is implemented via the Atomic Energy Control Act which authorizes its agency, the AECB, to regulate the acquisition, use, storage and transport of nuclear materials in Canada.

3) Important Considerations in the Design of Safeguards Provisions

The assumed UFDC safeguards requirements are based on existing safeguards procedures for nuclear facilities, consideration of the UFDC operational requirements, AECB regulations (AECB 1974), IAEA documentation (IAEA 1985; 1991a; 1991b), and published safeguards literature. From the latter, it is apparent that consideration has to be given to the following factors in the design of UFDC safeguards provisions:

i) The Non-Proliferation Treaty is due to be reviewed by its signatories in 1995 to determine how it may be extended. The UFDC safeguards system design should be designed on the assumption that the NPT will be endorsed and renewed. It is probable that Canada will reach an agreement with the IAEA on how effective safeguards provisions can be provided for the UFDC in all its life cycle stages.

ii) The quantity of nuclear material in the Canadian underground disposal vault could eventually be very large, comprising tens of thousand times a significant quantity of nuclear material (8 kg of plutonium). Although plutonium and other nuclear material in the used fuel are not in a form directly usable for nuclear weapons, the nuclear material in the UFDC nevertheless constitutes a potential proliferation hazard and thus safeguards provisions acceptable to the IAEA will be needed for as long as deemed necessary by Canadian authorities and the IAEA.

iii) The UFDC safeguards should meet current safeguards objectives and principles, but would use the improved equipment that may be available by the time of implementation. Until the UFDC is decommissioned, its safeguards provisions should provide a sufficient level of assurance of non-diversion of nuclear material (IAEA 1991b).

iv) There is no physical change in the used fuel bundles between the originating nuclear generating station and the UFDC vault. Thus the reactor operator's used fuel data would be applicable for the nuclear material content of bundles or disposal containers at the UFDC. The UFDC safeguards should, therefore, be designed to facilitate item (i.e. used fuel bundle) accountancy (IAEA 1991b).

v) The issue of "retrievability" of the used fuel from the UFDC is an important consideration in developing the safeguards system that would unambiguously prove non-diversion. Successive backfilling of UFDC tunnels would provide improved containment and thereby increase the difficulty of both diversion and inspection (IAEA 1980). The used fuel will remain in the UFDC for centuries and as the fuel γ-radioactivity declines, the fuel's "self-protecting" capability will decrease (since it is hazardous to handle the used-fuel without protective equipment, its radioactivity level is protecting it against diversion attempts).

vi) The IAEA is placing increasing emphasis on the verification of nuclear materials in the back-end of the fuel cycle. Verification in the safeguards sense includes means of ensuring that the used fuel bundle is not a dummy and that it actually contains the nuclear material. Once the used fuel has been sealed in a disposal vault, it is likely to be classified as "difficult to access" fuel for which the need for inventory re-verification may be waived under certain circumstances (IAEA 1991b). To support this classification the IAEA would require that all significant diversion paths are safeguarded (Buttler et al. 1985).

vii) Another aspect of the non-verifiability of the used fuel is that if false alarms are given by the containment and surveillance (C/S) equipment and/or anomalies occur in the safeguards procedures (e.g. an apparent problem with accounting records, breakdown of equipment or lighting), the nuclear material inventory in a material balance area of the UFDC could not be directly re-verified once sealing of the material balance area has been carried out. A fully integrated safeguards system (IAEA 1991c) would have to be considered. Also, overlapping functions for all safeguards

instruments and equipment are essential, so that the failure of or false alarm from one type of C/S equipment can be checked against other C/S equipment.

viii) Safeguards seals (a tamper-indicating device used to join movable parts of a container) are an important component of existing safeguards systems. A safeguards seal helps in: (i) the effective management of material control, accountability and inventory verification; and (ii) maintaining containment and surveillance to provide information on access to or movement of nuclear material, or interference with equipment or data. Thus, a safeguards seal can be an invaluable element in both the materials accountancy and containment/surveillance measures of any safeguards system. The application of safeguards seals in a disposal facility is quite difficult at some locations, owing to the relative inaccessibility of the used fuel and the size of the containers. Thus, the careful selection of safeguards seals is an important consideration to minimize the IAEA inspectors' time involvement and radiation exposure.

4) Requirements for the UFDC

(a) General Requirements

General safeguards activities for each stage are as follows:

i) pre-operating stage - design review by regulatory authorities, and, during UFDC construction, design verification;

ii) active operating stage - design re-verification as new rooms and tunnels are constructed, item accountability for used fuel bundles/containers and/or loaded disposal containers, and also IAEA inspection including containment and surveillance;

iii) passive operating stage (after a disposal room has been backfilled) - continuation of records and reports, and also inspection; and

iv) post-operating stage (following vault closure) - continuation of records and reports, and also inspection.

(b) Detailed Requirements

i) the prime requirement is that the UFDC meets, in all its life cycle stages, the requirements of the IAEA safeguards program;

ii) design verification during the UFDC pre-operating stage and possible design re-verification as new tunnels and rooms are excavated during the UFDC operating stage;

iii) the used fuel is non-verifiable once sealed in the disposal vault. Thus, the safeguards system must be an effective combination of various integrated safeguards instruments and procedures, with sufficient redundancy, such that the system is not degraded if any element fails to function as

intended (i.e. the failure of, or false alarm from, one instrument can be checked against other safeguards equipment, and safeguards equipment output can be authenticated);

iv) the design, manufacture and testing of all safeguards equipment must ensure acceptable reliability and availability in the UFDC environment. This would mean that the equipment should function under the range of temperature, humidity (waterproof and corrosion resistant equipment might be required in some locations), radiation field and vibrations present at the UFDC;

v) remote application of safeguards seal should be possible (such as in the hot cell when the disposal container is closed and sealed), as well as remote verification by IAEA inspectors;

vi) safeguards equipment to meet the IAEA requirements where applicable should: (i) be tampered resistant; (ii) have minimum need for maintenance; (iii) conceal its operating status to facility operators; (iv) possess self-diagnosis capability to prompt the IAEA inspector of the equipment's operational status (i.e. system ok, system failure); (v) provide high resolution surveillance images; (vi) be capable of recording, storing and reporting (as required) performance and/or event data while operating; and (vii) be capable of transferring such recorded data to other locations, including IAEA headquarters; and

vii) capability of providing the IAEA with a nuclear material inventory at any time.

6.7.1.2 Security

1) Background

Security in the context of used fuel disposal consists of physical protection measures developed to protect against wilful acts which could result in the theft of nuclear material, or sabotage of the disposal centre facilities or of the contained used fuel, so as to endanger the public and UFDC staff health and safety. Physical protection of nuclear material is the responsibility of each state. The potential hazards from used fuel are radioactive contamination and the radiation fields arising from the decay of used fuel isotopes. An additional hazard is the potential theft of the used fuel for the purpose of using its plutonium to produce a nuclear explosive device.

With the concern that the public has for nuclear power and radioactive materials (Greber and Anderson 1989), it was recognized that the security procedures for the UFDC must be comprehensive and effective enough to protect the public, and must inspire public confidence.

2) Applicable Regulations

As with safeguards, there are neither AECB security regulations nor IAEA standards specific in the geological disposal of used fuel. The responsibility for ensuring that physical protection (or security) as applied to nuclear materials in Canada lies with the federal government. The AECB would exercise their authority on disposal security through the licensing process. The AECB has issued regulations (AECB 1983) for nuclear material security, that apply to a nuclear facility where nuclear

material is to be "used, processed, stored or otherwise processed". These regulations specify the security procedures for nuclear material which has a radiation level of less than 1 $Gy \cdot h^{-1}$ at one meter. Security procedures for nuclear material with a higher radiation level (most used fuel is in this category) are specified by the AECB on a case-by-case basis. For a radiation field greater than 1 $Gy \cdot h^{-1}$ at one metre from the unshielded fuel, the used fuel is considered to be irradiated. This corresponds approximately to the radiation field from used fuel that has been out of the reactor for a period of less than about 90 years.

If the used fuel is classified as irradiated, it is considered to be "self-protecting" because its high radiation field is a hazard for people that come in direct contact with it. This feature would act as a deterrent to potential theft. If the used fuel is classified as "unirradiated", then more stringent security provisions are required.

The IAEA has also published recommendations on used fuel security under the title "The Physical Protection of Nuclear Materials" (IAEA 1989).

3) Requirements for the UFDC

As with safeguards provisions, the UFDC security requirements are based on existing security procedures for nuclear facilities in Canada, AECB (AECB 1987b) documentation, consideration of the UFDC operating requirements and IAEA documentation (IAEA 1989).

The security requirements for the UFDC would be as follows:

i) prevent unauthorized entry to the UFDC;

ii) ensure that all used fuel and any other nuclear material remains in its designated location or, during transfers, on its designated route; and

iii) minimize the possibility of deliberate damage to used fuel at the disposal centre.

These requirements apply for as long as necessary to meet applicable regulations of the AECB (and also possibly the government of the province in which the UFDC is located).

6.7.2 Summary of Safeguards and Security Measures

The following discussion is for the purpose of showing that the conceptual reference design for the Used Fuel Disposal Centre described in Simmons and Baumgartner (1994) can be safeguarded and have an adequate level of security protection.

6.7.2.1 Safeguards Measures

There would be an IAEA design review prior to facility construction and other design reviews during new tunnel/room excavation.

The following is a summary of the possible safeguards measures that may be used for the surface facilities during the active and passive operating stage (Simmons and Baumgartner 1994):

i) the IAEA inspectors would be enabled to verify seals (and/or other containment and identification devices) on the transportation casks when they arrive at the disposal centre to ensure that the numbered seals and casks received

correspond with those reported as being shipped to the disposal centre. They may also wish to check if the cask had been opened without violating the seals;

ii) the IAEA may periodically check the sealing devices on temporarily stored transportation casks;

iii) the inspectors may verify that the empty transportation casks being shipped back did not contain fuel;

iv) it is assumed that the IAEA inspectors would be present at the opening of the transportation casks in the hot cell and the operators would count and record the number of bundles;

v) if the module is to be temporarily placed in storage, it would be moved to the surge storage pool where it would be placed in a storage frame. The inspectors may remotely seal the storage frames in the surge-storage pool, periodically remotely inspect the seals, and verify the seals when the frame is opened to send the modules for packaging. The pool would be under surveillance by IAEA cameras;

vi) the inspectors could observe all operations in the module-handling cell, verify by remote radiation measurements that each used-fuel bundle contains irradiated fuel, and they may record the serial number and manufacturer of each used fuel bundle removed from the modules and placed in a disposal container. They would observe the sealing of the container and record the serial number of the disposal container, and confirm that it contains 72 used fuel bundles;

vii) IAEA surveillance cameras would operate continually in the hot cells so as to record all activities that occur in that section of the facility;

viii) if the disposal container was not to be immediately transferred to the vault, it would be transferred for temporary storage in the head frame surge storage pool. The inspectors may observe the transfer. When in this pool, the container would be under IAEA camera surveillance until returned to the hot cells for placement in a container cask;

ix) the inspectors may seal the container cask before it is transferred to the vault; and

x) the container casks would be weighed on entering and leaving the vault, and the weight recorded.

The following is a summary of the possible safeguards measures that may be used for the disposal vault:

i) the IAEA inspector(s) may monitor the serial numbers of loaded containers, identify the disposal containers in the emplacement holes and check seals on the backfilled holes;

ii) before opening of the cask seal, the inspector(s) may verify the seal and make sure that the cask contains used fuel;

iii) seismic monitoring instruments would be placed to detect any sign of excavation of a diversion path into a disposal room; and

iv) the inspector(s) would place a safeguards seal in the bulkheads that close each disposal room. They will periodically check these seals and the bulkheads to detect an attempt to open a disposal room.

All the used fuel surface and underground handling activities would be performed while under surveillance by IAEA safeguards cameras.

The following is a summary of the safeguards measures proposed for the closure and postclosure periods:

i) the ground above the backfilled vault would be under IAEA surveillance; and

ii) periodic inspection and seismic monitoring would take place to detect any attempts to reopen the vault. These would continue as long the IAEA and AECB consider necessary.

6.7.2.2 Security Provisions

Physical security at the UFDC would be provided by a combination of facility design and layout, defined procedures, personnel identification and authorization, and trained staff. The centre would be divided into controlled and protected zones.

The site would be posted with signs warning against unauthorized entry and regularly patrolled by security staff.

The protected area around the used fuel packaging plant and the upcast shaft complex would be securely fenced and have guarded or locked access points and would be patrolled by security staff. Intrusion detection systems would monitor the integrity and motion of the fence. Five metres of ground on each side of the fence kept clear for security monitoring would also form a fire break. The boundary of the protected area (along the fence) and the entrance to each building would be appropriately lighted. All access control gates would be surveyed by closed-circuit television cameras. Access to the protected zone is through manned security stations.

All employees would undergo a security screening before employment starts and at regular intervals during employment.

Security is a sensitive subject, and discussion of detailed security requirements may eventually prove to be counterproductive, as the security provisions may be easier to circumvent. Thus the description of the security requirements is kept to a general level of detail here.

The security provisions for the UFDC are similar to current security systems in place at nuclear facilities in Canada. Experience to date shows that this type of system would fulfill all the security requirements listed earlier.

6.7.3 Analysis of the UFDC Safeguards and Security Provisions

The assessment of the UFDC safeguards and security provisions (Simmons and Baumgartner 1994) is based mainly on the design requirements presented above, and could be implemented with current technology.

During the period prior to operation of the facility, the specific equipment and procedures available for the critical areas of safeguards and security would be developed to meet the IAEA requirements once they are clearly defined. Rather than anticipate future safeguards and security developments, the safeguards and security provisions were assessed against what equipment and procedures are approved or accepted for use by the IAEA and the AECB today.

6.7.3.1 Safeguards

The general safeguards measures for all UFDC life cycle stages have been outlined in (Simmons and Baumgartner 1994). These measures are assessed with respect to each detailed safeguards requirement:

i) the safeguards framework outlined (Simmons and Baumgartner 1994) should meet all the IAEA requirements such as those requiring complete documentation and auditing at all stages;

ii) the AECL safeguards measures outlined are specified (Simmons and Baumgartner 1994) to apply for as long as necessary to meet the provisions of the safeguards program;

iii) on-going design verification during facility construction is described in Simmons and Baumgartner (1994), and meets the current IAEA requirements;

iv) sufficient variety of overlapping safeguards measures and equipment redundancy would be provided (Simmons and Baumgartner 1994) such that instrumentation readings, failures and false alarms should be verifiable against other safeguards instruments and procedures;

v) the requirement for acceptable reliability and availability would be normally included in the IAEA specifications for UFDC safeguards equipment. Once the implementing organization has a clear indication of the range of temperature, air humidity and radiation fields in the UFDC, potential for groundwater contacting the equipment, and for earth tremors, then all IAEA or IAEA-approved safeguards equipment that has an application in the UFDC will presumably be thoroughly tested in such an environment to corroborate that its reliability and availability are acceptable, and also to establish its service life under these conditions. This will enable the IAEA to replace equipment before the end of the equipment service lifetime is reached;

vi) the remote application and verification of IAEA safeguards seals at the UFDC was specified. Simmons and Baumgartner (1994) discusses in detail the use of safeguards seals; and

vii) all safeguard equipment used in the UFDC will be provided or approved by the IAEA, and thus would presumably have the requisite reliability/availability under UFDC operating conditions. It would be the responsibility of the IAEA, AECB and the implementing organization, as appropriate, to ensure that the equipment operated with satisfactory reliability/availability under UFDC normal conditions. Other requirements here should be standard for all IAEA-approved safeguards equipment in 2025, when the UFDC

goes into operation. The IAEA would presumably confirm that the equipment maintained these functions when operating in the UFDC environment.

Conclusion on Adequacy

It is concluded that the safeguards provisions outlined in the UFDC conceptual design would meet the requirements of the IAEA safeguards program for expected operating conditions. Regarding the feasibility of effective safeguards for a used fuel disposal centre, with the special features inherent in safeguards for a disposal facility, some authors (Butler et al. 1985; Stein et al. 1987) have questioned whether effective safeguards can be achieved in the post-operational stage of geological disposal. However, Canadian authors (Smith et al. 1988) concluded that adequate safeguards equipment and procedures can be developed for all stages of a used fuel disposal facility. The IAEA considers that there are no insurmountable difficulties anticipated in developing reliable disposal safeguards (IAEA 1991b, Deutscher Bundestag 1985). The IAEA stated "all factors considered, it is the opinion of the Agency that effective controls can be applied equally in either case" (i.e., in reprocessing and direct used fuel disposal). Thus it is considered that the UFDC safeguards outlined would effectively prevent any diversion of nuclear material from the UFDC (Frost 1993a).

6.7.3.2 Security

The physical security provisions for the UFDC have been outlined in Simmons and Baumgartner (1994) and described in Chapter 2. These provisions are as follows:

i) physical security at the disposal centre would be provided by a combination of facility design and layout, personnel identification and authorization, and trained staff. Access control, and site and building inspection will be performed by security staff (design assumes 54) to prevent unauthorized entry to the UFDC and perform other security duties;

ii) the security staff would be equipped with independent communications systems such as two-way radios for on-site communication, and radio receivers and transmitters in the security room for off-site communication, in addition to the regular communication systems at the Centre;

iii) security personnel would have received training in the hazards and special procedures for dealing with radioactive materials;

iv) UFDC personnel would be screened to ensure that they are not a security risk; and

v) the site would be divided into controlled and protected areas.

Conclusion on Adequacy

The security provision proposed in Simmons and Baumgartner (1994) protect the public, UFDC personnel and the environment from wilful illegal acts of theft of nuclear material, or sabotage of UFDC and/or its contained used fuel, and meet current AECB regulations (Frost 1993a).

Based on:

i) the social climate in Canada,

ii) the application of nuclear power in Canada for about 40 years without significant security incidents, from the fabrication and transportation of new CANDU fuel, the safe operation of reactors to generate electricity (for 26 years), and the storage (for more than 40 years) and intermittent transportation (for more than 25 years) of used fuel, and

iii) the security provisions provided,

the probability of a successful illegal act of used fuel theft, or sabotage of UFDC facilities and/or the contained used fuel, is considered to be highly remote.

Several characteristics of the used fuel itself, and of the used fuel disposal centre, make such an illegal act relatively unattractive while the UFDC is in its operating stage, i.e.:

i) direct used fuel radiation fields are so high as to be potentially lethal, if the used fuel is removed from its shielded location in the UFDC without using appropriate equipment;

ii) the plutonium content of the used fuel is relatively low;

iii) complex, expensive facilities would be required to extract the plutonium, if extraction is desired for a subversive activity;

iv) considerable technical knowledge of a complex nature must be available to a subversive group to construct and operate such a plutonium extraction facility and to use the plutonium to fabricate a nuclear explosive device; and

v) the inherent physical security of any of the used fuel containers used in the UFDC.

Similarly, the probability of successful sabotage of any UFDC facilities during any UFDC operating stage, prior to closure of a disposal vault, is extremely remote. The consequence of sabotage (e.g. using explosives) of a UFDC disposal container loaded with used fuel on public health and safety would be less than the sabotage of a used fuel transportation cask, because of the relative remoteness of the UFDC from the general population. Sabotage of a used fuel transportation cask is discussed in the Chapter 7.

Sabotage, once a disposal vault has been closed, is not considered to be a credible possibility. The possibility of sabotage by UFDC personnel is minimized by the security screening of personnel prior to hiring, the constant patrolling of the site and buildings by security personnel, the access control and for the same reasons given above for sabotage from outside.

6.8 RESIDUAL EFFECTS

As mentioned in Chapters 4 and 5, because the significance of effects cannot be determined without a social and ecological context, the residual effects discussed here are our best estimates on what effects might be left after the application of impact management measures. These estimates would need to be validated with the site-specific human and natural environment settings.

6.8.1 Impacts of Normal Operation

On the Public

The radiological pathways analysis has shown that the public dose impact from the routine operation of the Used Fuel Disposal Centre in the three reference environments of the Canadian Shield in Ontario is very small. These results would need to be compared with the safety analyses that would be carried out on a site-specific basis once the site and a design have been selected.

On Workers

At this conceptual design stage, it is not possible to quantify precisely the non-radiological hazards to which workers would be exposed during normal operation of the disposal facility. Mitigation measures such as the use of protective equipment, and the establishment of strict operating procedures would keep these hazards to a minimum, and the impacts would be below the national statistics.

The safety analysis has shown that there would be no radiological exposures above current or proposed regulatory limits. In accordance with practice at other nuclear facilities, a formal occupational radiation management program to minimize occupational dose would be implemented at the disposal facility, based on the ALARA principle.

This type of program is in place at Ontario Hydro, New Brunswick Power, Hydro-Quebec, and AECL (including the URL), and have been successful in keeping radiological and non-radiological hazards below acceptable levels.

On the Natural Environment

The application of dust suppression measures would likely be necessary to minimize dust emissions from the waste rock pile. The water treatment provisions and run-off control would prevent degrading of existing water quality. The same kinds of effects on flora and fauna as during construction are expected during operation of the facility, but to a much smaller extent. Non-renewable resources, such as titanium, carbon steel, bentonite clay, glacial lake clay, silica sand, propane and glass would be used during operation of the facility. These materials are not in short supply, as there are substantial reserves in Canada. The bentonite industry in Canada has however undergone a major downturn in the late 1980's, and this has lead to the disappearance of a number of producers (Dixon et al. 1992). If more deposits of bentonite are not brought into production in the future, the facility operation would have to depend on importing this resource.

On the Socio-Economic Environment

In general residual adverse socio-economic impacts will be compensable. Unexpected impacts are likely to occur, as with any large-scale project. It is necessary to have a program that is flexible, i.e. open to the identification of new impacts, and ready to be creative in finding and implementing appropriate mitigation measures. The key to this readiness lies in:

(i) the active participation of the community in continuous socio-economic monitoring and management programs; and

(ii) periodic review of impact management strategies and programs.

Concerns about possible impacts to public health and safety can be considered an important residual impact, although the risk of radiological contamination is assessed as very small. It is important, therefore, to have an impact management program that is responsive to concerns about health and safety risks. Three possible measures are:

(i) continuing public and occupational health and safety monitoring, preferably linked to regulatory or academic health establishments;

(ii) community liaison and joint planning; and

(iii) encouragement of scientific research at the disposal facility, especially radiological research by national or international scientific institutions.

6.8.2 Effects from Accident Conditions

On the Public

Accident frequencies and radiological consequences were calculated for the six postulated accident scenarios defined in Table 6-18. Results are summarized and compared to the regulatory requirements in Table 6-27.

The analysis showed that the inhalation pathway makes the largest contribution to the total dose, with the groundshine contribution being three orders of magnitude lower. Failure of the filtration system increases the doses from inhalation and groundshine (by three orders of magnitude), while immersion doses are almost unaffected. Doses for all postulated accidents and their related frequencies are much lower than limitations imposed during the Darlington NGS licensing process (see Table 6-27).

In the present study, proven methods have been used to verify that a preliminary selection of worst case accident scenarios comply with the risk acceptance criterion. Further work will be required when the detailed design is developed to ensure that all the potentially significant accident scenarios have been included in the assessment.

On Workers

Estimated annual acute non-radiological risks to workers are presented in Table 6-32 based on Workmen Compensation Board and other industrial statistics (Myint 1989; Social Data Research Ltd. 1986). The total

fatality and loss time injury for a 41-year operating life are 10 fatalities and 2 493 lost-time injuries. Occupational safety features should be developed during final design to reduce these numbers.

There is no regulatory limit on the occupational radiation dose under accident conditions because the operator should be as free as possible to intervene and take actions to prevent/reduce consequences. Occupational dose and dose rate design criteria for nuclear facilities provide guidance to the levels of radiation dose that would be acceptable under accident conditions. Radiation doses estimated for UFDC workers under accident conditions are well below the acceptable dose limit of 30 mSv per individual. Emergency response plans to handle accident situations are described in Chapter 2.

On the Socio-Economic Environment

Even though the safety analysis showed that for all the base-case accident scenarios, doses were below the lowest action level of the Ontario Nuclear Emergency Plan, and well below the evacuation level, the potential socio-economic impacts of an accident cannot be completely discounted.

The potential impacts to a community as a consequence of an accident or abnormal situation could be very negative. It is therefore important that the disposal facility involve a jointly planned impact management program, including emergency response, implemented with the participation of the host community.