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CTECH

Radioactive Materials Management

Conceptual Designs for Four Centralized Extended Storage Facility Alternatives for Used Nuclear Fuel

Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro-Québec and Atomic Energy of Canada Limited

April 2003

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Summary

This report presents conceptual designs for four alternatives for the extended storage of used nuclear fuel in a Centralized Extended Storage Facility (CES). This report forms the main output from the conceptual design phase of the Extended Storage Facility (ESF) Options Study for Ontario Power Generation's (OPG), New Brunswick Power's (NBP), Hydro Québec's (HQ) and AECL's used nuclear fuel. The study is being carried out by CTECH on behalf of the Joint Waste Owners.

The four concepts for the CES, referred to as alternatives, were selected as representative of a range of possible centralized extended storage designs. The selected alternatives are:

- Casks and Vaults in Storage Buildings (CVSB)
- Surface Modular Vault (SMV)
- Casks and Vaults in Shallow Trenches (CVST)
- Casks in Rock Caverns (CRC)

The first two alternatives are above ground facilities, the CVST is partially below ground and mounded over and the CRC is at a nominal 50m below ground level.

The designs for the four alternatives have been developed in accordance with the Design Basis Document [1] and to a level sufficient to enable a global cost estimate to be produced for each alternative. The cost estimates will be produced in the cost-estimating phase of this study.

The CES facility will be designed to provide safe storage of all of the used nuclear fuel arising from the current Canadian nuclear program, which equates to approximately 3.6 million bundles. This used fuel will be transported to the CES facility in one of two formats, either in modules or in baskets. The projected used fuel inventory will comprise approximately 92% of the used fuel that will be transferred in module format, and approximately 8% of the fuel that will be transferred in basket format.
The CES facility will be capable of receiving, handling and packaging the used fuel, at a rate approaching 120,000 bundles per year.
The used fuel will be transferred from the 'donor' site to the CES facility in one of the following used fuel tranportation packages:

- Existing storage casks will be transferred as an assembly, complete with impact limiters, and hold-down equipment (each cask contains 4 modules)
- Used fuel modules will be transferred to the CES in the OPG Irradiated Fuel Transportation cask (IFTC). Each IFTC is designed to accommodate 2 modules
- Used fuel baskets will be transported to the CES facility in the Used fuel basket transportation cask (this cask is designed to accommodate 3 used fuel baskets).

The receipt facilities at the CES will be designed to accommodate the relevant fuel transportation package associated with that alternative.

The CES facility will be designed to perform the following functions:
- Provide safe containment for the used nuclear fuel
- Allow monitoring and inspection of the fuel containment
- Facilitate safe retrieval of the used fuel, when required

- Provide mechanical protection for the used fuel, during handling and storage operations
- Provide cooling of the fuel to prevent excessive temperatures both in the fuel and in the storage system
- Ensure adequate shielding is provided to minimise the radiological hazard to both operational staff and the public.

The design intention for the CES facility is to provide an environment for the storage of used fuel, in-line with the performance requirements outlined above. The facility will be designed to operate for an ‘extended period of time’, in the context of this project, an extended period of time means an indefinite period. To facilitate storage of used fuel over an extended period it will be necessary to retrieve the fuel from the existing storage facility, and transfer the fuel into new storage structures (as the existing facility reaches the end of their service life). It will also become necessary to transfer the fuel from its containment housing (cask/module or basket) as these containment housings reach the end of their service lives. The sequencing of both of these transfer operations is addressed within this report.

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1 Introduction

1.1 INTRODUCTION AND BACKGROUND

This report presents conceptual designs for four alternatives for the extended storage of used nuclear fuel in a Centralized Extended Storage Facility (CES). This report forms the main output from the conceptual design phase of the Extended Storage Facility (ESF) Options Study for Ontario Power Generation's (OPG), New Brunswick Power's (NBP), Hydro Québec's (HQ) and AECL's used nuclear fuel. The study is being carried out by CTECH on behalf of the Joint Waste Owners.

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- Casks in Rock Caverns (CRC)

There were five key factors that lead to the selection these four CES facility alternatives.
First, 3 of the 4 alternatives (CVSB, CVST, CRC) would minimise repackaging of fuel upon receipt at the CES facility, which would allow higher fuel throughput and minimise cost.
Second, there are above-ground (CVSB and SMV) and below ground concepts (CVST and CRC) on the list which meets the requirements of the Nuclear Fuel Waste Act. The CVST alternative would be constructed at a shallow depth in soil while the CRC alternative would be located in a competent bedrock formation.
Third, 3 of the 4 alternatives would use a passive system to cool the fuel, which is preferred for a CES facility.
Fourth, there is substantial experience with the SMV and CVSB alternatives, and the CVST and CRC alternatives are simple variants of proven technologies.
Last, the SMV and CVSB, and to a lesser degree, the CVST and CRC alternatives would be reasonably flexible with respect to finding a site with suitable characteristics. Site conditions should not be a major constraint in the implementation of these alternatives

A description of each of the four CES alternatives is provided in Sections 3, 4, 5 and 6 respectively with details of the ancillary facilities, mostly common between the alternatives, given in section 7.
The project was initiated by an Ontario Power Generation document [2]. Attachment 4 of that document identifies the top-level requirements for the CES facility and provides definitions for the various terms relating to the design and operation of the CES facility.

The requirements were embodied in the Design Basis Document [1], which was prepared and agreed with OPG at the start of the conceptual design phase, prior to proceeding with the design of the four alternatives. The designs presented in this report have been produced in accordance with the Design Basis Document.

1.2 CONTEXT

Currently, used nuclear fuel is stored at seven reactor sites in Canada, in both wet and dry storage facilities. These interim storage facilities have a nominal design life of 50 years.

There are various options for the management of the Canadian used nuclear fuel in the longer term, including:

- extended storage at the reactor sites;
- extended storage at a central location, and
- isolation by encapsulation and placement in a deep geologic repository.

Centralized extended storage could be above ground or underground, at one of the reactor sites or at a “greenfield” site. However for the purpose of this study it has been assumed that the centralized extended storage facility would be located on a greenfield site.

The purpose of this report is to describe four possible alternative designs for centralized extended storage. Other reports will describe possible designs for reactor-site extended storage at each of the seven reactor sites, and the deep geologic repository option. The information in these reports will be used as possible input to a study of options described in the Nuclear Fuel Waste Act, to be carried out by the future waste management organisation. At the end of its study, the waste management organisation will be required to report to the Government of Canada setting out its preferred approach for long-term management of nuclear fuel waste.

1.3 ORGANISATION OF DOCUMENT

The design report is organised into the following Sections.

Section 1 Introduction
This section provides an introduction to the report and sets it in the context of the study project.

Section 2 Design Overview
This section provides an overview of the storage facility concepts, common features and design approach.

Section 3 Casks and Vaults in Storage Buildings
This section describes the design of the first alternative storage concept.

Section 4 Surface Modular Vault
This section describes the design of the second alternative storage concept.

Section 5 Casks and Vaults in Shallow Trenches
This section describes the design of the third alternative storage concept.

Section 6 Casks in Rock Caverns
This section describes the design of the fourth alternative storage concept.

Section 7 Common Ancillary Facilities
This section describes the ancillary facilities and buildings required to support the operation of the storage facilities.

Section 8 Description of the Phases in Facility Development
This section reviews the various stages in the construction and operation of the facility including building repeats and repackaging of the fuel at various times in its life.

Section 9 Waste Management, Monitoring, Maintenance and Staffing
This section describes various common elements of the operations.

1.4 DEFINITIONS

Some terms used in this document are described below:

Basket is a sealed container designed to maintain the geometry of a used nuclear fuel bundle arrangement inside a cask, canister or vault. In this report it refers in particular to the type of fuel basket used by New Brunswick Power (NBP), Hydro Québec (HQ) and AECL (Refer Fig. 5.4).

Cask is a mobile durable container for enclosing and handling nuclear fuel waste for storage or transport. The cask wall shields radiation and heat is transferred by conduction through the wall. In this report it refers in particular to the dry storage container (DSC) (refer Fig.5.3) currently used by OPG and a new design of cask similar to the DSC to store fuel in baskets (Refer Fig. 5.5).

Centralized Extended Storage (CES) facility is a facility used for the extended storage of used nuclear fuel. The facility will be located at a single, central location and would accept used nuclear fuel from all reactor sites in Canada.

Extended storage means storage for periods of time significantly greater than 50 years from the time the facility is placed into service. In the context of this study it means permanent or indefinite storage.

Management in relation to used nuclear fuel, means long term management by means of storage or disposal including handling, treatment, conditioning or transport for the purpose of storage or disposal.

Module is a rack system for holding fuel bundles currently used by OPG for storage in fuel bays and in DSCs. 96 fuel bundles are stored in horizontal tubes held in a rectangular framework (refer Fig. 5.2).

Module canister is a sealed container holding a number of modules for loading into a store and long term storage (refer Fig.5.6).

On-site Transfer System is the system of transportation casks, tractors, trailers, rail trolleys, cask transporters etc required to move the fuel between the processing and storage buildings (refer Fig. 5.7 for typical cask transporter).

Processing Building houses the facilities for receiving the fuel deliveries, offloading the transportation casks, unloading the fuel, transfer to the storage containers and loading the containers onto the on-site transfer system. This is likely to be the main building on site and could incorporate other facilities and amenities.

Storage means the placement of used nuclear fuel in a nuclear facility where isolation, environmental protection and human control (e.g. monitoring) are provided. The facility provides containment, shielding and dissipates decay heat from the used nuclear fuel. The used nuclear fuel will be stored in such a manner that it could be safely retrieved at any time during the facility service life for transfer to another facility. To ensure safe retrieval the used nuclear fuel will be stored in an environment that ensures the potential effects of fuel degradation over the long term would be mitigated.

Storage Building provides the environment for the long-term storage of the fuel, in the alternatives constructed at ground level. The buildings will be essentially modular and constructed over time to match fuel arrival on site. The buildings will be close together and interconnected to form a Storage Building Complex.

Storage Chamber provides the environment for the long-term storage of the fuel in shallow trenches. The chambers will be interconnected modular concrete structures constructed in an open trench and mounded over to form a complex accessible by a ramp from ground level.

Storage Cavern provides the environment for the long-term storage of the fuel in the below ground alternative. The caverns will be interconnected to form a Storage Cavern Complex, which will have access ramps to the surface for transporting the fuel casks to the caverns.

Used Fuel, (also referred to as nuclear fuel waste) means the irradiated fuel bundles removed from commercial or research nuclear fission reactor (refer Fig. 5.1).

2 Design Overview

2.1 OVERVIEW OF EXTENDED STORAGE FACILITY CONCEPTS

The CES facility comprises two principal parts, irrespective of the alternative under consideration. Each comprises a Processing Building and a Storage Building Complex, Storage Chamber Complex or Storage Cavern Complex.

The storage arrangements are described more fully in the following sub-sections. Two alternatives comprise surface facilities, in which fuel is stored in a series of storage buildings built above grade.

The remaining two alternatives are below ground facilities, one near-surface and mounded over and one at about 50m below ground surface in competent bedrock. The near surface alternative, the Casks and Vaults in Shallow Trenches will be passively ventilated, with the deeper alternative, Casks in Rock Caverns, ventilated using a forced system.

Table 2 presents a comparative view and outline information on the four CES alternatives.

2.2 EXTENDED STORAGE FACILITY OPERATIONS

The extended storage facility life cycle will comprise three major phases: Siting, Construction and Operation. The operation phase has an indefinite duration and includes the following activities:

- Receipt of fuels, in the appropriate format, at the CES facility site, offloading and emplacement in the relevant storage facility.
- Periodic storage structure construction (to match scheduled deliveries of fuel) and refurbishment.
- Extended monitoring of the fuel condition and maintenance of the storage building and containment structures.
- Periodic transfer of stored used fuel to new storage structures as the life of existing structures is reached (facility repeats).
- Periodic repackaging of stored used fuel as the life of existing packages is reached.

The service life of a number of used fuel storage structures employed within the Canadian nuclear power generation and research fields is the subject of a separate study between OPG and CTECH. This Life Extension (or LEX) study [3] is reviewing the existing structures and determining their likely service lives. The LEX study has identified the main life limiting features of the current storage systems and proposed life expectancies in the order of 50 to 100+ years. The expected life depends to a large extent on the ambient conditions that are prevalent around and within the stores. If the environment around the fuel storage containers is maintained dry and at a relatively constant temperature then in most cases the life could be extended indefinitely. Other important factors include the presence of chemical pollutants in the store environment and exposure to freeze/thaw cycles. The findings of the LEX study have been taken into account in the designs but in many cases the issues need to be addressed in the detail designs of the store components to avoid weak points and potential corrosion hot spots. At this stage the designs have been based to a large extent on current practice to present a reasonably cost effective solution. The designs could be enhanced further to increase the life expectancy of the storage containers by such measures as dehumidification and air conditioning to ensure that the environment is optimised. These enhancements would be offset by increased initial and operating costs and have not been included in the current proposals. An estimate of the likely minimum service lives of the various fuel containers and structures used to house fuel containers are presented in Table 3.

Recognising that the storage buildings and principal containment structures have a finite life span, it will be necessary to move fuel baskets, module canisters or storage casks from an ageing storage complex to new facilities. Depending on the alternative under consideration, this may be achieved by the scheduled building of additional storage capacity on the site, permitting the transfer of fuel containers from one storage building to another. Once sufficient used fuel has been transferred and the storage building has been emptied, the redundant building will be demolished, and a replacement building constructed. Through use of this ‘rolling program’ of demolition and renewal, it is unnecessary to set aside twice the total storage area, for current and future needs. Rather, the facility renewal process can be accomplished within the land area required for storage of the total fuel inventory, with an additional limited area to ‘prime’ the transfer cycle.

It is also recognised that the condition of the primary fuel containment, in the form of fuel baskets, module canisters and storage casks, will require replacement, as containers meet the end of their service life. This is expected to be on a much longer timescale than the storage facility repeat cycle. It is anticipated that there will be periodic removal of the contents of existing fuel containers and the repackaging of fuel into fresh containers, in conjunction with the facility repeat cycle.

In essence, this repackaging cycle will be periodically grafted onto the facility repeat cycle. It is envisaged that the fuel containers will be returned to new facilities after repackaging of fuel bundles rather than being returned to existing facilities.

2.3 FUEL RECEIPT

2.3.1 Fuel Transportation Assumptions

The design of used fuel handling systems and surface facilities considers that the fuel might be received at the centralized extended storage facility surface facilities in packages of different types, originating from different donor fuel storage facilities.

The following assumptions have been made for the purposes of the CES study:
(a) Fuel will be shipped in road-weight storage casks.
(b) Fuel stored in modules within OPG's wet bays will be shipped in the Irradiated Fuel Transportation Cask (IFTC) (Refer to Fig 5.8).
(c) Fuel stored in baskets will be transported in a cask designed to accommodate three baskets of the type used for dry storage purposes by AECL, Hydro Québec and New Brunswick Power.

The IFTC is fully described in the Safety Analysis Report [4], and holds two modules, a total of 192 fuel bundles.

For the purposes of this study the basket transportation cask design will be assumed to be similar in design to the IFTC, but of cylindrical construction. The design includes solid monolithic stainless steel construction with 270mm thick walls and lid. The lid is sealed with a double elastomeric seal and held in place with 32 bolts. An impact limiter is fastened to the lid to protect the lid joint area. The basket transportation cask is designed to hold three fuel baskets.

Both transportation casks are unloaded by lifting the modules or baskets out vertically. Outline operating procedures for the IFTC are given in [4].

If a CES alternative involves storage of OPG's 384-bundle Dry Storage Containers (DSCs), it is assumed, for the purposes of this study, that they will arrive at the facility by rail to an off site railhead and make their final journey to the CES by road transporter. Reference [5] describes the transportation configuration and outline operating procedures for OPG's DSCs.

2.3.2 Inventory Summary

The conceptual design phase report uses the fuel inventory as outlined in Table 1. The inventory is assumed to be 3,557,451 fuel bundles, which is accumulated at the CES facility over a period of 30 years. The basket fuel arrives at the CES facility in the later years (year 35 onward), and comprises 283,020 fuel bundles. The balance (3,274,431 fuel bundles) will be delivered in fuel module form, within either storage casks, or module transportation casks. The peak receipt is taken as 120,000 fuel bundles per year.

Throughout this design report, it is assumed that all fuel baskets receipts will comprise the 60-bundle basket design, in use at the Gentilly 2 and Point Lepreau power stations. However, approximately 12% of the basket fuel would be received from AECL sites, which in some instances, will supply fuel bundles in smaller baskets. Through the use of spacers and other minor modifications to the handling equipment and storage structures it would be possible to accommodate these smaller diameter baskets.

Each facility alternative is required to store both fuel in module and basket forms. Within each facility description, the total numbers of fuel bundles accommodated are discussed. In some instances, a small over-capacity is provided. By review of the inventory totals in Table 1, the calculated minimum number of storage casks (or module canisters) and baskets required to house this inventory is 8,528 and 4,717 respectively. The general approach has been to provide storage capacity slightly in excess of these minimum calculated numbers.

2.4 DESIGN APPROACH

2.4.1 General

The design approach for the CES study is to generate designs for the four alternatives to an equal level of conceptual detail.
The designs have been based as far as reasonably practicable on existing and proven technologies, derived from Canadian and international experience.

The conceptual designs adopt safe fuel handling methodologies, and where fuel bundle transfers are effected, to employ shielded cells to minimise radioactive dose and maintain appropriate contamination control. In addition, consideration has been given to the safe handling of fuel containers, during transfer and placement in the storage facilities.

Any areas of uncertainty remaining in the designs and where more detailed investigation may be required to develop design solutions have been identified.

The design emphasis has been predominantly on initial fuel receipt and placement of fuel packages into the extended storage facility. Consideration has also been given to the operations phase, particularly the extended monitoring activities. The design approach has also been to identify outline designs for facility repeats and repackaging activities, which take place in distant time frames. Potentially, some of the techniques identified within this report may no longer be in common currency at these times. However, the basic premise employed has been to assume these activities take place in the present and identify designs, techniques and procedures relevant to their safe execution and ensure that no insoluble problems will be posed in the future.

2.4.2 Structural Design Requirements

In addition to meeting the general design requirements of the design codes and standards listed in Section 11, the steel and concrete structures comprising the shielded cell shall be designed to meet the following special requirements:

Wind:
Wind load shall be based on a probability of 1 in 100 years of being exceeded in any one year.

Earthquake:
The shielded cell structures shall be designed to survive the ‘design case earthquake’.

Structural Steelwork:
Long lasting epoxy-coating system shall be used on all steel members such as the following system manufactured by Ameron:
First coat: Organic zinc reach Epoxy (4 to 5 mil)
Second coat: PSX700 Engineered Syloxane-Epoxy (6 to 7 mils)

Concrete Structures:

Cast in place reinforced concrete shall meet the following requirements:

Concrete strength after 28 days	40 Mpa
Aggregates	Aggregates deemed reactive when tested for Alkali-Aggregate Reactivity in accordance with CAN/CSA A23.1M Appendix B shall not be used.
Cement	Moderate sulphate resistant cement conforming to CAN/CSA-A5 type 20
Water/Cement Ratio	Not more than 0.42
Slump	Superplastisising and water reducing admixtures shall be used to achieve 150mm slump minimum
Concrete cover to reinforcement	75mm

2.5 SITE LAYOUT

The CES facility is assumed to be located on a green field site. The CES facility will not rely on the services or provisions to other nuclear facilities, and will therefore be considered as a stand-alone facility.

It is assumed the facility will be constructed in Ontario, Canada.
In general terms, the site is assumed to have the following physical characteristics, (more specific site selection criteria is contained at section 8.1):

- be relatively flat
- be free draining and without muskeg deposits
- have stable soil structures
- have competent rock structures, where required.

The CES site layouts represent the storage requirements for the full fuel bundle inventory. Each site layout has been made as space efficient as practical. Sufficient space has been included to allow storage complex repeats and facilities necessary for repackaging events to be constructed.

The common approach across all layouts is that the radiologically ‘active’ facilities have been segregated from the ‘inactive’ facilities as far as possible. As such, there is a clear division between the two parts of the facility. A double security fence (typically 3.6m high) surrounds both the ‘active’ and ‘inactive’ parts of the facility, this double fence will house the facility guardhouse. The separation between the ‘active’ and ‘inactive’ parts of the facility will be achieved with a single security fence. There will be an unmanned gate connecting the two areas.

3 Casks and Vaults in Storage Buildings (CVSB)

3.1 GENERAL DESCRIPTION

The Casks and Vaults in Storage Buildings alternative comprises the storage of fuel bundles in one of two storage methods, either modules confined in self shielded storage casks, or fuel baskets confined in an array of concrete vaults. The storage casks and vaults are arranged within a series of independent storage buildings (Refer Fig. 1.1 for site layout and key overall dimensions).

Packages of fuel bundles are transferred from individual reactor sites to a central storage location via one of three potential transfer mechanisms, these are:

- storage cask transportation mode
- module transportation cask mode
- basket transportation cask mode.

Storage casks arriving at the CES facility are inspected on arrival. Inspection checks will include an assessment of the general cask external condition, visual examination for scrapes/blemishes to paint finishes, surface corrosion, condition of storage cask labelling and cross-checks with transportation documentation. The storage casks are then directed to the relevant dedicated storage building (Refer Fig. 1.8).

Fuel bundles arriving in modules are transferred into storage casks in the shielded cell and then after storage cask processing, the storage casks are transferred to the relevant dedicated storage building (Refer Fig. 1.9).

The maximum annual receipt rate is 117,066 used fuel bundles per year from the existing wet storage facilities in module format.

The used fuel will be transferred to the CVSB facility using the Irradiated Fuel Transportation Casks (IFTC), with each IFTC contains 2 used fuel modules.

The required throughput rate dictates the production of 1.32 storage casks per day. To achieve this throughput, the contents of 3 IFTCs will need to be received and processed per day.

To facilitate the receipt, transfer and handling activities associated with the processing of these casks it will be necessary to work two shifts for the duration of these operations.

At other times within the duration of the fuel receipt operations a combination of fuel (in module format) from both wet and dry storage, and baskets (dry) will be received at the facility.

The fuel receipt quantities during these combinations of, ‘wet and dry’; fuel receipt vary year by year. None of the combined wet and dry fuel receipt years generate higher CVSB production rates than the figures quoted above for the receipt of wet fuel only.

With two shift operations there is time available for possible cask decontamination activities. To enable more time for these non-routine decontamination activities, the processing building layout has a space allowance adjacent to the shielded cells to allow decontamination activities to be taken 'off-line', to ensure that any disruption to the production of casks for storage is minimised.

Fuel that arrives in baskets is transferred to the facility in the basket transportation cask, this cask is designed to accommodate 3 baskets. The cask is unloaded into the shielded cell and then the baskets are loaded individually into a transfer flask at the shielded cell, the transfer flask then delivers the basket to the dedicated vault in the relevant storage building (Refer Fig.1.10).
The maximum annual receipt rate for fuel baskets is nominally 500 baskets per year, (500 baskets x 60 bundles per basket = 30,000 bundles per year). The receipt of 1 basket transportation cask per day can satisfy this requirement.

Key features of the CVSB extended storage concept include:

- The facility accepts existing storage casks, fuel modules or fuel in basket format.
- Fuel is stored within sealed storage casks, or within sealed baskets inside sealed tubes in concrete vaults.
- After fuel receipt, all subsequent fuel movements are under cover, (minimising effects of adverse weather and maximising fuel container life by reducing environmental impact on 'housing'.
- Additional capacity is provided by the construction of storage buildings on a rolling program.
- Storage cask emplacement in storage buildings utilises a cask transporter, which will transfer the cask from the processing building to the pre determined storage building
- Basket emplacement within the vaults is achieved using a transfer flask, this will be transferred to the duty vault building using a transfer bogie and the transfer flask will then be raised onto the storage vault using the vault building crane.
- Storage building cooling is achieved by natural convection, through vents and louvers in the building walls and roof, and through engineered airflow paths in the vault structures.

3.2 PROCESSING BUILDING

The processing building (Refer Fig. 1.4) will be an industrial type building structure, designed to provide a safe operational area for the handling of used fuel storage and transfer casks.

3.2.1 Construction Materials

<u>Walls</u>
External. The processing building will have concrete block walls and exterior metal cladding, with appropriate insulation.
Internal. Concrete block in high traffic areas.

<u>Roof.</u>
The roof will have provisions for drainage of rainwater and melted snow. Access to the roof will be provided by use of a permanent all weather stairway. The building will be grounded to protect against lightening.
The roof will be pre-finished insulated material.
<u>Floor</u>
The floors of the receipt and the cask processing areas will be reinforced concrete slabs, designed to accommodate heavy-wheeled traffic. They will be constructed for minimal

maintenance, to retain surface alignment and provide a hard smooth and durable surface. Floors will be graded to provide drainage to floor drains.
Areas that do not receive wheeled traffic will not be designed to the same requirements.

The areas, which comprise the processing building, are outlined below in more detail:

3.2.2 Receipt Area

This area is served by a 120 tonne overhead crane and is designed to facilitate the transfer of the shielded fuel transportation casks from the transportation tractor-trailer unit to the relevant receipt bogie, for onward transfer and processing as necessary. The receipt area will have provision for the removal, set down and parking of the impact limiters and the hold down equipment associated with the fuel transportation casks, as well as accommodating the park positions for any auxiliary lifting equipment. Storage casks will also be lifted from their transportation vehicles and set down in this area, prior to being moved to the storage complex by the cask transporter.
Initial inspection and validation of the fuel casks and the associated transportation documentation will be conducted within the receipt area. The receipt area will also provide buffer capacity for the temporary storage of fuel transportation casks, either with or without fuel, to provide flexibility to meet the receipt schedule.

3.2.3 Cask Processing Area

The cask processing area is the area of the facility where the loaded casks are transferred to after they are dispatched from the shielded cell. The cask processing area has the capability to execute all of the cask closure, inspection and pre-storage operations and checks. These steps include:

- the preparation and welding of the cask lid to the cask body,
- welding of the vent plug,
- x-ray inspection of the cask flange weld,
- vacuum drying of the cask internals,
- backfilling of the storage cask with helium,
- welding of the storage cask drain plug,
- visual and dye penetrant inspection of the welds which have not been x-ray inspected,
- helium leak test,
- repair the external paintwork.

3.2.4 Shielded Cell

The shielded cell complex comprises three cells that are close coupled, but are physically isolated by the inclusion of vertical sliding steel shield doors. The crane maintenance/decontamination area (common to both handlers) is isolated from the transfer cells by shield doors between each cell and the crane maintenance/decontamination area).

The elements which comprise the shielded cell complex are:

- Module transfer cell
- Basket transfer cell
- Crane maintenance/decontamination area (common to both handlers)
- Operating gallery

Segregation of the module and basket transfer cells generates the following beneficial effects:
a) Minimises the potential for cross contamination of the fuel containers
b) Cells can operate in parallel, thereby maximising throughput
c) Allows process operations to continue during breakdown or maintenance activities in one cell.

The shielded cell complex will provide a concrete shielded ‘enclosure’ in which used fuel can be safely received and handled, using dry remote handling techniques. The design of the shielded cell and implementation of the proposed handling techniques minimise the potential for radiation dose uptake by the operational personnel.
Each of the transfer cells provides a fully shielded remotely operated facility, designed for the handling of the relevant fuel package (modules or baskets). Each transfer cell is configured for the relevant fuel package, and a dedicated overhead in-cell crane serves each transfer cell. Preliminary shielding calculations indicate that the shielded cell wall thickness will be approximately 1.0m. Man access into the shielded cell will not normally be permitted. Any in-cell equipment that requires maintenance or replacement will be transferred from the transfer cell into the common crane maintenance/decontamination area using the appropriate in-cell handler. After remote monitoring and any necessary decontamination, suitably equipped personnel will undertake repair or replacement. Should either of the in-cell handlers fail in service, mechanisms will be in place to facilitate manual (remote) recovery of the handler into the crane maintenance/decontamination area, for maintenance or repair.
Transfer of the in-cell handler from the transfer cell into the common crane maintenance/decontamination area will require the vertical shield door which separates the transfer cell from the common crane maintenance/decontamination area to be opened. This shield door is driven by drive mechanisms mounted on the top of the vertical drive lead screws. The drive mechanism is external to the cell complex and can be maintained from the cell roof. The drive couplings and connecting equipment is mounted on the crane maintenance/decontamination area side of the shield door, thereby permitting maintenance of the drive equipment with minimal risk of radiological exposure to the maintenance staff.

The shielded cell complex will operate at a slight negative pressure. This ‘depression’ within the cells has the effect of ensuring that any air leakage is always into the cells rather than the reverse. The cell ventilation system will be served by a dedicated extract system which will be equipped with High Efficiency Particulate Air (HEPA) filters prior to exhausting to atmosphere via the processing building exhaust stack.
Fuel transfers into the cell, from the transport casks, or out of the cell into storage casks or shielded transfer flasks are implemented through engineered gamma gates. These gamma gates serve as shielded valves and minimise the potential for the spread of contamination and operator exposure to unacceptable levels of radiation. The dedicated cell extract system will supplement the mechanical engineering of these penetrations. Any transitional aperture which is created will be engineered such that air movement will be into the cell, and at a velocity that will prevent any back diffusion of particulate which may be present within the cell environment.

An operating gallery around the external face of the cell will give operator access to the key faces of the shielded cell. Strategically positioned shielded viewing windows and control consoles will allow operator control of all of the operations within the cell (Refer Figs. 1.2 and 1.3). In cell, (through wall) lighting will be provided to supplement the viewing windows and to generate a well-lit working area to allow the operators a clear view of in-cell activities.

The current philosophy for used fuel transfer is initially a wet transfer operation. This wet transfer allows the used fuel currently stored within wet bays to be transferred into either modules, for wet loading into storage casks, or into baskets which are drained and dried and then dry transferred into vaults.

These initial wet transfer operations are well suited to the wet storage of the used fuel at reactor sites. The movement of fuel from reactor sites to the centralized extended storage facility is essentially a dry transfer process. It is recognised that following transportation cask receipt, the fuel could be re-immersed into wet bay buffer storage, before transfer to the appropriate fuel storage container is effected. However, this study builds on the gains made in drying the fuel for off-site transportation, and therefore concentrates on the dry processing operations (through the use of shielded cells) to convert the fuel into the storage format required for the alternative under consideration.

3.2.4.1 Construction Materials and Description

<u>Cell structure</u>

The shielded cell will be a reinforced concrete structure. All through wall penetrations will be positioned and engineered to minimise the risk of generating shielding weaknesses in the structure. Through wall penetrations will be positioned to not compromise the structural ligaments of the cell.

<u>Ancillary structure</u>

The internal cell surfaces will be coated with a finish to provide a covering that is decontaminable and suitable for remote viewing (i.e. does not generate glare from the in-cell lights)

The viewing windows will be radiation tolerant ‘lead’ glass. The windows will be constructed using a number of stepped glass blocks, these blocks are mounted in engineered frames which eliminate any shielding weaknesses around the periphery of the window.

An operating gallery around each of the operating faces will supplement the shielded cell.

3.3 STORAGE BUILDINGS

The storage aspect of the Casks and Vaults in Storage Buildings alternative, requires the long term storage of used fuel in purpose built buildings housing either module storage casks, or vaults for the storage of fuel baskets (Refer Fig. 1.5). The storage buildings are provided to protect the casks and vaults and to facilitate all weather operation. The buildings are not required to provide containment of radionuclide emissions, as this is a function of the seal welded casks and the sealed baskets and vaults.

3.3.1 Fuel Retrievability

If the storage systems for Casks or baskets do not perform according to the specification, it will be possible to easily retrieve the used fuel from storage, to repair the storage system or transfer the used nuclear fuel to a new storage facility.

The CES facility will be designed to allow safe retrieval of used nuclear fuel from the storage buildings at any point during the service life of the facility. The used fuel storage containers shall be stored so that any individual container can be easily retrieved at any time during the service life of the storage facility.

The CVSB storage alternative does not utilise the stacking of casks within the storage building, therefore retrieval of a specific cask requires removal of the casks within the same row as the designated cask to facilitate access for the cask transporter. A maximum of 9 casks would need to be removed to gain access to the last cask in a row. To retrieve a used fuel basket from a specific vault liner would require removal of the closing seal weld and removal of the cover plate. The shield plug can then be removed, allowing access to the fuel baskets within.

3.3.2 Construction Materials

Walls

External. The processing building will have pre-cast concrete block walls 0.2m thick, from the ground level to a height of 4.2m. Exterior metal cladding will form the remainder of the wall structure. The metal cladding will incorporate vertical louvres at the upper wall elevations. These louvres form the air inlets for the passive cooling system of the casks within the storage building. The louvres will be designed to prevent the ingress of rain snow or sand. Screens will be incorporated into the louvres to reduce the potential for small animals or birds entering the storage facility.
Internal. Concrete block in high traffic areas.

Roof.

The roof will be pre-finished steel material.
The roof will have provisions for drainage of rainwater and melted snow. Exhaust louvres will be incorporated into the roof. These louvres will be designed to allow the flow of 'exhaust air' and will also minimise the retention and build up of water, snow or ice.
The building will be grounded to protect against lightening.

Floor

The floors will be reinforced concrete slabs designed to accommodate heavy wheeled traffic. They will be constructed for minimal maintenance, to retain surface alignment and provide a hard smooth and durable surface. Floors will be graded to provide drainage to floor drains.

3.3.3 Cask Storage Buildings

The design capacity of the storage building complex is assumed to be 3,600,000 fuel bundles. For design purposes, the inventory is to be split approximately between 92% storage cask and 8% vaults or 3,312,000 fuel bundles in storage casks and 288,000 fuel bundles in vaults. Assuming 384 fuel bundles per storage cask, this equates to storage provision for approximately 8,625 storage casks. In storage building arrays of 520 storage casks, this population occupies approximately 17 cask storage buildings. The storage cask buildings are linked to the processing building by a network of transfer corridors. Each transfer corridor is sized to allow two-way traffic for the storage cask transporters, passing to and from the processing building, to the appropriate storage building (Refer Fig.1.6).

3.3.4 Vault Storage Buildings

The 288,000 fuel bundle inventory requires storage provision of 24 vaults, assuming each fuel basket contains 60 fuel bundles, and each vault contains 20 storage tubes, each capable of housing 10 fuel baskets. The 24-vault inventory is divided into four smaller arrays, each comprising six vaults, housed in four storage buildings. The storage buildings are linked at the head by a transverse corridor. The 'head end' transfer corridor links to the processing building. The transfer corridor is sized to allow transfer of storage complex maintenance equipment, and allow two way traffic for the powered bogies, passing to and from the processing building, to the appropriate storage building (Refer Fig. 1.7).

Each vault storage building contains an array of longitudinally positioned vaults serviced by an electrically powered overhead gantry crane, with main and auxiliary hoist capability. The gantry crane spans both the vault, and part of the adjacent operations corridor, which runs parallel to the long axis of each vault array. Once a storage building has reached capacity, the gantry crane is jacked through a door aperture at the storage building 'tail end', and winched across to the 'tail end' of the next storage building, where it is returned to service within the building.

The building structure framework for both the storage cask and the vault storage buildings will be steel framed buildings with cladding sheets fixed to the primary steelwork. The roofs will be pitched and will be designed and constructed in line with Canadian building codes and regulations for warehouse type structures. The store floors will be finished concrete, and will be designed to cater for all predicted static and dynamic loads.

3.4 SEQUENCE OF OPERATIONS

In overview, the initial receipt, processing and fuel container transfer operations are outlined below.

3.4.1 Storage Cask Operations

1. Receive and verify the transportation cask transportation package, (transportation package includes the storage cask, the impact limiters and tie-down equipment)
2. Position transportation package below main crane (120 tonnes)
3. Release transportation tie-downs
4. Raise transportation package from transporter and position into rotate frame
5. Secure transportation package in rotate frame
6. Rotate transportation package through 90°, to return the storage cask to the correct orientation
7. Release the wire rope assemblies which secure the impact limiters
8. Remove the top impact limiter
9. Lift the storage cask out of the bottom impact limiter
10. Park and check the storage cask
11. Transfer the storage cask to the store using the cask transporter
12. Return the impact limiters and tie-down equipment to the donor site.

3.4.2 Module Operations

1. Receive and verify the Irradiated Fuel Transportation Cask (IFTC)
2. Transfer IFTC onto the module cell bogie
3. Prepare IFTC for process operations
4. Transfer IFTC below shielded cell
5. Transfer modules from IFTC into shielded cell
6. Return empty IFTC to transportation vehicle and return to fuel owner
7. Repeat receipt and transfer operations for 2nd transportation cask
8. Position module storage cask, on module cell bogie below shielded cell
9. Load modules from shielded cell into module storage cask
10. Transfer lidded module storage cask to cask processing area
11. Seal, vacuum dry, inert and test module storage cask
12. Transfer module storage cask to pre determined storage position, using the cask transporter.

3.4.3 Basket Operations

1. Receive and verify basket transportation cask
2. Transfer basket transportation cask onto basket cell bogie
3. Prepare basket transportation cask for process operations
4. Transfer basket transportation cask below shielded cell
5. Transfer baskets from basket transportation cask into shielded cell
6. Return empty basket transportation cask to transportation vehicle and return to fuel owner
7. Repeat receipt and transfer operations for subsequent basket transportation casks
8. Position store transfer flask onto shielded cell roof gamma gate
9. Raise basket into store transfer flask, through roof and transfer flask gamma gates
10. Transfer loaded basket transfer flask to store
11. Raise transfer flask from bogie and locate onto vault roof gamma gate
12. Lower basket into vault storage liner
13. Repeat until liner is full (10 baskets)
14. Install vault liner shield plug
15. Remove roof gamma gate
16. Repeat operations for next vault storage liner

3.5 ACCESS

Access into the storage building complex is via the processing area. Individual storage buildings can be entered using the inter-connecting link corridors.

Storage casks will be ‘collected’ from the cask processing area and transferred to the storage building using the dedicated cask transporter.
The basket transfer flask, is a self-shielded assembly, baskets will be transferred from the processing area to the storage buildings in the basket transfer flask, which will be mounted on the transfer bogie. The transfer bogie and any accompanying operational personnel will have a direct access route from the processing area to the pre-determined storage building.

3.6 COOLING AND VENTILATION

3.6.1 Processing Building

Certain areas within the Processing Building are provided with active ventilation systems consisting of exhaust fans, radioactive filter assemblies and a discharge stack. The main areas served are the shielded cell complex and the ventilation system also provides localised exhaust for the welding bays in the workshop and active ventilation hook-up to storage casks for processing operations including vacuum drying.

The ventilation stack will be continually monitored for any airborne particulate contamination. High Efficiency Particulate Air (HEPA) filters will be used in the active ventilation system to remove airborne particulate in the air discharge. Pre-filters are used as needed to protect the HEPA filters from welding fumes.

3.6.2 Storage Buildings

The Cask and the Vault storage buildings use passive ventilation to provide cooling for the used fuel storage structures. This is achieved by allowing cooling air into the storage building through

low level wall louvers and out through high level roof louvers. This enables the decay heat to dissipate from used fuel in storage, to the atmosphere to maintain the storage area below an average ambient temperature of 38^0C in the proximity of casks. The louvers are designed to prevent the ingress of rain, snow and sand. Screens reduce the likelihood of small animals or birds entering the building through the ventilation system. The roof louvers are also designed to minimise the retention and build-up of water, snow or ice.
The concrete structure of the storage vaults is penetrated by labyrinthine low level inlet and high level outlet air ducts. These penetrations allow flows of cooling air to the storage tubes within, by natural convection.

3.7 SHIELDING

3.7.1 Storage Casks

Storage casks are constructed as double steel shell containers, each carbon steel shell is 13mm thick. The space between the inner and outer shell is filled with reinforced high-density concrete, which is approximately 520mm thick. The reinforced high-density concrete provides radiation shielding while maintaining the capability for used fuel decay heat dissipation. The high-density reinforced concrete has a density range of 3.5 to 3.7 Mg/m^3 and a full strength of 40 Mpa.

3.7.2 Storage Vaults

The monolithic concrete structure and the closure plug units in each storage tube provide the necessary radiation shielding of the storage vaults. The vault construction provides a minimum shielding thickness of 965mm of concrete, which ensures that the dose rate from the vaults when fully loaded is less than 25μSv/h.

3.8 CONTAINMENT

3.8.1 Storage Casks

Storage casks provide a single containment barrier for the used fuel. The containment is complete when the storage cask closure welds are made, these welds are the flange circumferential weld and both the drain and vent plug welds. The storage cask flange welds are full penetration welds, which are x-ray examined to confirm their integrity. The drain and vent plug have steel shielding plugs installed, which are then welded and the welds dye penetrant inspected. The assembly is inert gas filled and is then leak tested to prove the integrity of the assembly. Each storage cask, which passes this testing regime, will be labelled and will be marked with secure identification and IAEA verification seals.

3.8.2 Storage Vaults

Fuel baskets, which are housed inside steel liners within concrete vaults, provide two levels of containment for the used fuel. The primary containment for the fuel is the fuel basket. The basket is seal welded at the reactor site and is not compromised by any of the subsequent operations. The secondary containment, the vault liner, is only considered a containment boundary after successful completion of the top seal plate weld. The integrity of the secondary containment can be verified, since valved access lines are incorporated which penetrate the containment boundary. The air interspace between the containments can thus be monitored for fission products, whose presence would indicate a breach of the primary containment boundary.

3.9 WATER CONTROL

The storage buildings are engineered to ensure that the building fabric is generally weather tight. The only exceptions to this are the cooling penetrations. The storage buildings are cooled by the flow of ambient air through inlet louvers. These inlet louvers are arranged at low level, with the exhaust louvers at high level. Both sets of these louvers are arranged, and engineered such that the potential for the ingress of rain or snow is minimised. The floor in the storage buildings falls to a floor drain to collect any liquid arisings. This will drain to a collection sump where it can be sampled and disposed of accordingly. Space heaters may be provided to increase the ambient temperature in the store during cold weather and as the heat generated by the fuel bundles decreases in time to reduce condensation within the buildings.

The access routes from the Processing Building to the Storage Complex and between Storage Buildings are covered to provide weather protection to the casks and transporters and ensure that the casks remain dry.

4 Surface Modular Vault (SMV)

4.1 GENERAL DESCRIPTION

The surface modular vault concept comprises the storage of fuel bundles confined in either baskets or module canisters and placed into an array of tubes in a series of engineered vaults within the storage buildings (Refer Fig.2.1 & 2.5 for site layout and key overall dimensions). The fuel baskets or module canisters are placed in a series of vertical storage tubes within the vault, which ensures that they are correctly aligned and remain in place. The upper end of each storage tube is closed off with a closure shield plug unit. The fuel within the storage tubes is cooled by natural ventilation flow around and through the storage tube array. The modular vaults within a storage building are serviced by a common canister handling machine (CHM), which provides coverage to each array of storage tubes across a shielded charge hall floor. The CHM can engage with each tube in the array, remove the closure plug, and lower fuel baskets and module canisters into the storage tube. The storage buildings are linked together by an access corridor below the charge face level for transporting fuel baskets and module canisters to the buildings. Local to each storage tube array are a series of receipt ports, accessible to the CHM, which link with the access corridor below. Individual module canisters are hoisted into the charge machine, through the appropriate receipt port. The fuel is transferred from reactor sites to the CES either via the Irradiated Fuel Transportation Cask (IFTC) or the basket transportation cask. No storage casks (DSCs) are received at this facility.

The maximum annual receipt rate is 119,820 used fuel bundles per year from the existing facilities. This fuel will be in module format. Used fuel that is currently in dry storage containers at a reactor site, will be transferred out of the dry storage containers and transferred into the IFTC at the host site, in preparation for transfer to the CES facility.
The used fuel will be transferred to the SMV facility using the Irradiated Fuel Transportation Casks (IFTC), with each IFTC contains 2 used fuel modules.

The required throughput rate dictates the production of approximately 1.32 module canisters per day. To achieve this throughput, the contents of 3 IFTCs will need to be received and processed per day. (Refer Fig 2.10)
To facilitate the receipt, transfer and handling activities associated with the processing of these casks it will be necessary to work two shifts for the duration of these operations.
With two shift operations there is time available for IFTC decontamination activities. The processing building layout has a space allowance adjacent to the shielded cells to allow occasional decontamination activities to be taken 'off-line' and undertaken in a temporary enclosure, to ensure that any disruption to the production of module canisters for storage is minimised.

Fuel that arrives in baskets is transferred to the facility in the basket transportation cask, this cask is designed to accommodate 3 baskets. This cask is unloaded into the shielded cell and the baskets are loaded individually into a transfer flask at the shielded cell, the transfer flask then delivers the basket to the dedicated vault in the relevant SMV storage building (Refer Fig.2.11).
The maximum annual receipt rate for fuel baskets is nominally 500 baskets per year, (500 baskets x 60 bundles per basket = 30,000 bundles per year). The receipt of 1 basket transportation cask per day can satisfy this requirement.

Key features of the SMV extended storage concept include:

- The processing building accepts fuel modules or fuel in basket format
- Fuel modules are sealed into module canisters before placing in the store.
- After fuel receipt, all subsequent fuel movements are under cover, (minimising effects of adverse weather and maximising fuel container life by reducing environmental impact on 'housing'.
- Fuel is stored within storage tubes within the SMV vault modules
- Additional capacity is provided by construction of the SMV storage buildings on a rolling program,
- Module canisters are placed in storage vaults using a canister handling machine (Refer Fig. 2.10). Fuel baskets are placed in storage vaults using transfer flask and a dedicated crane (Refer Fig. 2.11)
- Cooling is achieved by natural convection across the array of storage tubes from vents in the building structure.

4.2 PROCESSING BUILDING

The processing building (Refer Fig. 2.4) will be an industrial type building structure, designed to provide a safe operational area for the handling of used fuel storage and transfer casks.
Refer to 3.2.1 for (CVST processing building) construction materials and description.

4.2.1 Receipt Area:

As per CVSB alternative, refer 3.2.2, but the SMV receipt area crane is sized at 50 tonnes, this accommodates the heaviest payload received at this facility.

4.2.2 Shielded Cell:

Refer to 3.2.4.1 for Construction Materials and description

The shielded cell comprises three cells that are close coupled, but are physically isolated. An operating gallery around the external face of the cell will give operator access to the key faces of the shielded cell. Strategically positioned shielded viewing windows and control consoles will allow operator control of all of the operations within the cell (Refer Figs. 2.2 and 2.3).

The three elements which make up the shielded cell are,

- Module transfer cell
- Basket transfer cell
- Crane maintenance/decontamination area (common to both handlers)

Segregation of the module and basket transfer cells generates the following beneficial effects:

a) Minimises the potential for cross contamination of the fuel containers
b) Cells can operate in parallel, thereby maximising throughput
c) Independence allows process operations to continue during breakdown or maintenance activities in one cell.

Both of the transfer cells provide a fully shielded remotely operated facility, designed for the handling of the relevant fuel package (modules or baskets). Each transfer cell is configured for the relevant fuel package, and a dedicated overhead in-cell crane serves each cell. Fuel transfers into the cell, from the transportation casks, or out of the cell into shielded transfer flasks are implemented through engineered gamma gates. These gamma gates serve as shielded valves and minimise the potential for the spread of contamination and operator exposure to unacceptable levels of radiation.

The principal difference between the SMV alternative and the CVSB is that for the SMV, modules are loaded into the module canisters within the module transfer cell. The loaded module canisters are then transferred using the module cell bogie, from the main cell into the welding area.
The welding area is a self shielded area, constructed as a part of the main cell but separated by a sliding shield door. The welding area is arranged with all of the equipment necessary for remotely seal welding the module canister lid to the canister body. The area is served by a dedicated ventilation extract, to draw off welding fume directly. See section 4.4.1 for the sequence of operations for the creation of a module canister.
The welding area can be accessed via a personnel shielded access door, should maintenance of the welding equipment become necessary. It would be prudent to remove any fuel from the shielded cells prior to undertaking maintenance activities.

4.3 STORAGE COMPLEX

4.3.1 Fuel Retrievability

If the SMV storage system does not perform according to the specification, it will be possible to easily retrieve the used fuel from storage so as to repair the storage system or transfer the used nuclear fuel to a new storage facility.
The CES facility will be designed to allow safe retrieval of used nuclear fuel from the storage vault at any point during the service life of the facility. The module canisters shall be stored so that any individual canister can be easily retrieved at any time during the service life of the storage facility. Retrieval of module canisters would necessitate the removal of the storage tube cover, followed by unbolting the storage tube lid, then removing the tube shield plug. The

charge machine can then access the module canisters, or in the case of the fuel basket vault, the crane can access the fuel baskets.

4.3.2 Construction Materials

General
An integral foundation slab supports each 10-vault building. The concrete labyrinth arrangement of the inlet structure provides radiological shielding for the stored fuel. The pre-cast concrete collimators set into pockets in the structural walls of the vault improve the distribution of cooling air across the array of storage positions. The cooling air leaves the vault through a second set of concrete collimators and is exhausted to atmosphere through a concrete outlet duct.
A steel canopy mesh provided on the top of the outlet duct, prevents the ingress of rain, snow, birds etc. The ambient cooling air does not come into contact with the fuel bundles, baskets, modules or module canisters, which are seated in the storage tubes, ensuring the internal walls of the vault remain radiologically clean.

Walls
The internal and external walls of the vaults are 1.0m thick reinforced concrete. These walls provide shielding and accommodate the thermally imposed loads of the vault total heat output. A 1.0m thick reinforced concrete Charge Face Structure forms the roof of the vaults. Steel liners through the Charge Face provide location and access into the Storage Tubes. The Charge Face Cover Plates fitted over each Storage Tube provide a smooth floor for operator activities and CHM movement.

Roof
Each row of vaults is covered by a continuous roof structure which provides a weather tight and illuminated enclosure for year round fuel loading, unloading and maintenance operations. This provides protection for the Canister Handling Machine and Basket Handling Crane and gives considerable operating flexibility during adverse weather conditions and hours of darkness. The enclosure constructed from a structural steel framework and cladding is designed to remain weather tight for design base environmental conditions.

4.3.3 Modular Vaults

A Surface Modular Vault (SMV) facility provides a controlled environment for the safe storage and retrieval of spent nuclear fuel. High integrity vertical storage tubes provide a sealed secondary containment boundary for fuel module canisters and baskets. The individual storage positions allow access to small quantities of irradiated fuel for monitoring, inspection or retrieval (Refer Fig.2.5).
The storage vault complex is located around a transfer tunnel. This transfer tunnel comprises the feed/access corridor, which runs through the store complex. The storage vault complex is made up of 6 storage buildings. Five storage buildings house the module canisters, with the 6th storage building split between module canister storage tubes, and fuel basket storage tubes. There are a total of 8800 canisters housed within the storage vault complex, each module canister contains 384 fuel bundles. Each storage building comprises 20 individual vaults with 40 storage tubes in each vault and each storage tube accepts 2 module canisters; i.e. 1600 canisters per building. Additionally there are 600 basket storage tubes housed within the storage vault complex, each holding 10 fuel baskets (Refer Fig.2.6 and 2.7).
The roof enclosure above and between the vaults allows year-round transfer, storage, maintenance and monitoring operations, ensuring severe weather does not interrupt the availability of the system.

The modular design of the SMV storage facility provides future extension and increased capacity options by extending the transfer tunnel to allow additional vaults to be built and serviced by the existing equipment and procedures.
At any time during the storage period or for facility repeat operations, fuel canisters or baskets can be removed from the storage tubes for inspection or transfer to newer vaults by simply reversing the loading procedure.
The design of the SMV facility is arranged to contain any potential contamination during operation and to facilitate its removal at the decommissioning stage ensuring existing vaults can be refurbished with minimal generation of radioactive waste.

4.3.4 Canister Handling Machine

The Canister Handling Machine (CHM) is a shielded cask assembly mounted on a bridge and trolley that runs on rails above the storage vaults. The CHM lifts loaded module canisters from the transfer flask and places them in the storage tubes inside the storage vaults (Refer Fig. 2.8). An electrically driven wire rope hoist and drum raise and lower a power operated canister grapple. The canister grapple jaws engage with the internal lifting ring on the module canisters. Reeling drums within the hoist unit provide the services and control signals between the grapple and the control system.
The CHM is fitted with double gamma gates, a retractable shield skirt and floating shielding blocks to its base. The gamma gates are electrically operated and retract via twin screw drives. The lower gamma gate is the charge face gamma gate and is detachable from the CHM. It is normally positioned above the chosen storage tube for loading/unloading operations (Refer Fig.2.9).
The floating shielding blocks on the base of the charge face gamma gate accommodate any unevenness in the concrete floor, eliminating shine paths during fuel transfer operations. The charge face gamma gate allows removal of the storage tube shield plug to prepare the module canister storage tube for loading or unloading with module canisters without compromising the overall shielding provided by the charge face structure. The CHM moves the charge face gamma gate to the appropriate storage tube by attaching it to screw jacks on the base of the machine. Once the charge face gamma gate is de-coupled from the machine, the CHM removes the storage tube shield plug and stows it in the shield plug stowage position.
The upper gamma gate is the CHM gamma gate and is permanently attached to the base of the shielded body of the CHM. Incorporated into the gamma gate is a retractable shield skirt. The CHM gamma gate ensures the base of the machine can be closed off when carrying module canisters or shield plugs. The retractable shield skirt is lowered during fuel and shield plug transfer operations to cover the gap beneath the machine required for running clearance during CHM travel.
The two CHM bridge girders span the width of the charge face structure on rails that run the full length of a row of storage vaults. The CHM is designed to allow the machine to be transported between the two storage buildings without dismantling. Temporary rails and a carriage fitted above the Transfer Tunnel roof provide a means of jacking the CHM cask, trolley and girders off one set of vault rails, transporting the assembly between the two buildings and placing it onto the next set of vault rails.

4.4 SEQUENCE OF OPERATIONS

In overview, the initial receipt, process and fuel container transfer operations are outlined below.

4.4.1 Irradiated Fuel Transportation Cask (IFTC)

1. Receive and verify IFTC
2. Transfer IFTC onto module cell bogie
3. Prepare IFTC for process operations
4. Transfer IFTC below shielded cell, on module cell bogie
5. Transfer modules from IFTC into shielded cell
6. Return empty IFTC onto transportation vehicle for return to fuel owner
7. Repeat receipt and transfer operations for 2^{nd} IFTC
8. Transfer empty module canister into shielded cell
9. Initiate hot air drying of modules, at buffer position in shielded cell
10. Load ‘dried’ modules (4 off) into module canister body
11. Lid module canister
12. Transfer lidded module canister into welding cell
13. Remotely weld lid to body
14. Return welded module canister into main cell
15. Transfer module canister into module canister transfer flask, on module cell bogie
16. Transfer module canister transfer flask to the load/unload port below surface modular vault charge machine, on module cell bogie.

4.4.2 Module Canister Loading

Before a Module Canister can be loaded into a storage tube from the transfer flask, on the module cell bogie, the storage tube needs to be prepared (Refer Fig.2.10). This involves manually removing the charge face cover plate and storage tube lid at the selected storage position. The storage tube shield plug is handled by the CHM and requires a temporary lifting ring attaching which replicate the module canister lifting ring to allow the CHM grapple to engage. Before the shield plug is removed the charge face gamma gate is positioned over the storage tube by the CHM. This gamma gate provides shielding from the contents of the storage tube while the shield plug is absent.

4.4.2.1 Prepare a Module Canister Storage Tube for Loading

17. Remove storage tube cover plate using mobile crane
18. Remove storage tube lid using mobile crane
19. Fit temporary lifting ring to storage tube shield plug
20. Position CHM over storage tube
21. Lower charge face gamma gate onto charge face
22. Lower CHM retractable shield skirt onto charge face shield gate
23. Disconnect charge face gamma gate from CHM
24. Open CHM and charge face gamma gates
25. Remove storage tube shield plug using CHM grapple
26. Close CHM and charge face gamma gates
27. Raise CHM retractable shield skirt
28. Move CHM to Shield Plug Stowage Position
29. Lower CHM retractable shield skirt onto stowage position
30. Open CHM gamma gate
31. Place storage tube shield plug in stowage position
32. Close CHM gamma gate and raise CHM retractable shield skirt

With the storage tube ready to accept a module canister the CHM visits the load/unload port positioned above the transfer tunnel. The cover plate over the port is manually removed before the CHM is positioned. The transfer flask will have been previously loaded with a sealed module canister at the processing building. The module cell bogie jacks the transfer flask up to align with a recess in the roof of the tunnel below the load/unload port to ensure a fully shielded route from the transfer flask into the CHM.

4.4.2.2 Load a Module Canister into a Storage Tube

1. Remove load/unload port cover plate using mobile crane
2. Position CHM over load/unload port
3. Lower CHM retractable shield skirt
4. Position module cell bogie, containing a sealed module canister below load/unload port
5. Open CHM gamma gate
6. Open transfer flask gamma gate
7. Raise module canister into CHM using CHM grapple
8. Close CHM and transfer flask gamma gates
9. Move CHM to prepared storage tube
10. Lower CHM retractable shield skirt onto charge face gamma gate
11. Open CHM and charge face gamma gates
12. Place module canister in storage tube
13. Close CHM and charge face gamma gates
14. Raise CHM retractable shield skirt
15. Repeat Steps 2 to 14 for 2^{nd} module canister

With the storage position fully loaded with 2 module canisters the storage tube can be closed and sealed. The CHM replaces the shield plug before the charge face gamma gate is removed from the storage position.

4.4.2.3 Close and Seal a Loaded Module Canister Storage Tube

1. Move CHM to shield plug stowage position
2. Lower CHM retractable shield skirt onto stowage position
3. Open CHM gamma gate
4. Raise storage tube shield plug using CHM grapple
5. Close CHM gamma gate and raise retractable shield skirt
6. Move CHM to loaded storage tube
7. Lower CHM retractable shield skirt onto charge face gamma gate
8. Open CHM and charge face gamma gates
9. Place storage tube shield plug in storage tube
10. Close CHM and charge face gamma gates
11. Connect charge face gamma gate to CHM
12. Raise CHM retractable shield skirt and charge face gamma gate
13. Move CHM away from the storage tube
14. Fit seal to storage tube lid
15. Place storage tube lid on storage tube. Torque tighten the storage tube bolts
16. Replace storage tube cover plate

4.4.3 Basket Loading

The following sequences of operation cover the receipt, transfer and emplacement into store of sealed fuel baskets.

4.4.3.1 Basket Receipt

1. Receive and verify basket transportation cask
2. Transfer basket transportation cask onto basket cell bogie
3. Prepare basket transportation cask for process operations
4. Transfer basket transportation cask below shielded cell
5. Transfer baskets from basket transportation cask into shielded cell
6. Return empty basket transportation cask to transportation vehicle and return to fuel owner
7. Repeat receipt and transfer operations for subsequent basket transportation casks
8. Position basket transfer flask onto shielded cell roof gamma gate
9. Raise basket into basket transfer flask, through roof and transfer flask gamma gates
10. Transfer basket transfer flask bogie from park position onto rails, and couple to module canister transfer bogie (module canister transfer bogie is powered, basket transfer flask bogie is not)
11. Transfer basket transfer flask from cell roof onto basket cell bogie
12. Transfer both bogies from processing building to present basket transfer flask bogie below basket transfer flask hatch cover plate at store.

Before a fuel basket can be loaded into a storage tube from the basket transfer flask, the storage tube needs to be prepared (Refer Fig.2.11). This involves manually removing the charge face cover plate and storage tube lid from the selected storage position. The storage tube shield plug is handled in a shielded housing and requires a temporary lifting ring attaching which replicates the basket lifting feature. Before the shield plug is removed an independent charge face gamma gate is positioned over the storage tube. This gamma gate provides shielding from the contents of the storage tube while the shield plug is absent.

4.4.3.2 Prepare a Basket Storage Tube for Loading

1. Remove storage tube cover plate using mobile crane
2. Remove storage tube lid using mobile crane
3. Fit temporary lifting feature to storage tube shield plug
4. Place independent charge face gamma gate over storage tube position
5. Place shielded housing onto charge face gamma gate
6. Open charge face gamma gates
7. Transfer shield plug to shielded housing
8. Close charge face gamma gates
9. Lift shielded housing away and place on charge face

With the storage tube ready to accept a basket, the basket-handling crane visits the basket transfer flask hatch positioned above the transfer tunnel. The cover plate over the hatch is manually removed before the crane is positioned. The basket cell bogie will have been previously loaded with a basket transfer flask containing a fuel basket at the processing facility. The basket-handling crane lifts the loaded transfer flask into the charge hall above the transfer tunnel and storage vault.

4.4.3.3 Load a Basket in a Storage Tube

1. Remove basket transfer flask hatch cover plate using mobile crane
2. Position basket cell bogie containing a transfer flask with loaded basket below basket transfer flask hatch
3. Raise transfer flask using basket handling crane
4. Move transfer flask to storage position. Place onto charge face gamma gate
5. Open transfer flask and charge face gamma gates
6. Place loaded basket into storage tube.
7. Close transfer flask and charge face gamma gates
8. Return transfer flask to transfer trolley
9. Repeat steps 2 to 8 for nine further baskets

With the storage position fully loaded with 10 fuel baskets the storage tube can be closed and sealed. The shielded housing replaces the shield plug before the charge face gamma gate is removed from the storage position.

4.4.3.4 Close and Seal a Loaded Basket Storage Tube

1. Move shielded housing containing shield plug to storage position. Place on charge face gamma gate
2. Open charge face gamma gates
3. Replace shield plug in storage tube
4. Close charge face gamma gates
5. Move shielded housing away from storage tube
6. Move charge face gamma gate away from storage tube
7. Fit seal to storage tube lid
8. Place storage tube lid on storage tube. Torque tighten the storage tube bolts
9. Replace storage tube cover plate

4.5 ACCESS

Access into the storage vault complex is via the processing area. Individual storage vaults can only be entered using the dedicated personnel access points.

Module canisters and fuel baskets will be transferred from the processing area to the storage buildings using transfer bogies. The transfer bogie runs on rails, which directly link the processing area to the storage vault complex. The transfer bogie will transfer the fuel (module canisters or fuel baskets) from the shielded cell within the processing area to the load/unload port in the storage vault area.
Man access onto the storage vault ‘charge face’ under normal operational conditions is considered to be standard operational practice. Store operating personnel will have open access to this area. Man access into the transfer tunnel is readily available. Maintenance and recovery personnel may need infrequent access to this area.

4.6 COOLING AND VENTILATION

4.6.1 Processing Building

As per CVSB alternative, refer 3.6.1

4.6.2 Storage Buildings

Cooling of the fuel is by a totally passive system of heat removal. The fuel discharges its decay heat to the Storage Tube wall by thermal radiation. Cooling air enters each vault through an inlet duct and the natural buoyancy of warm air as it rises out of the outlet duct drives the cooling flow past the Storage Tube arrays removing the residual heat. This is a self-regulating system in that the hotter the fuel, the more airflow is driven through the vault, maintaining acceptable fuel and concrete temperatures.

4.6.2.1 Heat Transfer Path

Fuel decay heat removal is via a once through airflow, through the vault structure as it passes around the storage tube arrays. The vault airflow results from a buoyancy induced thermo-syphon. The buoyancy head is created by the difference between the inlet and outlet air densities together with the height of the outlet duct. The pressure drops that result from the rate of airflow and the flow resistances created by the vault inlet duct arrangement, the storage tube bank array and the outlet duct arrangement balance this buoyancy head.

4.6.2.2 Heat Transfer for Module Canisters

The irradiated fuel bundle housed in a horizontal module tube within a fuel module transfers part of it heat load to the inside of the module tube by conduction and natural convection in the atmosphere in the module canister. The remaining heat is transferred by thermal radiation to the module tube. Metal conductivity transfers the heat through the module tube.
This conduction, convection and radiation process is repeated to transfer the heat from the module to the module canister and then to the storage tube. The heat is finally convected to the vault air and exhausted to atmosphere.

4.6.2.3 Heat Transfer for Fuel Baskets

The irradiated fuel bundle is stored vertically in positioning plates within sealed baskets. Part of the fuels heat load is transferred to the inside of the basket by conduction and natural convection in the atmosphere in the fuel basket. The positioning plates within the basket aid the heat transfer as they act as extended surfaces for the conduction process. The remaining heat is transferred by thermal radiation to the basket structure. Metal conductivity transfers the heat through the basket wall. This conduction, convection and radiation process is repeated to transfer the heat from basket to the storage tube. The heat is finally convected to the vault air and exhausted to atmosphere.

A steel canopy and mesh provided on the top of the outlet duct, prevents the ingress of rain, snow, and birds. The ambient cooling air does not come into contact with the fuel bundles, baskets or module canisters, which are sealed in the storage tubes, ensuring the internal walls of the vault remain radiologically clean.

4.7 CONTAINMENT

A design feature of the SMV storage concept is the double containment of the stored irradiated fuel. The used fuel is packaged in sealed module canisters or baskets. These components provide the primary containment boundary for the fuel. The sealed storage tube provides the secondary containment boundary. The enclosed atmosphere within the sealed storage tubes provides an environment that can be monitored for fission products, whose presence would indicate a breach of the primary containment boundary.

Each row of vaults is covered by a continuous roof structure which provides a weather tight and illuminated enclosure for year round fuel loading, unloading and maintenance operations. This provides protection for the canister handling machine and basket handling crane and gives considerable operating flexibility during adverse weather conditions and hours of darkness. The enclosure constructed from a structural steel framework and cladding is designed to remain weather tight for design base environmental conditions.
A storage tube lid with ring seal is bolted to the top of the tube body sealing the storage tube. A sealed port in the lid provides a means to monitor the internal atmosphere of the storage tube during routine maintenance and inspection operations.
The storage tube assembly forms the secondary containment boundary for both the module canisters and the fuel baskets.

The module canister storage tubes have in internal envelope of 1.83m diameter by 6.25m. The basket storage tubes have an internal envelope of 1.1m diameter by 6.575m.

4.8 SHIELDING

The concrete walls and charge face above the vaults and the steel structure of the Canister Handling Machine (CHM) provide the necessary radiation shielding during transfer and storage operations to maintain public and worker dose limits below those specified by the regulatory bodies.

An integral foundation slab supports each 10-vault building. Cooling air enters each vault through a louvered opening that is provided with a mesh to prevent the ingress of birds, large debris, and vermin. The concrete and labyrinth arrangement of the inlet structure provides radiological shielding for the stored fuel.
The internal and external walls of the vaults are 1.0m thick reinforced concrete. These walls provide shielding and accommodate the thermally imposed loads of the vault total heat output.
A 1.0m thick reinforced concrete charge face structure forms the roof of the vaults. Steel liners through the charge face provide location and access into the storage tubes. The charge face cover plates fitted over each storage tube provide a smooth floor for operator activities and CHM movement.
A concrete filled shield plug sits in the top of each storage tube to complete the shielding of the charge face structure. The shield plug is handled by the grapple on the CHM, a lifting ring is bolted to the top of the shield plug to mimic the lifting feature on the module canisters.

4.9 WATER CONTROL

The storage vaults are engineered to ensure that the vault fabric is generally weather tight, the only exceptions to this are the cooling penetrations. The storage vaults are cooled by the flow of ambient air through inlet louvers. These inlet louvers are arranged at low level, with the exhaust discharged through a stack at high level. Both the inlet and the exhaust are arranged, and engineered such that the potential for the ingress of rain or snow is minimised.

The access route from the Processing Building to the Storage Complex is covered to provide weather protection to the transfer flasks and trolleys and ensure that the baskets and module canisters remain dry.

5 Casks and Vaults in Shallow Trenches

5.1 GENERAL DESCRIPTION

The Casks and Vaults in shallow Trenches concept (CVST) comprises the storage of fuel modules confined in self shielded casks, or fuel baskets confined in concrete vaults. The casks and vaults will be housed in a series of parallel, modular chambers with concrete floors, walls and roofs constructed in a shallow trench and mounded over with earth cover. The chambers will be interconnected at both ends with corridors to form a complex accessible by a ramp from ground level. The earth cover will provide weather protection for the concrete chambers and added physical protection from sabotage and aircraft impact. The earth cover will also lessen the visual impact of the storage complex. The earthen cover will be applied over the roof and will be designed to protect the chamber structures against freeze/thaw and wetting and drying cycles, divert surface water, limit water infiltration, resist weathering, erosion and burrowing animals (Refer Fig. 3.1 for site layout and key overall dimensions).

Packages of fuel bundles are transferred from individual reactor sites to a central storage location via one of three potential transfer mechanisms, these are:

- storage cask transportation mode,
- module transportation cask mode
- basket transportation cask mode,

Storage casks arriving at the CES facility are inspected on arrival, then directed to the dedicated storage chamber (Refer fig.3.10).

Fuel bundles arriving in modules are transferred into storage casks in the shielded cell and after cask processing the storage casks are then transferred to the storage chamber (Refer Fig.3.11).

Fuel arriving in baskets is transferred from the transportation cask to a transfer flask at the shielded cell. The transfer flask then delivers the basket to a vault in the relevant storage chamber (refer Fig.3.12).

The maximum annual receipt rate is 117,066 used fuel bundles per year from wet storage facilities, in module format.
The used fuel will be transferred to the CVST facility from the existing wet storage facilities using the Irradiated Fuel Transportation Cask (IFTC), with each IFTC contains 2 used fuel modules. The required throughput rate dictates the production of 1.32 storage casks per day. To achieve this throughput, the contents of 3 IFTCs will need to be received and processed per day.
To facilitate the receipt, transfer and handling activities associated with the processing of these casks it will be necessary to work two shifts for the duration of these operations.

At other times within the duration of the fuel receipt operations a combination of fuel (in module format) from both wet and dry storage, and baskets will be received at the facility.
The fuel receipt quantities during these combinations of, ‘wet and dry’; fuel receipt vary year by year. None of the combined wet and dry fuel receipt years generate higher production rates than the figures quoted above for the receipt of wet fuel only.

With two shift operations there is time available for cask decontamination activities. The processing building layout has a space allowance adjacent to the shielded cells to allow occasional decontamination activities to be taken ‘off-line’ and undertaken in a temporary enclosure, to ensure that any disruption to the production of casks for storage is minimised.

Fuel that arrives in baskets is transferred to the facility in the basket transportation cask, this cask is designed to accommodate 3 baskets. The cask is unloaded into the shielded cell and the baskets are loaded individually into a transfer flask at the shielded cell, the transfer flask then delivers the basket to the dedicated vault in the relevant storage chamber.
The maximum annual receipt rate for fuel baskets is nominally 500 baskets per year, (500 baskets x 60 bundles per basket = 30,000 bundles per year). The receipt of 1 basket transportation cask per day can satisfy this requirement.

Key features of the CVST extended storage concept include:

- The processing building accepts existing casks, fuel modules or fuel in basket format
- Fuel is stored within sealed storage casks or within sealed tubes in concrete vaults
- Additional capacity provided by the construction of storage chambers on a rolling program
- After fuel receipt, all subsequent fuel movements are under cover, (minimising effects of adverse weather and maximising fuel container life by reducing environmental impact on the ‘housing’.
- Cask emplacement in storage chambers utilises a cask transporter.
- Casks are stacked two high in the storage chambers
- A single 80 tonne gantry crane is used to pick up the casks for placement in the final storage location
- Basket emplacement within vaults achieved using a transfer flask
- A single 30 tonne gantry crane is used to pick up the transfer flask and place it on top of the vault for transfer of the baskets to the storage tubes in the vault
- A trolley cart running on rails in the access corridor is used to move the gantry cranes between the storage chambers
- The earthen cover is designed to minimise precipitation infiltration and promote surface run off
- The engineered earthen cover and concrete chamber structure provide an improved level of intrusion resistance
- Cooling and ventilation for the storage chambers will be achieved by natural ventilation to regulate the temperature inside the chambers to suit operational requirements.
- The chamber complex will be constructed approximately 5m below site grade.

5.2 PROCESSING BUILDINGS

The processing building (Refer Fig. 3.4) will be an industrial type building structure, designed to provide a safe operational area for the handling of used fuel storage and transfer casks.
Refer to 3.2.1 for (CVST processing building) construction materials and description.

5.2.1 Receipt Area

As per CVSB alternative, refer 3.2.2.

5.2.2 Shielded Cell

As per CVSB alternative, refer 3.2.4 (Refer Figs. 3.2 and 3.3).

5.2.3 Cask Processing Area

As per CVSB alternative, refer 3.2.3.

5.3 STORAGE CHAMBERS

The design capacity of the storage chamber complex is based on an inventory of 3,557,451 fuel bundles. The inventory is split between 3,274,431 fuel bundles in 8,528 storage casks and 283,020 fuel bundles in 4,717 baskets stored in 24 vaults (Refer Fig. 3.5).

The 8,528 casks inventory will be stored in a series of parallel chambers. Fourteen cask storage chambers will be required based on placing 612 casks in six rows stacked two high per chamber (casks in lines of 51). Each chamber will be divided in two bays by a centre row of columns supporting the chamber roof. An 80 tonne electrically powered overhead gantry crane will service each bay. This crane will be classified as 'single failure proof', in order to minimise the potential for the accidental dropping of a storage cask. The gantry crane will span three rows of casks and a service aisle on one side, (approximately 13 m).
The decision to stack the casks within the storage chambers has several advantages over storing the casks 1 high, these advantages include: -

- Reduced construction and excavation costs (total storage chamber surface area approximately 60,000 m² rather than 120,000 m²)
- Simplifies ventilation arrangements, multiple inlets and 14 more extract stacks would be required, if only stacked one high
- Increased distance from process building would mean longer cask transfer times
- Storage facility has finite life, therefore facility repeat costs would be greatly increased.

The 24-vault inventory will be housed in two storage chambers. Each chamber will be divided in two bays by a centre row of columns supporting the chamber roof. Each storage bay will contain an array of six longitudinally positioned vaults serviced by a 30 tonne capacity electrically powered overhead gantry crane. The gantry crane will span both the vault, an aisle for the transfer flask transporter on one side and a service aisle on the other side.

The cask and vault storage chambers will be linked by access corridors on both ends of the store chambers. One of the access corridors will be linked to the process building, at grade level by a ramp. The storage chambers will be constructed over time to match arrival of the storage casks and baskets on site. The ends walls of the corridors where future expansion is anticipated will be constructed as knockout panels.
The storage chambers and connecting corridors will be cast in place reinforced concrete structures designed and constructed in accordance with Canadian building codes and regulations for this type of structure. The floor, walls and roof will be designed and detailed to safely withstand all predicted loads. Each chamber and parts of the corridors at the front and the back will be structurally independent and separated by isolation joints from adjacent chambers. An adequate number of joints will be introduced along the length of the chambers to prevent uncontrolled cracking of the chamber walls and slabs. The exterior surface of the walls and roofs will be coated with a 40-mil polymer coating before placing the earth cover to ensure the long term life of the storage complex.
Plans and sections of the cask and vault storage chambers are shown on Figures 3.6, 3.7, 3.8 and 3.9.

5.3.1 Fuel Retrievability

If the CVST storage system does not perform according to the specification, it will be possible to easily retrieve the used fuel from the storage vault, so as to repair the storage system or transfer the used nuclear fuel to a new storage facility.
The CES facility will be designed to allow safe retrieval of used nuclear fuel from the storage complex at any point during the service life of the facility. The used fuel storage containers shall be stored so that any individual container can be easily retrieved at any time during the service life of the storage facility.
The CVST storage alternative utilises the stacking of casks within the storage chambers, therefore retrieval of a specific cask requires removal of the casks adjacent to the target cask, using the gantry crane. A maximum of 3 casks would need to be removed with the crane to allow access to the target cask.
To retrieve a used fuel basket from a specific vault liner would require removal of the closing seal weld and removal of the cover plate. The shield plug can then be removed, allowing access to the fuel baskets within.

5.3.2 Cask Storage Chambers

The interior dimensions of the cask storage chambers will be 29m wide and 150m long. The floor of the chamber will be sloped toward the corridors at both ends. As a result, the height of the chamber varies from 13m at both ends to 12.7m at centre. The chamber roof carrying the soil cover will be supported on the sidewalls and on a row of columns spaced 6 m apart, which divide the chamber in two storage bays. Each storage bay will be provided with an elevated rail track mounted on 1.0m wide curb on each side to receive the 80 tonne gantry crane used for cask storage. The clear width between the side curbs and the clear height under the gantry are based on utilising the crane to place three rows of casks stacked two high close to one side and provide space on the other side for a fourth row of casks. The fourth row will not be used for cask storage, it will be left empty to provide space for re-positioning the casks to allow retrieval of any of the stored casks during the service life of the chamber.

5.3.3 Vault Storage Chambers

The interior dimensions of the vault storage chambers will be 29m wide and 150m long. The floor of the chamber will be sloped toward the corridors at both ends. As a result, the height of the chamber varies from 14m at both ends to 13.7m at centre. The chamber roof carrying the soil cover will be supported on the sidewalls and on a row of columns spaced 6m apart, which divide the chamber in two storage bays. Each storage bay will be provided with an elevated rail track mounted on 1.0m wide curb on each side to receive the 30 tonne gantry crane used for basket storage. The clear width between the side curbs and the clear height under the gantry are based on utilising the crane to pick up the transfer flask and place it on top of the vault for transfer of baskets to the storage tubes in the vault. Clear areas are also provide around the ventilation inlet and outlet ducts of the vaults.

5.3.4 Interconnecting Corridors

The storage chambers will be linked to the processing building by an access tunnel. The access tunnel is sized to allow two-way traffic of the storage transporters passing to and from the processing building. An access corridor will link the cask storage chambers. A rail track will be embedded in the access corridor floor to allow relocation of the gantry cranes. Once a storage

chamber has reached capacity, the gantry crane will be transferred to a trolley to relocate it to the next trench or chamber.
Air intake shafts will rise up to grade level from the storage chamber roof to air intake chambers, which will be constructed at grade level.
Vertical extract stacks will be constructed on the top of each storage chamber. These shafts will help to ensure natural ventilation (passive cooling). Escape ladders to grade level will be provided in the ventilation corridor for emergency exit.

The width of the access corridor will be 8m and the width of the ventilation corridor will be 6 m. The height of the corridors is the same as the height of the adjacent chambers.

The access ramp from the processing building will be constructed with 2.5% slope. The interior dimensions of the ramp will be 8m wide and 6m high.

5.3.5 Earthen Cover

The earthen cover above the storage chambers will be a maximum of 3.5m thick and will be crowned in the centre with one- percent slope to the sides. The cover will be made up of the following layers, from top to bottom:

- Topsoil layer, 0.7m
- Backfill material, 0.3m
- Drainage material, 0.3m
- 60-mil HDPE geomembrane
- Compacted clay liner, 0.3m
- Compacted backfill material, varies 1.9m maximum

The cover will have a side slope of 3 horizontal to 1 vertical. The service life of the earthen cover is assumed to exceed the concrete structure beneath, providing the outer surfaces of the earthen cover are properly maintained.

5.4 SEQUENCE OF OPERATIONS

In overview, the initial receipt, process and fuel container transfer operations are outlined below.

5.4.1 Module Operations

As per CVSB alternative, refer 3.4.1. Storage casks will be stacked in the storage chambers, the lower tier positioned by the cask transporter, the upper-tier casks are brought under the gantry crane using the cask transporter. The casks are loaded into their final storage location using the gantry crane.

5.4.2 Basket Operations

As per CVSB alternative, refer 3.4.2.

5.5 ACCESS

Access to the chambers will be via an enclosed ramp that goes from the processing building to the access corridor at a 3.5 % gradient. The interior dimensions of the ramp will be 8m wide and 6m high. This will provide sufficient width for two-way traffic within the ramp.

The ramp will be reinforced concrete similar to the chambers. A double door air lock system will be provided at the entrance into the ramp from the processing building.

5.6 COOLING AND VENTILATION

5.6.1 Processing Building

As per CVSB alternative, refer 3.6.1

5.6.2 Storage Chamber

Cooling and ventilation for the storage chambers will be provided by natural ventilation based on the principles of the stack effect, supplemented by heat released from the casks or vaults. Vertical stacks constructed on top of each chamber, will rise above grade level to induce the stack effect required for ventilation. Rain hoods will be provided at the top of the stacks to prevent any ingress of rain or snow. Air intake houses with weather louvers will be located at grade level above the access corridors, at both ends of the storage chamber, to allow ambient air to infiltrate the trench, due to the negative pressure created within the chambers, created by the stack effect.

The airflow through the storage chambers will be set manually by adjusting the dampers or openings located at the exhaust stack on each chamber. The dampers or openings will be adjusted and locked in place to provide similar flows through each chamber.

During initial periods of storage and when personnel are conducting inspections of the storage facility, forced air ventilation systems located above the access corridors may be utilised to supplement the passive ventilation system. This will only be necessary before the storage chambers are fully loaded, as a partially loaded storage chamber may not provide enough energy to initiate the natural convection flow of air.

5.7 SHIELDING

The shielding provided by the Casks and Vaults ensures that both the facility operators, who are regularly in close proximity to the storage structures, and the general public, who will be excluded from the storage/processing complex by the facility security systems only receive acceptable levels of radiation exposure. The design and construction of the storage trenches provides supplementary shielding to personnel who are outside the trench, thereby further reducing the available dose rate to the public.

5.7.1 Storage Casks

As per CVSB alternative, refer 3.7.1.

5.7.2 Storage Vaults

As per CVSB alternative, refer 3.7.2.

5.8 CONTAINMENT

5.8.1 Storage Casks

As per CVSB alternative, refer 3.8.1.

5.8.2 Storage Vaults

As per CVSB alternative, refer 3.8.2.

5.9 WATER CONTROL

Water control is a function of site conditions and the implementation of specific construction design solutions. For the purposes of this study it is assumed that the CVST will be constructed in a low permeability glacial till deposit where the water table is located at least 1m or more below ground surface.

The following measures have been incorporated into the construction and design to minimise the potential for the ingress of water into the chambers.

- A high-density polyethylene liner will be incorporated in the earth cover above the chamber complex.
- The earth cover will be sloped toward perimeter lined ditches to collect surface runoff from precipitation.
- Perforated drainpipe will be installed outside around the perimeter of the chambers and corridors to prevent seasonal rise of the ground water table above the floor slab level. The perforated pipes located between the walls of the chambers will drain into solid pipes encased in concrete placed under the floor slabs.
- Water from the ditches and drainpipes will be collected in catch basins and pumped to the site collection pond.
- Water stops will be provided in all construction and control joints in the floors, walls and roofs of the chamber complex.
- As an added precaution, the floor of the chambers will be sloped toward trenches in the access and ventilation corridors. The trenches will be sloped towards collection sumps.
- Water entering the chamber complex will be pumped to a separate pond for monitoring before being discharged.

The collection sumps within the chambers will be equipped with monitors and alarms to provide indication of the operational condition of the pumping systems. Water level monitoring within the sumps will be provided to warn of any increase in level, above that normally allowed. Failure of the pumping system to control the water level will result in remedial action being initiated. This remedial action could include introducing a temporary additional pumping system, or the introduction of a system with increased capacity. Short term increase in the water levels within storage chambers would not present a safety significant event.

The access route from the Processing Building to the Storage Complex is covered to provide weather protection to the casks and transporters and ensure that the casks and baskets remain dry, and to minimise the potential for water ingress during fuel transfers.

6 Casks in Rock Caverns (CRC)

6.1 GENERAL DESCRIPTION

The Casks in Rock Cavern concept comprises the storage of fuel bundles confined in self shielded storage casks. The casks are stored in underground caverns excavated from competent bedrock (Refer Fig.4.1 for site layout and key overall dimensions). There are two storage cask designs, a module cask and a basket cask. The storage casks are arranged within a series of separate storage caverns that are accessed from the processing building on the surface by an access ramp.

The storage caverns will be constructed in competent bedrock at a nominal depth of 50meters, this depth of store construction will provide a high degree of physical protection and stability. The fuel is transferred from reactor sites to the CES via either the storage cask transportation mode, the module transportation cask mode or the basket transportation cask mode. Following receipt at the CES facility, existing storage casks arriving at the CES facility from donor reactor sites are checked on arrival, and are then transferred to the appropriate dedicated storage cavern using the cask transporter (Refer Fig.4.9 and 5.7). Fuel modules or baskets are received and placed into the relevant storage casks in the shielded cell within the Processing Building. The casks are sealed, checked and are then transferred, using the cask transporter, to the pre-determined underground storage cavern (Refer Figs. 4.10 and 4.11).
The cask transporter will position the casks on the lower tier within the appropriate storage cavern. The cavern crane will facilitate the final movement of the cask, from the transfer position to the cask storage position, on the upper tier.
The maximum annual receipt rate is 117,066 used fuel bundles per year from the existing wet storage facilities in module format.
The used fuel will be transferred to the CRC facility using the Irradiated Fuel Transportation Casks (IFTC), with each IFTC contains 2 used fuel modules.
The required throughput rate dictates the production of 1.32 storage casks per day. Each storage cask is designed to accommodate 4 used fuel modules (4 x 96 = 384 fuel bundles storage cask). To achieve this throughput 3 IFTCs will need to be received and processed per day.
To facilitate the receipt, transfer and handling activities associated with the processing of these casks it will be necessary to work two shifts for the duration of these operations.

At other times within the duration of the fuel receipt operations a combination of fuel in module and basket format will be received at the facility. The basket fuel will be transferred in basket storage casks. These casks are designed to accommodate 7 fuel baskets (7 x 60 = 420 fuel bundles)
The fuel receipt quantities during these combinations fuel receipts vary year by year. None of the combined module and basket fuel receipt years generate higher production rates than the figures quoted above for the receipt of module fuel only.

With two shift operations there is time available for cask decontamination activities, however to enable more time for these non-routine decontamination activities it may become necessary to occasionally initiate operation of a 3rd shift. The processing building layout has a space allowance adjacent to the shielded cells to allow occasional decontamination activities to be taken 'off-line' and undertaken in a temporary enclosure, to ensure that any disruption to the production of casks for storage is minimised.

Fuel that arrives in baskets is transferred to the facility in the basket transportation cask, this cask is designed to accommodate 3 baskets. The cask is unloaded into the shielded cell and then the baskets are loaded individually into the basket storage cask
The maximum annual receipt rate for fuel baskets is nominally 500 baskets per year, (500 baskets x 60 bundles per basket = 30,000 bundles per year). The receipt of 1 basket transportation cask per day can satisfy this requirement.

Key features of the CRC extended storage concept include:

- The processing building accepts existing storage casks, fuel module transport casks or fuel basket transport casks.
- All fuel is received in modules or baskets, which are then sealed within storage casks.
- Increased storage capacity can be provided by the outfitting of further storage caverns on a rolling construction program.
- After fuel receipt, all subsequent fuel movements are under cover, (minimising effects of adverse weather and maximising fuel container life by reducing environmental impact on 'housing'.
- Cask emplacement in storage caverns utilises an overhead gantry crane. Casks will be stacked two high in the storage cavern complex.
- The storage caverns are situated in a competent rock structure and are designed to provide maximum protection and containment.
- The depth of the cavern complex provides a high level of physical protection and intrusion resistance
- Cooling is provided by forced air convection through vents to ground level.

6.2 PROCESSING BUILDING

The processing building (Refer Fig. 4.4) will be an industrial type building structure, designed to provide a safe operational area for the handling of used fuel storage and transfer casks.
Refer to 3.2.1 for (CVST processing building) construction materials and description.

6.2.1 Receipt Area:

As per CVSB alternative, refer 3.2.2.

6.2.2 Shielded Cell:

As per CVSB alternative, refer 3.2.4 (refer Figs. 4.2 and 4.3). The only difference is that the shielded cell must also interface with and create basket casks, which are nominally taller than the module casks, this difference has been integrated into the CRC shielded cell design.

Cask Processing Area:

As per CVSB alternative, refer 3.2.3.

6.3 STORAGE CAVERNS

The design capacity of the storage casks in rock caverns (CRC) concept is based on an inventory of 3,557,451 fuel bundles. The inventory is split between 3,274,431 fuel bundles in 8,528 module type casks and 283,020 fuel bundles in 4,717 baskets to be stored in basket type casks. The basket casks hold 7 baskets, each with 60 bundles, i.e. 420 fuel bundles per basket cask, therefore 678 basket casks are required. The total number of casks is thus 9206 and these will be arranged in 158 rows in the rock caverns (Refer Fig. 4.5). Casks will be stacked one on top of the other, each row will consist of 3 sets of 2 stacked casks, or a total of 6 per row (Refer fig.4.6). Each cavern will be developed with sufficient length to provide storage for 948 casks. An 80 tonne electrically powered overhead gantry crane will service each cavern. This crane will be classified as 'single failure proof', in order to minimise the potential for the accidental dropping of a storage cask. The gantry crane will span three rows of casks and a service aisle on one side, (approximately 14 m)
The decision to stack the casks within the storage caverns has several advantages over storing the casks 1 high, these advantages include: -

- Reduced construction and excavation costs (total storage cavern surface area approximately 68,000 m² rather than 136,000 m²)
- Simplifies ventilation arrangements, multiple inlets and 14 more extract stacks would be required, if only stacked one high
- Increased distance from processing building would mean longer cask transfer times
- Storage facility has finite life, therefore facility repeat costs would be greatly increased.

The complete complex will comprise 11 storage caverns. Nine caverns will be used for storing module casks, one will be used for storing basket storage casks. A spare cavern will be available to provide interim storage space during repackaging activities or to provide an alternate storage site in the event that one of the caverns experiences adverse conditions. Additional caverns will be constructed as required.

6.3.1 Fuel Retrievability

If the CRC storage system does not perform according to the specification, it will be possible to easily retrieve the used fuel from the storage cavern, so as to repair the storage system or transfer the used nuclear fuel to a new storage facility.
The CES facility will be designed to allow safe retrieval of used nuclear fuel from the storage complex at any point during the service life of the facility. The used fuel storage casks shall be stored so that any individual cask can be easily retrieved at any time during the service life of the storage facility.
The CRC storage alternative utilises the stacking of casks within the storage caverns, therefore retrieval of a specific cask requires removal of the casks adjacent to the target cask, using the gantry crane. A maximum of 3 casks would need to be removed with the crane to allow access to the target cask.

6.3.2 Rock Cavern Configuration

The storage caverns will resemble typical underground civil structures such as roadways or railway tunnels, underground powerhouses or underground warehouses where expensive equipment or materials must be protected for long periods of time (i.e. >50 years).
The caverns will be 15m in width by 16m high. The actual dimension may vary slightly due to minor "over-break" which can occur with underground excavations. However, by adopting

recent developments in drilling and blasting technologies, stress fracturing normally associated with drilling and blasting can be minimised.

The caverns for the CES will be drilled and blasted such that the arched roof will be developed during excavation. This technique provides better distribution of the rock stresses and minimises the potential for rock movement, and is common practice in underground mining. An underground rectangular opening will, over time, naturally develop an arched roof as the inherent rock stresses are relieved (Refer Fig. 4.7).

As the caverns are excavated, the walls and roof will be scaled to remove all loose material that may be present after blasting. Once scaling has been completed the cavern roof and walls will be "rock bolted" to provide additional support to the opening. Rock bolting involves drilling a small diameter hole into the rock and installing a steel bolt. The rock bolts have an anchoring mechanism on one end, which secures the bolts in place as they are tightened. The purpose of rock bolting is to ensure that any exposed rock inside the opening is anchored to the solid rock surrounding the cavern. Rock bolts installed in the roof of the cavern may be augmented with either steel strapping of heavy steel mesh to provide additional protection from rock falls. The rock bolts will be grouted to protect them from corrosion due to possible seepage of ground water. Another benefit of grouting is that it provides additional holding strength along the entire length of the bolt.

The cavern floors will be concrete lined to provide a level surface for placement of the casks. Floors will be constructed such that there will be a 0.5m elevation difference between the centre and either end of the cavern. This will ensure that any seepage water will drain out of the caverns.

Each cavern will be provided with an elevated rail track mounted on 1m wide curb on each side to receive the 80 tonne gantry crane used for cask storage (Refer Fig.4.8). The clear width between the side curbs and the clear height under the gantry are based on utilising the crane to place three rows of casks stacked two high close to one side and provide space on the other side for personnel access, or a fourth row of casks. The fourth row will not be used for cask storage, it will be left empty to provide space for re-positioning the casks during retrieval operations. Along either side of the cavern there will be a space between the crane rail curb and the rock wall. This space will form a channel that will be used to catch seepage water. It will be graded towards the access and ventilation corridors to promote the drainage of water out of the cavern.

6.3.3 Interconnecting Corridors

The storage caverns will be linked at the head end by an access corridor. A rail track is embedded in the access corridor floor to allow relocation of the gantry cranes. Once a storage cavern has reached capacity, the gantry crane is transferred to a trolley, which relocates it to the next cavern.

The storage caverns will be linked at the tail end to a ventilation corridor. Adjustable louvered openings and access doors separate the chambers from the ventilation corridor, and allow control of the extract ventilation.

The width of the access corridor will be 8m, and the ventilation corridor will be 6m. The height of the corridors is the same as the height of the adjacent caverns.

6.4 SEQUENCE OF OPERATIONS

In overview, the initial receipt, process and fuel container transfer operations are outlined below.

6.4.1 Module Cask Operations

As per CVSB alternative, refer 3.4.1. Storage casks will be stacked in the storage caverns, the lower tier positioned by the cask transporter, the upper-tier casks are located using the gantry crane.

6.4.2 Basket Cask Operations

1. Receive and verify transportation cask
2. Transfer cask onto shielded bogie
3. Prepare cask for process operations
4. Transfer cask below shielded cell
5. Transfer baskets from cask into shielded cell
6. Return transportation cask to fuel owner
7. Repeat receipt and transfer operations for subsequent basket transportation casks
8. Position storage cask below shielded cell
9. Load baskets from shielded cell into storage cask
10. Transfer lidded storage cask to cask processing area
11. Seal, vacuum dry, inert and test storage cask
12. Transfer cask to pre determined storage position.

6.5 ACCESS

Access into the storage facility will be via two ramps that will extend from surface to the rock caverns at a –7% gradient. At this grade the resulting access ramps will have a total length of 714m. The interior dimensions of the ramp will be 8m wide and 6m high. This will provide sufficient width to permit two-way traffic within the ramp.

Initially there will be only one access ramp constructed. This initial ramp will then serve as the main access for fuel placement and the inlet for fresh air. During the second phase of construction a second access ramp will be developed to allow the uninterrupted placement of fuel as additional underground construction work proceeds.

The entrance for the initial access ramp will be housed within the Processing Building. The entrance for the second ramp will be housed inside a separate structure to prevent precipitation from entering the access tunnel. The access tunnels will be concrete lined for approximately 80 meters or to the point where competent, non-weathered rock is encountered during construction. The remainder of the access tunnels will be excavated in a similar fashion to that used for the storage caverns. The floor of the tunnels will have drainage and ditches constructed along both walls. The roof of the tunnel will be arched for proper distribution of rock stresses. The roof and walls of the tunnels will be rock bolted and screened to provide support and protection from rock falls. Grouting will be used to control any potential ground water seepage.

Vent shafts will be constructed in both access ramps to provide inlets for fresh air. These vent shafts will be constructed within the concrete portions of the access ramp down slope from the Processing Building.

6.6 COOLING AND VENTILATION

6.6.1 Processing Building

As per CVSB alternative, refer 3.6.1

6.6.2 Storage Caverns

The ventilation and cooling of the casks in the underground caverns will be provided using a forced ventilation system. The access ramps described in Section 6.5 will act as the air inlets or downcast shafts for fresh air. The air inlets will be equipped with propane heaters to provide heating during construction in the winter seasons. They will also ensure that icy conditions do not exist on the access ramp during cask emplacement activities in winter, by keeping the temperature above freezing.
The completed underground storage complex will comprise two decline ramps, eleven storage caverns, an access corridor, a ventilation corridor and three upcast shafts or ventilation raises.

The exact dimensions of the ventilation raises will depend upon the quantity of air required to ventilate the facility. Factors to consider when determining the ventilation raise dimensions will include:

- Fresh air volume required during excavation;
- Fresh air volume required to maintain proper air quality; and
- Fresh air volume for “heat dissipation”.

The access and transfer corridors will be used for the transport of the casks and the delivery of fresh air, while the ventilation corridor will be used to carry the return air to the exhaust vent raises. The general flow of fresh air will be from the downcasts or access ramps, through the storage caverns and then into the ventilation corridor. Airflow will be regulated via adjustable louvered ‘bulkheads’ located at the tail end (ventilation corridor) of each storage cavern.

The ventilation system will include extract fans mounted at the surface within the extract ductwork. These fans will generate an air-flow, from the air inlets at the access ramp(s) through the caverns, thus removing heat from the casks.
These extract fans will be supplied with a system to monitor the fan speed and flow rate to ensure the design conditions are being met. A comprehensive set of spare parts will be maintained at the facility to allow efficient repairs to be carried out should any of the fans fail in service. A 4th extract fan (3 duty and 1 spare) should be held at the facility. Should a breakdown occur that could not be repaired with the fan in place, the spare unit will need to be installed. This change over may take several days to complete, and require heavy crane access to facilitate the change over. During this change over, the caverns will be ventilated using the 2 duty extract fans, with some readjustment of the control dampers to compensate for the revised flow. The quality of the air within the chamber should not be adversely effected by this situation, but the air quality will be continually monitored and assessed. The unit that has been removed will be overhauled and will be made available as the ‘new’ spare unit.

A forced ventilation system is necessary in this alternative because the system resistance of the cavern complex, (the air inlet system and the necessary extract flow control mechanism), is greater than the reduction in air pressure that can be created by a reasonably dimensioned stack.

6.7 SHIELDING

6.7.1 Storage Casks

Storage casks (modules or baskets) are constructed as double steel shell containers, each carbon steel shell is 13mm thick. The space between the inner and outer shell is filled with reinforced high-density concrete. The reinforced high-density concrete provides radiation shielding while maintaining the capability for used fuel decay heat dissipation. The high-density reinforced concrete typically has a density range of 3.5 to 3.7 Mg/m^3 and a full strength of 40 Mpa. The cask lids are welded onto the cask body and provide full shielding to the cask top face.

6.8 CONTAINMENT

6.8.1 Module Storage Casks

As per CVSB alternative, refer 3.8.1.

6.8.2 Basket Storage Casks

Basket Storage Casks provide two levels of containment for the used fuel. The primary containment for the fuel is the fuel basket. The basket is seal welded at the reactor site and is not compromised by any of the subsequent operations. The secondary containment is the cask containment, which is only considered a containment boundary after successful completion of the cask lid seal weld. The integrity of the secondary containment can be verified, since the assembly is inert gas filled and is then leak tested to prove the integrity of the cask assembly. Each storage cask that passes this testing regime will be labelled and will be marked with secure identification and IAEA verification seals.

6.9 WATER CONTROL

To ensure that any water inflow during construction and operation of the CRC is kept to a minimum, the facility will be built in a solid homogenous rock mass that contains minimal geologic structuring. Tightly spaced uniform joints will be acceptable as they contain little water and they can be controlled easily. A poorly jointed rock mass or one containing faults will not be acceptable sites for CRC construction. The CRC storage cavern complex would be constructed in a competent rock mass would no major water-bearing fault structures.
See section 8.1.2 for further details on assumed site conditions.

As previously stated in Section 6.3.1 the caverns will be constructed such that the floors will slope towards the access and ventilation corridors. Drainage channels will extend along both sides of the caverns between the crane rail curb and the wall. These drainage channels will also be graded towards the main corridors. During construction it is expected that the caverns will not experience significant visible water inflows. However should inflows be encountered then rock will be grouted to control seepage of ground water. In areas where seepage is persistent, stainless steel sheeting could be suspended just below the roof to prevent water from dripping onto the storage casks. Troughs and down pipes will be incorporated to direct the water to the side drainage channels. However, areas that may be prone to persistent seepage would be avoided during the construction of the storage cavern complex.

Drainage channels and sumps will be constructed in both the access and ventilation corridors to gather any seepage water that drains out of the storage caverns. Sump pumps will then pump this water to surfaces where it will be collected in a storage pond. This pond will provide sufficient retention time to allow solids to fall out of suspension. Any water that originates from caverns containing casks will be monitored before discharge to the environment. Water pumped from the underground caverns will be passed through a skimmer weir to remove any engine oil, hydraulic fluids or any other effluents that may have leaked from the machinery during construction or placement of the casks.

The collection sumps within the caverns will be equipped with monitors and alarms to provide indication of the operational condition of the pumping systems. Water level monitoring within the sumps will be provided to warn of any increase in level, above that normally allowed. Failure of the pumping system to control the water level will result in remedial action being initiated. This remedial action could include introducing a temporary additional pumping system, or the introduction of a system with increased capacity. Short term increase in the water levels within storage caverns would not present a safety significant event.
The access route from the Processing Building to the Storage Complex is covered to provide weather protection to the casks and transporters and ensure that the casks remain dry, and minimise the potential for water ingress during transfers.

7 Common Ancillary Facilities

7.1 ADMINISTRATION AND SUPPORT FACILITIES

7.1.1 Administration and Visitors Building

7.1.1.1 Function

This building serves as both the main administrative offices for the extended storage facility, and as an information centre for the adjacent communities and other visitors. There will be an element of segregation between these two functions, reflected in the building layout.

The administrative area will comprise training and conference facilities, fireproof records vault, central mail/communication equipment, and a lunchroom for administrative and related office personnel.

Garaging facilities for a fire tender and the storage of fire fighting equipment will also be provided in a firehall located within the. Administration and Visitors Building.

The visitors reception area will be served by a separate entrance and comprise two adjoining meeting rooms, capable of seating 25 persons each. A small coffee, vending and snack area is located near the front entry. The building will also include washroom facilities. Information explaining the site and site activities will be available and an attendant will be available to answer questions regarding the extended storage facility.

7.1.1.2 Construction Materials

The building footprint will be 30m x 20m**.**

Roof
Insulated protected membrane roofing on metal deck.

Walls
Exterior Walls: Preformed insulated modular metal panels with an integrated curtain wall glazing system.
Internal Walls: Concrete block in high traffic areas. Gypsum board on metal studs (demountable type in office areas).

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Quarry tile or similar ceramic tile for washrooms and kitchen area,
Vinyl composite tiles in areas requiring higher degree of finish than exposed concrete,
Carpet in administration office areas.

Ceilings
Exposed structure with fire protection as required in fire hall and service area.
Suspended gypsum board in areas requiring fire protection and a higher degree of finish other than exposed structure.
Suspended acoustic tile in all other areas.

7.1.2 Operations Support, Health Physics and Test Facility Building

7.1.2.1 Function

The building will serve as the operations centre for the extended storage facility. It will also serve as the entrance and exit point for all personnel entering and leaving the restricted area of the extended storage facility. The building will house the following major areas:

- Health Physics station – for health physics staff to review, document and analyse all incoming waste package shipments and perform radiation/decontamination surveys in support of the facility.
- Health Physics laboratory – for analysing samples taken during routine monitoring.
- Instrument Repair Area – for the maintenance, calibration, and issue of health physics related instruments.
- Personnel Survey and Decontamination Area – used by all personnel exiting the controlled area to ensure no spread of contamination into non-controlled areas. Decontamination of personnel, if required, can be performed in this area.
- Change rooms/locker rooms – for male and female site workers.
- Lunch room – for site workers and building personnel.
- Office space – for site operations/used fuel receipt shift supervisory personnel.
- IAEA office – an enclosed office for IAEA personnel (2 persons)

An area adjacent to the Operations Support and Health Physics Building will be reserved for the construction of a test facility, which will be capable of supporting experiments and monitoring the long term condition of the used fuel, in mimic form. The building will comprise test facility space, computer room, staff coffee room, lab storage, test facility mechanical/electrical areas and heating and ventilation plant and control equipment for replicating the environmental storage conditions for various experiments.

7.1.2.2 Construction Materials

The building footprint will be 50m x 30m. An equivalent space allocation will be reserved adjacent to this building for an extension.

Roof
Insulated protected membrane roofing on metal deck.

Walls
Exterior Walls: Preformed insulated modular metal panels with an integrated curtain wall glazing system.
Internal Walls: Concrete block in high traffic areas. Gypsum board on metal studs (demountable type in office areas).

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Quarry tile or similar ceramic tile for washrooms and kitchen area,
Vinyl composite tiles in areas requiring higher degree of finish than exposed concrete,
Carpet in administration office areas.

Ceilings
Exposed structure with fire protection as required in fire hall and service area.
Suspended gypsum board in areas requiring fire protection and a higher degree of finish other than exposed structure.
Suspended acoustic tile in all other areas.

7.1.3 Equipment Storage and Maintenance Building

7.1.3.1 Function

The building will serve a maintenance shop for site equipment. Maintenance facilities will include one service bay and one wash bay. Maintenance will be conducted on any equipment that may be contaminated because of its use in an active area (with the exception of equipment which has its own decontamination stations (such as cranes within the fuel receipt building) only after the equipment has been washed down and decontaminated. The wash bay will be equipped with manual wash equipment for wash down of on site mobile equipment items. A water collection and recycling system consisting of a collection tank, mud settling basin, oil separator, water filtration system and a 10m³ water holding tank will be provided. The service bay will be equipped with a 20-tonne/5-tonne auxiliary overhead travelling crane with a 6m crane hook height. Compressed air and welding outlets will be provided in the service bay. The building will also contain tools/parts room, parts storage room, locker/toilet rooms, and maintenance supervisors' offices.

7.1.3.2 Construction Materials

The building footprint will be 50m x 30m.

Roof
Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Vinyl composite tiles in washrooms and office areas

Ceilings
Exposed structure.
Suspended acoustic tile in washroom and office areas.

7.1.4 Storage Cask/Module Canister Store

7.1.4.1 Function

This building will be tailored to the requirements of particular extended storage alternative being considered at the site. It will comprise either:

- Buffer stock storage for freshly received (module or basket) storage casks direct from the manufacturer.
- Buffer stock storage of fresh module canisters received from the manufacturer.

The facility will have an 100 tonne/5 tonne auxiliary electric overhead travelling crane to permit offload and set down of freshly received storage casks (and lids) or module canisters.

The building foundation and floor structures will be capable of supporting the wheel loads generated by cask transportation vehicles and on site storage cask transporters.

An auxiliary function for this building will be:

- to house any transportation vehicles, complete with (full) transportation cask and overpacks, should the extended storage facility be unable to receive the transportation cask immediately,
- to house an (empty) transportation cask vehicle temporarily unable to return to the donor site, local rail head or barge offload point.

The building will also offer the potential for storage of transportation casks, to release the cask transportation vehicle, if required.

7.1.4.2 Construction Materials

The building footprint will be 40m x 30m.

Roof

Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Vinyl composite tiles in washrooms and office areas

Ceilings
Exposed structure.
Suspended acoustic tile in washroom and office areas.

7.1.5 Active-Solid Waste Handling Building

7.1.5.1 Function

This building will receive solid wastes, in the form of process consumables and redundant equipment, for examination and waste categorisation during the fuel receipt and operation stages of the extended storage facility. It is envisaged that bagging of wastes and compaction of some waste streams will be performed in this building.

7.1.5.2 Construction Materials

The building footprint will be 30m x 30m.

Roof
Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Vinyl composite tiles in washrooms and office areas

Ceilings
Exposed structure.
Suspended acoustic tile in washroom and office areas.

7.1.6 Active Solid Waste Storage Building

During fuel receipt and process operations, some process equipment, and secondary solid wastes will be generated, as a result of operation and (normal and breakdown) maintenance activities. These materials may remain sufficiently contaminated as not to permit direct free release of the scrap materials. This ‘contaminated’ material will be designated as active solid waste, and will be processed accordingly.

During repackaging events, fuel is transferred from storage casks, module canisters or baskets that have reached the end of their service life, to new fuel 'housings'. It is anticipated that no more than 1% of modules and baskets and 0.25% of storage cask internals and module canister internals will remain sufficiently contaminated as not to permit direct free release of the scrap materials. This 'contaminated' material will be designated as active solid waste, and will be processed accordingly.

7.1.6.1 Function

This building will provide covered storage to categorised solid wastes. The unheated building will provide limited storage for accumulations of solid waste arisings from the solid waste handling building. Periodically, once sufficient materials have been accumulated, solid waste will be transferred to offsite ILW and LLW disposal facilities.

7.1.6.2 Construction Materials

The building footprint will be 50m x 30m.

Roof
Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete

Ceilings
Exposed structure.

7.1.7 Active Liquid Waste Treatment Building

Decontamination of materials recovered from the shielded cells may require 'wet' decontamination prior to hands on maintenance. This wet decontamination may generate small volumes of liquid that will be treated as active liquid waste. Additionally decontamination of solid waste material during repackaging events may also require 'wet' decontamination. These liquids will be treated as active liquid waste.

7.1.7.1 Function

This building will provide treatment for active liquors arising from the receipt and storage operations. In addition it will treat potentially contaminated waters from the retention/sedimentation pond, within the protected area.

The treatment process will include a combination of:

- Ion exchange and resin treatment
- Concentration of liquors through evaporation.

7.1.7.2 Construction Materials

The building footprint will be 30m x 30m.

Roof
Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Vinyl composite tiles in washrooms and office areas

Ceilings
Exposed structure.
Suspended acoustic tile in washroom and office areas.

7.1.8 Active Liquid Waste Storage Building

7.1.8.1 Function

This building will provide covered-tanked storage of categorised liquid wastes. The heated building will provide limited storage for accumulations of liquid waste arisings from the liquid waste treatment building. A bund wall will surround the tanks, to ensure no inadvertent loss of tank contents will occur. The building will house tank emptying equipment, including pumps, hoses and similar. Periodically, once sufficient materials have been accumulated, liquid waste will be transferred to offsite ILW and LLW disposal facilities, by road going tanker transportation vehicles.

7.1.8.2 Construction Materials

The building footprint will be 40m x 30m.

Roof
Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Exposed structure.

7.1.9 General Warehouse

7.1.9.1 Function

This building will serve as a covered storage location for general equipment, site housekeeping and maintenance equipment and seasonally used plant and equipment. The general warehouse will also have an open storage yard, for storing miscellaneous items.
The building will be single story pre-engineered steel structure with a total gross floor area of 1,500 square meters.

7.1.9.2 Construction Materials

The building footprint will be 50m x 30m.

<u>Roof</u>
Pre-finished insulated metal.

<u>Walls</u>
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

<u>Floors</u>
Non-dusting hardener treatment applied to areas with exposed concrete,
Vinyl composite tiles in washrooms and office areas

<u>Ceilings</u>
Exposed structure.
Suspended acoustic tile in washroom and office areas.

7.1.10 Guardhouse and Perimeter Security System

7.1.10.1 Function

This building will serve as security control for the facility. The building will serve as a check in point for personnel and vehicle entry and exit control, radio control, contraband, and visitor control. Site surveillance will also be performed from this location. The building will include a guard office area, an area for security files and records, an area for issuing personnel badges, and a washroom. The building will also provide secure access between the inner and outer security fences.

The double security fence will define the site boundary. The site boundary will be set 100m minimum from the nearest used fuel storage building, and a minimum of 30 meters from other buildings on the CES site. The chain link fences will be 3.6 meter high, supported on cranked posts (facing outwards) and overtopped with stranded barbed wire. The fence construction will be typically of plastic coated carbon steel posts set in concrete, supporting a 4mm diameter plastic coated 50mm woven wire mesh fence. A single security fence (with unmanned gate) of equivalent design will define the inactive/active site division boundary, within the overall CES site. Refer to Section 7.2.2 for a description of CES site security measures.

7.1.10.2 Construction Materials

The building footprint will be 25m x 15m.

Roof
Insulated protected membrane roofing on metal deck.

Walls
Exterior Walls: Preformed insulated wall metal panels.
Insulated masonry cavity dado wall to 2.4 m above grade.
Internal Walls: Concrete block in high traffic areas.
Gypsum board on metal studs (demountable in office areas).

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,
Quarry tile or similar ceramic tile for change rooms and lockers and health physics areas,
Vinyl composite tiles in areas requiring higher degree of finish than exposed concrete,
Carpet in office areas.

Ceilings
Exposed structure with fire protection as required in shop area.
Suspended gypsum board in areas requiring fire protection and a higher degree of finish other than exposed structure.
Suspended acoustic tile in all other areas.

7.1.11 Truck Inspection/Wash Facility

7.1.11.1 Function

This building will serve as the entrance/inspection point at which cask transportation trucks entering the site are inspected prior to entry into the extended storage facility. This building will also provide wash down facilities for the storage container handling vehicles. The building will be equipped with radiation monitoring equipment for equipment and personnel.

Other trucks entering the facility may also require wash down to remove accumulated snow, ice mud and debris prior to being inspected and admitted to the extended storage facility. Two wash down/inspection bays will be provided. The facility will be equipped with pressurised wash equipment. A water collection and recycling system consisting of a collection tank, mud settling basin, oil separator, water filtration system and a $10m^3$ water holding tank will be provided. The truck wash water will be piped to the temporary below grade holding tank where the wash water can be sampled for contamination and then reused (if not contaminated). Should contamination be detected, the wash water will be treated on site prior to discharge.

7.1.11.2 Construction Materials

The building footprint will be 35m x 25m.

Roof
Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete.

Ceilings
Exposed structure.

7.1.12 Utility Building

7.1.12.1 Function

This building will house the diesel-powered emergency generator, diesel fuel day tanks, and emergency firewater pump system. The firewater storage tank will be located outside the building. The electrical switchgear and panels, associated with the generator and the firewater system, will also be located within the structure. It is assumed that potable water and electricity will be available at the site boundary.

7.1.12.2 Construction Materials

The building footprint will be 50m x 30m.

Roof
Pre-finished insulated metal.

Walls
Exterior Walls: Pre-finished insulated metal.
Internal Walls: Concrete block in high traffic areas.

Floors
Non-dusting hardener treatment applied to areas with exposed concrete,

Ceilings
Exposed structure.

7.2 OTHER SITE SYSTEMS

7.2.1 Fire Protection Systems

The site protection system will prevent and control fires throughout the extended storage facility. To assure physical safety and to control the risk of release, the fire protection system is equipped with a dedicated firewater supply and an automatically activated diesel powered firewater pump for operation during power outage. Wet pipe firewater sprinkler systems will be installed in all the buildings on the site and connected to the firewater supply system. The firewater supply system will comprise heated and insulated 500m³ storage tanks, pumping system and a firewater header supply pipeline. The pipeline will also serve fire hydrants at strategic points on the site to ensure adequate coverage for all buildings and traffic areas. The firewater distribution system will be extended to suit the scheduled construction of the storage buildings. The system will be supplemented with hand held fire extinguishers and chemical or foam extinguishers for use in areas where the use of firewater supply system is not advisable.

For the underground storage concepts, dry riser extensions to the fire fighting systems will be used to convey water to the head end service tunnels of the underground storage complex. These will also be extended to match the scheduled construction of underground storage caverns or trenches, as applicable.

7.2.2 Security and Communications Systems

Security and alarm systems will be installed throughout the site facilities. All access gates and doors to the site property and perimeter buildings will be alarmed as well as the gates, doors and personnel entrances into the storage buildings or underground facilities. Security access devices will be provided for computer rooms, media storage and other areas beyond reception areas. All alarms will be connected to the secure monitoring room in the guardhouse at the entry point to the site operations area.

Intruder alarms, located between the inner and outer perimeter fences will be used to detect attempted unauthorised access onto the extended storage site.

Closed circuit cameras will provide area views of the site, plus a number of cameras will be deployed at strategic locations, to give specific views of sensitive areas, such as transportation cask receipt facilities, storage cask transporter routes, storage complex access declines and similar.

In addition to the telephone system, a two-way mobile radio system will be provided on the site for communication between the operations building and mobile equipment operators on the site and within the storage buildings and underground storage complex. Relay stations will ensure communications are maintained between surface and sub-surface operators.

7.2.3 Electrical and Emergency Power

Electrical power will be provided to the site from an overhead power line located near the site boundary. The supply system will interface with the facilities electrical distribution system, at a fused, interrupter switchgear station located on site. Power distribution transformers, protected by fuses and surge arrestors and containing all the breakers for the required loads, will be installed at an on site substation. The substation will step down the utility power voltage to a 575-volt system for distribution throughout the facility.

In the case of a utility power outage, an emergency diesel generator set will be provided in the Utility building to service essential loads to the site facilities. The emergency diesel generator, in conjunction with battery-operated systems are intended to minimise any potential adverse effects on essential facility operations in the event of a power outage.

Specific attention will be given to the electrical distribution system, such that subsequent stages of the used fuel storage complex can be incorporated into the electrical distribution system with the minimum of disruption to the established systems. Temporary construction electrical power distribution systems, albeit safely configured, will be isolated from the operational systems, such that their potential failure will not adversely impact the existing storage complex.

7.2.4 Sanitary Sewer System

All buildings on the site will be served by an underground piped sanitary wastewater collection system. Sanitary sewage will be treated and disposed of on-site at the facility sewage treatment plant. The treatment plant will be designed to meet effluent discharge criteria. Effluent will discharge to the local drainage course.

7.2.5 Potable Water System

A water supply system will deliver fresh water to various consumption points throughout the facility. Water will be supplied from a nearby municipal water supply system through a buried main water pipeline. The main water supply pipeline feeding the site will be equipped with a meter, shut off valve and check valve located in an underground vault accessed through a manhole. Water will be distributed from the vault through underground water distribution piping to each building. All underground piping will be located below the frost line. The water distribution system will be extended to suit the scheduled construction of the storage buildings.

In addition, the water distribution system will top up the firewater storage tanks, as necessary.

A small water treatment plant will supply and store stocks of demineralised water for use in experimental programs or for equipment calibration purposes, as necessary.

7.2.6 Retention/Sedimentation Pond

The retention/sedimentation pond serves to collect surface run off and settle any suspended matter from within the restricted area. It will be excavated in native soil and will have an HDPE liner. The pond will have a controlled outlet and will store rainfall from a major precipitation event. The discharge system will allow monitoring of the pond prior to discharge or diversion for treatment if necessary. The site within the restricted area will be graded to ensure that only run off from within the main protected area will be sent to the Retention/Sedimentation Pond.

The pond would be excavated with two (horizontal) to one (vertical) side slopes. It will have an area of 150m x 75m x 5m deep and an approximate volume of 50,000m^3.

7.2.7 Storm Water Pond

The storm water pond serves to collect surface run off and settles any suspended matter from the public/secure operations area of the facility. It will be excavated in native soil and will have an HDPE liner. The pond will have a controlled outlet and will store rainfall from a major precipitation event. It will have a controlled outlet and will be equipped to allow a monitoring of the pond prior to discharge or diversion for treatment if necessary.

The pond would be excavated with two (horizontal) to one (vertical) side slopes. It will have an area of 100m x 50m x 5m deep and an approximate volume of 20,000m^3.

7.2.8 Batch Plant and Construction Materials Storage Area

During the initial construction phase and subsequent building stages to create additional storage capacity, a number of temporary areas will require creation and management. These include:

- A cement storage building, comprising either covered bulk bays or bulk cement storage hoppers.
- Covered sand storage bays.
- Open aggregate storage bays.
- Concrete and cement batching plants.
- A reinforcing bar bending shed. It is anticipated that most reinforcing structures will be constructed off site and trucked to the extended storage facility. This facility will perform minor remedial and bespoke bar bending operations only.

An alternative to the provision of a material stockpile area is to truck all material (including wet concrete) onto the site, directly to the point of use. This assumes that adequate concrete supplies can be derived in the locality of the CES facility.

7.2.9 Site Materials Storage Area

Site material will require relocation as a result of construction activities. Depending on the extended storage alternative under consideration, these will comprise:

- A waste rock storage area
- A top soil storage area

These storage areas will be extended/modified as a result of the staged construction of the storage facilities. The waste rock storage area will arise primarily from the excavation of the CRC alternative. The topsoil storage area will be used extensively in the CVST alternative, as a source of backfill material after trench wall construction, and as a source of material for the earthen cover.

The material in the site materials storage areas will be deposited and landscaped to ensure the site drainage requirements are met.

An alternative to the waste rock storage area is to crush the extracted rock material on site, then truck the crushed rock off-site. Unless a specific application for this material can be identified at the time of generation, the cost of off-site disposal may be prohibitively expensive.

7.2.10 Access Roads and Vehicle Compounds

The access roads will perform the following functions, and be constructed accordingly:

- Site access and distribution roads. These will be capable of carrying storage cask and cask transportation vehicles and on site laden storage cask transporters. All roads will be sufficiently wide to accommodate two-way traffic.
- Excavation haulage routes. These will be temporary haulage routes, laid across the site as necessary. They will permit the movement of haulage trucks from the points of excavation (after the stage 1 construction has been completed), to the site materials storage area. Spoil haulage will be routed off permanent site roads, as far as possible. On completion of all building stages of the extended storage facility, these haulage routes will be decommissioned and landscaped in line with site drainage requirements.
- Site monitoring and surveillance routes. These roadways will allow vehicular access to personnel engaged in monitoring the condition of the building structures and surface features of the underground alternatives, health physics surveys, and environmental monitoring, to reach identified locations around the site.

- Security vehicles access routes. In addition to accessing all areas of the site via the permanent roadways identified above, a peripheral security vehicle patrol road will be provided inside the fence line of the extended storage facility.

The majority of private vehicular parking will be provided inside of the perimeter security fence, but outside the restricted area. Suitable hard-standing areas will be provided local to site buildings.

During the construction phase, temporary vehicle compounds will be arranged on site for the storage and maintenance of excavation, earthmoving and haulage vehicles. On completion of all construction stages of the extended storage facility, these vehicle compounds will be decommissioned and landscaped in line with site drainage requirements.

8 Description of the Phases in Facility Development

8.1 SITING

It is assumed that the location of the CES facility will be selected through a siting process spanning several years.

In general terms, a suitable CES facility must have the following physical attributes:

- Well drained competent soil
- Geotechnically capable of supporting extended storage facility structures
- Location of water table at least 1m below surface
- Stable geomorphology
- Relatively flat site

The information outlined above is generic to each of the 4 selected alternatives, the information presented below highlights the specific requirements for the CVST and the CRC alternatives.

8.1.1 CVST

A site for the CVST complex is assumed to have the following conditions:

- Glacial till
- Stable geomorphology
- Geotechnically stable and capable of supporting extended storage facility structures and being excavated mechanically
- Location of water table at least 1m below surface, in relatively impermeable till
- Relatively flat site
- Borrow material for earthen cover available at site

8.1.2 CRC

A site for the CRC complex is assumed to have the following conditions:

- Stable limestone bedrock
- Relatively flat site
- Roof of storage caverns not exceeding 50m below ground surface
- Low permeability, large joint spacing, no faults, tight joints
- Construction of ~15m wide spans possible

- 20m of overburden

The CRC surface buildings will require:
- Well drained competent soil
- Geotechnically capable of supporting facility buildings
- Location of water table at least 1m below surface
- Stable geomorphology
- Relatively flat site

8.2 CONSTRUCTION

The construction phase will require the majority of buildings necessary for the long-term management of the facility to be constructed. In the construction phase, in addition to receipt and processing buildings, a limited capacity storage complex will be constructed.

The CES facility will be required to accept used fuel in various formats, over a number of years, in accordance with the fuel inventory, given in Table 1. The CES facility will receive module transportation cask consignments from years 18 to 42 of the fuel receipt operations. From year 22 to 47, dry storage casks will be received from donor sites (except for the SMV alternative). From year 35 to year 47, basket transportation cask consignments will be received.

It is therefore likely that basket storage capacity will not be provided until after the mid-point of this initial fuel receipt stage.

8.2.1 CVSB

The first stage of storage complex construction will provide a 7-year storage capacity for module casks. These will be housed in 4 storage buildings, linked to the processing building by an access corridor complex. The three subsequent storage complex construction stages will be completed during the operational phase.

8.2.2 SMV

The first stage of the modular vault complex construction will provide a 5-year storage capacity for module canisters. These will be housed in 1 storage building, which comprise a total of 20 individual storage vaults, and comprises one sixth of the total storage capacity. The first module storage building will be closest to the processing building and connected by the transfer flask rail link.

The five subsequent storage complex construction stages will be completed during the operational phase and will be added to the central transfer tunnel spine. The fourth stage will contain the basket storage tube vaults.

8.2.3 CVST

The construction of the CVST storage complex will comprise one access ramp, sixteen storage chambers, an access corridor, a ventilation corridor, four exhaust stacks connected to the ventilation corridor and four intake houses on top of the access corridor.

It is envisioned that the total construction for the CVST complex will occur in four stages. Four chambers housing casks will be constructed in the first stage. Construction of the first stage will start by digging an access ramp along the access tunnel and five meters deep excavation to accommodate the four chambers and associated corridors. The excavated material will be stockpiled for future use in constructing the earth cover on top of the chambers. The excavation will be done in sections to avoid disturbance of the native soil under the concrete structures. The excavated surface will be immediately covered by a free draining layer of compacted granular fill followed by thin layer of lean concrete formed to the shape of the underside of the floor slabs. Pipes encased in concrete for draining the space between the chamber walls and the perimeter perforated drainpipe will be installed as part of the preparation for construction of the floor slabs.

As each chamber and parts of the corridors at the front and the back will be structurally independent and separated by isolation joints from adjacent chambers, construction of the chambers can proceed sequentially completing one chamber at a time or simultaneously completing all floors then all walls then all roofs. The end of the corridors will be closed by concrete walls designed as knockout panels, to be removed after completion of the adjacent stages.

After completing construction of the concrete structures to be covered by earth, the outside surface of the walls and roof slabs will be coated with the protective polymer coating. The drainage system will be completed by installing the perforated pipes between the walls. The earth cover will be constructed in the sequence described in section 5.3.4.

8.2.4 CRC

The construction of the CRC complex will comprise two access ramps, three ventilation shafts, an access corridor for cask placement, a ventilation corridor for exhaust air and a total of 11 storage caverns. The ventilation shafts will be equipped with ladders to provide emergency exits.

All underground construction work will be conducted in such a manner as stipulated in the Occupational Health and Safety Act and Regulation for Mines and Mining Plants for the Province of Ontario.

It is envisioned that the total construction for the CRC complex will occur in 3 stages. The staged approach provides for simultaneous placement of the casks and construction activities. The stages have been scheduled such that an empty storage cavern will remain between the placement operations and construction. This will minimise the effects of blasting vibrations on the placement of the casks.

Stage 1 construction of the CRC complex will commence with the development of an access ramp from surface. The ramp will be developed at a gradient of –7%. During this time ventilation will be provided by fans blowing air into the working area.

The primary focus for initial development work will be to establish a complete ventilation circuit. This will involve partial construction of the access ramp (-7% grade), development of the top half of the first storage cavern (at 0% grade), and then development of the ventilation raise. Once

the ventilation shaft has been completed, an exhaust fan will be installed and the ventilation can then be converted from a blowing to an exhausting system.
Once the ventilation system has been established the access ramp will be completed and the first cavern will be constructed to it full dimensions. Next, the main access and ventilation corridors will be constructed and then the remaining rock caverns. Pillars left between the storage caverns will be 35m in width. The pillar design criteria used for the CRC complex included the depth of cover, the estimated rock compressive strength, the cavern dimensions and a safety factor that considered the required longevity for this excavation.

In all, 5 storage caverns will be constructed during Stage 1. This will provide sufficient storage capacity for 7 years of fuel cask deliveries. It will also provide additional capacity to enable Stage 2 construction and the continued delivery of casks to proceed uninterrupted.

Also constructed during Stage 1 will be sections of the access and ventilation corridors and a second ventilation shaft. This will enable the Stage 2 construction to establish a ventilation circuit in a more timely fashion.

8.2.4.1 Waste Rock Disposal

An estimated 1.9 million cubic meters of broken rock will be excavated during construction of the entire CRC complex. This quantity was based on an assumption that the average swell factor for excavated rock would be 35%.

During construction, waste rock will be hauled and stockpiled in a storage area. This stockpile will be constructed in 2 x 12m lifts. Once the 12m lift has completed a safety berm will be left and a second 12m lift will be constructed.

The stockpile lifts will be constructed by end-dumping the material and allowing it to assume its natural angle of repose. For broken rock, the typical angle of repose is 37^{o}. When construction of the CRC complex has been completed and the waste stockpiling facility is no longer required, the stockpile will be undergo site reclamation.

During site reclamation the stockpile will be re-sloped using bulldozers to 26.5^{o} or 2:1 slope. Once the stockpile has been re-sloped the topsoil stored in the salvage stockpile will be hauled and spread over the waste rock. It will then be re-vegetated and returned to a more aesthetically appealing state.

During construction of the CRC complex and the waste rock storage facility it is envisioned that the site reclamation can be carried out progressively rather than at the end of construction. Management of the waste stockpile facility will also involve collection of run-off water so that it can be properly handled. Collected run-off water will be carried in drainage ditches to the sedimentation/retention ponds where it will be monitored and, if necessary, treated prior to its release back into the environment.

8.3 OPERATIONS – INITIAL FUEL RECEIPT

Initial fuel receipt covers the used fuel being brought to the CES facility using one of the following mechanisms:

- Used fuel bundles contained within baskets, shipped in the basket transfer flask, (3 baskets per flask)

- Used fuel bundles housed within modules, shipped in the Irradiated Fuel Transportation Cask (IFTC) 2 modules per cask
- Used fuel bundles in dry storage containers, shipped as a storage cask transport system, including the sealed, complete cask with impact limiters and tie down equipment. (4 modules per cask = 384 fuel bundles)

Regardless of the concept being considered and the transfer mechanism employed for the used fuel transfer, the major process operations are the same, these major process operations include:

1. Security personnel to review the receipt package manifest, to verify the origin, documentation and unique identification for each shipment
2. Health physics technicians to perform a radiological survey of the external surfaces of the receipt package.

If the shipping documentation is correct and the package passes the radiological survey the receipt package is transferred into the processing area of the facility.

3. The receipt package will be unloaded from the transport vehicle awaiting subsequent operations
4. Depending upon the package received the following actions can be taken,
   a) Storage casks will be transferred directly to the relevant storage complex, using the cask transporter
   b) Fuel baskets or modules will be directed to the shielded cell for conversion into the correct fuel ‘housing’ for the relevant storage concept.
5. After ‘conversion’ in the shielded cell the used fuel is transferred to the appropriate storage concept ready for emplacement.

The initial fuel receipt event will be a relatively short duration stage within the operational phase. This 30-year stage will be predominantly dedicated to the receipt and processing of the fuel inventory and transfer of appropriate fuel containers to a storage building/cavern complex. It is assumed that these receipt, processing and transfer operations are performed for 230 days per year. The staffing requirements for the operations phases are identified in Section 9.4.

The storage capacity of the CES facility will be extended in a number of post operational stages, which will provide additional storage capacity. It may be necessary to develop several years of additional capacity during each stage, if this offers economies in site construction costs. Subsequent stages will be constructed sufficiently in advance of operational requirements.

8.3.1 CVSB

In addition to the storage capacity identified above, three further construction stages will each add a further 7 year capacity for module casks, by the addition of 4 further storage buildings in each (except the final stage, where 5 buildings will be added).
Basket casks will be housed vaults in dedicated storage buildings. Two storage buildings will be constructed in the 3rd stage, and 2 further buildings in the 4th stage. The staged construction will require progressive construction of the interconnecting cask transporter corridors. Construction activities will be segregated from storage operations.

8.3.2 SMV

The SMV complex will expand by the addition of further storage buildings to the transfer tunnel ‘spine’. Each additional building will provide a further 5-year storage capacity. The 4th (of 6) stage expansion will include the fuel basket storage capacity. Each building erected must be provided with charge machine access to the transfer tunnel spine. It will be necessary to provide the early buildings will a ‘temporary’ end wall, to maintain the completed modular vaults in a weather tight condition. As staged development of the SMV storage complex proceeds, these dividing walls are progressively removed to connect all storage buildings to the transfer tunnel spine.

8.3.3 CVST

Construction of the other three stages will be performed following essentially the same procedure during Stage 1 construction, except the excavation will be done against the sidewall of the previous stage. Also, as part of the third stage, the concrete vaults for basket storage will be constructed before construction of the roof slabs.

Four chambers housing casks will be constructed in the second stage on one side of the original construction. Two chambers housing vaults and two chambers housing casks will be constructed in the third phase on the other side. The last four chambers housing casks will be constructed in Stage 4, adjacent to the third stage. The construction of each phase will be timed to meet the estimated 30-year placement schedule. The phased approach requires simultaneous storage and construction activities to be performed.

8.3.4 CRC

Stage 2 construction will essentially follow the same sequence as Stage 1. A second access ramp will be developed and again the priority will be to establish the ventilation circuit. Once established, the construction activities and the placement of the storage casks will continue on separate ventilation systems.

During the Stage 1 construction, a portion of the access and ventilation corridors for the Stage 2 will have been constructed and a second ventilation shaft will have been developed. Concrete block bulkheads will be constructed in the access and ventilation corridors to isolate construction activities from cask placement operations. Once the Stage 2 construction work has been completed these bulkheads will be removed.

The total construction for Stage 2 will comprise a second access ramp and 3 additional storage caverns.

During the Stage 2 construction, cavern development proceeded in the direction from the second access ramp towards the Stage 1. In Stage 3, the development will proceed in the opposite direction. A concrete block bulkhead will be constructed to isolate the placement of casks from the Stage 3 construction activities. The second access ramp will be used to provide ventilation. Establishing the ventilation circuit in Stage 3 will require the construction of one of the storage caverns and the development of the third and final ventilation shaft. Once the ventilation shaft has been completed, an exhaust fan will be installed and the ventilation can then be converted from a forced inlet system to a forced extract system.

The total construction for Stage 3 will comprise a third ventilation shaft and 3 additional storage caverns.

8.4 OPERATIONS – EXTENDED MONITORING

The extended monitoring stage of the operational phase will be a relatively dormant phase. The principal activities undertaken during the extended monitoring stage are described in sections 9.2.3 and 9.2.4. Staffing requirements are outlined in section 9.4.

With particular respect to the CVST, buried concrete structures, if designed and constructed to meet stringent quality control requirements and the temperature and humidity inside is maintained within a moderate range, will last for hundreds of years essentially maintenance free. However, a program for periodic checking of the concrete floors, walls and roofs for signs of deterioration will be established as part of the monitoring program. The ventilation system will have to be to checked periodically to ensure that it is functioning satisfactorily. The internal drainage systems will have to be checked to ensure that the pumps are in good operating condition and that the trenches and collection sumps are free of sediments. The outside drainage systems and the level of the ground water table will also have to be monitored to ensure that the perforated pipes are not blocked and the collection sumps and pumps are in good operating condition. Signs of leakage of water from precipitation through the HDPE geomembrane will also have to be monitored.

8.5 OPERATIONS – FACILITY REPEATS

It is recognised that the storage facilities and principal containment structures have a finite life span. Thus it will be necessary to move fuel baskets, module canisters and storage casks from an ageing storage complex to new facilities. Depending on the alternative under consideration, this may be achieved by the staged building of additional storage capacity on the site, permitting the transfer of fuel containers from one storage location to another. Once the used fuel has been transferred and the storage unit has been emptied, the redundant building will be demolished, and a replacement unit constructed. Through use of this ‘rolling program’ of demolition and renewal, it will be unnecessary to set aside twice the total storage area, for current and future needs. Rather, the facility renewal process will be accomplished within the land area required for storage of the total fuel inventory, with an additional limited area to ‘prime’ the transfer cycle.

It is assumed that the storage structures will receive suitable maintenance throughout their service lives, but may ultimately deteriorate, due to normal wear and tear, and weathering processes. Periodically, the storage facilities will be replaced or refurbished, appropriate to the extended storage alternative under consideration. In some instances, the extended storage facility may be beyond repair. It is assumed that the order in which the individual units (storage buildings, modular vaults, tunnels or caverns) reach the end of their service life will replicate the order in which the facilities were constructed.

Broadly, the steps necessary to perform a building repeat cycle are:

- Construction of a new storage facility,
- Provision of appropriate fuel package handling equipment,
- Establish a fuel transfer route,
- Transfer fuel packages from the redundant storage facility,
- Refurbish empty storage facility, if appropriate,
- Demolish empty storage facility, if appropriate.

There may be a significant delay in the refurbishment of the vacated facility, particularly trenches or caverns in the underground storage alternatives. For example it is likely that the (module or basket) storage casks in the CRC alternative will be transferred from one underground location to another. The particular cavern vacated will only need to be refurbished immediately prior to a requirement for its reuse.

A similar refurbishment strategy could be implemented for the CVST alternative, although it lies in relatively close proximity to the land surface. It may be preferable to locally remove the earthen cover, to expose the redundant trench structure, remove it and any empty storage structures within, and build a new trench structure in its place.

8.5.1 CVSB

8.5.1.1 Facility Repeats for Storage Cask Buildings

Facility repeats for storage casks are engineered by the progressive transfer of storage casks from an old storage building to a new storage building.

The facility repeat sequence will comprise:

- Staged building of one new storage building adjacent to the existing storage facility.
- Storage cask transfer is achieved using a storage cask transporter.
- Transfer between storage buildings will be performed on site roads with suitable load bearing capacity.
- Once the old storage building has been emptied, the building structure and floor slabs will be dismantled. The concrete will be crushed and reinforcing bar removed for separate disposal.
- Once the storage building site is cleared, a replacement base slab, and replacement storage building structure will be erected.

Each storage cask building will house 520 module storage casks, which will be approximately 1.67 years receipt of storage casks. The building demolition activities will only commence once a building has been emptied. Assuming there will be effort dedicated solely to storage cask transfers in one year, this will equate to a cask transfer rate of 2.3 storage casks per day, to empty an existing storage building.

8.5.1.2 Facility Repeats for Fuel Basket Vault Buildings

Facility repeats for fuel basket vaults are engineered by the progressive transfer of fuel baskets from vaults in an old storage building to a new storage building.

The facility repeat will comprise:

- Staged building of one storage building and vault array adjacent to the existing storage facility.
- Fuel basket transfer is achieved using powered bogies, each carrying a basket transfer flask.
- An offloading and a reloading gantry crane are required to effect fuel basket retrieval and placement operations. A gamma gate is needed at both the existing and new vault storage tubes, to permit safe vault tube shield plug removal and fuel basket removal/placement operations. In addition, a shielded housing is required at both storage vaults, to facilitate safe handling of the shield plugs removed from the storage vaults during fuel basket removal/placement operations.

- Once the old storage building is emptied, the storage building, the vault array and slabs can be dismantled. Vault liners, and plugs are monitored for contamination and disposed of accordingly. Concrete can be crushed and reinforcing bar removed for separate disposal.
- Once a storage building site is cleared, a replacement base slab, vault array and storage building structure will be erected.

Each basket vault building will house in 1,200 fuel baskets (72,000 fuel bundles) in 6 storage vaults. A storage building will house approximately 2.5 years receipt of fuel baskets. The building demolition activities will only commence once a building has been emptied. Assuming there will be effort dedicated solely to storage fuel basket transfers in one year, this will equate to a transfer rate of 5.3 fuel baskets per day, to empty an existing storage building.

8.5.2 SMV

8.5.2.1 Facility Repeats for Module Canister Storage Buildings

Facility repeats are engineered by the progressive transfer of module canisters from one surface modular vault to another.

The facility repeat will comprise:

- Staged building of one surface modular vault array adjacent to the existing facility.
- Withdrawal of a module canister from an existing storage tube, into the charge machine. Discharge of the module canister into a rail mounted shielded transfer bogie, in the transfer corridor below. Movement of the shielded canister to the new modular vault receipt port, followed by withdrawal of the module canister into a second charge machine. The second charge machine will then deposit the module canister into the appropriate storage tube.
- Once the old modular vault has been emptied, the building will be isolated from the remaining modular vault buildings and the common charge machine transfer corridor, by the erection of a weatherproof end wall.
- Once isolated, the empty store can be demolished. Storage tube liners, and plugs are monitored for contamination and disposed of accordingly. Concrete can be crushed and reinforcing bar removed for separate disposal.
- Once a redundant modular vault building has been cleared a modular vault building is constructed and reconnected with the remaining facility.

A modular vault building (comprising 20 individual vaults) has the capacity to store 1600 module containers, which represents approximately 5 years storage capacity. Transfer from an existing storage building to another requires the operation of two charge machines and shuttle transfer of a shielded trolley in the transfer tunnel. The building demolition activities will only commence once a storage building has been emptied. Assuming there will be effort dedicated solely to module canister transfers for two years, this will equate to a transfer rate of 3.5 module canisters per day to empty an existing storage building.

8.5.2.2 Facility Repeats for Fuel Basket Storage Buildings

Facility repeats are engineered by the progressive transfer of fuel baskets from one dedicated surface modular vault to another.
The facility repeat will comprise:

- Staged building of one surface modular vault array adjacent to the existing storage modular vault complex.

- Fuel basket transfer is achieved using bogies, each carrying a basket transfer flask.
- An offloading and a reloading gantry crane are required to effect fuel basket retrieval and placement operations. A gamma gate is needed at both the existing and new vault storage tubes, to permit safe vault tube shield plug removal and fuel basket removal/placement operations. In addition, a shielded housing is required in both modular vault buildings, to facilitate safe handling of the shield plugs removed from the modular vaults during fuel basket removal/placement operations.
- Once the old modular vault has been emptied, the building will be isolated from the remaining modular vault buildings, by the erection of a weatherproof end wall. The redundant modular vault building, vault array and slabs can be dismantled. Storage tubes liners and plugs are monitored for contamination and disposed of accordingly. Concrete can be crushed and reinforcing bar removed for separate disposal.
- Once a redundant modular vault building has been cleared a new modular vault building is constructed and reconnected with the remaining facility.

The 4,717 basket inventory is stored within 10 half vaults, in one storage building. The transfer of baskets from an existing building to a new building requires a transfer flask and a suitable transport bogie. It also requires the availability of a basket handling crane in each vault building. Assuming there will be effort dedicated solely to basket transfers for approximately four years, this will equate to a transfer rate of 5.3 basket transfers per day, to empty an existing storage building.

8.5.3 CVST

8.5.3.1 Facility Repeats for Storage Cask Storage Trenches

Facility repeats for storage casks are engineered by the progressive transfer of storage casks from an old storage trench to a new storage trench.

The facility repeat will comprise:

- Staged building of one storage trenches (comprising 2 bays) adjacent to the existing storage facility.
- Storage cask transfer is achieved using a storage cask transporter. This transporter moves the storage cask from one trench to another. Where storage casks are stacked, a gantry crane is used to lift the upper tier storage cask and lower it to floor level. A similar gantry crane is used to re-stack the storage casks in the new trench.
- Once the old storage trench has been emptied, the earthen cover is removed, and the concrete roof, wall and floor slabs will be dismantled.
- The concrete will be crushed and reinforcing bar removed for separate disposal.
- Once a storage trench has been cleared a replacement storage trench is constructed and the earthen cover restored.

A shallow trench (comprising 2 bays) has the capacity to store 612 storage casks, which represents approximately 2 years storage capacity. Transfer from an existing trench to another requires the operation of a cask transporter and gantry cranes in each trench. The trench demolition activities will only commence once both bays have been emptied. Assuming there will be effort dedicated solely to storage transfers for two years, this will equate to a transfer rate of 1.4 storage casks per day, to empty an existing storage trench.

8.5.3.2 Facility Repeats for Fuel Basket Storage Trenches

Facility repeats for basket vaults are engineered by the progressive transfer of fuel baskets from vaults in an old storage trench to a new storage trench.

The facility repeat will comprise:

- Staged building of one storage trench adjacent to the existing storage trench.
- Fuel basket transfer is achieved using powered bogies, each carrying a basket transfer flask.
- An offloading and a reloading gantry crane are required to effect fuel basket retrieval and placement operations. A gamma gate is needed at both the existing and new vault storage tubes, to permit safe vault tube shield plug removal and fuel basket removal/placement operations. In addition, a shielded housing is required at both storage vaults, to facilitate safe handling of the shield plugs removed from the storage vaults during fuel basket removal/placement operations.
- Once the old storage trench is emptied, the storage trench, the vault array and slabs can be dismantled. Vault liners, and plugs are monitored for contamination and disposed of accordingly. Concrete can be crushed and reinforcing bar removed for separate disposal.
- Once a storage trench has been cleared a replacement storage trench is constructed and the earthen cover restored.

A shallow trench (comprising 2 bays) has the capacity to house 12 basket vaults, which represents approximately 6.5 years storage capacity. Transfer from an existing trench to another requires the operation of a basket transfer flasks, powered trolleys and gantry cranes in each trench. The trench demolition activities will only commence once both bays have been emptied. Assuming there will be effort dedicated solely to basket transfers for two years, this will equate to a transfer rate of 5.3 baskets per day to empty an existing storage trench.

8.5.4 CRC

8.5.4.1 Facility Repeats for (module or basket) Storage Casks Caverns

Facility repeats are engineered by the progressive transfer of storage casks (modules and baskets) from an ‘old’ cavern to a ‘new’ cavern.
The facility repeat will comprise:

- The outfitting of a buffer cavern(s) adjacent to the existing storage cavern complex.
- Storage cask transfer is achieved using a storage cask transporter. This transporter moves the storage cask from one cavern to another. Where storage casks are stacked, a gantry crane is used to lift the upper tier storage cask and lower it to floor level. A similar gantry crane is used to re-stack the storage casks in the new cavern.
- As old caverns are emptied, they will be refurbished so that they can accept storage casks for another storage cycle. Refurbishment activities may include repair of the rock cavern walls, repair and/or replacement of floor slab and any other concrete structures, repair and/or replacement of drainage systems, and repair and/or replacement of services in the cavern. A refurbished cavern will constitute a “new” cavern.

A storage cavern has the capacity to store 948 module storage casks, which represents approximately 3 years storage capacity. Transfer from an existing cavern to another requires the operation of a cask transporter and gantry cranes in each cavern. The cavern refurbishment activities will only commence once the cavern has been emptied. Assuming there will be effort dedicated solely to storage transfers for three years, this will equate to a transfer rate of 1.4 storage casks per day, to empty an existing cavern.

The cavern dedicated to the 678 basket storage casks will be emptied at a similar rate (approximately 1.5 per day). It will take approximately 2 years to effect the transfer of the total basket cask cavern content.

8.6 OPERATIONS – REPACKAGING

8.6.1 General

Periodically, and on a longer timeframe than storage facility repeats, the used fuel bundles will be removed from their existing packages (storage casks, baskets or module canisters) and transferred to new packages. This transfer will be effected within a shielded facility. Although some of the operations are similar to those which will be effected in the processing facility deployed after initial fuel receipt, as described above, the infrequency with which these operations will occur probably preclude the long-term care and maintenance of the original facility. Only limited facilities will be required to support the Storage Building Complex during the long term storage period so new facilities will be constructed at the appropriate time. An outline description of the facility design, including a layout and staffing levels, is included in the conceptual design to provide sufficient information for the cost estimate of the repackaging cycle.

Depending on the requirements of the alternative, the used fuel repackaging facility will perform some of the following functions. It is assumed that the repackaging facility will comprise a shielded cell complex, housed within a large building. The building will be capable of receiving storage casks, delivered by a storage cask transporter, or baskets or module canisters in shielded flasks, delivered on suitably powered trucks. When the alternative involves the handling of storage casks, the building will have an 80 tonne crane to allow safe movement of the storage cask. The used fuel repackaging facility will also have the necessary facilities for the removal of existing storage cask body/lid seal welds. In addition, the building will include storage cask closure weld completion and testing facilities (for repackaging facility layouts, refer Figs. 7.1 for CVSB and CVST, Fig. 7.2 for SMV, and Fig. 7.3 for CRC).

The shielded cell complex will be capable of allowing the opening of the storage casks, withdrawal of the modules and withdrawal of fuel bundles from the modules. The fuel bundles will be transferred to ‘fresh’ modules, which will then be loaded into a new storage cask. Where basket storage casks are employed, a similar shielded cell will be configured to accept the taller basket storage cask, and permit the removal of fuel baskets stored within.

Similarly, the shielded cell complex will permit the opening of seal welded baskets and the withdrawal of the fuel bundles within. The fuel bundles will be inserted into ‘fresh baskets’, and the basket assembly seal welded.

In addition, the shielded cell complex will have the capability to open module canisters, withdraw the existing modules, transfer fuel to ‘fresh’ modules and encase these modules in a new welded canister.

8.6.2 Alternative Strategies for Repackaging

The repackaging event will provide the opportunity for the possible optimisation of the storage medium, by transferring all fuel bundles to a common fuel container type, and returning these containers to an optimised storage facility for further periods of extended storage. This has the potential long-term benefits:

- Introduces common handling techniques for all fuel containers
- Potential improvements to fuel packing densities
- Take benefit from changes in fuel bundle heat generation and radioactive inventory
- Revised fuel container may allow prolongation of fuel condition
- Potential reductions in future waste arisings (from fuel containers and facility repeats)
- Smaller footprint for storage facility

This report does not seek to identify a specific fuel container, to which all fuel bundles will be re-consigned. Each alternative presently identifies different storage arrangements for module and basket fuels. The repackaging event provides the opportunity for conversion of fuel from one format to the other, or into an alternative form. As repackaging events are relatively infrequent, this time-scale permits consideration of the most appropriate fuel storage arrangement, and proposals for change can be efficiently managed within this time-scale.

Any revised fuel storage arrangements are unlikely to substantially alter the life-time cost estimation of the proposed extended storage facilities. This report assumes the fuel inventory is stored indefinitely in the format identified in optioneering phase of this study, and identified in the conceptual design study Design Basis Document (DBD).

An alternative strategy to the use of shielded cells is to effect the fuel bundle transfers from one fuel container to another during the repackaging event, using a small pool facility, similar to the wet bays already used by the fuel owners for fuel storage and existing fuel package loading. The advantages and disadvantages of this technique were discussed during the optioneering phase, with particular emphasis on long term storage of fuel in wet bays. This storage method was discounted at this stage. By comparison, the fuel transfer during the repackaging event is a relatively short duration process.

The advantages of wet bay fuel transfers are:
- Allows relatively flexible fuel transfer routines to be executed, under a water cover
- Lends itself to buffer storage of fuel bundles within the wet bay

The disadvantages of wet bay fuel transfers are:
- Requires maintenance of water cover throughout repackaging operations
- Increased maintenance of wet bay facility, by comparison to shielded cells
- Re-wets fuel bundle and new fuel container externals, with possible consequences for fuel bundle corrosion and radio-nuclide leaching

On balance, this alternative strategy to use wet bays in preference to shielded cells for fuel repackaging has been discounted.

8.6.3 Repackaging Operation Facilities

The table below assists in describing the repackaging operations applicable to each alternative. The operations are described briefly.

Table of Repackaging Operations

Alternative	Storage cask de-lidding operations	Module fuel transfer operations	Module canister fuel transfer operations	Basket fuel transfer operations
CVSB	√	√		√
SMV			√	√
CVST	√	√		√
CRC	√	√		√

8.6.4 Storage Cask De-lidding Cell

The purpose of the storage cask de-lidding cell will be to take receipt of a prepared storage cask, and allow the safe removal of its contents. A de-lidding cell will be required for the CVSB and CVST alternatives, to handle module storage casks. The CRC alternative will utilise one de-lidding cell for module storage casks and a second de-lidding cell to handle basket storage casks.

Typically, a storage cask will be retrieved from the appropriate facility, and delivered to the repackaging building. Following storage cask set down by the transporter, the storage cask will be prepared by the removal of the storage cask seal weld. This will need to be done in a ventilated enclosure, with personnel wearing suitable respiratory equipment in case there is a build up of active gas in the cask from failed fuel pins. This activity is followed by the application of storage cask lid transport clamp, and the attachment of a dedicated lifting beam to the storage cask lid. The lid transport clamp will ensure the storage cask lid is retained on the cask body during subsequent lifting operations within the used fuel repackaging facility. The dedicated storage cask lid lifting beam will comprise a three-legged lifting beam, which overlays and couples with the eye bolt holes in the storage cask lid. This tri-form beam will have a central lifting pintle, to permit remote removal of the storage cask lid.

The prepared storage cask will be lifted onto a robust transfer bogie, prior to entering the shielded cell. This self-powered bogie will run on floor mounted rails, and will have a jacking capability.

The transfer bogie will travel through a maintenance/decontamination cell and enter the de-lidding shielded cell, by the sequenced opening and closing of the intervening shield doors. Once isolated in the de-lidding cell, the cask lid transport clamp will be released remotely, and the cask lid transport clamp and removal mechanism will be raised clear of the storage cask lid. The central pintle of the tri-form clamp will then be engaged remotely, and a lifting mechanism will hoist the storage cask lid clear or the storage cask body.

The storage cask body will then be moved forward, and positioned beneath a closed port, leading to the appropriate repackaging cell above. The transfer bogie will then raise the storage cask body to the underside of the closed port. The storage cask body will make contact with an elastomeric seal around the port aperture, and the transfer bogie will be isolated in this raised position.

Following opening of the cask port shield hatch, the contents of the storage cask are removed into the repackaging cell, using the in cell handler, and the shield hatch closed.
In the case of module storage casks (CVSB, CVST and CRC), the storage cask will be re-lidded, by a reverse of the content withdrawal sequence, before exiting the de-lidding cell. The emptied modules will be removed from the repackaging cell via a different route.

In the case of the basket storage casks (CRC), the storage cask will exit the de-lidding cell after removal of its basket payload, since emptied baskets will be removed from the fuel basket repackaging cell via a different route.

The de-lidding cell will also serve as the filling route for new storage casks, which will be presented under the cask port shield hatch and receive newly filled fuel modules or fuel baskets as appropriate.

8.6.5 Fuel Module Repackaging

The fuel module transfer operations will be performed in a dedicated shielded cell (Refer Figs. 7.4 and 7.5). For CVSB and CVST alternatives, these operations will be performed once existing modules have been withdrawn from storage casks, described above. The CRC alternative will transfer fuel from an existing module to a new module by the same method described in this section. For the SMV alternative, the receipt and disposal of the existing modules follows a separate routine, since the fuel modules arrive at the repackaging cell in a module canister, and the disposal routes for existing modules and module canisters is different from the CVSB and CVST alternatives. These differences will be identified in a later section.

To execute a fuel module repackaging event, the existing fuel modules will be brought into the repackaging cell and set down on four dedicated positions, using the in cell handler. Following closure of the cask port aperture, four new modules are sequentially introduced through the shielded cell roof, via a dedicated shielded port. Each new module will be transferred and set down on four dedicated positions.
The module repackaging operation will be performed by a dedicated transfer mechanism, which comprises a moveable table and a through wall push rod mechanism. The table will have limited x axis and z-axis movement. The table will accommodate an existing fuel module and an empty new module, lying transversely on the table. The through wall push mechanism will have limited travel extendable rams, which will push the fuel bundles from the support tubes of existing module in into the new module. In combination with the table movements, all the fuel will be progressively transferred from the existing module.

The sequence will be performed four times, until all the fuel bundles have been transferred from the four existing fuel modules, into the four new modules. These modules will be returned to separate storage positions, as the fuel transfer operation progresses. By setting these storage positions at differing heights within the shielded cell, the support tubes of each module will be directly observed, via viewing windows in the cell walls. This will allow the operator to confirm that fuel bundles have been successfully relocated from existing modules to new modules.

The existing (now empty) modules will be discharged from the shielded cell into an existing storage cask, positioned beneath the cask port shield hatch.
The new modules (now filled) will be discharged from the shielded cell into a new storage cask, positioned beneath the cask port shield hatch.

8.6.6 Module Canister Repackaging

The fuel module transfer operations within the module canister repackaging cell will be performed in a similar manner to that described above. The principal differences will be:

- Receipt of existing module canisters
- Discharge of newly filled module canisters
- Disposal of empty module canisters and empty fuel modules

The existing module canisters will be received from the SMV storage facility contained in a module canister transfer flask, on board a transfer trolley with jacking feature (Refer Fig.7.10 and 7.11). The flask trolley is positioned in the receipt bay beneath a shield hatch in the shielded cell floor. The flask is raised to maintain a seal and both the receipt port hatch and the transfer flask shield hatches are opened. The module canister is then lifted into the cell using the in-cell handler, and transferred onto an in-cell transfer bogie, which will then shuttle the module canister into a de-lidding cell.

Within the de-lidding cell, the module canister closure lid to body seal weld will be machined or ground off. Any gaseous fume and weld grinding particulate will be contained within the dedicated cell, and drawn off via a local ventilation extract system.

The module canister body and loose lid will be returned to the main repackaging cell. The module canister lid will then be removed and set down locally, before the fuel modules are withdrawn from the existing module canister. These are routed to the appropriate fuel bundle set down positions, in readiness for fuel bundle transfer operations, as previously described. New module canisters are loaded in to the repackaging cell via a dedicated transfer flask route. The flask is positioned on the shielded cell roof, and the new module canister will be lowered into the shielded cell, via a dedicated shielded port. The module canister lid is loosely positioned on the canister body. After the new module canister has been set down, the lid is removed and set down locally. New fuel modules are then loaded into the module canister, and the lid replaced.

The module canister will then be lifted onto an in cell transfer bogie, which will shuttle the module canister into a welding cell. Following completion of the welding operations (canister lid to body) the in cell transfer bogie will return the module canister to the main shielded cell. The welded module canister will then be lifted from the in-cell transfer bogie using the in-cell handler, and lowered through the cell floor shield hatch, into the module canister transfer flask.

The existing (now redundant) modules and module canisters will then be discharged to dedicated decontamination cells, set below the module canister repackaging cell.

8.6.7 Fuel Basket Repackaging

The fuel basket transfer operations will be performed in a dedicated shielded cell (Refer Figs 7.8 and 7.9). For the CVSB, CVST and SMV alternatives, the cell will handle a feed of individual fuel baskets. Each basket will be recovered from the existing storage facility by the means described in the facility repeats section. Rather than going directly to a new storage facility, the basket will be diverted to the repackaging cell, and loaded through the shielded cell roof, via a dedicated shielded port.
The existing basket will then be transferred to a dedicated position within the cell, using an in cell handler. The peripheral seal weld and the central lifting post welds will be machined or

ground off. Any gaseous fume and weld grinding particulate will be contained within the dedicated enclosure, and drawn off via a local ventilation extract system. The existing basket is then returned to its set down position, and the basket lid lifted from the basket body. Concurrent with the basket grinding operations, a new basket will be loaded into the cell. The new basket lid will then be lifted clear of the body.

Within the shielded cell, a fuel bundle transfer hoist will be deployed. The machine will have two set down positions, one for the existing basket body, complete with fuel bundles, the second set down position will accept the new basket body. The two basket bodies will be aligned (either by rotation of two turntable bases on which the baskets will sit, or the in cell handler will employ an optical recognition system) to permit accurate fuel bundle transfer operations.

The fuel bundle transfer hoist will comprise a lightweight x-y motion crane, with a z-axis retractable mast. The hoist will be furnished with a 4-jaw grab, which will have a limited gripping effect. The operator, viewing the procedure through shielded windows and cameras as appropriate, will hoist, cross travel and lower individual fuel bundles from the existing basket to the new basket. Once the transfer process has been completed, the basket lids will be returned to their respective bodies and the baskets returned to their set down positions, using the in cell handler.

The new basket, with fuel bundle contents, will then be transferred to an in cell basket transfer bogie, which will shuttle the fuel basket into a basket welding cell. Following completion of the welding operations (basket lid to base, and basket lid to central lifting post), the in cell basket transfer bogie will return the fuel basket to the main shielded cell. The in cell transfer bogie will be aligned with a dedicated shielded port in the cell roof, and the fuel basket winched into a shielded transfer flask.

The now redundant basket will be lifted from its dedicated set down position, and lowered through a shielded hatch into a decontamination cell, located at a level below the shielded cell. The shielded cell dedicated to basket storage casks stored in the CRC alternative will function in a similar manner to that describe above. The notable difference will be the inclusion of a floor port and shielded hatch, and dedicated basket-stacking positions within the shielded cell, to receive the 7 existing baskets, which will be conveyed to the shielded cell in a basket storage cask (refer Figs. 7.6 and 7.7). Once this transfer has been effected, the empty basket storage cask will be released from the cell below, and the fuel bundle transfer operations will commence, taking existing baskets from the dedicated basket stacking positions.

9 Waste Management, Monitoring, Maintenance & Staffing

9.1 WASTE TREATMENT AND ARISINGS

9.1.1 Decontamination

Decontamination activities apply both to facilities employed on the CES site and to redundant fuel containers. Other items, such as redundant charge machines and on-site transfer flasks and in cell bogies may need aggressive decontamination to remove potentially ground in contaminants. It is intended that the majority of materials will be decontaminated sufficiently so that they are free-releasable. In limited instances, contaminated materials will be transferred to off-site storage/disposal locations, appropriate to their level of residual contamination.

It has been assumed throughout this concept that spread of radioactive contamination will be minimised within receipt, processing and repackaging cells by good detail design and attention to the process operations. Regulation of ventilation flows throughout the shielded cells will ensure back diffusion of airborne contaminants do not occur.

There may need to be periodic cleaning of the shielded cell internals and the in cell cranes and handlers, to ensure levels of contamination do not rise to levels which require remote decontamination of the facilities.

Further, as the levels of contamination on fuel containers has not presently been confirmed by direct measurement, the initial approach is to conservatively assume that all material may be heavily contaminated, until proven otherwise. Consequently, the discharge of any material from the repackaging cells will be via shielded transfer cells, where remote monitoring, vacuuming and swabbing operations will be performed. (Refer Figs. 8.1 to 8.5).

Where more aggressive decontamination techniques are applied, it is assumed these will employ water jetting, chemical dissolution of the surface layers or material removal by mechanical abrasion [6]. Once complete, and contamination levels have been appropriately reduced, hands on techniques may be applied to residual areas of contamination.

9.1.2 Dismantling

Dismantling applies both to fuel processing and storage facilities employed on the CES site.
It is assumed that decontamination activities will reduce radioactive contaminant levels sufficiently within fuel receipt, processing and repackaging cells to facilitate the decommissioning of the majority of these facilities by normal dismantling and demolition techniques. It may be necessary to implement specific contaminant control measures during the post operative clean out operations, including the removal of shielded cell stainless steel cladding, handling equipment and any active drainage systems from these facilities, and avoiding the generation of significant quantities of secondary contaminated waste. Active waste will be routed off-site to appropriate ILW and LLW disposal locations. Conventional construction materials will either be recycled, or directed to appropriate landfill sites.

The inactive materials from redundant facility demolition can be segregated during the dismantling/demolition process. Since the majority of the material arisings is bulk shielding, providing radioactive contaminants have been removed from the surface layers (shielded cell cladding and paint finishes), the majority of materials will be suitable for free release. Materials will simply be cut up, size reduced and trucked off to a disposal site.

There may be some accumulation of materials over limited periods, but it has been assumed that most waste materials will ultimately be disposed off-site. . Some uncontaminated materials could be recycled (such as aggregates) for use in future building stages.
The relatively small quantities of contaminated metal waste generated are assumed to be disposed off-site. However it is possible that these metals could be re-melted for reuse within the CES facility.

During demolition events, dust generation is most likely to occur. Dust suppression measures (water sprays) may be invoked during processing, storage and repackaging facility demolition events.

9.1.3 Redundant Fuel Containers

A table within Appendix A outlines the numbers of fuel containers that will require decontamination and disposal as a result of the repackaging event. Each CES alternative will require the assessment of substantial numbers of fuel containers within the 30 year (assumed) period. Strictly, the table underestimates the daily number of baskets which require assessment, since these will be generated over a 12-13 year timeframe rather than the full 30 years, if baskets are presented for decontamination (and disposal) at the original rate of receipt.

It is assumed that after decontamination, storage casks will be loaded onto an appropriate transporter and transported up to an off-site disposal facility. The intact storage casks will be treated as free release material. Similarly, after decontamination, module canisters will be treated as free release material. Some size reduction (volume reduced by half) will be effected in the fuel container buffer storage area, before the module canisters are packed into reuseable ISO freight containers.

It is assumed that after initial decontamination, modules and baskets will be packed into reuseable ISO freight containers in the fuel container buffer storage area, and transported up to an off-site LLW disposal facility.

9.1.4 Waste Arisings

Significant quantities of waste steel and concrete would be generated during facility repeat and repackaging events over a 300 year period. The total waste arisings for each CES alternative have been derived from estimates of the material quantities and the frequency with which they are anticipated to arise. They therefore reflect the waste arisings from the demolition of storage complexes, given their differing service lives and the waste generated as part of the repackaging operations, comprising both the repackaging facilities used and the redundant fuel containers. A nominal cycle of 300 years has been used throughout the four alternatives to allow comparison of the overall waste arisings. Within that 300 year cycle, there may be a number of facility repeat and repackaging events for the alternative under consideration.

Within Appendix A, Section A1 identifies the waste arisings from facility repeats.
Section A2 identifies the waste arisings from the facilities necessary to perform repackaging operations. Section A3 identifies the waste arisings from redundant fuel containers, which result from the repackaging operations.

Section A4 of Appendix A summates the waste arisings from facility repeats, repackaging facilities and redundant fuel containers, over the nominal 300 year period. Based on data in Appendix A, it is estimated that the CVSB alternative will generate about 272,000 tonnes of waste steel and 1.84 million tonnes of waste concrete from the off-site disposal of redundant storage buildings, repackaging facilities, and storage containers. Similarly, the SMV alternative would generate 244,000 tonnes of waste steel and 1.6 million tonnes of waste concrete, and the CVST would generate 247,000 tonnes of waste steel and 2.6 million tonnes of waste concrete. The CRC alternative would generate 208,000 tonnes of waste steel and 1.7 million tonnes of waste concrete.

9.2 MONITORING AND INSPECTION

9.2.1 Site Surveys

The environmental protection goal for the CES facility is that there will be no predicted future impacts on the environment that would not be currently accepted. The CES site will be surveyed before site construction activities commence, and after the initial construction phase has been completed, but prior to the fuel storage at the site. Activity measurements will form a base-line from which any subsequently measured variances can be identified.

The site hydrology will also be determined, prior to and after construction, to ensure the movement of site run off waters is understood.

Site staff will be regularly deployed in measuring liquid and aerial discharges from the activities being performed on the site. Liquid sampling will be performed on site water run off, both on the active and inactive portions of the site. If necessary, site run off will be directed to on-site active liquid treatment facilities.

A series of monitoring stations will be arranged across the CES site, including both perimeter locations and at locations specific to each alternative. These will include both within and outside the fuel bundle storage buildings, and from the ventilation stacks of the CVST and CRC alternatives. Sampling for radioactive contaminants will be performed at these locations.

During specific site activities, such as rock haulage, excavation, shaft boring or facility demolition operations, noise level measurements and dust generation levels will be measured, and remedial actions implemented as appropriate.

9.2.2 Conditions of Acceptance

All used fuel will arrive at the CES site in either:

- Existing storage casks
- Module transportation casks
- Basket transportation casks.

It is assumed all transportation cask loading and transportation operations from the donor sites meet the conditions of the cask transportation licenses, and casks arrive at the CES site without incident.

The outer surfaces of all casks will be subjected to a Health Physics survey to determine if any surface contaminants are present. Any non-conformances will be dealt with at the CES facility. Wash facilities will be available, at which transportation vehicle, cask and overpack may be washed down, and the washings directed to the active liquid effluent treatment facilities.

Non conformances will be either physical or procedural. Physical remediation (such as lid bolt cross threading release) will be performed in either the Processing Building receipt bay or in the Storage Cask/Module canister store. Procedural non-conformances might include cask inventory manifest discrepancies. Either location could be used to store transportation vehicles on a short-term basis.

9.2.3 Fuel Condition Monitoring

Throughout the period of extended storage, fuel condition monitoring activities will be performed.

The fuel condition monitoring will comprise:

- Direct monitoring/surveillance during fuel during packaging operations.
- Selection of fuel samples for examination during re-packaging (i.e. a verification step at every repeat cycle)
- Continuous monitoring of storage facility parameters (such as temperature, ventilation exhaust gases) at various locations.
- Operation of an experimental test facility where the condition of inactive fuel containers is monitored on a regular basis, e.g. via sampling of containment gases and monitoring of the containment structure internal temperatures.
- Implementation of a parallel program for shielded-cell examination of the fuel stored in a shielded test facility.

The experimental test facility will be equipped to support non-routine operations. It shall be capable of housing dummy fuel and test containers in conditions representative of fuel in the storage complex and monitoring the relevant storage parameters.

A small population of used fuel will also be examined. Fuel will be withdrawn from the storage complex and the fuel condition examined in a purpose built shielded facility. The frequency of examination will be every 25 years, and will permit the fuel condition to be assessed at intervals between fuel repackaging events.

During certain repackaging events (every 300 years), the fuel will be withdrawn from module canisters, modules and baskets. These infrequent events provide the opportunity for facility operators to directly view and assess the condition of fuel bundles and make comparison with the condition of dummy fuel held in the experimental test facility.

Generically, where the alternatives provide the possibility of monitoring the atmosphere local to the fuel bundle containers, an in situ monitoring program will be implemented. In the case of basket storage, this will involve the sampling of storage tube atmospheres, in the CVSB, CVST and SMV alternatives. Similarly, the gaseous environment between the SMV module canister and the storage tube will also be monitored. Storage casks (module or basket) do not have tapping connections suitable for the regular testing of internal atmospheres. However, monitoring of the atmosphere (for helium content loss) around the storage casks will be performed, as a measure of the containment performance of the storage cask structure.
The CES facility will provide extended storage for a considerable fuel inventory. It is unlikely that staff will be able to monitor the condition of all the fuel storage containments and structures on an equal frequency. It may be necessary to identify representative casks, vaults or modular vault structures in terms of storage location and relative age, to receive regular attention, to fingerprint larger numbers of fuel bundles. In addition, less frequent monitoring of the entire storage structure population will be performed. With operating experience, it may be possible to extend the intervals between inspections.

9.2.3.1 CVSB

For storage casks, a population representing 1% of the total cask inventory will be surveyed on a 3 –monthly basis. Activities will include a radiation survey, atmospheric monitoring, and general storage cask condition. An assessment of all storage casks will be performed on a biennial basis.

For basket vaults, an individual storage vault will be surveyed on a 3 monthly basis. Activities will include a radiation survey, atmospheric monitoring by connection to tappings on each storage tube, and general basket vault condition. An assessment of all basket vaults will be performed on a biennial basis.

9.2.3.2 SMV

For module canister stores, a population representing 2% of the storage tube inventory will be surveyed on a 3 monthly basis. This sample population will be interspersed amongst the total number of modular buildings and the number of vault sections in operation.

For basket stores, a population representing 2% of the storage tube inventory will be surveyed on a 3 monthly basis. This sample population will be interspersed amongst the total number of vault sections in operation.

Activities will include a radiation survey, atmospheric monitoring by connection to tappings on each storage tube plug. It will be necessary to lift overlying cover plate and charge hall floor structures, a necessary. Given the access conditions which have to be established, each storage tube plug will be sampled over a 5-year cycle.

The SMV module charge machine provides the ability to transfer module canisters from a service storage tube to a reserve storage tube, should the storage tube internals require (remote) investigation.

9.2.3.3 CVST

For storage casks, a population representing 1% of the total cask inventory will be surveyed on a 3 –monthly basis. Activities will include a radiation survey, atmospheric monitoring, and general storage cask condition. An assessment of all storage casks will be performed on a biennial basis.
For basket vaults, an individual storage vault will be surveyed on a 3 monthly basis. Activities will include a radiation survey, atmospheric monitoring by connection to tappings on each storage tube, and general basket vault condition. An assessment of all basket vaults will be performed on a biennial basis.

9.2.3.4 CRC

For (module or basket) storage casks, a population representing 1% of the total cask inventory will be surveyed on a 3 –monthly basis. Activities will include a radiation survey, atmospheric monitoring, and general storage cask condition. An assessment of all storage casks will be performed on a biennial basis.

9.2.4 Storage Structure Monitoring

Storage structure monitoring will include the following activities:

- Regular review of the building structure
- Regular review of the fuel container handling equipment
- Automatic monitoring of ambient conditions at the storage locations

Regular review of the building fabric will include an assessment of the building structure, including the status of roof and wall cladding/insulation for surface storage facilities, and a similar assessment of underground roof and wall structures. The review will also check for signs of gross cracking of load bearing lay-down areas and access roadways.

Regular review of the handling equipment will include checks on the operability of fuel package handling equipment, and statutory testing of lifting equipment, performed in situ if appropriate. Equipment necessary for the recovery of fuel containers will also be exercised on a regular basis, should fuel container movements be necessary.

Automatic monitoring of temperature, humidity, salinity and air composition in storage buildings, surface modular vaults, shallow trenches and rock caverns will be implemented, and all trends and cycles recorded.

9.2.4.1 CVSB

The storage cask and basket storage vault external condition will be assessed visually.

The storage cask condition checks will include:
- Paintwork condition
- Metalwork corrosion
- Seal weld condition
- Identification labels
- Integrity of IAEA seals

Other significant observations, such as staining or degradation of casks in contact with the concrete floor will be recorded.

The basket storage vault condition checks will include:
- Signs of concrete spalling/degradation
- Condition of external concrete/steel interfaces
- Condition of vault air cooling louvers
- Condition of tapping points
- Integrity of IAEA seals

9.2.4.2 SMV

The concrete structure around the storage tube array will be inspected externally. The ventilation stacks will also be assessed. Any signs of concrete degradation will be logged, and the extended service life of the SMV building predicted accordingly. The charge hall cladding will be inspected on a routine basis. It may be necessary to replace the charge hall cladding at a greater frequency than the concrete structure below.

The charge hall face represents the only readily accessible surface within the SMV.
The storage tube array cannot be accessed directly, though it will be possible to assess the condition of the storage tube internals, as previously identified. The external surfaces can be

reached using remote in service inspection cameras (or tracked vehicles), through strategically placed penetration plugs, between the storage tube arrays.

9.2.4.3 CVST

Generally, as per 9.2.4.1 above.

Periodically, the amount of water entering the CVST drainage channels in each tunnel will be assessed, to identify if there is increase any water flows permeating the structure. Health Physics surveys of collected water will confirm that no ingressing waters have been contaminated by contact with fuel containing structures within the shallow trench.

Operator access will be permitted after monitoring of the air quality within the storage chambers and enclosed ramp.

The earthen cover will be inspected on a regular basis for erosion and repaired as required.

9.2.4.4 CRC

The storage cask (module and basket cask) conditions will be assessed visually as per 9.2.4.1.

Periodically, the amount of water entering the CRC drainage channels in each cavern will be assessed, to identify if there is increase any water flows permeating the rock structure. Health Physics surveys of collected water will confirm that no ingressing waters have been contaminated by contact with storage casks within the rock cavern.

Operator access will be permitted after monitoring of the air quality within the rock caverns and access tunnels.

9.2.5 IAEA Safeguards

The safeguarding of used nuclear fuel is the responsibility of the IAEA. The IAEA may require the surveillance monitoring equipment to be installed in any of the receipt, processing, storage and repackaging facilities, such that continuous custodial control of the used fuel can be demonstrated.

The design concepts assume that the IAEA will specify and provide the monitoring equipment and the CES facility owner will be responsible for the provision of the appropriate mounting and electrical connections. Where this involves siting equipment within processing and repackaging cells, early consideration of the location of monitoring equipment will be required at the detail design stage, to ensure all aspects of its safe retrievability and maintenance are considered.

A specific review of the chosen CES alternative with the IAEA will be required to demonstrate that used fuel cannot be discharged or diverted from the processing/repackaging cells. Monitoring features (area monitors, cameras) and relevant features (system interlocks) will be designed into the interface points between cask and flask and the shielded cell complexes.

The storage systems are largely modelled on existing Canadian used fuel storage methodologies. It is anticipated seal locking devices can be applied to storage cask designs, and basket vaults, which cover the CVSB, CVST and CRC alternatives. The SMV alternative might require the provision of an equivalent seal locking arrangement. Once the module canisters are placed in the storage tube, and the shield plug and seal plate are installed, a seal locking device could then be applied at the charge face floor. Any sealing arrangement must not interfere with the deployment of the charge machine engaged in fuel loading/unloading in adjacent storage tubes, or pose a hazard to operators walking across the charge hall floor.

9.3 MAINTENANCE

During the service life of the storage facilities planned routine maintenance operations will be undertaken. None of the selected dry storage options present unacceptable radiological complications to the projected maintenance regimes. Periodic monitoring and inspection of the store structures will be included in the maintenance schedules; these monitoring schedules will include monitoring the condition of the interior surfaces of the Shallow Trenches and the Rock Caverns.

Underground maintenance will require periodic checks of the ventilation system to ensure that it is functioning satisfactorily. The underground de-watering system will also have to be monitored to ensure that the pumps are in good operating condition and that the ditches and collection sumps are free of sediments. It may be necessary to periodically remove sediment build-up from the de-watering system. Finally, the CRC facility will be reconnoitred for the purpose of examining the overall conditions of the underground excavations. If integrity of the support systems appear to be weakening then remedial measure will be taken. This may involve installing new rock bolts or injecting grout.

The CRC complex will include an additional cavern that will remain empty until such time that additional storage space is required. Should the interior surface of a Rock Cavern require maintenance, it may become necessary to transfer storage casks to the spare cavern away from the immediate area to minimise the potential for the lining material to be inadvertently dropped onto the storage casks.

9.4 STAFFING REQUIREMENTS

9.4.1 General

The CES facility is assumed to be located on a green field site. The CES facility will not rely on the services or provisions to other nuclear facilities, and will therefore be considered as a stand-alone facility. Site staff will perform all tasks relating to the normal management of the stored fuel bundle inventory. It is assumed that suitably qualified and experienced staff can be attracted from local centres of population. Particular site maintenance activities and periodic construction activities will be derived from an off site labour pool.

The staffing requirements will match the processes and activities taking place during specific stages of the extended storage cycles. By necessity, the site staffing levels are therefore likely to be cyclic.

It is assumed that all consumables, such as new fuel modules, fuel baskets, module containers and storage casks are fabricated off-site, and transported to the CES facility as required. Small buffer stocks of such assemblies will be stored on site. No CES staff will be involved directly in their fabrication.

A fundamental assumption is that the initial fuel receipt, facility repeats and repackaging operations will be performed over a 230 day working year, based on a 5-day working week. The remaining days per year will be reserved for facility maintenance operations.

Further, it is assumed that staff engaged in the initial fuel receipt, facility repeats and repackaging operations will be available on a 10-hour day shift (8 hours of productive work). There are specific activities that will take longer that the shift length permits (such as storage cask welding); these will either recommence the next working day, or a second shift will complete these specific tasks.

It is also assumed that facility repeats will be scheduled for completion over approximately the same time-scales as initial fuel receipt. Similarly, the repackaging event will occur over a similar duration, though less frequent time-scale, and will periodically coincide with certain facility repeat events.

An assessment of the staffing levels necessary to construct, secure, operate and maintain the CES facility will be performed during the cost estimating phase of the conceptual design study. An explanation of the functions of the staff is given below.

9.4.1.1 Security

Site security will be maintained 24 hours a day, with a 5-shift pattern to provide additional cover for absence, sick leave, holidays, training and similar. Security will actively patrol the CES site boundaries, control access to the facility from the gatehouse, issue security passes, run background checks on staff and monitor and regulate fuel transportation cask receipt onto the site. The security numbers are greater during the during the initial receipt event, to cater for the receipt of transportation casks, arriving from the donor sites.

9.4.1.2 Management

The CES will have a dedicated management team, comprising a manager and two deputies. The manager will represent the facility to regulatory bodies. The deputies will be responsible for the day to day management and operation of the CES facility, recruitment and training.

9.4.1.3 Administration

Administrative staff will provide day to day support to the management team. Duties will include record keeping, purchasing of goods and services for the facility, and interfacing with the general public. The number of administration staff will track the total staff inventory, depending on the project phase.

9.4.1.4 Construction

Construction personnel will be required to establish the CES site and construct the relevant facilities and establish the site infrastructure.
Construction staff will be sourced locally, and be required only during periods of substantive change on the CES facility. The construction workforce numbers and skills mix will vary, depending on the work-scope in progress. The construction personnel requirements will also fluctuate within each stage, (for example, peak workforce requirements during initial construction of the receipt and processing facilities and initial numbers of storage buildings, followed by secondary peaks reflecting the staged building of storage buildings, as the fuel inventory stored

on site increases). Though sizeable, the construction workforce requirements are relatively short duration events in the extended storage life-cycle.

9.4.1.5 Process Operations

The primary responsibilities of the process operators will be the receipt of transportation casks, fuel receipt and placement in the appropriate storage building. In addition, process operators will be periodically employed in stored fuel movements, from one facility repeat to another. In addition, they will be required to meet the commitments of a repackaging event including the decontamination and disposal of used fuel containers, redundant storage casks, empty modules and baskets.

9.4.1.6 Maintenance Operations

The primary responsibilities of maintenance personnel will be to maintain the fuel receipt, process and repackaging shielded cells and appropriate service equipment. Process workers will assist the maintenance personnel, when process and repackaging operations are not in progress. Maintenance personnel will also oversee specialist maintenance crews (crane and lifting equipment re-certification, and specialised systems, such as fire detection equipment) which require servicing intermittently.

9.4.1.7 Monitoring and Surveillance

Monitoring and surveillance personnel will perform measurement tasks which will identify any deviance from base-line surveys of the CES site. Activities will include monitoring the receipt and departure of transportation cask vehicles to prevent the dispersal of radioactive contamination, aerial and liquid discharges from the site, sampling activities, such as dust and noise measurement from site activities. These activities will likely increase during periods of change in site activity.

9.4.1.8 Site Infrastructure

Site Infrastructure maintenance will be performed by a maintenance crew, comprising either site staff, or local contractors, or a mixture of resources. The site infrastructure maintenance will include perimeter fence repairs, signage, lighting maintenance, joinery, re-glazing, grass cutting, office cleaning and any pest control measures.
A subjective staffing review for each CES alternative is included below, base-lined on the CVSB alternative. Estimation of labour requirements for each CES alternative will be examined in the cost estimating phase of the conceptual design study.

9.4.2 Initial Fuel Receipt

The principal operations will include:

- Facility construction (in a number of stages)
- Transportation cask and storage cask receipt
- Fuel processing operations

- Fuel placement operations

Staged facility construction will therefore introduce periodic increases in the staffing requirements for all the CES alternatives. The receipt, processing and placement of fuel will be relatively labour intensive, over the first nominal 30 years of the facility operation.

9.4.3 Extended Monitoring

The principal operations will include:

- Storage facility monitoring
- Maintenance of building structures

The extended monitoring stage will utilise the least labour resource. With the exception of preventative maintenance on building structures, and periodic review of mimic samples in the test facility, the extended monitoring stage will be in a relatively dormant period.

The operational phase is of indefinite duration for all the alternatives. The extended monitoring stage will commence at the conclusion of initial fuel receipt, and will be punctuated by facility repeat and repackaging events. The underground alternatives, CVST and CRC should have longer periods of extended monitoring between repeat and repackaging events, by comparison to the above ground alternatives, CVSB and SMV, where storage building life and storage package life are anticipated as being relatively shorter.

9.4.4 Facility Repeats

The principal operations will include:

- Construction of new facilities or refurbishment of existing facilities
- Transfer of fuel packages between old and new facilities
- Demolition of redundant facilities, as appropriate

The facility repeat event is anticipated to be less labour intensive than the initial receipt event, since there are no fuel processing operations performed during the transfer of fuel packages from one storage facility to another.

It is anticipated that fewer staff will be required to refurbish and outfit the CRC underground facilities, than those alternatives which require demolition of storage facilities (CVSB and SMV), and the CVST, which requires removal of the earthen structure to provide access for facility repeat demolition/construction activities.

9.4.5 Repackaging

The principal operations will include:

- Construction of new facilities or refurbishment of existing facilities
- Transfer of fuel packages from old facilities to repackaging facilities
- Repackaging activities
- Transfer of fuel packages to new facilities from repackaging facilities
- Demolition of redundant facilities, as appropriate

The repackaging event is anticipated to be at least as labour intensive as the initial receipt event, since there are fuel transfers to be effected from redundant storage containers, in addition to the operations performed during the transfer of fuel packages from one storage facility to another.

10 Unresolved Design Issues

The following represent Unresolved Design Issues:

- The basket transportation cask is an OPG conceptual design. Significant deviation from the assumptions stated may influence the interface with the basket receipt shielded cell.
- The basket storage cask identified in the CRC is a conceptual design only. No heat dissipation, radiological shielding assessment or structural assessment have been performed.
- The concept of stacking two casks in the storage chambers and caverns was proven safe by applying the National Building Code requirements for flat bottom storage tanks placed at grade level. However, the code does not address specifically the response of stacked objects during a seismic event. Since the viability of the two below grade storage concepts relies on the concept of stacking, it is recommended that mathematical modelling is performed simulating two stacked casks subjected to a seismic event. The objective would be to determine the magnitude of the lateral force that causes the top cask to slide or topple and confirm the safety of stacking the casks in a seismic zone 1 environment. For added security a locating collar could be inserted between the upper and lower casks to prevent the relative movement during a seismic event.
- Cask stacking may represent a loss of available surface area for heat rejection purposes.
- Detailed thermal analysis would be required on the alternative designs to confirm that the ventilation arrangements described will be adequate to cool the fuel and maintain a relatively dry environment in the stores.

11 Codes and Standards

Mining Regulations:

Occupational Health and Safety Act and Regulation for Mines and Mining Plants for the Province of Ontario.

Codes:

National Building Code of Canada (NBCC), 1995 and its supplements National Fire Code of Canada, 1995
National Plumbing Code of Canada (NPCC), 1995
Ontario Building Code, 1997

Dry Storage Standard:

CAN/CSA N292.2-96	Dry Storage of Irradiated Fuel

Structural Standards:

CSA-S16.1-M	Structures for Buildings
CISC	Code of Standard Practice for Structural Steel
CAN/CSA-G40.21-M	Structural and Quality Steels
CAN3-A23.3-M	Code for Design of Concrete Structure for Buildings
CAN/CSA-A23.1-M	Concrete Materials and Methods of Concrete Construction
CAN/CSA-A23.2-M	Methods of Test for Concrete

12 References

1 Design Basis for Centralized Extended Storage Alternatives for Used Nuclear Fuel, CTECH Report no. 1105/MD18084/REP/04, May 2002.
2 Request for Proposal Number RFP-SMA-00179637-2001 Study of Extended Storage Facility Options for OPG, New Brunswick Power, Hydro Québec and AECL's Used Nuclear Fuel July 2001
3 Assessment of Service Life of Used Fuel Dry Storage Systems, OPG ref. PO 00086183, CTECH ref. 1104.
4 Ontario Hydro 1995. Safety Analysis Report for Irradiated Fuel Transportation Cask. A Report to the Atomic Energy Control Board. Rev 3, March 1995
5 Ontario Hydro 1995. Safety Analysis Report for the Dry Storage Container Transportation Package. Report to the Atomic Energy Control Board. Rev 1, March 1995.
6 Decommissioning Options for Dry Storage Containers, CTECH report, October 2000.

Table 1: Assumed Annual Rate of Fuel Bundle Retrieval at OPG's, NBP's, HQ's and AECL's Reactor Sites

Nominal Year	Year	OPG		NBP	HQ	AECL	Total
		Wet Storage	Dry Storage				
18	2023	117,066	-				117,066
19	2024	117,066	-				117,066
20	2025	117,066	-				117,066
21	2026	117,066	-				117,066
22	2027	103,247	13,614				116,861
23	2028	103,247	13,614				116,861
24	2029	55,852	61,262				117,114
25	2030	55,852	61,262				117,114
26	2031	55,852	63,870				119,722
27	2032	48,426	70,679				119,106
28	2033	89,837	29,972				119,810
29	2034	89,837	29,972				119,810
30	2035	66,770	52,248				119,018
31	2036	57,488	62,332				119,820
32	2037	57,488	62,332				119,820
33	2038	46,134	72,734				118,868
34	2039	46,134	72,734				118,868
35	2040	27,681	61,700	17,072	12,960		119,412
36	2041	27,681	61,700	17,072	12,960		119,412
37	2042	32,294	57,414	17,072	12,960		119,740
38	2043	46,134	42,792	17,072	12,960		118,958
39	2044	27,681	62,182	17,072	12,960		119,894
40	2045	27,681	62,214	17,072	12,960		119,926
41	2046	27,681	62,214	17,068	12,960		119,922
42	2047	13,840	92,190		12,960		118,990
43	2048	-	99,355		12,960	6,137	118,452
44	2049	-	99,355		12,960	6,137	118,452
45	2050	-	109,406		3,238	6,137	118,781
46	2051	-	112,355			6,137	118,492
47	2052	-	109,832			6,134	115,966
Total		**1,575,099**	**1,699,332**	**119,500**	**132,838**	**30,682**	**3,557,451**

Table 2: Summary of Engineered Features

Storage Concept	Engineered Feature					
	Primary containment barrier	**Secondary containment barrier**	**Isolation**	**Intrusion barrier**	**Shielding**	**Cooling**
CVSB	Module storage cask	None	Storage cask body	Storage building	Storage cask body	Ventilation louvers in storage building
	Fuel basket	Vaults housing fuel baskets	Vault structure	As above	Vault structure	Ventilation ducts in basket vaults and louvers in building
SMV	Module canister	Storage tubes in SMV array	SMV walls and charge floor	SMV walls and upper building structure	SMV walls, charge face & shield plugs	Ducted airflow across storage vault tube array
	Fuel basket	As above	As above	As above	As above	As above
CVST	Module storage cask	None	Storage cask body	Shallow trench structure and earthen overburden	Storage cask body	Ventilation ducts from surface to underground storage chamber complex
	Fuel basket	Vaults housing fuel baskets	Vault structure	As above	Vault structure	Ventilation ducts in basket vaults and from surface to underground storage chamber complex
CRC	Module storage cask	None	Storage cask body	Cavern/tunnel complex	Storage cask body	Ventilation ducts complete with surface mounted extract fans, from the underground storage complex to the surface.
	Fuel basket	Basket storage cask	As above	As above	As above	As above

Table 3: Assumed Service Lives for Facility Components

Component	CVSB	SMV	CVST	CRC
Cask	100	-	100*	100*
Module	300	300	300	300
Basket	300	300	300	300
Module Canister	-	300	-	-
Storage Vault	100	100	100+**	-
Storage Chamber	-	-	200	-
Storage Building	50***	50***	-	-
Storage Cavern	-	-	-	300
Processing Building	50	50	50	50

Notes

* The figure of 100 years assumes water ingress has been minimised by the selection of either a competent rock structure (for the CRC), or the CVST alternative structures remains substantially weather-tight.

** The figure for the underground storage vault reflects concern over the concrete/steel interface, which may preferentially corrode the storage tubes within the vault structures, and ultimately defeat the secondary containment. The assumed service life figure therefore differs from the underground concrete structure figure for the CVST alternative, but may approach the same, if atmospheric conditions within the CVST alternative were favourable, and corrosion was minimised.

*** This figure represents the assumed service life for the (CVSB) storage buildings and the SMV above vault weatherproof structure. The roof/wall cladding comprises an inner and outer skin, with insulating material sandwiched within.
It is assumed that individual external cladding sheets are regularly inspected, and replaced, where they exhibit excessive corrosion or suffer mechanical damage. Providing the structural steelwork members within this structure remain free from corrosion, it may is possible to ‘re-skin’ the building structure, by wholesale renewal of the building cladding on a phased program. This will raise the service life to that of the storage casks and vaults (CVSB) and the SMV vault structure.

Figures

APPENDIX A

Waste Arisings

A1	**Waste Arisings from Facility Repeats**
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A1.2	CVSB
A1.3	SMV
A1.4	CVST
A1.5	CRC
A2	**Waste Arisings from Repackaging Buildings**
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A3	**Waste Arisings from the Disposal of Fuel Containers**
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A3.2	Spent Cask Waste Arisings
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A5	**Fuel Container Decontamination**
A5.1	Cask Component Examination and Separation
A5.2	Cask Body Decontamination
A5.3	Cask Lid Decontamination
A5.4	Module Decontamination
A5.5	Module Canister Decontamination
A5.6	Basket Decontamination
A5.7	General Decontamination and Recovery

Table A1: Fuel container arisings following repackaging events.

A1 Waste Arisings from Facility Repeats

A1 Waste Arisings from Facility Repeats

A1.1 Background

In addition to the requirement to periodically replace fuel containers (described in section A3), the facilities in which the fuel is processed, handled and stored also have finite lives, (see main report Table 3). These facilities will need to be replaced/refurbished on a rolling programme. The replacement of these facilities will generate large quantities of waste. The vast majority of the waste generated will be radiologically clean. The internal surfaces of the shielded cell are the only areas that may require some decontamination prior to release. The shielded cells and the processing buildings will not be required after the initial fuel receipt phase at the CES facility, but are included within this section since they will generate a waste arising, if dismantled at any time prior to the first facility repeat.

A1.2 CVSB

Listed below are the component facilities that comprise the CVSB:

A1.2.1 Processing Building

The processing building comprises the receipt area and the cask processing area, the shielded cell is not included:

Waste volumes	Steel	994 tonnes
	Concrete	2,091 tonnes

A1.2.2 Shielded Cell

The shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used fuel:

Waste volumes	Steel	934 tonnes
	Concrete	6,695 tonnes
	Lead Glass	11.5 tonnes

A1.2.3 Cask Storage Building

The cask storage building is the building in which the casks will be stored and monitored. The quantities quoted below are for a single cask storage building and for the total CES requirement of 17 cask storage buildings:

Waste volumes (per storage building)	Steel	1,254 tonnes
	Concrete	4,058 tonnes
Waste volumes (17 off storage buildings)	Steel	21,318 tonnes
	Concrete	68,986 tonnes

A1.2.4 Vault

The vault is a monolithic concrete structure, reinforced with rebar, containing steel storage tubes which house the used fuel baskets. The quantities quoted below are for a single vault and for the total CES requirement of 24 storage vaults:

Waste volumes (per vault)	Steel	140 tonnes
	Concrete	1,680 tonnes
Waste volumes (24 off vaults)	Steel	3,360 tonnes
	Concrete	40,320 tonnes

A1.2.5 Vault Storage Building

The vault storage buildings are the buildings in which the vaults will be sited, which in turn house used fuel baskets. The quantities quoted below are for a single vault storage building and for the total CES requirement of 4 storage buildings:

Waste volumes (per storage building)	Steel	914 tonnes
	Concrete	2,456 tonnes
Waste volumes (4 off storage buildings)	Steel	3,656 tonnes
	Concrete	9,824 tonnes

A1.2.6 CVSB Waste Totals

Steel	**30,262 tonnes**
Concrete	**127,916 tonnes**
Lead Glass	**11.5 tonnes**

A1.3 SMV

Listed below are the component facilities that comprise the SMV:

A1.3.1 Processing Building

The processing building comprises the receipt area and the cask processing area, the shielded cell is not included:

Waste volumes	Steel	694 tonnes
	Concrete	1,349 tonnes

A1.3.2 Shielded Cell

The shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used fuel:

Waste volumes	Steel	1,014 tonnes
	Concrete	7,481 tonnes

Lead Glass	14 tonnes

A1.3.3 Surface Modular Vault

The surface modular vault is a concrete structure containing the storage tubes for the used fuel housings (module containment or basket). The concrete structure provides the shielding for the fuel and includes labyrinth inlets for the surface modular vault cooling air. The quantities quoted below are for a single surface modular vault and for the total CES requirement of 6 surface modular vault buildings:

Waste volumes (per surface modular vault)	Steel	9,940 tonnes
	Concrete	87,630 tonnes
Waste volumes (6 off surface modular vaults)	Steel	59,636 tonnes
	Concrete	525,780 tonnes

A1.3.4 Vault Building

The vault building, when related to the SMV, refers to the superstructure over the storage vault. The vault building provides weather protection to the storage vault:

Waste volumes (per vault building)	Steel	744 tonnes
(6 off vault buildings)	Steel	4,464 tonnes

Vault building handling equipment
(including canister handling machine, basket crane, mobile crane and transfer flask)

Steel	674 tonnes

A1.3.5 SMV Waste Totals

Steel	**66,482 tonnes**
Concrete	**534,610 tonnes**
Lead Glass	**14 tonnes**

A1.4 CVST

Listed below are the component facilities that comprise the CVST:

A1.4.1 Processing Building

The processing building comprises the receipt area and the cask processing area, the shielded cell is not included:

Waste volumes	Steel	994 tonnes
	Concrete	2,091 tonnes

A1.4.2 Shielded Cell

The shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used fuel:

Waste volumes	Steel	934 tonnes
	Concrete	6,695 tonnes
	Lead Glass	11.5 tonnes

A1.4.3 Vault

The vault is a monolithic concrete structure, reinforced with rebar, containing steel storage tubes which house the used fuel baskets:

Waste volumes (per vault)	Steel	140 tonnes
	Concrete	1,680 tonnes
Waste volumes (24 off vaults)	Steel	3,360 tonnes
	Concrete	40,320 tonnes

A1.4.4 Transfer Tunnel

The transfer tunnel links the processing building and the storage chamber complex. The transfer tunnel provides cover for the fuel transfers, thereby minimising the potential for disruption due to adverse weather:

Waste volumes	Steel	170 tonnes
	Concrete	8,360 tonnes

A1.4.5 Shallow Trench Chamber

The storage chamber is a reinforced concrete structure, constructed within a shallow trench. The storage chamber houses either casks or vaults:

Waste volumes (per chamber)	Steel	2,051 tonnes
	Concrete	39,107 tonnes
Waste volumes (16 off chambers)	Steel	32,816 tonnes
	Concrete	625,712 tonnes
Shallow Trench handling equipment	Steel	72 tonnes

A1.4.6 CVST Waste Totals

Steel	**38,346 tonnes**
Concrete	**683,178 tonnes**
Lead Glass	**11.5 tonnes**

A1.5 CRC

Listed below are the component facilities that comprise the CRC:

A1.5.1 Processing Building

The processing building comprises the receipt area and the cask processing area, the shielded cell is not included:

Waste volumes	Steel	994 tonnes
	Concrete	2,091 tonnes

A1.5.2 Shielded Cell

The shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used fuel:

Waste volumes	Steel	934 tonnes
	Concrete	6,695 tonnes
	Lead Glass	11.5 tonnes

A1.5.3 Transfer Tunnel

The transfer tunnel links the processing building and the rock cavern. The transfer tunnel provides cover for the fuel transfers, thereby minimising the potential for disruption due to adverse weather:

Waste volumes	Steel	850 tonnes
	Concrete	41,800 tonnes

A1.5.4 Rock Cavern (concrete structure)

The rock caverns will be ‘cut’ into a suitable rock structure. A concrete floor slab and gantry crane support structure will be constructed within the cavern. These concrete structures will be refurbished or replaced as they reach he end of their service life. A figure of 50% has been used as the division between the concrete structure to be replaced and the concrete structure which will be refurbished:

Waste volumes (per cavern)	Steel	623 tonnes
	Concrete	6,797 tonnes
Waste volumes (10 off caverns)	Steel	6,230 tonnes
	Concrete	67,970 tonne

A1.5.5 CRC Waste Totals

Steel	**9,008 tonnes**
Concrete	**118,556 tonnes**
Lead Glass	**11.5 tonnes**

A2 Waste Arisings from Repackaging Buildings

A2.1 Background

The process of periodically repackaging fuel into new fuel containers requires a dedicated shielded cell suite housed in a repackaging building. The size and configuration of such a building is dependent on which of the four alternatives is selected.

Once the fuel has been transferred into its new fuel container and the existing containers have been decontaminated and sent for disposal, the shielded cell and repackaging building are then treated as waste and can be demolished. The waste arising from the repackaging buildings from the four alternatives is described below, these 4 alternatives assume both baskets and modules are being repackaged at the same event.

A2.2 CVSB

Listed below are the component facilities that comprise the CVSB Repackaging Building:

A2.2.1 Basket Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used basket fuel:

Waste volumes	Steel	493 tonnes
	Concrete	5,283 tonnes
	Lead Glass	7.7 tonnes

A2.2.2 Basket Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel baskets:

Waste volumes	Steel	161 tonnes
	Concrete	1,403 tonnes
	Lead Glass	3.8 tonnes

A2.2.3 Module Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used module fuel:

Waste volumes	Steel	587 tonnes
	Concrete	6,244 tonnes
	Lead Glass	11.5 tonnes

A2.2.4 Module Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel modules:

Waste volumes	Steel	153 tonnes
	Concrete	1,350 tonnes
	Lead Glass	3.8 tonnes

A2.2.5 Cask & Lid Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling used module storage casks and lids:

Waste volumes	Steel	435 tonnes
	Concrete	2,623 tonnes
	Lead Glass	9.6 tonnes

A2.2.6 Processing Building

The processing building comprises the receipt area, export area and the cask processing area, the shielded cells are not included:

Waste volumes	Steel	2,296 tonnes
	Concrete	5,341 tonnes

A2.2.7 CVSB Waste Totals

Steel	**4,125 tonnes**
Concrete	**22,244 tonnes**
Lead Glass	**36 tonnes**

A2.3 SMV

Listed below are the component facilities that comprise the SMV Repackaging Building:

A2.3.1 Basket Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used basket fuel:

Waste volumes	Steel	493 tonnes
	Concrete	5,283 tonnes
	Lead Glass	7.7 tonnes

A2.3.2 Basket Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel baskets:

Waste volumes	Steel	161 tonnes
	Concrete	1,403 tonnes
	Lead Glass	3.8 tonnes

A2.3.3 Module Canister Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used module fuel:

Waste volumes	Steel	753 tonnes
	Concrete	7,234 tonnes
	Lead Glass	9.1 tonnes

A2.3.4 Module Canister Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used module canisters:

Waste volumes	Steel	290 tonnes
	Concrete	3,058 tonnes
	Lead Glass	3.8 tonnes

A2.3.5 Module Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel modules:

Waste volumes	Steel	153 tonnes
	Concrete	1,350 tonnes
	Lead Glass	3.8 tonnes

A2.3.6 Processing Building

The processing building comprises the receipt area, export area and the cask processing area, the shielded cells are not included:

Waste volumes	Steel	1,642 tonnes
	Concrete	3,540 tonnes

A2.3.7 SMV Waste Totals

Steel	**3,492 tonnes**
Concrete	**21,868 tonnes**
Lead Glass	**38 tonnes**

A2.4 CVST

Listed below are the component facilities that comprise the CVST Repackaging Building:

A2.4.1 Basket Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used basket fuel:

Waste volumes	Steel	493 tonnes
	Concrete	5,283 tonnes
	Lead Glass	7.7 tonnes

A2.4.2 Basket Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel baskets:

Waste volumes	Steel	161 tonnes
	Concrete	1,403 tonnes
	Lead Glass	3.8 tonnes

A2.4.3 Module Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used module fuel:

Waste volumes	Steel	587 tonnes
	Concrete	6,244 tonnes
	Lead Glass	11.5 tonnes

A2.4.4 Module Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel modules:

Waste volumes	Steel	153 tonnes
	Concrete	1,350 tonnes
	Lead Glass	3.8 tonnes

A2.4.5 Cask & Lid Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling used module storage casks and lids:

Waste volumes	Steel	435 tonnes
	Concrete	2,623 tonnes
	Lead Glass	9.6 tonnes

A2.4.6 Processing Building

The processing building comprises the receipt area, export area and the cask processing area, the shielded cells are not included:

Waste volumes	Steel	2,296 tonnes
	Concrete	5,341 tonnes

A2.4.7 CVST Waste Totals

Steel	**4,125 tonnes**
Concrete	**22,244 tonnes**
Lead Glass	**36 tonnes**

A2.5 CRC

Listed below are the component facilities that comprise the CRC Repackaging Building:

A2.5.1 Basket Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used basket fuel:

Waste volumes	Steel	675 tonnes
	Concrete	5,665 tonnes
	Lead Glass	7.7 tonnes

A2.5.2 Basket Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel baskets:

Waste volumes	Steel	161 tonnes
	Concrete	1,403 tonnes
	Lead Glass	3.8 tonnes

A2.5.3 Module Repackaging Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the remote handling and transfer of used module fuel:

Waste volumes	Steel	587 tonnes
	Concrete	6,244 tonnes
	Lead Glass	11.5 tonnes

A2.5.4 Module Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling of used fuel modules:

Waste volumes	Steel	153 tonnes
	Concrete	1,350 tonnes
	Lead Glass	3.8 tonnes

A2.5.5 Cask & Lid Decontamination Shielded Cell

This shielded cell is a concrete structure that will provide a shielded boundary for the decontamination and remote handling used module storage casks and lids:

Waste volumes	Steel	435 tonnes
	Concrete	2,623 tonnes
	Lead Glass	9.6 tonnes

A2.5.6 Processing Building

The processing building comprises the receipt area, export area and the cask processing area, the shielded cells are not included:

Waste volumes	Steel	2,171 tonnes
	Concrete	4,631 tonnes

A2.5.7 CRC Waste Totals

Steel	**4,182 tonnes**
Concrete	**21,916 tonnes**
Lead Glass	**36 tonnes**

A3 Waste Arisings from the Disposal of Fuel Containers

A3.1 Background

The periodic repackaging of fuel will generate quantities of steel and concrete, some of which may be contaminated by contact with, or through leakage from fuel bundles. Given the total fuel inventory (approximately 3.6 million bundles) this will be a significant periodic waste arising. It is assumed that the repackaging event and therefore the decontamination and disposal of redundant fuel containers extends over a 30 year period. Depending on the dry storage alternative, various forms of solid waste will arise as spent fuel containers. (Refer table A1)

Waste fuel container types comprise:

- Spent (module and basket) casks
- Spent modules
- Spent module canisters
- Spent baskets

A3.2 Spent Cask Waste Arisings

For CVSB and CVST, assuming 3,274,431 fuel bundles are stored in 8,528 storage casks, this equates to 533,000 tonnes of material.

For CRC, assuming 3,557,451 fuel bundles are stored in 9,202 storage casks, this equates to 575,125 tonnes of material.

The assessed weight of a storage cask is taken as 62.5 tonnes, comprising 6.5 tonnes steel and 56 tonnes of concrete.

A3.3 Spent Module Waste Arisings

Assuming 3,274,431 fuel bundles are stored in 34,112 modules, this equates to 6,992 tonnes of material.

A module has dimensions 990mm x 1290mm x 600mm and occupies 0.767m³. The weight of a module is 205kg.

A3.4 Spent Module Canister Waste Arisings

Assuming 3,274,431 fuel bundles are stored in 8528 module canisters, this equates to 34,964 tonnes of material.

A module canister has dimensions diameter 1800mm x 2570mm and occupies 6.54m³. The weight of a module is 4,100kg.

A3.5 Spent Basket Waste Arisings

Assuming 283,020 fuel bundles are stored in 4,717 baskets, this equates to 2,123 tonnes of material.

A basket has dimensions diameter 1067mm x 533mm and occupies 0.476m³. The weight of a basket is 450kg.

A4 Total Waste Arisings for Each CES Alternative

The total waste arisings for each alternative have been derived from estimates of the material quantities and the frequency with which they are anticipated to arise. They therefore reflect the waste arisings from the demolition of storage complexes, given their differing service lives and the waste generated in the repackaging of fuel containers. A nominal cycle of 300 years has been used throughout the four alternatives to allow comparison of the overall waste arisings. Within that 300 year cycle, there may be a number of facility repeat, and repackaging events, for the alternative under consideration

In some instances, the repackaging timescale for different fuel container types is not co-incident (for examples, modules and baskets). A percentage of the waste arisings from the demolition of the repackaging facility has therefore been included, based on the relative contribution of the fuel form to the overall volume of the repackaging building and shielded cell structures constructed.

Fuel container waste arisings have been calculated from figures derived in Section A3 above, and from quantities identified in Table A1.

The estimates do not include the material quantities of ancillary buildings on the CES site, although this is expected to be common across the four alternatives.

A4.2 CVSB

Within the 300 year cycle, the waste arisings from the following activities have been included:

CVSB	Steel Totals	Concrete Totals
Processing cell and shielded cell for initial receipt of fuel at the CES facility	1928	8786
Facility repeats for all storage buildings (storage casks and vaults) (3 repeats)	74922	236430
Facility repeats for vaults (3 repeats)	10080	120960
Cask repackaging buildings and shielded cells (3 events, including 1 event with transfer of fuel to new	8817	34773

modules)		
Basket to basket repackaging (1 event)	1279	8060
Storage cask waste arisings (3 events)	166296	1432704
Module arisings (1 event)	6993	
Basket arisings (1 event)	2123	
Totals	**272,438**	**1,841,713**

A4.3 SMV

Within the 300 year cycle, the waste arisings from the following activities have been included:

SMV	**Steel Totals**	**Concrete Totals**
Processing cell and shielded cell for initial receipt of fuel at the CES facility	1708	8830
Facility repeats for all modular vault buildings (3 repeats)	194322	1577340
Module canister to module canister and basket to basket repackaging building and shielded cells (1 event)	3492	21868
Module canister arisings (1 event)	34964	
Module arisings (1 event)	6993	
Basket arisings (1 event)	2123	
Totals	**243,602**	**1,608,038**

A4.4 CVST

Within the 300 year cycle, the waste arisings from the following activities have been included:

CVST	**Steel Totals**	**Concrete Totals**
Processing cell and shielded cell for initial receipt of fuel at the CES facility	1928	8786
Facility repeats for all storage chambers (storage casks and vaults) (1.5 repeats)	49479	951108
Facility repeats for vaults (3 repeats)	10080	120960
Cask repackaging buildings and shielded cells (3 events, including 1 event with transfer of fuel to new modules)	8817	34773
Basket to basket repackaging (1 event)	1279	8060
Storage cask waste arisings (3 events)	166296	1432704
Module arisings (1 events)	6993	
Basket arisings (1 event)	2123	
Totals	**246,995**	**2,556,391**

Note: An allowance of factor of 1.5 has been applied to the facility repeat for storage chambers. Only one renewal of storage chambers will take place (after 200 years) within the 300 year cycle. However, two renewals will occur in the next 300 year cycle (after 400 and 600 years respectively)

A4.5 CRC

Within the 300 year cycle, the waste arisings from the following activities have been included:

CRC	**Steel Totals**	**Concrete Totals**
Processing cell and shielded cell for initial receipt of fuel at the CES facility	1928	8786
Storage cavern refurbishment (1 repeat)	6230	67970
Cask repackaging buildings and shielded cells (3 events, including 1 event with transfer of fuel to new modules)	8778	40305
Basket to basket repackaging (1 event)	2926	13371
Storage cask waste arisings (3 events)	179439	1545936
Module arisings (3 events)	6993	
Basket arisings (1 event)	2123	
Totals	**208,417**	**1,676,368**

In addition, the CRC alternative, 1.9 million cubic meters of broken rock is generated during initial cavern excavation.

A5 Fuel Container Decontamination

The CES alternatives that require the periodic repackaging of storage casks and module canisters will generate a stream of spent modules, from which fuel bundles have been discharged. All the CES alternatives require the periodic repackaging of fuel baskets and will therefore generate a stream of spent baskets, from which fuel bundles have been discharged. Modules and baskets are potentially contaminated, either as a result of initial fuel loading underwater, before discharge from reactor site wet storage facilities, or later, through defective fuel leakage during extended dry storage. Similarly, module canisters are potentially contaminated, either as a result of initial fuel loading or later, through defective fuel leakage during extended dry storage.

All activities will be performed remotely initially, using the least aggressive procedures first. Once surface contamination has been reduced to appropriate levels, man entry to the shielded cell is permissible, and ‘hands on’ procedures can be applied.
Shielded cell internal walls and floor finishes can be regularly decontaminated, by swabbing or sparge water ring actuation.
Ventilation services are arranged to draw air in from areas of lower contamination, to areas of highest contamination, such that the spread of contamination is minimised.

A5.1 Cask Component Examination and Separation

General assumptions:

1. Cask exterior surface has already passed contamination examination
2. Decontamination facility is remote from repackaging facility
3. Decontamination facility receives casks via the cask transporter route
4. Decontamination facility comprises a shielded cell, which serves cask body, and cask lids on separate lines.
5. Craneage, appropriate to the component form is present within the cell.
6. As precautionary measure, assume cask internals are contaminated, until proven otherwise.

Initial orientation: Cask and lid are in normal configuration.

- Manually remove any transit clamps connecting cask body to cask lid.
- Attach a lid lifting tri-form attachment point to cask lid.
- Manoeuvre assembly into shielded cell suite receipt bay using cask transporter.
- Set down cask and withdraw transporter, close outer shield door.
- Open inner shield door, travel crane out to cask and pick up.
- Set down cask within shielded cell.
- Remotely measure count rate from cask assembly.
- Remotely engage cask lid lifting attachment point and remove cask lid.
- Remotely measure count rate from module hull and above cask payload void.
- Transfer cask lid to a parallel line, for a separate decontamination sequence.

A5.2 Cask Body Decontamination

Refer Figure 8.1.

- Remotely measure count rate from cask body closure flange region and internal void.
- Map areas of highest contamination on cask body closure flange region and c internal void.
- Vacuum cask body closure flange region and internal void.
- Remotely measure count rate from cask body closure flange region and from internal void.
- Re-map areas of highest contamination on cask body closure flange region and internal void.
- Locally swab cask body closure flange region and internal void.
- Remotely measure count rate from cask body closure flange region and internal void.
- Re-map areas of highest contamination on cask body closure flange region and internal void.
- Masking cask exterior, apply spray water wash to cask body closure flange region and internal void.

NB. It will be necessary to pump extract any wash waters accumulating in the cask void, since the storage cask drain route is sealed by a blanking plug, during service life. The extraction rate should match the delivery rate, to ensure any accumulation of contaminant does not settle on cask internal base plate and lower void walls. Convey all used wash-waters to the active drainage system.

- Allow all wetted affected areas to dry.
- Remotely measure count rate from cask body closure flange region and internal void.
- Re-map areas of highest contamination on cask body closure flange region and internal void.
- Once contamination levels have been reduced sufficiently to permit man access to the shielded cell, repeat decontamination monitoring and perform ‘hands on’ decontamination activities appropriate to the final waste disposal route.

- Hoist cask body, open inner shield door, and long travel crane out into shielded cell suite export bay, and deposit cask body through containment hatch onto a suitable trolley. Return crane into shielded cell.
- Withdraw trolley, close outer roller shutter door and transfer cask body to buffer storage area, to be prepared for off-site shipment.

A5.3 Cask Lid Decontamination

Refer Fig.8.2.

Initial orientation: Cask lid is positioned held on suitable lifting attachment for subsequent decontamination operations.

- Remotely measure count rate from cask lid underside.
- Map areas of highest contamination on cask lid underside.
- Vacuum cask lid.
- Remotely measure count rate from cask lid underside.
- Re-map areas of highest contamination on cask lid underside.
- Locally swab cask lid underside.
- Remotely measure count rate from cask lid underside.
- Re-map areas of highest contamination on cask lid underside.
- Transfer cask lid to decontamination booth.
- Apply spray water wash to cask lid underside. Wash sequence ensures that spray waters progressively wash contaminants off cask lid surfaces (from top, to sides to bottom). Convey all used wash-waters to active drainage system.
- Allow all wetted affected areas to dry.
- Remotely measure count rate from cask lid.
- Re-map areas of highest contamination on cask lid.
- Once contamination levels have been reduced sufficiently to permit man access to the shielded cell, repeat decontamination monitoring and perform ‘hands on’ decontamination activities appropriate to the final waste disposal route.
- Transfer cask lid to discharge port. Open shield hatch and lower cask lid into export bay, onto pallet or suitable stillage. Close the shield hatch.
- Open outer discharge bay door, and retrieve cask lid on pallet or stillage using forklift truck or similar.
- Transfer cask lid to a buffer storage area, to be prepared for off-site shipment.

A5.4 Module Decontamination

The following description assumes modules (4 off) have been extracted from a storage cask body or from a module canister. Such batches are transferred to a dedicated decontamination cell, under the repackaging cell suite (Refer Fig. 8.3)

The 4 off modules are treated in turn. Direct contact between personnel and modules residing at this position is restricted by a shield wall, over which modules are lifted, during remote handling operations only.

Initial orientation: Module hull is held on suitable lifting attachment for subsequent decontamination operations.

- Remotely measure count rate from module hull.
- Map areas of highest contamination on module hull.
- Vacuum module hull, including tubular bores.
- Remotely measure count rate from module hull.
- Re-map areas of highest contamination on module hull.
- Locally swab module hull.
- Remotely measure count rate from module hull.
- Re-map areas of highest contamination on module hull.
- Transfer module hull to decontamination booth.
- Apply spray water wash to module hull. Wash sequence ensures that spray waters progressively wash contaminants off module hull surfaces (from top, to sides to bottom). Convey all used wash-waters to the active drainage system.
- Allow all wetted affected areas to dry.
- Remotely measure count rate from module hull.
- Re-map areas of highest contamination on module hull.
- Once contamination levels have been reduced sufficiently to permit man access to the shielded cell, repeat decontamination monitoring and perform 'hands on' decontamination activities appropriate to the final waste disposal route.
- Transfer cask lid to discharge port. Open shield hatch and lower module hull into discharge bay, onto pallet or suitable stillage. Close shield hatch.
- Open outer discharge bay door, and retrieve module hull on pallet or stillage using forklift truck or similar.
- Transfer module hull(s) to a buffer storage area, to be prepared for off-site shipment.

A5.5 Module Canister Decontamination

The SMV alternative generates a stream of spent module canisters, from which fuel modules have been discharged. They are discharged from the repackaging cell and transferred to a shielded cell, before undergoing a decontamination sequence (Refer Fig.8.4).
The following description assumes individual module canisters have been generated as a result of fuel transfer operations.

General assumptions:

1. All empty modules hulls (from SMV) have already been discharged in repackaging operations.
2. Decontamination facility is connected to the repackaging facility
3. Decontamination facility receives module canisters (singly) via the spent module canister transfer port
4. Decontamination facility comprises a series of interconnected shielded cells, progressively decontaminating the module canister.
5. Craneage, appropriate to the component form is present.
6. As precautionary measure, assume the module is contaminated, until proven otherwise.
7. The module canister assembly comprises a welded body and a lid. The lid/body seal weld has previously been removed as a result of module removal activities. The module canister shell decontamination is described. A separate sequence for the monitoring and

decontamination of the module canister will be executed, but many of the steps will be similar to the shell sequences. A decontamination booth dedicated to the decontamination of module canister lids will be required.

8. Module canister shells will be monitored on receipt at the decontamination cell suite, to establish the presence of surface contaminants.
9. The module canister components are extracted from a 'dirty storage location'. Direct contact between personnel and module canister components residing at this position is restricted by a shield wall, over which module canister components are lifted, during remote handling operations only.

Initial orientation: Module canister shell is held on suitable lifting attachment for subsequent decontamination operations.

- Remotely measure count rate from module canister shell.
- Map areas of highest contamination on module canister shell.
- Vacuum module canister shell, including lifting features.
- Remotely measure count rate from module canister shell.
- Re-map areas of highest contamination on module canister shell.
- Locally swab module canister shell.
- Remotely measure count rate from module canister shell.
- Re-map areas of highest contamination on module canister shell.
- Transfer module canister shell to decontamination booth.
- Apply spray water wash to module canister shell. Wash sequence ensures that spray waters progressively wash contaminants off module canister shell surfaces (from top, to sides to bottom).

NB. Both the internal and external surfaces of the module canister require decontamination. As there is no drainage route for wash waters from the interior of the module canister, these will have to be pumped from within the module canister shell. Convey all used wash-waters to active drainage system.

- Allow all wetted affected areas to dry.
- Remotely measure count rate from module canister shell.
- Re-map areas of highest contamination on module canister shell.
- Once contamination levels have been reduced sufficiently to permit man access to the shielded cell, repeat decontamination monitoring and perform 'hands on' decontamination activities appropriate to the final waste disposal route.
- Transfer cask lid to discharge port. Open shield hatch and lower module canister shell into discharge bay suitable stillage. Close shield hatch.
- Open outer discharge bay door, and retrieve module canister shell on stillage using forklift truck or similar.
- Transfer module canister shell to a buffer storage area, to be prepared for off-site shipment.

A5.6 Basket Decontamination

The following description assumes individual baskets have been generated as a result of fuel transfer operations. They have been discharged from the repackaging cell and transferred to a decontamination cell, before undergoing a separate decontamination sequence. In the case of a basket cask, up to seven baskets can result from each repackaging operation (refer Fig.8.5).

Basket assemblies arriving at the decontamination facility effectively comprise two sub assemblies, the basket lid and basket base. The lid sub assembly comprises a circular top plate, with a peripheral plate barrel suspended below. The base subassembly comprises the circular base-plate, intervening grid plate and the central lifting pintle. The decontamination processes will be effected after the separation of these two subassemblies which has taken place within to the decontamination cell, All subsequent operations describe the decontamination of a component. Given their circular plan, the processes are similar for the two component types. It will be necessary to customise the monitoring operations and decontamination booth profiles to suit.

General assumptions:

1. All empty baskets have already been discharged in repackaging operations.
2. Decontamination facility is connected to the repackaging facility
3. Decontamination facility receives baskets (singly) via the spent basket transfer port
4. Decontamination facility comprises a series of interconnected shielded cells, progressively decontaminating the basket.
5. Craneage, appropriate to the component form is present.
6. As precautionary measure, assume the basket is contaminated, until proven otherwise.
7. Basket components will be monitored on receipt at the decontamination cell suite, to establish the presence of surface contaminants.
8. A buffer storage capability of up to 7 off ‘dirty’ baskets is established at one end of the cell. Each basket component is extracted from a ‘dirty storage row’ and each basket is treated in turn. Direct contact between personnel and baskets residing at this position is restricted by a shield wall, over which baskets are lifted, during remote handling operations only.

Initial orientation: Basket component is held on suitable lifting attachment for subsequent decontamination operations.

- Remotely measure count rate from basket component.
- Map areas of highest contamination on basket component.
- Vacuum basket component, including tubular bore of lifting pintle.
- Remotely measure count rate from basket component.
- Re-map areas of highest contamination on basket component.
- Locally swab basket component.
- Remotely measure count rate from basket component.
- Re-map areas of highest contamination on basket component.
- Transfer basket component to decontamination booth.
- Apply spray water wash to basket component. Wash sequence ensures that spray waters progressively wash contaminants off basket component surfaces (from top, to sides to bottom). Convey all used wash-waters to active drainage system.
- Allow all wetted affected areas to dry.
- Remotely measure count rate from basket component.
- Re-map areas of highest contamination on basket component.
- Once contamination levels have been reduced sufficiently to permit man access to the shielded cell, repeat decontamination monitoring and perform ‘hands on’ decontamination activities appropriate to the final waste disposal route.
- Transfer cask lid to discharge port. Open shield hatch and lower basket component into discharge bay, onto pallet, or suitable stillage. Close shield hatch.

- Open outer discharge bay door, and retrieve basket component on pallet or stillage using forklift truck or similar.
- Transfer basket component to buffer storage area, to be prepared for off-site shipment.

A5.7 General Decontamination and Recovery

In the event that there is a handler failure during the normal decontamination processes, the handlers within the decontamination cells will be recovered to decontamination/maintenance facilities. Handler movements will be accomplished by the operation of remote recovery drives, actuated by through wall lances, such that any contaminated package could be set down within the cell. In the event of long travel failure, the handlers will be recovered by means of recovery cables (part of the cable reeling system).

Periodically, the cells and equipment (principally the handlers and decontamination equipment) within the decontamination suite will be subject to decontamination routines themselves. To establish the extent of contamination accumulation, the cranes and equipment should be monitored with greater frequency during active commissioning, to establish the projected build up and dispersal of contaminants within the cell. At levels which permit man access to the cells, monitoring, vacuuming, local swabbing and local washing should be implemented, balancing the need to maintain man access for maintenance purposes against the generation of the minimum of waste arisings.

Table A1: Fuel container arisings following repackaging events.

Alternative	Fuel container weights	Total No of casks	Total No of baskets	Total No of modules	Total No of module canisters	Daily No of casks	Daily No of baskets	Daily No of modules	Daily No of module canisters
CVSB									
Casks	62.5 tonne	8528				*1.23* **(76.9)**			
Modules	0.205 tonne			34112				*4.94* **(*1.01*)**	
Module canisters	4.1 tonne								
Baskets	0.45 tonne		4717				*0.68***(0.31)**		
SMV									
Casks	62.5 tonne								
Modules	0.205 tonne			34112				*4.94* **(*1.01*)**	
Module canisters	4.1 tonne				8528				*1.23* **(5.04)**
Baskets	0.45 tonne		4717				*0.68* **(0.31)**		
CVST									
Casks	62.5 tonne	8528				*1.23* **(76.9)**			
Modules	0.205 tonne			34112				*4.94* **(*1.01*)**	
Module canisters	4.1 tonne								
Baskets	0.45 tonne		4717				*0.68* **(0.31)**		
CRC									
Casks	62.5 tonne	9202				*1.33* **(83.1)**			
Modules	0.205 tonne			34112				*4.94* **(*1.01*)**	
Module canisters	4.1 tonne								
Baskets	0.45 tonne		4717				*0.68* **(0.31)**		
(Not in baskets)	**3274431**								
(In baskets)	**283020**								

Notes:

Repackaging takes place over a 30-year duration. Repackaging facility operates 230 days per year. Therefore waste fuel container arisings calculated over that period.

Daily totals in *Italics*, daily weights in **(bold)**.