Radioactive Materials Management

Conceptual Designs for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel

Alternatives for the Pickering, Bruce and Darlington Reactor Sites

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

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Preface

Currently, used nuclear fuel is stored at seven reactor sites in Canada, in both wet and dry storage facilities. The used fuel storage facilities are owned by four companies, and are located on the following reactor sites:

Ontario Power Generation	Pickering, Bruce and Darlington
New Brunswick Power	Point Lepreau
Hydro-Québec	Gentilly
Atomic Energy of Canada Ltd	Chalk River and Whiteshell

This report focuses on the Reactor-Site Extended Storage (RES) alternatives for consideration at the Pickering, Bruce and Darlington sites. Implementation of a RES alternative would provide an extended dry storage facility on a reactor site. In the context of this study extended storage means permanent or indefinite storage with the necessary maintenance and facility repeats. Three RES alternatives have been developed for each of the Pickering, Bruce and Darlington sites and they are described in this report. Separate reports have been produced to describe the alternatives for consideration at the New Brunswick Power [1], Hydro-Québec [2] and Atomic Energy of Canada Ltd [3] sites.

Other options for the management of Canadian used nuclear fuel in the longer term include extended storage at a central location (Centralized Extended Storage, CES) or isolation by encapsulation and placement in an underground disposal facility (Deep Geologic Repository, DGR). Other reports describe possible designs for CES facility and the DGR facility options. The CES Design Report is available should more detail be required [4]. The information in the RES, CES and DGR 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 Nuclear Waste Management Organisation (NWMO). At the end of its study, the NWMO will be required to report to the Government of Canada, setting out its preferred approach for long-term management of used nuclear fuel.

Summary

This report provides a technical description of the RES used fuel storage alternatives being considered for the Pickering, Bruce and Darlington sites. The alternatives under consideration at each site are:

- Casks in Storage Buildings (CSB)
- Surface Modular vault (SMV)
- Casks in Shallow Trenches (CST)

The CSB and SMV are above ground facilities, and the CST is partially below ground and will mounded over with an earthen cover. The CSB alternative represents a continuation of the current OPG dry storage methodology. Implementation of CSB alternative as an RES solution will not require any major design changes, but will require a review of the monitoring and inspection programme.

Implementation of a SMV alternative will require that all new used fuel arisings be placed in the SMV module canisters and then placed in storage. The implementation of the SMV alternative will also dictate that the cask processing buildings and the cask storage buildings, which would exist at the time of SMV implementation, become redundant. All existing casks in storage will be opened and the fuel modules inside transferred into module canisters within the new SMV processing building. The module canisters are stored within the SMV. Each redundant cask body and lid will be monitored and decontaminated as necessary, and then sent to disposal. After the all casks have been removed from existing storage buildings, the processing and storage buildings would be dismantled and waste materials sent to disposal.

The CST alternative utilises casks housed within concrete storage chambers located below grade level. Used fuel that arises after CST implementation will continue to placed into casks and then sent directly to the CST concrete storage chambers. The CST alternative would continue to use cask processing facilities that already exist on each reactor site. Existing casks in storage buildings will be transferred into the shallow concrete storage chambers, and then the cask storage buildings would be dismantled and waste materials sent to disposal.

The following table outlines the current interim used fuel storage activities at each of the sites, the date when initiated and the projected fuel inventory at the time of proposed implementation of the RES solutions.

	Pickering	**Bruce**	**Darlington**
Casks in Storage Building (CSB)			
Date interim storage implemented	January 1996	March 2003	
Target In service date for interim storage			October 2007
Projected earliest RES initiation date	July 2006	July 2006	July 2006
Total CSB basket cask inventory *		104	
Total CSB module cask inventory	2,421	3,825	2,282
Date CSB loading complete	2038	2041	2045
Surface Modular Vault (SMV)			
Earliest implementation date for SMV	2016	2018	2020
Cask storage buildings when SMV implemented.	3	3	2
Casks in storage buildings at implementation of SMV	1,200	1,489	679
Baskets transferred to SMV storage **		413	
Total SMV module canister inventory	2,421	3825	2,282
Date SMV loading complete	2053	2059	2054
Casks in Shallow Trenches (CST)			
Earliest implementation date for CST	2016	2018	2020
Cask storage buildings when CST implemented.	3	3	2
Casks in storage buildings at implementation of CST	1,200	1,490	679
Total CST basket cask inventory *		104	
Total CST module cask inventory	2,421	3,825	2,282
Date CST loading complete	2044	2049	2049

* Total number of basket casks produced when baskets transferred from Douglas Point silos to CSB or CST storage on the Bruce Site

** Total number of Douglas Point baskets transferred to SMV storage on Bruce site

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1 Introduction

1.1 Introduction and Background

The purpose of this report is to describe potential RES alternatives for the Pickering, Bruce and Darlington sites. The report first describes the current fuel storage methodology at each of the Ontario Power Generation (OPG) managed dry storage sites. Subsequent sections of the report describe the changes necessary at the dry storage facilities in order to implement any of the RES alternatives under consideration.

The alternatives under consideration for each site are:

- Casks in Storage Buildings (CSB)
- Surface Modular Vault (SMV)
- Casks in Shallow Trenches (CST).

Currently all of the used fuel bundles (Refer Figure 1), contained at each of the OPG sites is either in wet bays awaiting transfer into module format, or is already in dry storage containers (DSCs) which are housed within storage buildings. The exception to this is the Atomic Energy of Canada Limited (AECL) Douglas Point used fuel. This fuel is currently housed in baskets, which are stored inside concrete canisters (silos) on the Bruce site. The fuel within these concrete canisters, although owned and controlled by AECL, is assumed to be integrated into the alternatives under consideration for the much greater inventory of 'module format' fuel on the Bruce site.
The alternatives under consideration within this report which utilise the OPG Dry Storage Container (DSC) technology are the CSB and CST alternatives, consist of a dry storage system, based on the OPG standard wet loading of used fuel into DSCs.
The current or planned used fuel dry storage facilities at Pickering, Bruce and Darlington sites will provide interim storage capability for used fuel owned by OPG. Implementation of RES alternatives on the Pickering, Bruce and Darlington sites will provide an extended dry storage facility for the used fuel. In the context of this study extended storage means permanent or indefinite storage, with the necessary maintenance and facility repeats.

1.2 Organisation of Document

The design report is organised into the following sections.

Section 1	Introduction and Background This section provides an introduction to the report, background and context information, and definitions of key terms.
Section 2	Current and Planned Used Fuel Storage Operations. This section describes the current used fuel storage activities on each of the reactor sites.
Section 3	Alternative Descriptions This section provides generic descriptions of the alternatives under consideration, but does not apply the alternatives to specific sites.

Section 4 Site Specific Application of Alternatives
This section reviews each of the alternatives and considers the requirements for instigation of the alternatives to each site.

Section 5 References

1.3 Definitions

The major 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 AECL

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 Figure 5.3) currently used by OPG and a new design of cask similar to the DSC to store fuel in baskets

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.

IAEA International Atomic Energy Agency

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

Module canister is a sealed container holding a number of modules for loading into a SMV storage vault.

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 Figure 6 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.

Reactor Extended Storage (RES) facility is a facility used for the extended storage of used nuclear fuel. The storage facilities will be located at each of the current Reactor sites. Each fuel owner will implement a storage solution selected for the specific circumstances of that site.

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 and shielding as necessary, 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. Each chamber comprises two storage bays. 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.

Used Fuel means the irradiated fuel bundles removed from commercial or research nuclear fission reactor.

2 Current and Planned Used Fuel Storage Operations

OPG's used fuel is generated by the operation of 20 nuclear reactors at the Pickering, Bruce and Darlington sites. Bruce Power operates the reactors at the Bruce Site but OPG receives and manages the used fuel for fees based on an agreement between OPG and Bruce Power. Of these 20 reactors, four reactors at Pickering and four reactors at Bruce are currently laid up. A recovery plan has been developed to return Pickering 1-4 to service in the 2003 to 2006 timeframe. Bruce Power has indicated an intent to restart Bruce 3 & 4 in 2003 and 2004.

OPG has developed plans for the management of used fuel based on the assumption that all reactors will operate a nominal 40 years. It is estimated that a total of 3.3 million used fuel bundles will be generated from the committed nuclear program and as of 31 December 2002 there were 1.4 million bundles in wet and dry storage. At the end of the nuclear program it is estimated that there will be 2.3 million bundles in dry storage and about 1 million bundles in wet storage.

OPG currently operates dry storage facilities on the Pickering and Bruce sites and plans to construct a third dry storage facility on the Darlington site. All OPG dry facility designs are based on the storage of casks or dry storage containers (DSCs) within storage buildings. DSCs are loaded with four used fuel storage modules (Refer Figure 2), each with a capacity to store 96 fuel bundles, these modules are loaded into a DSC inside a loading bay built adjacent to the Station Irradiated Fuel Bays. The DSC (Refer Figure 3) loaded with 384 fuel bundles is then drained, vacuum dried and transferred to the DSC Processing Building. In the DSC Processing Building, the DSC is seal welded, vacuum dried, backfilled with helium, leak tested, provided with the appropriate Safeguards seals, and transferred to a DSC storage building for storage, using a dedicated cask transporter, (Refer Figure 6).

The SMV alternative does not utilise casks as the fuel housing. The SMV alternative requires modules to be loaded and sealed into module canisters (Refer Figure 5). The transfer of the fuel from DSCs to module canisters is carried out inside a shielded cell. The sealed module canisters are then transferred, in a shielded flask, loaded within the SMV storage vault. In addition Atomic Energy of Canada Limited (AECL) operates a silo dry storage facility on the Bruce site. The following sections describe the current and/or planned used fuel dry storage facilities on the three reactor sites. Additional design information about OPG's dry storage system can be found in Section 3.1 of this report.

2.1 Pickering Site

2.1.1 Pickering Site

The Pickering reactor site is located on the north shore of Lake Ontario, 32 km east of Toronto. The Pickering site has two stations, Pickering A and Pickering B. The entire 240-ha site is fenced and access is restricted and controlled by OPG. The Pickering Waste Management Facility located at the southeast corner of the Pickering site, and comprises the Used Fuel Dry Storage Facility and the Retube Components Storage Facility.

At the end of the committed nuclear program it expected that about 930,000 fuel bundles will be in storage on the Pickering site.

2.1.2 Pickering Used Fuel Dry Facility – Existing Facilities

The Pickering Used Fuel Dry Storage Facility went into operation in January 1996. It accepts used fuel that has been loaded into DSCs after a minimum of 10 years of cooling in the station wet bays. The dry storage facility comprises a Processing Building used for preparing DSCs loaded with used fuel bundles for storage, and two Storage Buildings used to store the DSCs (Refer Figure 7). This used fuel storage process is approved and licensed by the CNSC.

The Processing Building includes an area for receiving and preparing new DSCs, an area for painting, and a workshop area that houses the following dedicated systems for processing DSCs:

- Closure welding and welding-related equipment
- X-ray radiography system; and
- Leak testing system

The two existing Storage Buildings are referred to as Stage 1 and Stage 2. Stage 1 has the capacity to store 185 DSCs and Stage 2 has the capacity to store of 470 DSCs. Stage 1 is already full, and the transfer of loaded DSCs into Stage 2 began in 2001. Figure 9 shows DSCs in the Stage 2 Storage Building. The Storage Buildings provide shielding, passive ventilation for cooling and weather protection for the welded DSCs in storage.

2.1.3 Pickering Used Fuel Dry Facility – Future Facilities

OPG is planning to expand dry storage capacity of the Pickering Waste Management Facility. Since there is insufficient space in the vicinity of the existing storage buildings, the new storage buildings will be constructed at a separate nearby location on the Pickering site. The proposed location of the two new storage buildings is called the Eastern Complex, which is located east of the existing dry storage facilities (Refer Figure 8).

Construction of the new storage buildings will be completed in two stages with the first building targeted for in-service in 2007. The new buildings will be designed similar to the existing storage buildings and the recently constructed storage building at the Western Waste Management Facility, (Refer Figure 9). They will both be single storey, commercial-type pre-engineered or pre-cast concrete structures with a concrete slab-on-grade floor. The Storage Buildings will be provided with passive ventilation and inactive drainage, and will be enclosed by a security fence. Each building will be designed to hold 490 DSCs for a total storage capacity of 980 DSCs.

2.2 Bruce Site

The Bruce Nuclear Power Development, hereafter referred to as the Bruce site, is located within the administrative boundaries of Bruce Township in the County of Bruce. The Bruce site has been leased to Bruce Power since May 2001. Parts of the site, including the Western Waste Management Facility, were then leased back to OPG. The Bruce site covers 932 hectares and the site is fenced, and access is restricted and controlled by Bruce Power. Also located on the Bruce site are the Bruce A and Bruce B Nuclear Generating Stations, the Bruce Heavy Water Plant and AECL's Douglas Point Nuclear Generating Station.

At the end of the committed nuclear program about 1.5 million fuel bundles will be in storage on the Bruce site. The following sections describe the existing and planned dry storage facilities on this site.

2.2.1 Western Used Fuel Dry Storage Facility – Existing Facilities

The Western Used Fuel Dry Storage Facility (WUFDSF) is located within OPG's Western Waste Management Facility. The WUFDSF received its operating license from the Canadian Nuclear Safety Commission (CNSC) on 30 August 2002 and received the first DSC loaded with used fuel from the Bruce B in March 2003.

The WUFDSF comprises the Processing Building and one Storage Building (Refer Figures 10 and 11). The two-storey Processing Building has office and utility areas, receiving bay and workshop area. The building also has a mezzanine and is constructed with concrete block walls and metal cladding. Reinforced floor is able to accommodate the heavy wheel load traffic and the weight of loaded DSCs. Design processing rate of the facility is 3.5 DSCs per week. It is expected that 130 DSCs will eventually be delivered each year (65 each from Bruce A and Bruce B). Thus 130 DSCs will be processed in 38 weeks leaving 14 weeks per year for scheduled and unscheduled maintenance.
The Storage Building has an approximate area of 5,278 m^3 and a design storage capacity of 490 DSCs. The walls consist of 200-mm thick pre-cast concrete panels from ground level to a height of 4.2 m. Vertical louvers and metal cladding are installed at the upper wall elevations. The Storage Building uses passive ventilation through the wall and roof louvers to dissipate heat decay from the used fuel in storage to the atmosphere.

2.2.2 Western Used Fuel Dry Storage Facility – Future Facilities

OPG has CNSC approval to construct three additional buildings and the site has been prepared for the construction of these buildings. It is planned to bring the next storage building into service in 2007. The three additional Storage Buildings will be constructed immediately adjacent to the first Storage Building to form a contiguous and interconnected set of four storage buildings. There are also plans to build other Storage Buildings in the vicinity of the first four buildings. CNSC approval would be required to construct these additional buildings.

2.2.3 Douglas Point Waste Management Facility

The Douglas Point Nuclear generating station was shutdown permanently after 17 years of operation. Decommissioning began in 1986 and in late 1987 22,256 used fuel bundles were transferred into 46 concrete silos (also called canisters) located external to the station (Refer

Figure 12). The silos were built on-site and in the open following a concept developed by AECL. This storage facility is located approximately 1.5 km west of OPG's WUFDSF on the Bruce site.

The storage facility consists of silos arranged in three rows of 12 and one row of 11. The silos rest on a concrete foundation, 44 m x 15 m in area, and 0.6 m thick, which in turn rests directly on bedrock. There is a surrounding security fence to control access to the silos. Each silo is a cylindrical reinforced concrete shell with an internal carbon steel liner. The silo has a 2.6-m outside diameter, a height of 6.2 m and an inside diameter of 0.85 m. The silos accept 9 fuel baskets and each basket has a maximum capacity of 54 fuel bundles. The fuel basket with an 810-mm diameter and 540-mm height is constructed of stainless steel. The basket is designed to be leak-tight after seal welding. There are 413 used fuel baskets in storage.

AECL is currently planning to decommission the existing Douglas Point dry storage facility within the period 2040 to 2045.

2.3 Darlington Site

The Darlington site is located about 70 km east of Toronto on the north shore of Lake Ontario, in the Municipality of Clarington, in the Regional Municipality of Durham. The 485 Ha site is fenced, and access is restricted and controlled by OPG. The Darlington Nuclear Generating Station is located on the site and all used fuel produced by the station is now being stored in the station wet bays. At the end of the committed nuclear program about 880,000 fuel bundles will be in storage on the Darlington site.

OPG plans to construct a new dry storage facility on the Darlington site (Refer Figure 14). Before OPG can construct the DUFDSF, an environmental assessment (EA) of the project must be completed, and construction approval must be obtained from the CNSC. The EA study report and the supporting technical documents has been submitted to the CNSC in November 2002. The EA has been carried out to meet the requirements of a Screening Study as defined by the Canadian Environmental Assessment Act (CEAA).

It is anticipated that the EA review will be complete in the Spring of 2004. The CNSC is expected to provide approval to prepare the site and construct the facility in the Fall of 2004. Construction and commissioning of the facility will take about 3 years to complete. OPG has established a target in-service date of October 2007 for the new DUFDSF.

The DUFDSF will be similar in design to the dry storage facility at the Western Waste Management Facility. It will comprise a Processing Building with a design processing rate of 3.5 DSCs per week, Storage Buildings and ancillary facilities such as offices, lunch room, change rooms and parking.
Construction approval will be sought to build three Storage Buildings. However, only one building will be constructed initially with a design capacity of 490 DSCs. The construction of the other two buildings will be staged as additional storage space is required.

3 Alternative Descriptions

3.1 Casks in Storage Buildings (CSB)

The Casks in Storage Buildings alternative comprises the storage of fuel modules stored in self shielded storage casks. Each cask houses 4 modules, each module contains 96 used fuel bundles, (384 fuel bundles per cask). The storage casks are housed within a series of storage buildings.

Key features of the CSB extended storage concept include:

- Fuel is stored within sealed storage casks
- 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 transfers the cask to the pre determined cask 'park' position within the storage building
- Cooling of the casks within the storage buildings is achieved by natural convection, through vents and louvers in the storage building walls and roof.

The following CSB parameters are indicative of the existing facilities at the Western Waste Management Facility. They are described here to represent typical values only. The final RES CSB design will not be constrained by these values, but may use them for guidance.

The CSB the dry storage technology currently used by OPG at the Pickering and Bruce sites and that will be used at the Darlington site. The following is a generic description of the CSB dry storage technology employed by OPG.

3.1.1 Cask Storage Buildings

The cask storage buildings provide a weatherproof enclosure for the storage of casks. Each storage building is designed to accommodate nominally 500 casks, the number of buildings required will vary from site to site depending upon the fuel inventory of each OPG site. Where possible each storage building is close coupled with the adjacent storage buildings, and access between storage buildings is achieved using the clear corridors generated by the pre-determined positioning of the casks within each store. The storage buildings are provided to protect the casks and to facilitate all weather operation. The buildings are not required to provide containment of radionuclide emissions, as this is a function of the fully seal welded casks. The building structure framework for the cask storage buildings is steel framed buildings with precast concrete wall panels from ground to approx. 4m height, with cladding sheets above, fixed to the primary steelwork. The roofs are pitched and designed and constructed in line with Canadian building codes and regulations for warehouse type structures. The store floors are finished concrete, and designed to cater for all predicted static and dynamic loads (Refer Figures 15 and 16).

3.1.2 Fuel Retrievability

If the storage systems for casks do not perform according to the specification, it will be possible to retrieve the used fuel (in the cask), from storage, to repair the cask as necessary or to transfer the used nuclear fuel to a new storage facility. The storage facility is designed to allow safe retrieval of used nuclear fuel from the storage buildings at any point during the service life of the facility. The casks are stored so that any individual cask can be retrieved at any time during the service life of the storage facility.
The CSB storage alternative does not utilise the stacking of casks within the storage building, therefore retrieval of a specific cask requires removal of the foregoing casks within the same row as the designated cask, utilising the cask transporter. A maximum of 9 casks would need to be removed to gain access to the last cask in a row.

3.1.3 Storage Cask Loading Operations

In overview, the cask loading operations are outlined below:

- Used fuel is cooled in the Irradiated Fuel Bay (IFB) for a minimum of 10 years after discharge from the reactor. This allows the fuel to cool and loose some of its radioactivity.
- The storage cask body is submerged in the fuel-loading bay, adjacent to the IFB.
- Four full (96 bundles each) modules are loaded into the cask body.
- The cask lid is then lowered onto the cask body (underwater) and is clamped in-place using the in-bay clamp.
- The cask assembly is raised out of the loading bay and allowed to drain.
- The in-bay clamp is removed and replaced by the cask transfer clamp.
- The assembly is then transferred to the cask processing area using the cask transporter, where the cask is seal welded, vacuum dried, backfilled with helium, leak tested, provided with the appropriate safeguards seals and is then transferred to the duty storage building, again using the cask transporter.

3.1.4 Access

Access into the storage building complex is monitored and controlled. Individual storage buildings can be entered using the cask transporter corridors within the storage buildings. Storage casks will be ‘collected’ from the cask processing area or from existing cask storage buildings and transferred to the RES storage building using the dedicated cask transporter.

3.1.5 Cooling and Ventilation

The cask storage buildings use passive ventilation to provide cooling for the used fuel storage casks. 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 approximately 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.

3.1.6 Shielding

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.

3.1.7 Containment

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.

3.1.8 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.

3.2 Surface Modular Vault (SMV)

3.2.1 General Description

The Surface Modular Vault (SMV) concept comprises the storage of fuel bundles confined in module canisters and placed into an array of tubes in a series of engineered vaults within the storage buildings. The 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 module canisters into the storage tube. The storage buildings are linked together by an access corridor below the charge face level for transporting 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 (Refer Figures 17,18 and 19).

Key features of the SMV extended storage concept include:

- A processing building is required to handle fuel modules from storage casks, or direct from the wet bay, transferred to the processing building using the 4-module transfer flask and transporter.
- Fuel modules (4 off) are sealed in a module canister before emplacement into 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 the ‘housing’)
- Fuel is stored within storage tubes within the SMV vault buildings
- Additional capacity is provided by construction of the SMV storage buildings on a rolling program,
- Module canisters are placed in storage vault tubes using a canister handling machine
- Cooling is achieved by natural convection across the array of storage tubes from vents in the building structure.

3.2.2 Processing Building

The processing building will be an industrial type building structure, designed to provide a safe operational area for the handling of used fuel storage and de-lidding of storage casks.
The elements that make up the Processing Building are,

- Receipt area
- Module transfer shielded cell (shielded cell)
- Cask body/lid decontamination and monitoring shielded cell
- Crane maintenance/decontamination area
- Cask lid weld removal ventilated enclosure

The shielded cell provides a fully shielded remotely operated facility, designed for the receipt, handling and repackaging of fuel modules. The shielded cell is configured to handle the fuel modules, using a dedicated in-cell overhead crane. Fuel transfers into the cell, will be from either storage casks or the 4-module transfer flask. The 4-module transfer flask will be transferred directly from the wet bay using the associated transporter. Casks will be transferred to the shielded cell using the cask transporter. After removal of the cask lid weld, in the cask lid weld removal area, the storage cask lid will be temporarily retained on the cask body with a transfer clamp, before being transferred to the SMV shielded cell, (see section 3.2.7 for specific operational sequences).
The shielded module transfer cell will be designed to accept fuel modules from either source, and is capable of loading a module canister with the required 4 fuel modules. The shielded module transfer cell has a shielded annex, the module canister welding area, which has the capability to remotely seal weld the top plate onto the module canister body. Completion of this weld will allow the completed module canister to be transferred, in the module canister transfer flask to the SMV store.
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. 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 (Refer Figures 20, 21, 22 and 23).

3.2.3 Fuel Retrievability

If the SMV storage system does not perform according to the specification, it will be possible to 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 RES 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 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.

3.2.4 Construction Materials

<u>General</u>

An integral foundation slab supports each 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, 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 nominal 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.

3.2.5 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 the fuel module canisters. The individual storage positions allow access to small quantities of irradiated fuel for monitoring, inspection or retrieval.

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 a number of storage buildings. Each storage building comprises a series of individual vaults. 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 can be removed from the storage tubes for inspection or transfer to new 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.

3.2.6 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. 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. 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.

3.2.7 Sequence of Process Operations

In overview, the initial receipt, process and fuel container transfer operations are outlined below. The SMV will receive fuel module from either existing DSC which are retrieved from storage buildings. These DSCs will need to be opened at the SMV processing building. Fuel modules will also be received directly from the wet bay. These two alternatives are outlined in sections 3.2.7.1 and 3.7.2.2 respectively (refer Figure 23).

3.2.7.1 Module Transfer from Cask

1. Receive cask into processing building
2. Transfer cask into cask lid weld removal area
3. Manually remove cask lid weld
4. Install cask lid transfer clamp
5. Transfer cask from lid weld removal area to module transfer shielded cell
6. Move cask onto cask transfer bogie
7. Move cask transfer bogie to cask lid removal / replacement position
8. Remove cask transfer clamp
9. Close shield door
10. Remove and retain cask lid
11. Move cask body, on transfer bogie, through inner shield door to module transfer position
12. Close inner shield door
13. Transfer 4 modules into shielded cell
14. Return empty cask to lidding position
15. Replace cask lid

16. Remove empty cask / lid assembly from module transfer cell and transfer to decontamination cell
17. Remove cask lid inside decontamination cell
18. Swab, vacuum, monitor and decontaminate cask body and lid as necessary to permit ‘hands on access’
19. Transfer cask body and lid to dismantling/breakdown area in preparation for final disposal.

3.2.7.2 Module Transfer from Wet Bay

1. Receive 4-module transfer flask and associated transporter, from the wet bay, into the processing building
2. Load 4-module transfer flask onto transfer bogie
3. Move 4-module transfer flask below module transfer cell receipt position
4. Transfer 4 fuel modules into module transfer cell
5. Return empty 4-module transfer flask to transfer bogie park position
6. Return empty 4-module transfer flask to wet bay
7. Initiate module drying sequence at module park position in module transfer cell

3.2.7.3 Module Canister Receipt, Loading and Seal Welding

1. Transfer empty module canister assembly, (body and lid) from buffer area into machined rebate in cask transfer bogie base platform
2. Move cask transfer bogie to module canister transfer port
3. Transfer empty module canister from transfer bogie into cell
4. Remove module canister lid
5. Load 4 dried modules into module canister body
6. Lid module canister
7. Transfer lidded module canister through shield door into welding cell
8. Remotely weld module canister lid onto body
9. Return seal welded module canister into main cell
10. Transfer module canister into module canister transfer flask (module transfer flask has been positioned below cell, after removal of cask transfer bogie)
11. Transfer module canister transfer flask to the load/unload port below surface modular vault charge machine, on module canister transfer flask bogie.

3.2.7.4 Module Canister Loading into SMV storage tube

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. 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.

3.2.7.5 Prepare a Module Canister 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 ring to storage tube shield plug

4. Position CHM over storage tube
5. Lower charge face gamma gate onto charge face
6. Lower CHM retractable shield skirt onto charge face shield gate
7. Disconnect charge face gamma gate from CHM
8. Open CHM and charge face gamma gates
9. Remove storage tube shield plug using CHM grapple
10. Close CHM and charge face gamma gates
11. Raise CHM retractable shield skirt
12. Move CHM to Shield Plug Stowage Position
13. Lower CHM retractable shield skirt onto stowage position
14. Open CHM gamma gate
15. Place storage tube shield plug in stowage position
16. 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.

3.2.7.6 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 2nd 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.

3.2.7.7 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

3.2.8 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 will be transferred from the processing area to the storage buildings using a transfer bogie. The transfer bogie runs on rails, which directly link the processing area to the storage vault complex. The transfer bogie will transfer the module canisters 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 a 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.

3.2.9 Cooling and Ventilation

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.

3.2.9.1 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.

3.2.9.2 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.

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 or module canisters, which are sealed in the storage tubes, ensuring the internal walls of the vault remain radiologically clean.

3.2.10 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. 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 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 the module canisters. Provision for IAEA safeguards will be integrated into the design to allow duplicate seals to be applied to the filled storage tube. Duplicate seals are provided to ensure redundancy in case of accidental damage to either one, thereby reducing the probability of a need to re-verify the storage tube contents.

Temporary seals are applied to part-loaded canisters between each insertion of a spent fuel basket. The temporary seals are electronic and can be easily removed and replaced but only by an IAEA inspector. After the storage tube has been filled the permanent seals will be installed. The module canister storage tubes have in internal envelope of 1.83m diameter by 6.25m.

3.2.11 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.

3.2.12 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 raiser 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 grade level down to the Storage Complex is covered to provide weather protection to the transfer flasks and trolleys and ensure that the module canisters remain dry.

3.3 Casks in Shallow Trenches (CST)

3.3.1 General Description

The Casks in Shallow Trenches concept (CST) comprises the storage of fuel modules confined in self shielded casks. The cask design is assumed to be identical to that used in the CSB concept. The casks 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 an earthen cover. The chambers will be interconnected at both ends with corridors to form a complex accessible by a ramp from ground level. The earthen cover will provide weather protection for the concrete chambers and added physical protection. The earthen cover will also lessen the visual impact of the storage chamber 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 Figures 24 and 25).

Key features of the CST extended storage concept include:

- The CST storage facility utilises the standard module storage cask (Refer Figure 3)
- Existing storage casks can be transferred directly from the existing cask storage buildings to the CST storage chamber, using the cask transporter
- Additional storage capacity is 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 (upper storage tier only)
- 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.

3.3.2 Storage Chambers

The design capacity of the storage chamber complex is designed to store the site specific inventory. The casks will be stored in a series of parallel chambers, the total number will be determined with placing casks in six rows stacked two high per chamber. 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 cask 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 receipt building, at grade level by a ramp. The storage chambers will be constructed over time to match arrival of the storage casks. 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.

3.3.3 Fuel Retrievability

If the CST storage system does not perform according to the specification, it will be possible to retrieve the used fuel from the storage chamber, so as to repair the storage system or transfer the used nuclear fuel to a new storage facility.
The RES 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 retrieved at any time during the service life of the storage facility.
The CST 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.

3.3.4 Cask Storage Chambers

The interior dimensions of the cask storage chambers will be 29m wide and of length to suit the site specific inventory. The floor of the chamber will be sloped toward the corridors at both ends. As a result, the height of the chamber varies from the ends to the 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 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.

3.3.5 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 cask 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 raisers 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.

3.3.6 Earthen Cover

The earthen cover above the storage chambers will be approximately 3.5m thick and will be crowned in the centre with a 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.

3.3.7 Sequence of Operations

In overview, the initial receipt, process and fuel container transfer operations are outlined below. Used fuel is cooled in the Irradiated Fuel (IFB) bay for several years after discharge from the reactor. This allows the fuel to cool and loose some of its radioactivity. The storage cask body is submerged in the fuel-loading bay, adjacent to the IFB. Four full (96 bundles each) modules

are loaded into the cask body. The cask lid is then lowered onto the cask body and is clamped in-place using the in-bay clamp. The cask assembly is raised out of the loading bay and allowed to drain. The in-bay clamp is removed and replaced by the cask transfer clamp. This assembly is then transferred to the cask processing area using the cask transporter, where the cask is seal welded, vacuum dried, backfilled with helium, leak tested, provided with the appropriate safeguards seals and is then transferred to the duty storage building, again using the cask transporter.
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.

3.3.8 Access

Access to the storage chambers will be gained using an enclosed ramp that goes from grade level via the access corridor at a 2.5 % 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 construction will be reinforced concrete similar to the chambers.

3.3.9 Cooling and ventilation

Cooling and ventilation for the storage chambers will be provided by natural ventilation based on the principles of the exhaust raiser effect, supplemented by heat released from the casks. Vertical raisers constructed on top of each chamber, will rise above grade level to induce the raiser effect required for ventilation. Rain hoods will be provided at the top of the raisers 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 raiser effect.

The airflow through the storage chambers will be set manually by adjusting the dampers or openings located at the exhaust raiser 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.

3.3.10 Shielding

The shielding provided by the casks 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.

3.3.11 Containment

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.

3.3.12 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 CST 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 grade level down to the storage complex is covered to reduce the potential for weather ingress into the storage complex during fuel emplacement operations.

4 Site Specific Application of Alternatives

This section of the report describes the site specific application of the following alternatives on the Pickering, Bruce and Darlington sites:

- Casks in Storage Buildings (CSB)
- Surface modular Vaults (SMV)
- Casks in Shallow Trenches (CST)

Should there be a decision made to implement reactor-site extended storage based on the CSB technology, then this alternative could be implemented immediately following the decision. OPG would continue to store fuel in casks (DSCs) within storage building as is being done at the present time, and new storage structures would be built as per the regulatory approvals already in hand. New approvals would be sought, as necessary, for refurbishment/replacement of the storage structures, periodic repackaging of the fuel and decommissioning of facilities.

Should there be a decision made to implement either the SMV or CST technology, then additional time would be required, following the decision, to transition to new dry storage systems on each of the reactor sites. Additional time would be required to locate suitable sites, to develop site specific designs, to gain all necessary approvals, and to construct and commission new facilities. Therefore, for the purposes of this study, it has been assumed that the earliest in-service date for a facility based on either SMV or CST technology would be January 2016. Following in-service, the new dry storage facilities would operate indefinitely with refurbishment/replacement of the storage structures and periodic repackaging of the fuel. The new dry storage facilities would initially accept fuel transferred directly from wet bays. After the wet bays are emptied, fuel stored in casks within existing storage buildings would be transferred to the new storage structures as soon as practical.

Tables 2 to 8 inclusive, provide details of the site-specific fuel inventories. Also included are assumed processing rates for casks or module canisters, assumed dates for constructing new storage facilities, assumed times periods over which used fuel would be transferred from old storage buildings to new storage structures (SMV and CST only), and assumed dates when storage buildings would be decommissioned for each of the alternatives under consideration. For the purpose of developing these tables it has been assumed that a decision to implement reactor-site extended storage would be made no sooner than July 2006. The following sections provide a more detailed description of the implementation of the CSB, SMV and CST dry storage systems on the Pickering, Bruce and Darlington sites.

4.1 Pickering Site

4.1.1 Casks in Storage Buildings (CSB)

CSB is a continuation of the current Pickering used fuel storage methodology.
Implementation of this alternative will utilise the existing cask processing building. It is assumed that three cask storage building will have been commissioned for interim cask storage, and will be in service prior to implementation of the RES alternative. If CSB is the selected RES alternative, cask production will continue using the existing cask processing area and transferred to a storage building. Storage buildings will be constructed as required on a rolling construction programme, which will be matched to the cask production rate (Refer Figure 26).
The annual cask production rate, the cumulative number of casks in store and the phasing of the future construction of storage buildings is described in Table 1. Table 1 also identifies the availability of cask storage buildings for use as an interim storage facility, prior to implementation of CSB as a RES alternative.

The completed RES CSB facility at Pickering will comprise six cask storage buildings. Existing Stage 1 and Stage 2 buildings have a capacity of 655 casks. New storage buildings are assumed to have a nominal capacity of approximately 490 storage casks. The total fuel inventory (929,624 fuel bundles), stored in 2,421 storage casks will completely fill five storage buildings. The sixth cask storage building will accommodate the remaining storage casks, with some spare capacity. This spare capacity will provide 'buffer' storage spaces for the movement of casks during cask monitoring activities or could provide temporary parking for casks which need to be moved to facilitate access to casks currently positioned on the inside of the storage arrays. It may also be advantageous for casks to occupy this extra space during routine building maintenance activities.

4.1.2 Surface Modular Vault (SMV)

Implementation of a SMV facility at Pickering will require the creation of an SMV processing complex in line with the facility described in section 3.2.2. It will be capable of transferring fuel modules into module canisters and seal welding the module canister assembly. Additionally the facility will also require the capability to ‘open’ existing storage casks, remove the fuel modules and repackage them into module canisters. After having the fuel modules removed, the cask bogies and lids will require monitoring, possible decontamination and dismantling.

The Pickering SMV storage facility will contain 4 storage buildings. Each storage building houses eight (8) storage vaults:

- Each storage vault will house 40 storage tubes, in a 4 x 10 array,
- The SMV complex = 4 buildings x 8 vaults per building x 40 tubes per vault = 1280 storage tubes.
- Each storage tube is designed to accommodate 2 module canisters,
- Each module canister holds 4 fuel modules
- Each module holds 96 fuel bundles.

This equates to a total SMV storage complex capacity of - 1280 x 2 x 4 x 96 = 983,040 used fuel bundles (Refer Figure 27).

Implementation of the SMV alternative requires the transfer of used fuel, currently in storage cask format into modular canister format, this transfer will be undertaken in the dedicated shielded cell within the Processing Building. Table 2 identifies the annual cask production rate, and the cumulative number of casks in store, prior to implementation of the SMV facility. Table 2 also identifies the availability of the first SMV storage vault and the subsequent annual production rate for module canisters. SMV storage vaults will be produced in-line with the schedule outlined in Table 2.

Transfer of the used fuel previously held in storage casks into SMV module canisters is assumed to occur from years 2039 to 2053.

The consequence of the transfer of fuel out of casks is the generation of a waste stream of redundant, empty storage cask assemblies (casks and lids). These will require monitoring, decontamination and dismantling prior to release from the site as inactive waste. The amount of waste arising from the dismantling of each storage cask will be approximately, 56 tonnes (16 m^3) of concrete and 6.5 tonnes (0.85 m^3) of steel. A total of 1,200 casks will need to be opened and the fuel transferred into module canisters. These 1,200 redundant casks will be treated as waste.

It is anticipated that no more than 0.25% of storage cask 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. The footprint of the storage facility described above would be approximately 102 m x 158 m. The footprint of the SMV processing complex described above would be approximately 42 m x 90 m, which includes an allowance for a cask and module dismantling/breakdown area.

4.1.3 Casks in Shallow Trenches (CST)

Implementation of a CST alternative for the Pickering site will require the creation of 4 storage chambers.

- Each storage chamber comprises two bays.
- Each bay will be designed to accommodate the 80 tonne mobile crane, which is used to position upper tier casks on top of the casks stored at ground level.
- Each storage bay is designed to accommodate 330 casks, (55 casks long, x 3 wide x 2 high), thus 660 casks per chamber.
- The total store capacity will be 660 x 4 = 2640 casks.

To implement the CST alternative at the Pickering site will require the eventual storage of a total of 2,421 module casks, therefore the 8th storage bay will not be full and will have spare capacity (Refer Figures 28).

The existing cask production facility at Pickering will remain operational as the cask production facility for the CST. If the CST alternative is selected for implementation then casks will be transferred from the existing storage building to the CST storage facility as soon as practical. Table 5 identifies the annual cask production rate, and the cumulative number of casks in storage buildings, prior to implementation of the CST facility. Table 5 identifies the availability of the first CST storage chamber and the subsequent annual production rate for storage casks. Additional CST storage chambers would be produced in-line with the schedule outlined in Table 5. Transfer of the used fuel previously held in storage buildings into CST storage chambers is assumed to be transferred from years 2039 to 2044.

Movement of the casks from the storage buildings to the CST storage complex will be performed using the cask transporter. Storage casks are stacked 2 high, within the storage chamber. The cask transporter will park casks in their designated storage position on the lower tier, or will position the casks below the chamber crane for movement onto the upper tier.

This figure assumes the Processing Building is subject to a programme of preventative maintenance and repair (as necessary).

4.2 Bruce Site

4.2.1 Casks in Storage Buildings (CSB)

Implementation of the CSB alternative would simply be a continuation of the current Bruce used fuel storage methodology. Fuel that is stored in the IFB at the time of implementation of this RES alternative will, upon completion of the require cooling period, be loaded into casks and processed in the usual manner. The casks generated by this process will then be transferred directly to the predetermined storage building. Implementation of this alternative will utilise the existing cask processing building.

One cask storage building is assumed to be commissioned and in service prior to implementation of the CSB alternative.

When the first storage building is full, similar storage buildings will be constructed on a rolling construction programme that will be matched to the cask production rate. The assumed annual cask production rate, the cumulative number of casks in store and the phasing of the future construction of storage buildings is described in Table 1.

The CSB facility at Bruce will eventually require the creation and storage of a total of 3,929 casks. This quantity is made up of 3,825 ‘conventional’ module casks and 104 casks containing the AECL Douglas Point (DP) used fuel (Refer Figure 29). The Douglas Point fuel is currently held in baskets on the OPG site. The DP inventory, comprising 22,256 fuel bundles is currently housed within 413 fuel baskets. These baskets are currently inside an array of concrete canisters (silos). The fuel baskets will be withdrawn from the silos and loaded into storage casks, 4 baskets per cask at the shielded transfer enclosure, adjacent to the AECL silo array (Refer Figure 30). The cask transportation clamp will be applied to the loaded cask and the cask transporter will deliver the loaded cask to the cask processing area. The cask will be processed in the same way as the module casks, i.e. seal welded, vacuum dried, backfilled with helium, leak tested, provided with the appropriate safeguards seals, and then transferred to the storage building. The baskets will be guided and restrained within the storage cask void using a basket adapter frame (Refer Figure 31).

For the RES alternatives the physical geometry of the module cask and basket cask is the same. The CSB facility at Bruce will comprise eight storage buildings. Each storage building has a nominal capacity of between 490 and 500 storage casks (some slight adjustment of the building capacity would be made to facilitate the cask production rates (Refer Table 1). The total fuel inventory, stored in 3,929 storage casks will completely fill seven storage buildings. An eighth building will accommodate the remaining casks.

The 104 basket storage casks (containing the DP fuel) will be integrated into the eighth storage building which will contain both module casks and basket storage casks, with some spare capacity. This spare capacity will provide 'buffer' storage spaces for the movement of casks during cask monitoring activities or could provide temporary parking for casks which need to be moved to facilitate access to casks currently positioned on the inside of the storage arrays. It may also be advantageous for casks to occupy this extra space during routine building maintenance activities.

Where possible each storage building would be close coupled with the adjacent storage buildings. Access between storage buildings is achieved using the clear corridors generated by the pre-determined positioning of casks within each store.

4.2.2 Surface Modular Vault (SMV)

Implementation of a SMV facility at the Bruce site will require the creation of an SMV processing building in line with the facility described in section 3.2.2. It will be capable of transferring fuel modules, transferred to the shielded cell from the wet bay, into module canisters and seal welding the module canister assembly. Additionally the facility will also require the capability to ‘open’ existing storage casks, remove the fuel modules and repackage them into module canisters. Casks, after having the fuel modules removed will require monitoring, possible decontamination, and dismantling.

The Bruce SMV storage facility will contain 4 storage buildings. Each storage building will house twelve (12) vaults.

- Each vault will house 40 storage tubes, in a 4 x 10 array
- The SMV storage complex = 4 buildings x 12 vaults per building x 40 tubes per vault = 1920 storage tubes
- Each storage tube is designed to accommodate 2 module canisters
- Each module canister holds 4 fuel modules
- Each module holds 96 fuel bundles.
- This equates to a total SMV storage complex capacity of - 1920 x 2 x 4 x 96 = 1,474,560 used fuel bundles (Refer Figures 32 and 33).

In addition to the module fuel described above, the Bruce SMV storage building complex will accommodate the AECL Douglas Point (DP) fuel, in an annexe adjacent to one of the module

canister storage buildings. The DP inventory, comprising 22,256 fuel bundles in 413 baskets will be housed in 42 basket storage tubes. This basket store will be a single vault and will be constructed adjacent to one of the module canister vaults. The basket store will have a 60 storage tube capacity, 42 of the tubes will be occupied, with 18 spare. Each SMV basket storage tube is designed to accommodate 10 DP fuel baskets. The basket surface modular vault will have its own loading arrangements, comprising a basket flask handling crane, capable of lifting a basket transfer flask from a road transporter, up onto the charge hall, for storage tube loading.
Table 3 identifies the assumed annual cask production rate and the cumulative number of casks in store, prior to implementation of the SMV facility. Table 3 also identifies the availability of the first SMV storage vault and the subsequent annual production rate for module canisters.
Additional SMV storage vaults will be produced in-line with the schedule outlined in Table 3.
Transfer of the used fuel previously held in storage casks into SMV module canisters is assumed to occur from years 2041 to 2059.
The consequence of the transfer of fuel out of casks, is the generation of a waste stream of redundant, empty storage cask assemblies (casks and lids). The amount of waste arising from the dismantling of each storage cask will be approximately, 56 tonnes (16 m^3) of concrete and 6.5 tonnes (0.85 m^3) of steel. These will require monitoring, decontamination and dismantling prior to release from the site as inactive waste. A total of 1,490 casks will need to be opened and the fuel transferred into module canisters. These 1,490 redundant casks will be treated as waste. It is anticipated that no more than 0.25% of storage cask 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.

The footprint of the total storage facility described above would be approximately 161m x 158m. The footprint of the SMV processing building described above would be approximately 42 m x 90 m, which includes an allowance for a cask and module dismantling/breakdown area.

4.2.3 Casks in Shallow Trenches (CST)

Implementation of a CST alternative for the Bruce site will require the creation of 6 storage chambers. Each storage chamber comprises two bays.
Each bay will be designed to accommodate the 80 tonne mobile crane which is used to position upper tier casks on top of the casks stored at ground level. Each storage bay is designed to accommodate 330 casks, (55 casks long, x 3 wide x 2 high), thus giving 660 casks per chamber. The total cask storage capacity of this storage complex is 660 x 6 = 3960 casks. Implementation of CST alternative at Bruce will require the creation and storage of a total of 3,929 casks, (3825 module casks, and 104 casks containing AECL Douglas Point baskets). This fuel inventory will fill 11 storage bays and the 12th storage bay will have spare capacity (Refer Figure 34).
The existing cask production facility at Bruce will be utilised as the cask production facility for the CST.
If the CST alternative is selected for implementation then casks would be transferred from the existing storage buildings to the CST storage facility. Table 6 identifies the assumed annual cask production rate, and the cumulative number of casks in storage buildings, prior to implementation of the CST facility. Table 6 also identifies the availability of the first CST storage chamber and the subsequent annual production rate for storage casks. Additional CST storage chambers will be produced inline with the schedule outlined in Table 6. Transfer of the used fuel previously held in storage buildings into CST storage chambers is assumed to occur from years 2042 to 2049.
For the operations necessary to transfer the AECL Douglas Point fuel baskets refer to the second paragraph of section 4.2.1 (Refer Figure 31).

4.3 Darlington Site

4.3.1 Casks in Storage Buildings (CSB)

Implementation of the CSB alternative on the Darlington site would simply be the implementation of the dry storage technology as currently planned for this site. OPG currently has plans to build a processing building and 3 storage buildings. However in the event a decision is made to store all Darlington used fuel produced to the end of the committed nuclear program, then two additional storage buildings would have to be constructed. The storage buildings would be constructed on a rolling construction programme, which will be matched to the cask production rate. The assumed annual cask production rate, the cumulative number of casks in store and the phasing of the future construction of storage buildings is described in Table 1.

The completed RES CSB facility at Darlington will comprise five cask storage buildings. Each storage building has a nominal capacity for approximately 490 storage casks. The total fuel inventory (876,096 fuel bundles), stored in 2,282 storage casks will completely fill four storage buildings. The fifth cask storage building will accommodate the remaining storage casks, with some spare capacity. This spare capacity will provide 'buffer' storage spaces for the movement of casks during cask monitoring activities or could provide temporary parking for casks which need to be moved to facilitate access to casks currently positioned on the inside of the storage arrays. It may also be advantageous for casks to occupy this extra space during routine building maintenance activities (Refer Figure 35).

4.3.2 Surface Modular Vault (SMV)

Implementation of a SMV facility at Darlington will require the creation of an SMV processing building in line with the facility described in section 3.2.2. It will be capable of transferring fuel modules into module canisters and seal welding the module canister assembly. Additionally the facility will also require the capability to ‘open’ existing storage casks, remove the fuel modules and repackage them into module canisters. Casks, after having the fuel modules removed will require monitoring, (possible decontamination) and dismantling.

The Darlington SMV storage facility will consist of 4 storage buildings, each storage building will consist of eight (8) vaults.

- Each vault will house 40 storage tubes, in a 4 x 10 array
- The SMV complex = 4 buildings x 8 vaults per building x 40 tubes per vault = 1280 storage tubes.
- Each storage tube is designed to accommodate 2 module canisters
- Each module canister holds 4 fuel modules
- Each module holds 96 fuel bundles.
- This equates to a total SMV storage complex capacity of 1280 x 2 x 4 x 96 = 983,040 used fuel bundles (Refer Figure 36).

Implementation of the SMV alternative requires the transfer of used fuel, currently in storage cask format into modular canister format, this transfer will be undertaken in the dedicated processing facility shielded cell.

Table 4 identifies the assumed annual cask production rate, and the cumulative number of casks in store, prior to implementation of the SMV facility. Table 4 also identifies the availability of the first SMV storage vault and the subsequent annual production rate for module canisters. Additional SMV storage vaults will be produced in-line with the schedule outlined in Table 4. Transfer of the used fuel previously held in storage casks into SMV module canisters is assumed to occur from years 2047 to 2054.

The consequence of the transfer of fuel out of casks, is the generation of a waste stream of redundant, empty storage cask assemblies (casks and lids). These will require monitoring, decontamination and dismantling prior to release from the site as inactive waste. The amount of waste arising from the dismantling of each storage cask will be approximately, 56 tonnes (16 m^3) of concrete and 6.5 tonnes (0.85 m^3) of steel. A total of 679 casks will need to be opened and the fuel transferred into module canisters. These 679 redundant casks will be treated as waste. It is anticipated that no more than 0.25% of storage cask 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.

The footprint of the storage facility described above would be approximately 102 m x 158 m.

The footprint of the SMV Processing Building described above would be approximately 42 m x 90 m, which includes an allowance for a cask and module dismantling / breakdown area.

4.3.3 Casks in Shallow Trenches (CST)

Implementation of a CST alternative for the Darlington site will require the creation of 4 storage chambers. Each storage chamber comprises two bays. Each bay will be designed to accommodate the 80 tonne mobile crane which is used to position upper tier casks on top of the casks stored at ground level. Each storage bay is designed to accommodate 306 casks, (51 casks long, x 3 wide x 2 high), thus 612 casks per chamber.

The total store capacity will be 612 x 4 = 2448 casks.

To implement a CST at Darlington will require the eventual storage of a total of 2,282 module casks, therefore the 8th storage bay will not be full and will have spare capacity (Refer Figure 37).

The existing cask production facility at Darlington will remain operational as the cask production facility for the CST.

If the CST alternative is selected for implementation then casks will be transferred from the existing storage building to the CST storage facility. Table 7 identifies the assumed annual cask production rate, and the cumulative number of casks in storage buildings, prior to implementation of the CST facility. Table 7 also identifies the availability of the first CST storage chamber and the subsequent annual production rate for storage casks. Additional CST storage chambers will be produced in-line with the schedule outlined in Table 7.

Transfer of the used fuel previously held in storage buildings into CST storage chambers is assumed to occur from years 2047 to 2049.

Movement of the casks from the storage buildings to the CST storage complex will be performed using the cask transporter. Storage casks are stacked, 2 high, within the storage chamber. The cask transporter will park casks in their designated storage position on the lower tier, or will position the casks below the chamber crane for movement onto the upper tier.

4.4 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 below.

4.4.1 Storage Structures

4.4.1.1 CSB.

The fabric of the cask storage buildings will be regularly monitored to ensure the condition of the building remains suitable for housing fuel casks. A programme of preventative maintenance and repair will be established to ensure the store condition remains acceptable, throughout the service life.

4.4.1.2 SMV.

The building fabric and the storage vault concrete structure will be regularly monitored to ensure that the vault and the 'cover' building condition remain acceptable over the service life of the structure. A programme of preventative maintenance with repair work carried out when necessary will be established to maintain the condition of the storage structure.

4.4.1.3 CST

With particular respect to the CST, 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 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.

4.4.2 Fuel Condition Monitoring

Throughout the period of extended storage, fuel condition monitoring activities will be performed. The fuel condition monitoring will comprise two elements: non invasive and invasive monitoring:

Non-Invasive monitoring will include:

- Continuous monitoring of storage facility parameters (such as temperature, ventilation exhaust gases) at various locations.
- Operation of a test facility where test containers or modules are monitored in greater detail, e.g. via sampling of containment gases and monitoring of the containment structure internal temperatures. Representative, non-radioactive, mimic fuel can be held in conditions which match the storage conditions. The mimic fuel will be monitored and assessed to judge its actual condition against the predicted condition.

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 SMV alternative. 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.

Invasive Monitoring will include:

- Implementation of a program parallel to the non-invasive monitoring for shielded-cell examination of the fuel.

- Direct monitoring/surveillance during fuel during packaging operations. Additionally, between the major repackaging events (every100 years) 2 casks will be opened every 25 years to allow the fuel condition to be examined. That is, there will be 3 events requiring 2 DSCs to be removed from store between the repackaging events. This will require the 2 DSCs to be taken to the Shielded Cell within the Processing Building, the Cask lids removed, the fuel modules removed and taken into the cell and individual fuel bundles examined to monitor the fuel condition. The fuel bundle will be replaced into the module and the module repackaged into a new cask body. This cask will be lidded, welded and tested, after successful completion of all necessary tests the cask will be placed into the store.

4.4.2.1 CSB

For storage casks, a population representing approximately1% of the total cask inventory will be subjected to a non-invasive monitoring program 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.

4.4.2.2 SMV

For SMV stores, a population representing approximately 2% of the storage tube inventory will be subjected to a non-invasive monitoring program 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 SMV basket stores (Bruce only), a population representing approximately 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.

4.4.2.3 CST

For storage casks, a population representing approximately 1% of the total cask inventory will be subjected to a non-invasive monitoring program 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.

4.5 Operations – Facility Repeats

It is recognised that the storage facilities and principal containment structures have a finite life span. An estimate of the minimum service life of the various fuel containers and the structures used to house the fuel containers are presented in Table 8. 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, storage chambers) 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.

4.5.1 Cask Storage Buildings (CSB)

Facility repeats for casks storage buildings 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.

4.5.2 Module Canister or Basket Storage Vaults (SMV)

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.

4.5.3 Cask Storage Chamber (CST)

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

The facility repeat will comprise:
- Staged building of one storage chamber (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 chamber 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 chamber.
- Once the old storage chamber 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 chamber has been cleared a replacement storage chamber is constructed and the earthen cover restored.

4.6 Operations – Repackaging

4.6.1 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 previously in this report, 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.

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.
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. 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.

Repackaging Operations

Alternative	Storage cask de-lidding operations	Module fuel transfer operations	Module canister fuel transfer operations	Basket fuel transfer operations
CSB	√	√		√ (Bruce only)
SMV			√	√
CST	√	√		√ (Bruce only)

4.6.2 Cask De-lidding Cell

The purpose of the 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 CSB and CST alternatives, to handle module 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 performed 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 (CSB and CST), the 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.

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.

4.6.3 Fuel Module Repackaging

The fuel module transfer operations will be performed in a dedicated shielded cell. For CSB and CST alternatives, these operations will be performed once existing modules have been withdrawn from storage casks, described above. 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 CSB and CST 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.

4.6.4 Fuel Basket Repackaging

The fuel basket transfer operations will be performed in a dedicated shielded cell. For the CSB, CST 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.

5 Unresolved Design Issues

For Unresolved Design Issues refer to the Centralized Extended Storage Facility Design Report [4]

6 Codes and Standards

For relevant Codes and Standards refer to the Centralized Extended Storage Facility Design Report [4]

7 References

1 Conceptual Designs for Reactor-Site Extended Storage Facility Alternatives for Used Nuclear Fuel. (New Brunswick Power) CTECH Report No: 1105/MD18084/REP/13 December 2002

2 Conceptual Designs for Reactor-Site Extended Storage Facility Alternatives for Used Nuclear Fuel. (Hydro-Québec) CTECH Report No: 1105/MD18084/REP/14 December 2002
3 Conceptual Designs for Reactor-Site Extended Storage Facility Alternatives for Used Nuclear Fuel. (Atomic Energy of Canada Ltd) CTECH Report No: 1105/MD18084/REP/15 December 2002
4 Conceptual Designs for Four Centralized Extended Storage Facility Alternatives for Used Nuclear Fuel. CTECH Report No: 1105/MD18084/REP/08 September 2002.

Table 1: CSB Alternative - Assumed Annual Rate of Cask (DSC) Production at Pickering, Bruce & Darlington Reactor Sites

Year	Pickering					Bruce					Darlington					Total	
	Bundles	DSCs	Cum DSCs	Storage Capacity	Cum Capacity	Bundles	DSCs	Cum DSCs	Storage Capacity	Cum Capacity	Bundles	DSCs	Cum DSCs	Storage Capacity	Cum Capacity	Bundles	DSCs
31-Dec-01	79,697	208	208	655	655	-	-	-	-	-	-	-	-	-	-	79,697	208
2002	21,120	55	263		655	2,304	6	6	490	490	-	-	-		-	23,424	61
2003	22,491	59	322		655	30,803	80	86		490	-	-	-		-	53,294	139
2004	25,462	66	388		655	31,341	82	168		490	-	-	-		-	56,803	148
2005	27,709	72	460		655	32,360	84	252		490	-	-	-		-	60,069	156
2006	26,468	69	529		655	34,701	90	342		490	-	-	-		-	61,169	159
2007	26,780	70	599	490	1,145	38,331	100	442	490	980	2,304	6	6	490	490	67,415	176
2008	26,537	69	668		1,145	30,432	79	522		980	21,705	57	63		490	78,674	205
2009	26,789	70	738		1,145	36,470	95	617		980	21,192	55	118		490	84,451	220
2010	24,639	64	802		1,145	43,386	113	729		980	21,642	56	174		490	89,667	234
2011	24,701	64	866		1,145	42,990	112	841		980	21,642	56	230		490	89,333	233
2012	33,478	87	953		1,145	41,286	108	949	490	1,470	21,705	57	287		490	96,470	251
2013	32,600	85	1,038		1,145	41,670	109	1,057		1,470	21,642	56	343		490	95,912	250
2014	30,972	81	1,119	490	1,635	40,362	105	1,163		1,470	21,642	56	400		490	92,976	242
2015	31,197	81	1,200		1,635	42,148	110	1,272		1,470	21,128	55	455	490	980	94,473	246
2016	31,723	83	1,283		1,635	42,538	111	1,383	490	1,960	21,705	57	511		980	95,966	250
2017	32,401	84	1,367		1,635	40,859	106	1,490		1,960	20,984	55	566		980	94,245	245
2018	33,125	86	1,453		1,635	42,131	110	1,599		1,960	21,642	56	622		980	96,899	252
2019	33,125	86	1,540		1,635	44,373	116	1,715		1,960	21,642	56	679		980	99,141	258
2020	33,125	86	1,626	490	2,125	43,246	113	1,827		1,960	21,181	55	734		980	97,553	254
2021	29,682	77	1,703		2,125	46,061	120	1,947	500	2,460	20,365	53	787		980	96,109	250
2022	29,734	77	1,781		2,125	46,061	120	2,067		2,460	20,365	53	840		980	96,161	250
2023	28,831	75	1,856		2,125	45,596	119	2,186		2,460	18,205	47	887		980	92,633	241
2024	29,799	78	1,933		2,125	45,596	119	2,305		2,460	22,385	58	946	490	1,470	97,780	255
2025	29,799	78	2,011		2,125	50,812	132	2,437	500	2,960	20,476	53	999		1,470	101,086	263
2026	29,799	78	2,088		2,125	50,812	132	2,569		2,960	21,699	57	1,055		1,470	102,309	266
2027	10,653	28	2,116	490	2,615	50,812	132	2,702		2,960	21,699	57	1,112		1,470	83,164	217
2028	10,653	28	2,144			50,812	132	2,834	500	3,460	21,699	57	1,168		1,470	83,164	217
2029	10,653	28	2,172			50,812	132	2,966		3,460	21,351	56	1,224		1,470	82,816	216
2030	10,653	28	2,199			50,812	132	3,099		3,460	19,930	52	1,276		1,470	81,395	212
2031	10,653	28	2,227			50,812	132	3,231		3,460	25,744	67	1,343		1,470	87,209	227
2032	10,653	28	2,255			25,331	66	3,297		3,460	25,744	67	1,410	490	1,960	61,729	161
2033	10,653	28	2,283			25,331	66	3,363		3,460	25,744	67	1,477		1,960	61,729	161
2034	10,653	28	2,310			25,331	66	3,429	500	3,960	25,744	67	1,544		1,960	61,729	161
2035	10,653	28	2,338			25,331	66	3,495			25,744	67	1,611		1,960	61,729	161
2036	10,653	28	2,366			25,331	66	3,561			25,744	67	1,678		1,960	61,729	161
2037	10,653	28	2,394			25,331	66	3,627			25,744	67	1,745		1,960	61,729	161
2038	10,653	28	2,421			25,331	66	3,693			25,744	67	1,812		1,960	61,729	161
2039						25,331	66	3,759			25,744	67	1,879		1,960	51,075	133
2040						25,331	66	3,825			25,744	67	1,946	490	2,450	51,075	133
2041						22,256	104	3,929			25,744	67	2,013			48,000	171
2042											25,744	67	2,080			25,744	67
2043											25,744	67	2,147			25,744	67
2044											25,744	67	2,214			25,744	67
2045											25,744	67	2,282			25,744	67
Total	**929,624**	**2,421**		**2,615**		**1,490,967***	**3,929**		**3,960**		**876,096**	**2,282**		**2,450**		**3,296,687**	**8,632**

Assumed schedule for fuel bundles requiring dry storage based upon OPG's 2001 Nuclear Waste Management System Plan with schedule modified in later years to reflect removal of all bundles from wet bays and transfer to dry storage. * Figures for Bruce include 22,256 fuel bundles from Douglas Point.

Table 2: SMV Alternative - Assumed Annual Rate of Module Canister Production at the Pickering Reactor Site

Year	Bundle Production	Storage Buildings					Surface Modular Vault				
		DSCs Produced	DSCs Removed	Cum DSCs	Storage Bldg Capacity (DSCs)	Cum Bldg Capacity (DSCs)	DSCs Received	Canisters Produced	Cum Canisters	SMV Capacity (Canisters)	Cum SMV Capacity (Canisters)
31-	79,697	208		208	655	655					
2002	21,120	55		263		655					
2003	22,491	59		322		655					
2004	25,462	66		388		655					
2005	27,709	72		460		655					
2006	26,468	69		529		655					
2007	26,780	70		599	550	1,205					
2008	26,537	69		668		1,205					
2009	26,789	70		738		1,205					
2010	24,639	64		802		1,205					
2011	24,701	64		866		1,205					
2012	33,478	87		953		1,205					
2013	32,600	85		1,038		1,205					
2014	30,972	81		1,119		1,205					
2015	31,197	81		1,200		1,205				640	640
2016	31,723			1,200		1,205		83	83		640
2017	32,401			1,200		1,205		84	167		640
2018	33,125			1,200		1,205		86	253		640
2019	33,125			1,200		1,205		86	340		640
2020	33,125			1,200		1,205		86	426		640
2021	29,682			1,200		1,205		77	503		640
2022	29,734			1,200		1,205		77	581	640	1,280
2023	28,831			1,200		1,205		75	656		1,280
2024	29,799			1,200		1,205		78	733		1,280
2025	29,799			1,200		1,205		78	811		1,280
2026	29,799			1,200		1,205		78	888		1,280
2027	10,653			1,200		1,205		28	916		1,280
2028	10,653			1,200		1,205		28	944		1,280
2029	10,653			1,200		1,205		28	972		1,280
2030	10,653			1,200		1,205		28	999		1,280
2031	10,653			1,200		1,205		28	1,027		1,280
2032	10,653			1,200		1,205		28	1,055		1,280
2033	10,653			1,200		1,205		28	1,083		1,280
2034	10,653			1,200		1,205		28	1,110		1,280
2035	10,653			1,200		1,205		28	1,138		1,280
2036	10,653			1,200		1,205		28	1,166		1,280
2037	10,653			1,200		1,205		28	1,194		1,280
2038	10,653			1,200		1,205		28	1,221	640	1,920
2039			-80	1,120		1,205	80	80	1,301		1,920
2040			-80	1,040		1,205	80	80	1,381		1,920
2041			-80	960		1,205	80	80	1,461		1,920
2042			-80	880	-185	1,020	80	80	1,541		1,920
2043			-80	800		1,020	80	80	1,621		1,920
2044			-80	720		1,020	80	80	1,701		1,920
2045			-80	640		1,020	80	80	1,781		1,920
2046			-80	560		1,020	80	80	1,861	640	2,560
2047			-80	480		1,020	80	80	1,941		2,560
2048			-80	400	-470	550	80	80	2,021		2,560
2049			-80	320		550	80	80	2,101		2,560
2050			-80	240		550	80	80	2,181		2,560
2051			-80	160		550	80	80	2,261		2,560
2052			-80	80		550	80	80	2,341		2,560
2053			-80	0		550	80	80	2,421		2,560
2054					-550						
Total	**929,624**	**1,200**	**-1,200**		**-**			**2,421**		**2,560**	

Table 3: SMV Alternative - Assumed Annual Rate of Module Canister Production at the Bruce Reactor Site

Year	Bundle Production	Storage Buildings					Surface Modular Vault				
		DSCs Produced	DSCs Removed	Cum DSCs	Storage Bldg Capacity (DSCs)	Cum Bldg Capacity (DSCs)	DSCs Received	Canisters Produced	Cum Canisters	SMV Capacity (Canisters)	Cum SMV Capacity (Canisters)
2002	2,304	6		6	490	490					
2003	30,803	80		86		490					
2004	31,341	82		168		490					
2005	32,360	84		252		490					
2006	34,701	90		342		490					
2007	38,331	100		442	490	980					
2008	30,432	79		522		980					
2009	36,470	95		617		980					
2010	43,386	113		729		980					
2011	42,990	112		841		980					
2012	41,286	108		949	510	1,490					
2013	41,670	109		1,057		1,490					
2014	40,362	105		1,163		1,490					
2015	42,148	110		1,272		1,490					
2016	42,538	112		1,384		1,490					
2017	40,859	105		1,489		1,490				960	960
2018	42,131			1,489		1,490		110	110		960
2019	44,373			1,489		1,490		116	226		960
2020	43,246			1,489		1,490		113	338		960
2021	46,061			1,489		1,490		120	458		960
2022	46,061			1,489		1,490		120	578		960
2023	45,596			1,489		1,490		119	697		960
2024	45,596			1,489		1,490		119	816		960
2025	50,812			1,489		1,490		132	948	960	1,920
2026	50,812			1,489		1,490		132	1,080		1,920
2027	50,812			1,489		1,490		132	1,213		1,920
2028	50,812			1,489		1,490		132	1,345		1,920
2029	50,812			1,489		1,490		132	1,477		1,920
2030	50,812			1,489		1,490		132	1,609		1,920
2031	50,812			1,489		1,490		132	1,742		1,920
2032	25,331			1,489		1,490		66	1,808		1,920
2033	25,331			1,489		1,490		66	1,874	960	2,880
2034	25,331			1,489		1,490		66	1,940		2,880
2035	25,331			1,489		1,490		66	2,006		2,880
2036	25,331			1,489		1,490		66	2,072		2,880
2037	25,331			1,489		1,490		66	2,138		2,880
2038	25,331			1,489		1,490		66	2,204		2,880
2039	25,331			1,489		1,490		66	2,270		2,880
2040	25,331			1,489		1,490		66	2,336		2,880
2041			-80	1,409		1,490	80	80	2,416		2,880
2042			-80	1,329		1,490	80	80	2,496		2,880
2043			-80	1,249		1,490	80	80	2,576		2,880
2044			-80	1,169		1,490	80	80	2,656		2,880
2045			-80	1,089		1,490	80	80	2,736		2,880
2046			-80	1,009		1,490	80	80	2,816	960	3,840
2047			-80	929		1,490	80	80	2,896		3,840
2048			-80	849	-490	1,000	80	80	2,976		3,840
2049			-80	769		1,000	80	80	3,056		3,840
2050			-80	689		1,000	80	80	3,136		3,840
2051			-80	609		1,000	80	80	3,216		3,840
2052			-80	529		1,000	80	80	3,296		3,840
2053			-80	449		1,000	80	80	3,376		3,840
2054			-80	369	-490	510	80	80	3,456		
2055			-80	289		510	80	80	3,536		
2056			-80	209		510	80	80	3,616		
2057			-80	129		510	80	80	3,696		
2058			-80	49		510	80	80	3,776		
2059			-49	0		510	49	49	3,826		
2060					-510						
Total	**1,468,711**	**1,489**	**-1489**		**-**			**3,825**		**3,840**	

Note:
The table does not include the transfer of 413 baskets from the Douglas Point silos to the SMV facility.

Table 4: SMV Alternative - Assumed Annual Rate of Module Canister Production at the Darlington Reactor Site

Year	Bundle Production	Storage Buildings					Surface Modular Vault				
		DSCs Produced	DSCs Removed	Cum DSCs	Storage Bldg Capacity (DSCs)	Cum Bldg Capacity (DSCs)	DSCs Received	Canisters Produced	Cum Canisters	SMV Capacity (Canisters)	Cum SMV Capacity (Canisters)
2002	-	-		-	-	-					
2003	-	-		-	-	-					
2004	-	-		-	-	-					
2005	-	-		-	-	-					
2006	-	-		-	-	-					
2007	2,304	6		6	490	490					
2008	21,705	57		63		490					
2009	21,192	55		118		490					
2010	21,642	56		174		490					
2011	21,642	56		230		490					
2012	21,705	57		287		490					
2013	21,642	56		343		490					
2014	21,642	56		399		490					
2015	21,128	55		454	200	690					
2016	21,705	57		511		690					
2017	20,984	56		567		690					
2018	21,642	56		623		690					
2019	21,642	56		679		690				640	640
2020	21,181			679		690		55	55		640
2021	20,365			679		690		53	108		640
2022	20,365			679		690		53	161		640
2023	18,205			679		690		47	209		640
2024	22,385			679		690		58	267		640
2025	20,476			679		690		53	320		640
2026	21,699			679		690		57	377		640
2027	21,699			679		690		57	433		640
2028	21,699			679		690		57	490		640
2029	21,351			679		690		56	545		640
2030	19,930			679		690		52	597	640	1,280
2031	25,744			679		690		67	664		1,280
2032	25,744			679		690		67	731		1,280
2033	25,744			679		690		67	798		1,280
2034	25,744			679		690		67	865		1,280
2035	25,744			679		690		67	932		1,280
2036	25,744			679		690		67	1,000		1,280
2037	25,744			679		690		67	1,067		1,280
2038	25,744			679		690		67	1,134		1,280
2039	25,744			679		690		67	1,201		1,280
2040	25,744			679		690		67	1,268	640	1,920
2041	25,744			679		690		67	1,335		1,920
2042	25,744			679		690		67	1,402		1,920
2043	25,744			679		690		67	1,469		1,920
2044	25,744			679		690		67	1,536		1,920
2045	25,744			679		690		67	1,603		1,920
2046			-80	599		690	80	80	1,683		1,920
2047			-80	519		690	80	80	1,763		1,920
2048			-80	439		690	80	80	1,843	640	2,560
2049			-80	359		690	80	80	1,923		2,560
2050			-80	279		690	80	80	2,003		2,560
2051			-80	199	-490	200	80	80	2,083		2,560
2052			-80	119		200	80	80	2,163		2,560
2053			-80	39		200	80	80	2,243		2,560
2054			-39	0		200	39	39	2,282		2,560
2055					-200						
Total	**876,096**	**679**	**-679**		**-**			**2,282**		**2,560**	

Table 5: CST Alternative - Assumed Annual Rate of Cask (DSC) Production at the Pickering Reactor Site

Year	Bundle Production	Storage Buildings					Casks in Shallow Trench				
		DSCs Produced	DSCs Removed	Cum DSCs	Storage Bldg Capacity (DSCs)	Cum Bldg Capacity (DSCs)	DSCs Received	DSCs Produced/ Placed	Cum DSCs	CST Capacity (DSCs)	Cum CST Capacity (DSCs)
31-Dec-01	79,697	208		208	655	655					
2002	21,120	55		263		655					
2003	22,491	59		322		655					
2004	25,462	66		388		655					
2005	27,709	72		460		655					
2006	26,468	69		529		655					
2007	26,780	70		599	550	1,205					
2008	26,537	69		668		1,205					
2009	26,789	70		738		1,205					
2010	24,639	64		802		1,205					
2011	24,701	64		866		1,205					
2012	33,478	87		953		1,205					
2013	32,600	85		1,038		1,205					
2014	30,972	81		1,119		1,205					
2015	31,197	81		1,200		1,205				660	660
2016	31,723			1,200		1,205		83	83		660
2017	32,401			1,200		1,205		84	167		660
2018	33,125			1,200		1,205		86	253		660
2019	33,125			1,200		1,205		86	340		660
2020	33,125			1,200		1,205		86	426		660
2021	29,682			1,200		1,205		77	503		660
2022	29,734			1,200		1,205		77	581		660
2023	28,831			1,200		1,205		75	656	660	1,320
2024	29,799			1,200		1,205		78	733		1,320
2025	29,799			1,200		1,205		78	811		1,320
2026	29,799			1,200		1,205		78	888		1,320
2027	10,653			1,200		1,205		28	916		1,320
2028	10,653			1,200		1,205		28	944		1,320
2029	10,653			1,200		1,205		28	972		1,320
2030	10,653			1,200		1,205		28	999		1,320
2031	10,653			1,200		1,205		28	1,027		1,320
2032	10,653			1,200		1,205		28	1,055		1,320
2033	10,653			1,200		1,205		28	1,083		1,320
2034	10,653			1,200		1,205		28	1,110		1,320
2035	10,653			1,200		1,205		28	1,138		1,320
2036	10,653			1,200		1,205		28	1,166		1,320
2037	10,653			1,200		1,205		28	1,194		1,320
2038	10,653			1,200		1,205		28	1,221	660	1,980
2039			-200	1,000		1,205	200	200	1,421		1,980
2040			-200	800		1,205	200	200	1,621		1,980
2041			-200	600		1,205	200	200	1,821	660	2,640
2042			-200	400	-185	1,020	200	200	2,021		2,640
2043			-200	200		1,020	200	200	2,221		2,640
2044			-200	0		1,020	200	200	2,421		2,640
2045			0	0	-1,020						
Total	**929,624**	**1,200**	**-1200**		**-**			**2,421**		**2,640**	

Table 6: CST Alternative - Assumed Annual Rate of Cask (DSC) Production at the Bruce Reactor Site

Year	Bundle Production	Storage Buildings					Casks in Shallow Trench				
		DSCs Produced	DSCs Removed	Cum DSCs	Storage Bldg Capacity (DSCs)	Cum Bldg Capacity (DSCs)	DSCs Received	DSCs Produced/ Placed	Cum DSCs	CST Capacity (DSCs)	Cum CST Capacity (DSCs)
2002	2,304	6		6	490	490					
2003	30,803	80		86		490					
2004	31,341	82		168		490					
2005	32,360	84		252		490					
2006	34,701	90		342		490					
2007	38,331	100		442	490	980					
2008	30,432	79		522		980					
2009	36,470	95		617		980					
2010	43,386	113		729		980					
2011	42,990	112		841		980					
2012	41,286	108		949	510	1,490					
2013	41,670	109		1,057		1,490					
2014	40,362	105		1,163		1,490					
2015	42,148	110		1,272		1,490					
2016	42,538	111		1,383		1,490					
2017	40,859	106		1,490		1,490				660	660
2018	42,131			1,490		1,490		110	110		660
2019	44,373			1,490		1,490		116	225		660
2020	43,246			1,490		1,490		113	338		660
2021	46,061			1,490		1,490		120	458		660
2022	46,061			1,490		1,490		120	578	660	1,320
2023	45,596			1,490		1,490		119	697		1,320
2024	45,596			1,490		1,490		119	815		1,320
2025	50,812			1,490		1,490		132	948		1,320
2026	50,812			1,490		1,490		132	1,080		1,320
2027	50,812			1,490		1,490		132	1,212	660	1,980
2028	50,812			1,490		1,490		132	1,345		1,980
2029	50,812			1,490		1,490		132	1,477		1,980
2030	50,812			1,490		1,490		132	1,609		1,980
2031	50,812			1,490		1,490		132	1,742		1,980
2032	25,331			1,490		1,490		66	1,807		1,980
2033	25,331			1,490		1,490		66	1,873		1,980
2034	25,331			1,490		1,490		66	1,939	660	2,640
2035	25,331			1,490		1,490		66	2,005		2,640
2036	25,331			1,490		1,490		66	2,071		2,640
2037	25,331			1,490		1,490		66	2,137		2,640
2038	25,331			1,490		1,490		66	2,203		2,640
2039	25,331			1,490		1,490		66	2,269		2,640
2040	25,331			1,490		1,490		66	2,335		2,640
2041	22,256			1,490		1,490		104	2,439	660	3,300
2042			-200	1,290		1,490	200	200	2,639		3,300
2043			-200	1,090	-490	1,000	200	200	2,839		3,300
2044			-200	890		1,000	200	200	3,039		3,300
2045			-200	690		1,000	200	200	3,239	660	3,960
2046			-200	490	-490	510	200	200	3,439		3,960
2047			-200	290		510	200	200	3,639		3,960
2048			-200	90		510	200	200	3,839		3,960
2049			-90	0		510	90	90	3,929		3,960
2050					-510						
Total	**1,490,967***	**1,490**	**-1,490**		**-**			**3,929**		**3,960**	

* Figure for Bruce includes 22,256 fuel bundles from Douglas Point

Table 7: CST Alternative - Assumed Annual Rate of Cask (DSC) Production at the Darlington Reactor Site

		Storage Buildings					Casks in Shallow Trench				
Year	Bundle Production	DSCs Produced	DSCs Removed	Cum DSCs	Storage Bldg Capacity (DSCs)	Cum Bldg Capacity (DSCs)	DSCs Received	DSCs Produced/ Placed	Cum DSCs	CST Capacity (DSCs)	Cum CST Capacity (DSCs)
2002	-	-		-		-					
2003	-	-		-		-					
2004	-	-		-		-					
2005	-	-		-		-					
2006	-	-		-		-					
2007	2,304	6		6	490	490					
2008	21,705	57		63		490					
2009	21,192	55		118		490					
2010	21,642	56		174		490					
2011	21,642	56		230		490					
2012	21,705	57		287		490					
2013	21,642	56		343		490					
2014	21,642	56		400		490					
2015	21,128	55		455	200	690					
2016	21,705	57		511		690					
2017	20,984	55		566		690					
2018	21,642	56		622		690					
2019	21,642	56		679		690				612	612
2020	21,181			679		690		55	55		612
2021	20,365			679		690		53	108		612
2022	20,365			679		690		53	161		612
2023	18,205			679		690		47	209		612
2024	22,385			679		690		58	267		612
2025	20,476			679		690		53	320		612
2026	21,699			679		690		57	377		612
2027	21,699			679		690		57	433		612
2028	21,699			679		690		57	490		612
2029	21,351			679		690		56	545		612
2030	19,930			679		690		52	597	612	1,224
2031	25,744			679		690		67	664		1,224
2032	25,744			679		690		67	731		1,224
2033	25,744			679		690		67	798		1,224
2034	25,744			679		690		67	865		1,224
2035	25,744			679		690		67	932		1,224
2036	25,744			679		690		67	1,000		1,224
2037	25,744			679		690		67	1,067		1,224
2038	25,744			679		690		67	1,134		1,224
2039	25,744			679		690		67	1,201	612	1,836
2040	25,744			679		690		67	1,268		1,836
2041	25,744			679		690		67	1,335		1,836
2042	25,744			679		690		67	1,402		1,836
2043	25,744			679		690		67	1,469		1,836
2044	25,744			679		690		67	1,536		1,836
2045	25,744			679		690		67	1,603		1,836
2046			-200	479		690	200	200	1,803	612	2,448
2047			-200	279	-490	200	200	200	2,003		2,448
2048			-200	79		200	200	200	2,203		2,448
2049			-79	0		200	79	79	2,282		2,448
2050				0	-200				2,282		2,448
Total	**876,096**	**679**	**-679**		**-**			**2,282**		**2,448**	

Table 8: Assumed Service Lives for Facility Components

Component	CSB	SMV	CST
Cask	100*	-	100*
Basket (CSB & CST at Bruce only)	300	300	300
Fuel Module	300	300	300
Module Canister	-	300	-
Storage Chamber	-	-	200
Storage Building	100**	100**	-
Processing Building	50***	50***	50***

Notes

* The figure of 100 years assumes water ingress has been minimised and the CST alternative structures remains substantially weather-tight.

** This figure represents the assumed service life for the (CSB) 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, as and when they exhibit excessive corrosion or suffer mechanical damage.

*** This figure assumes the Processing Building is subject to a programme of preventative maintenance and repair (as necessary).

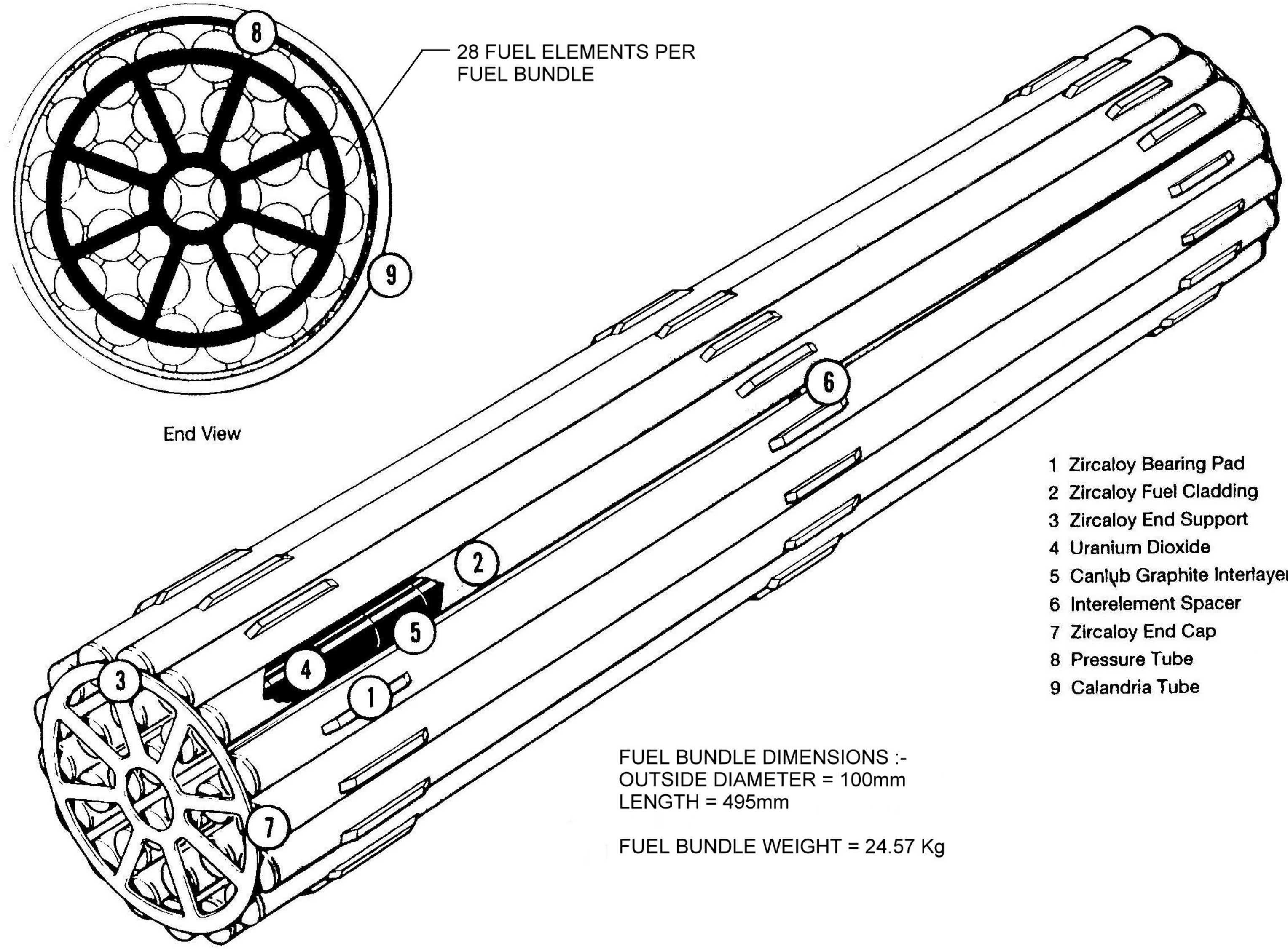


Figure 1 – CANDU Fuel Bundle

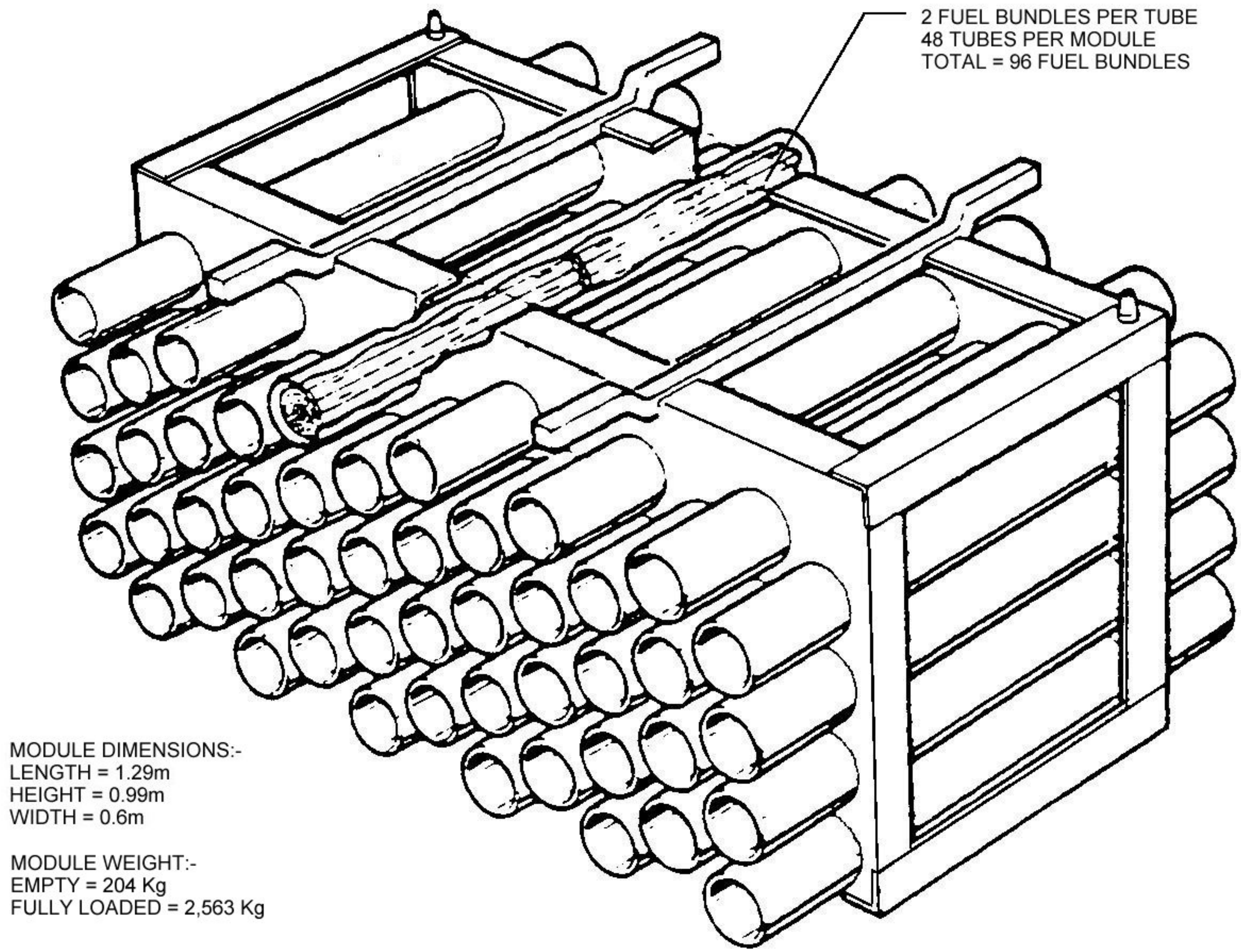
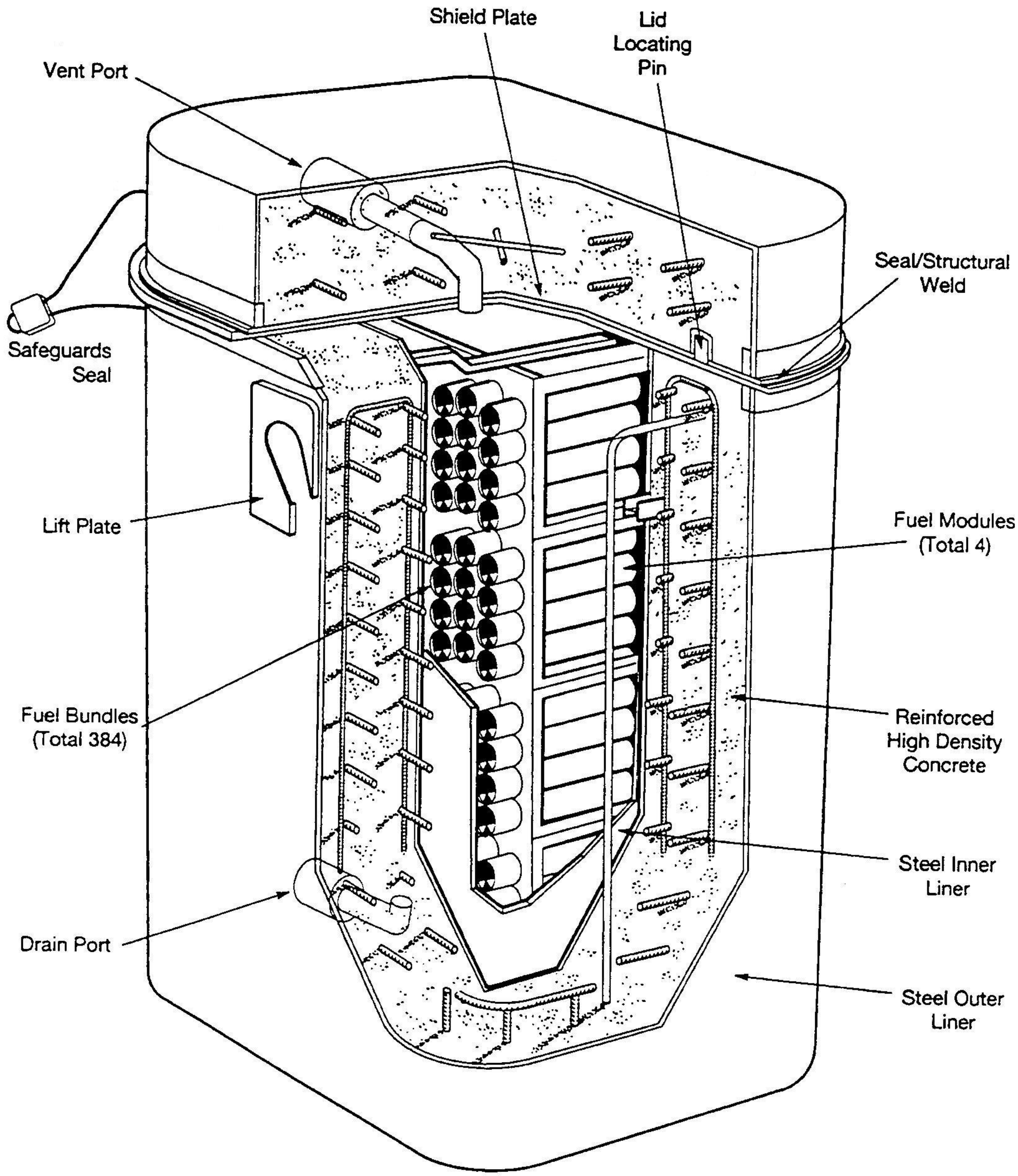


Figure 2 – Fuel Module



MODULE STORAGE CASK DIMENSIONS:-
WIDTH = 2.120m
DEPTH = 2.419m
HEIGHT - 3.550m

MODULE STORAGE CASK WEIGHTS:-
EMPTY = 60,000 Kg
FULLY LOADED = 70,000 Kg
(384 FUEL BUNDLES)

Figure 3
Module Storage Cask

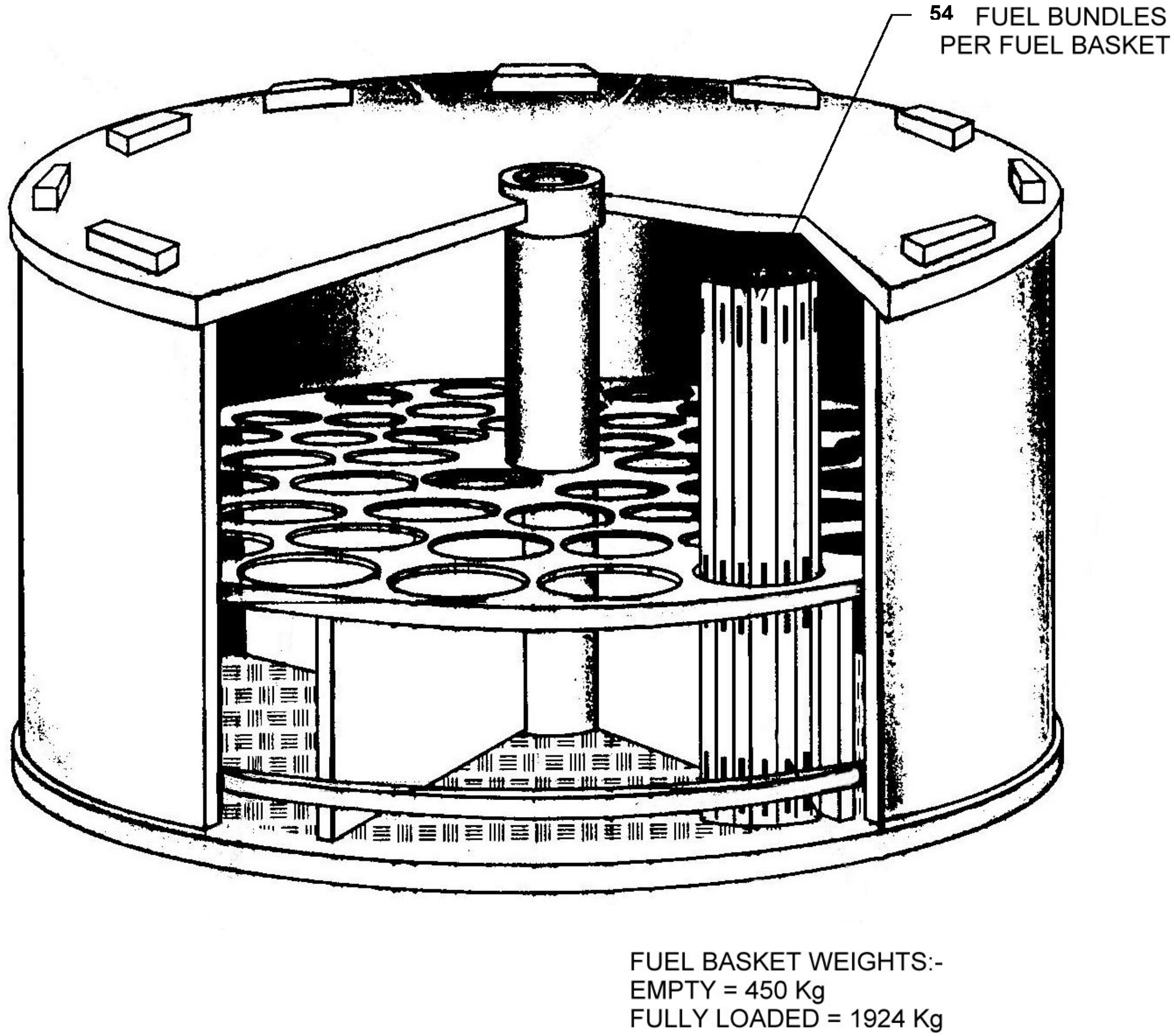


Figure 4 – Fuel Basket

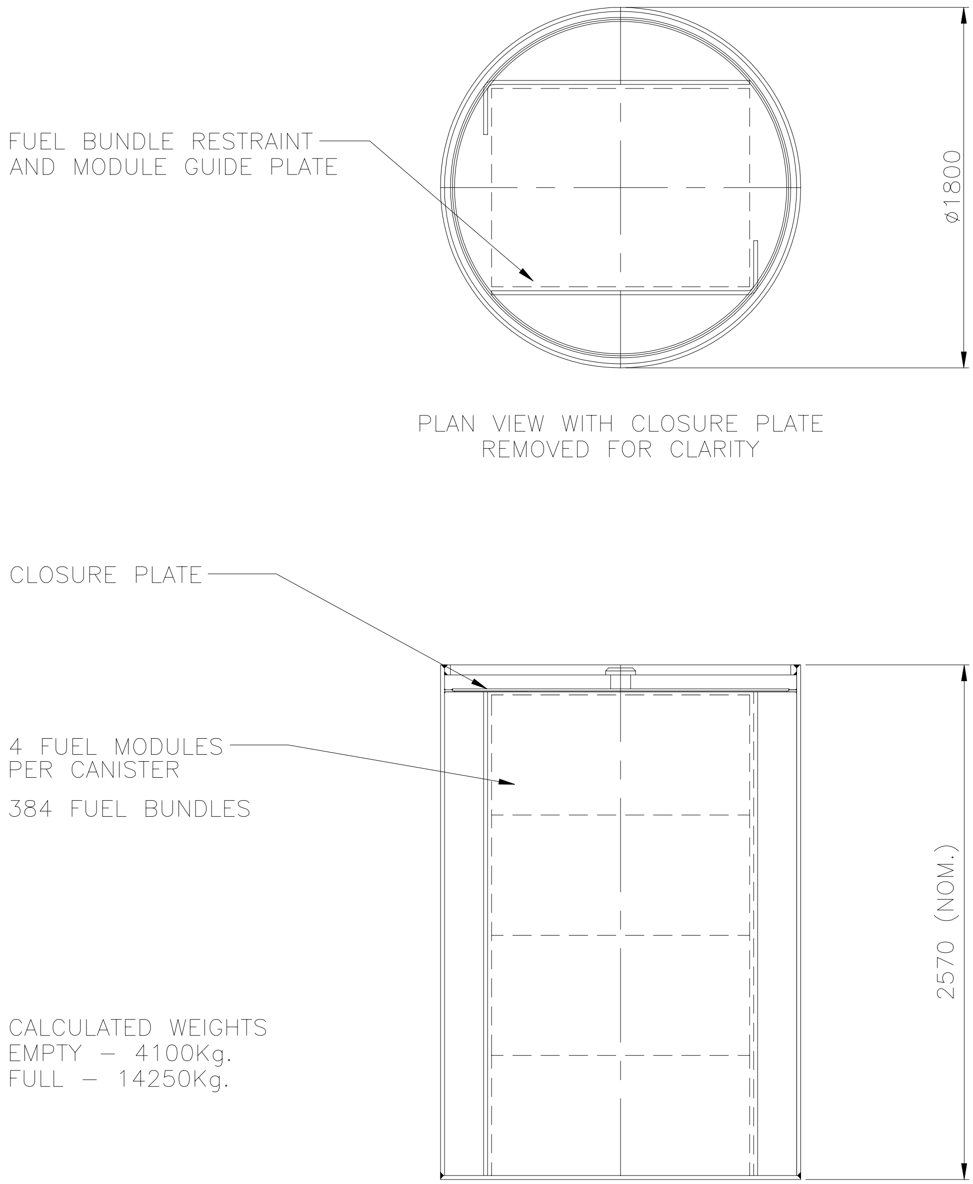


Figure 5
Module Canister

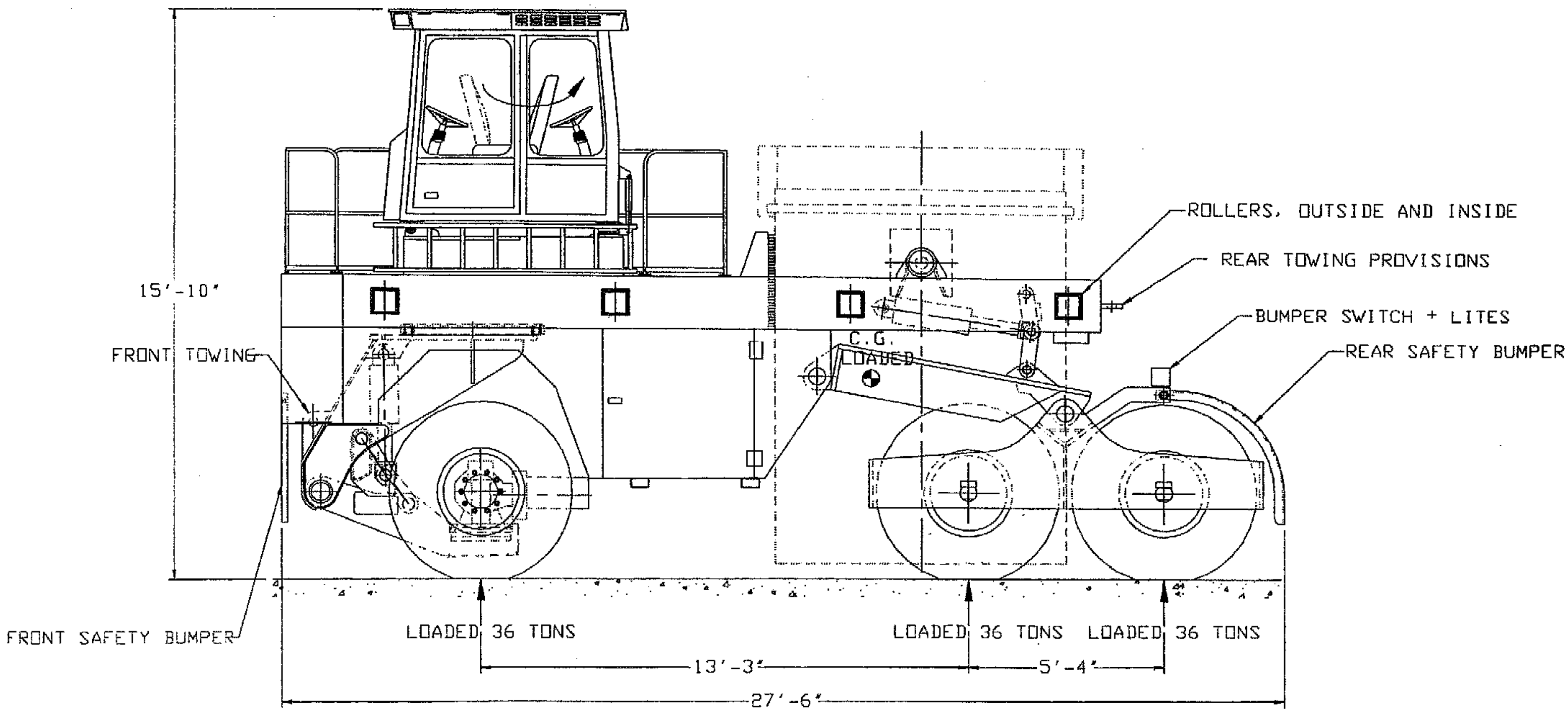


Figure 6 – Typical Cask Transporter

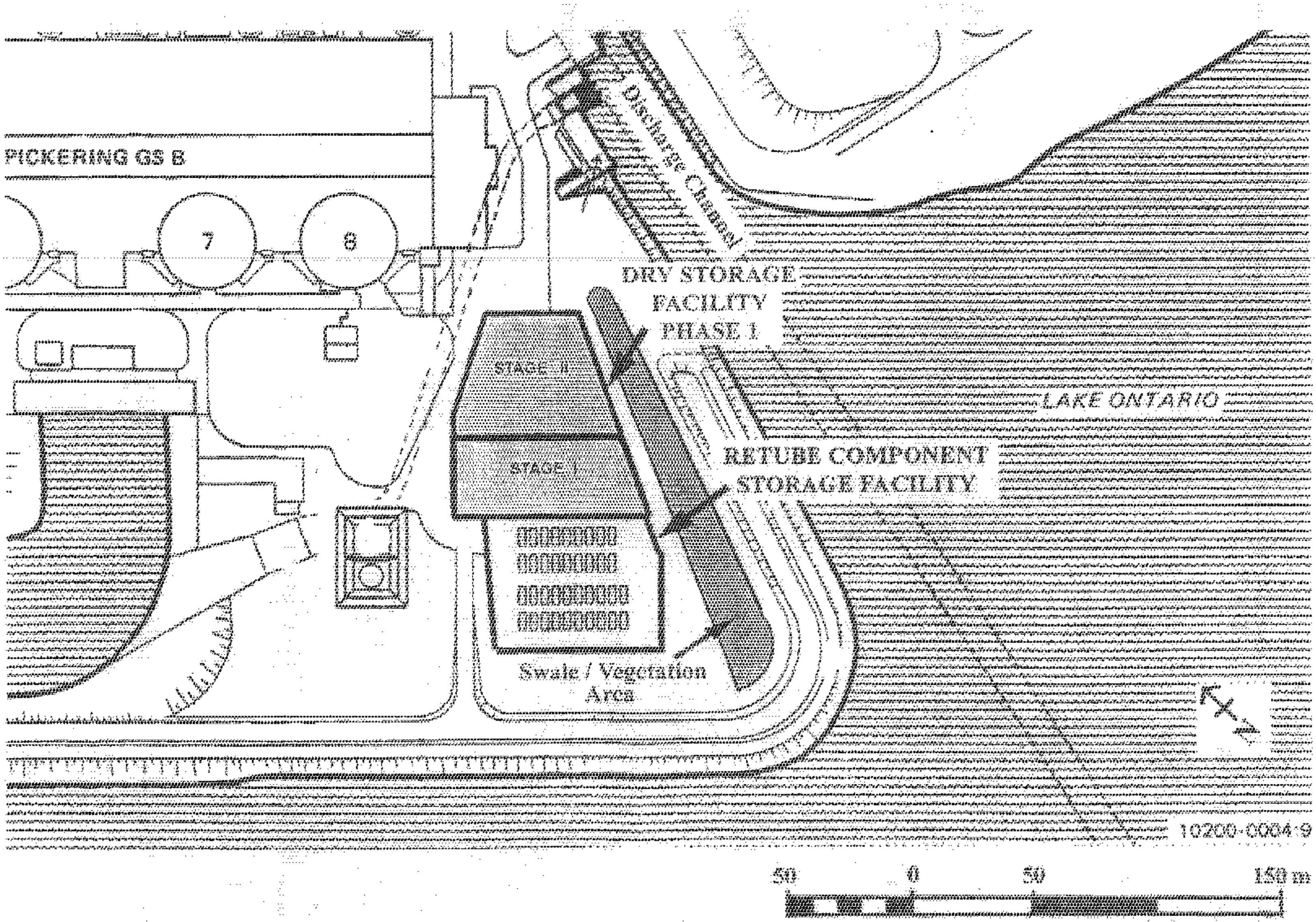


Figure 7
Pickering Reactor Site - Plan

Figure 8. Pickering Site Overview.

Figure 9. Pickering Existing Cask Storage.

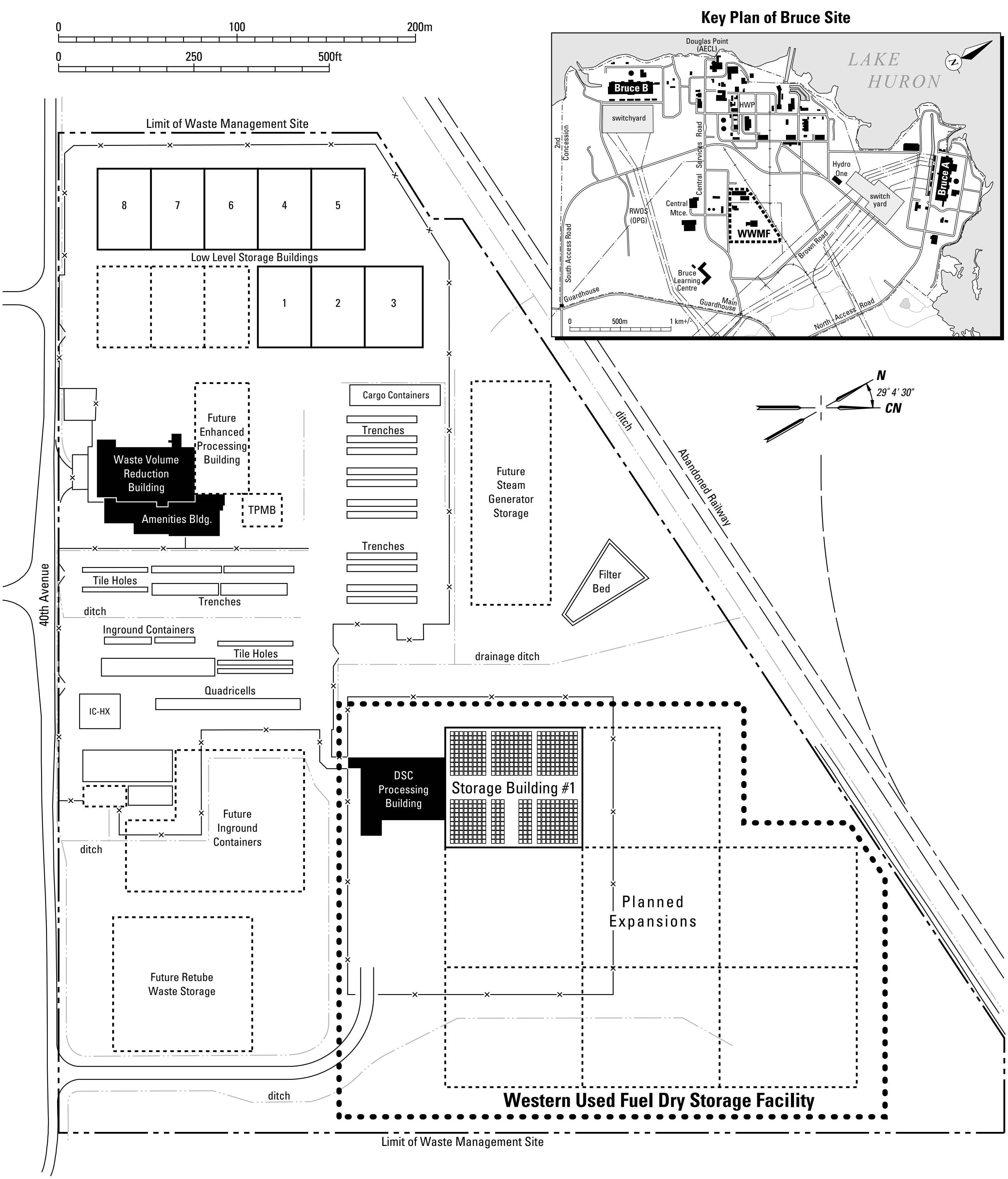


Figure 10
Western Waste Management Facility Showing Location of Existing and Planned Dry Storage Facilities

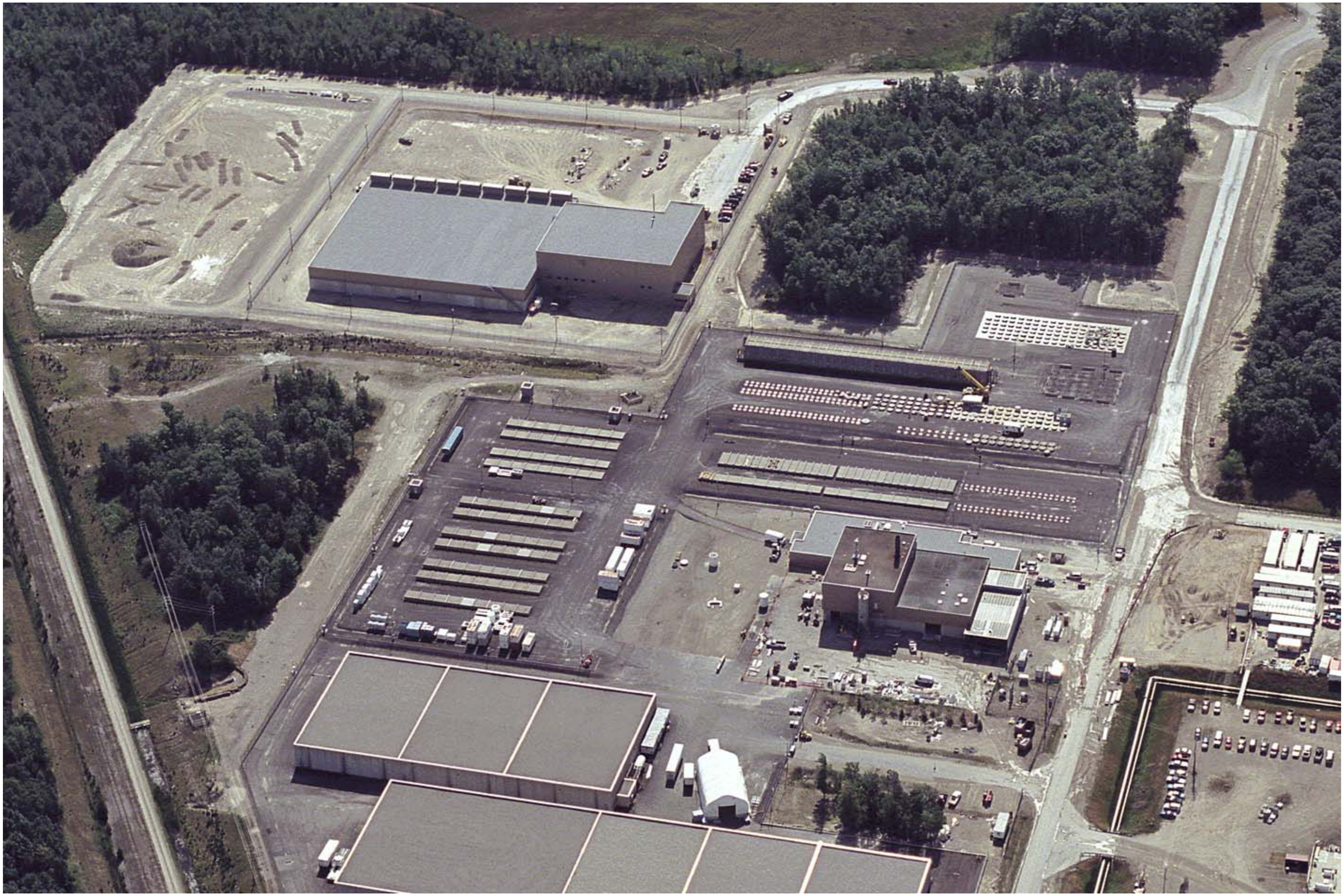


Figure 11. Western Used Fuel Dry Storage Facility Overview.

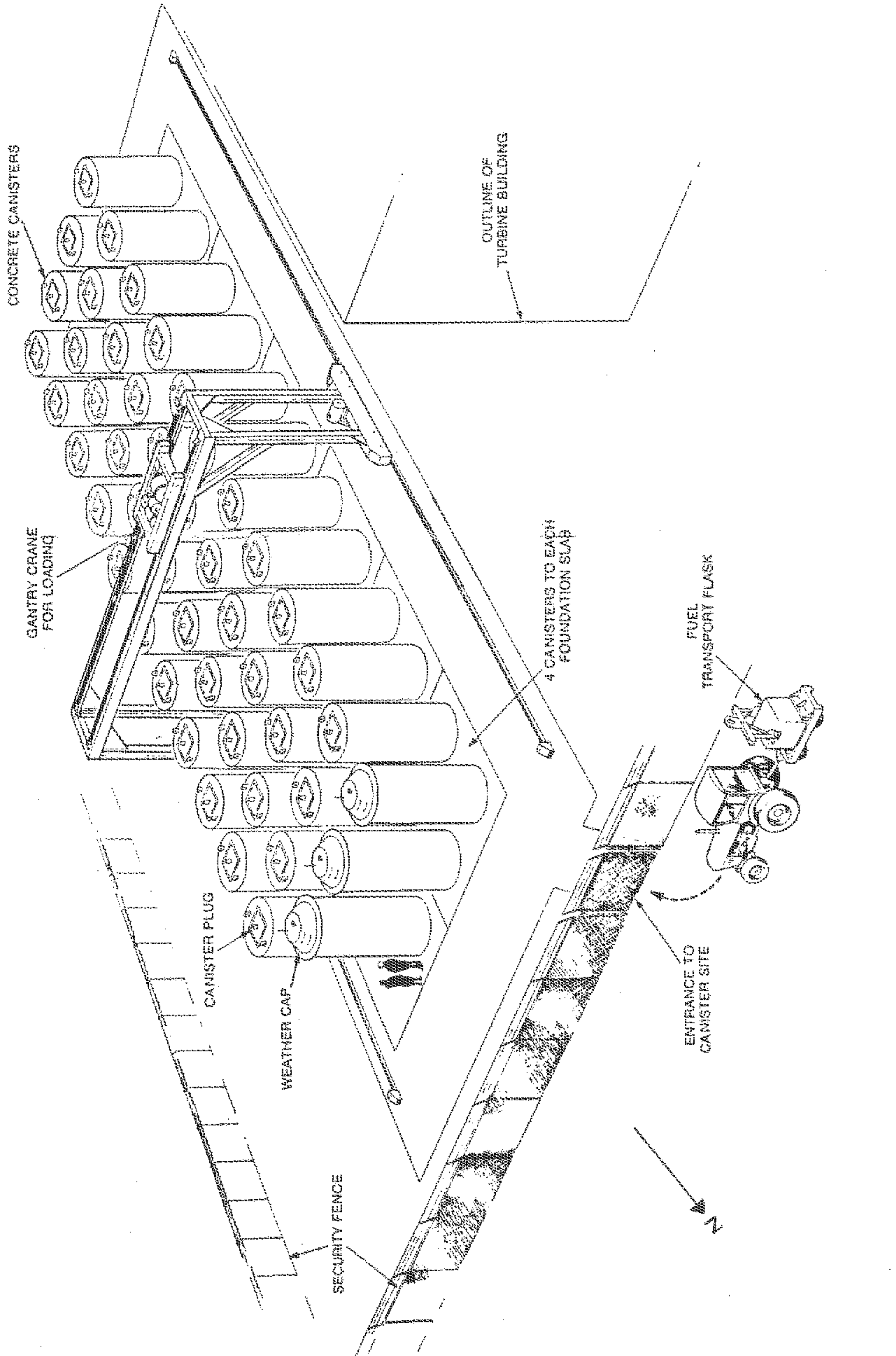


Figure 12
Douglas Point Storage Silos.

Figure 13. (page intentionally left blank)

Figure 14
Darlington Reactor Site showing location of proposed Used Fuel Dry Storage Facility

FOR SECTION A–A SEE FIG. 16

NOTE– FIGURE SHOWS A TYPICAL 4 BUILDING STORAGE ARANGEMENT. FOR INDIVIDUAL SITE REQUIREMENTS AND QUANTITY OF STORAGE BUILDINGS REFER TO RELEVANT SITE SPECIFIC FIGURES.

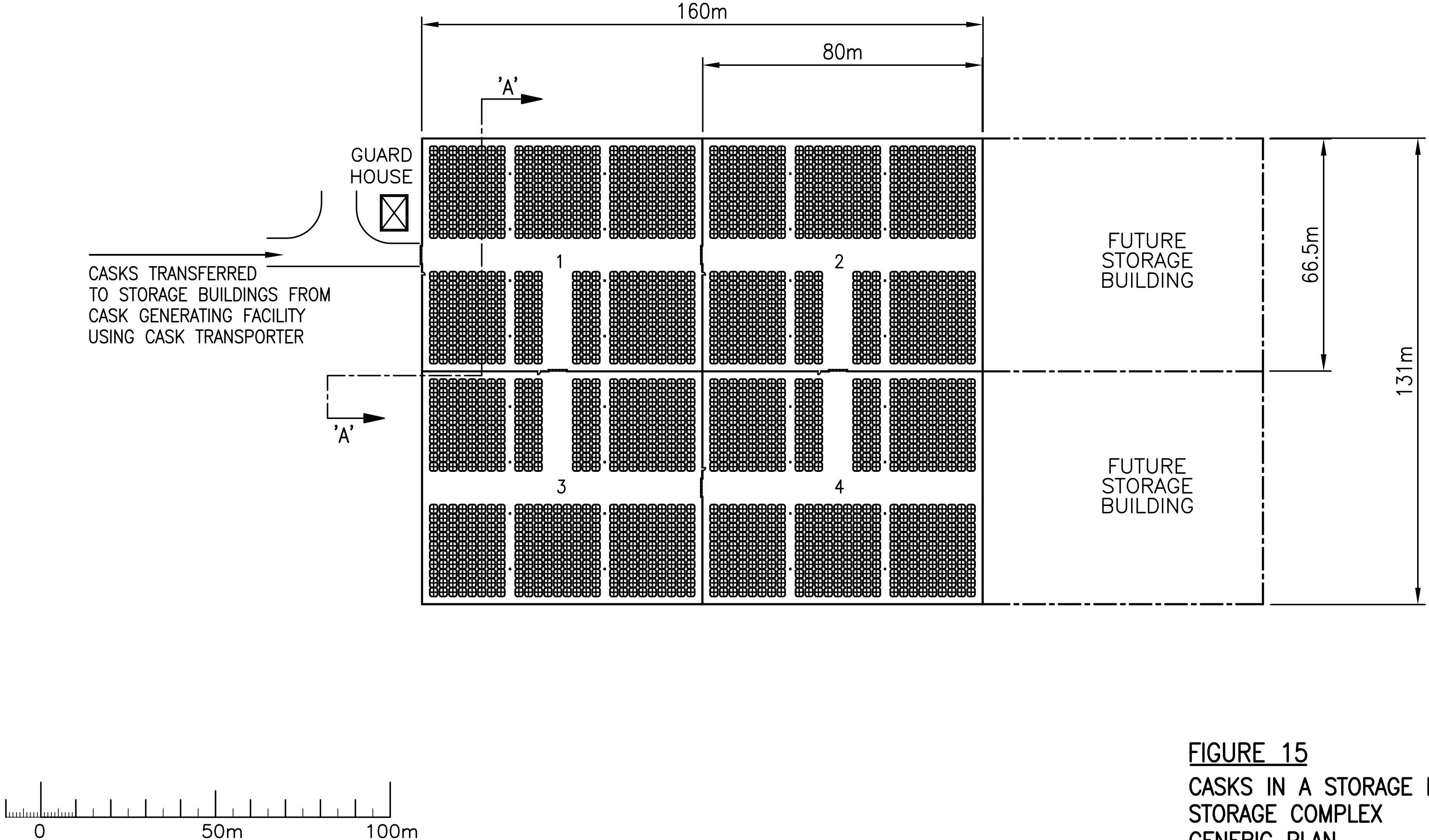


FIGURE 15

CASKS IN A STORAGE BUILDING STORAGE COMPLEX GENERIC PLAN

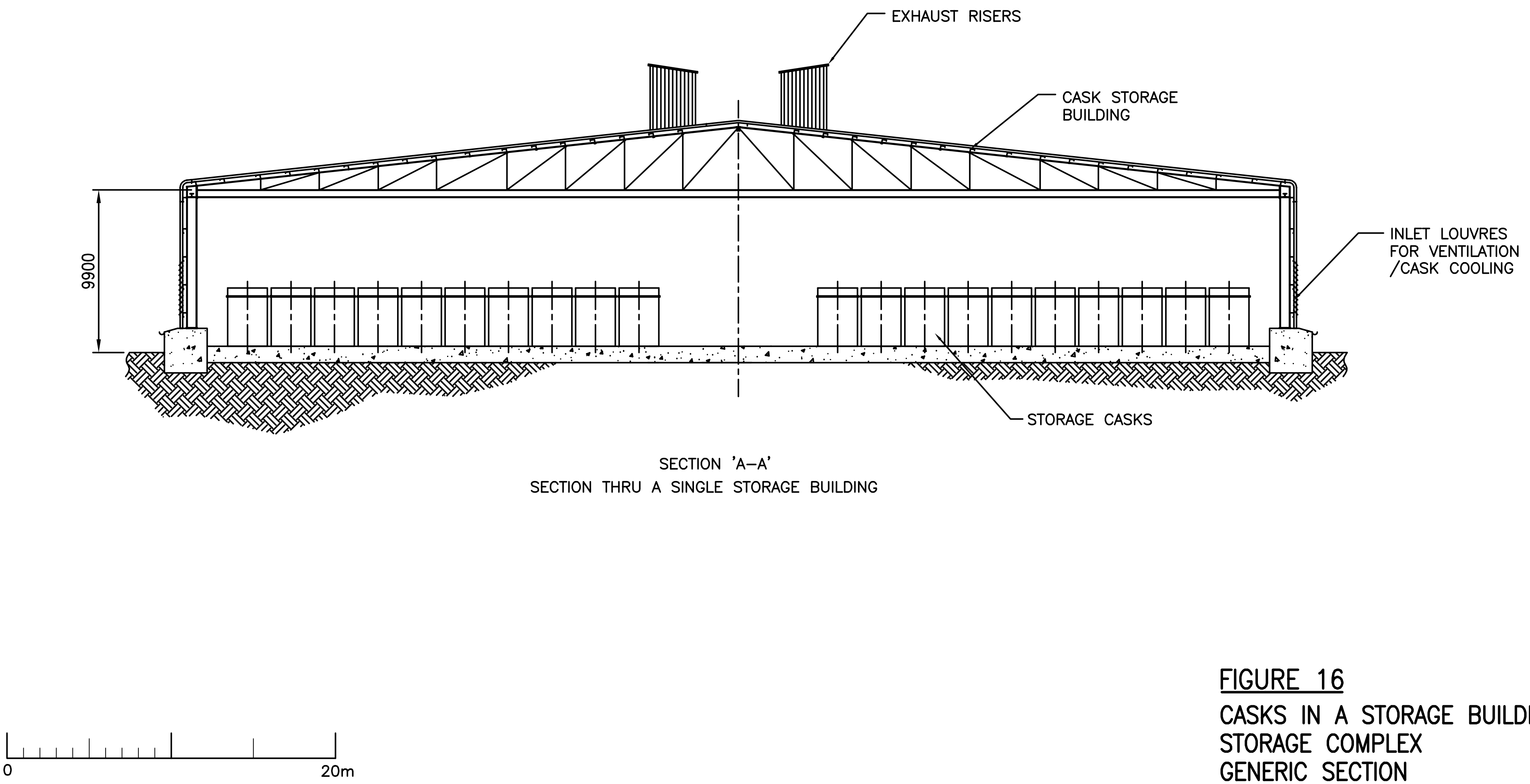


FIGURE 16

CASKS IN A STORAGE BUILDING
STORAGE COMPLEX
GENERIC SECTION

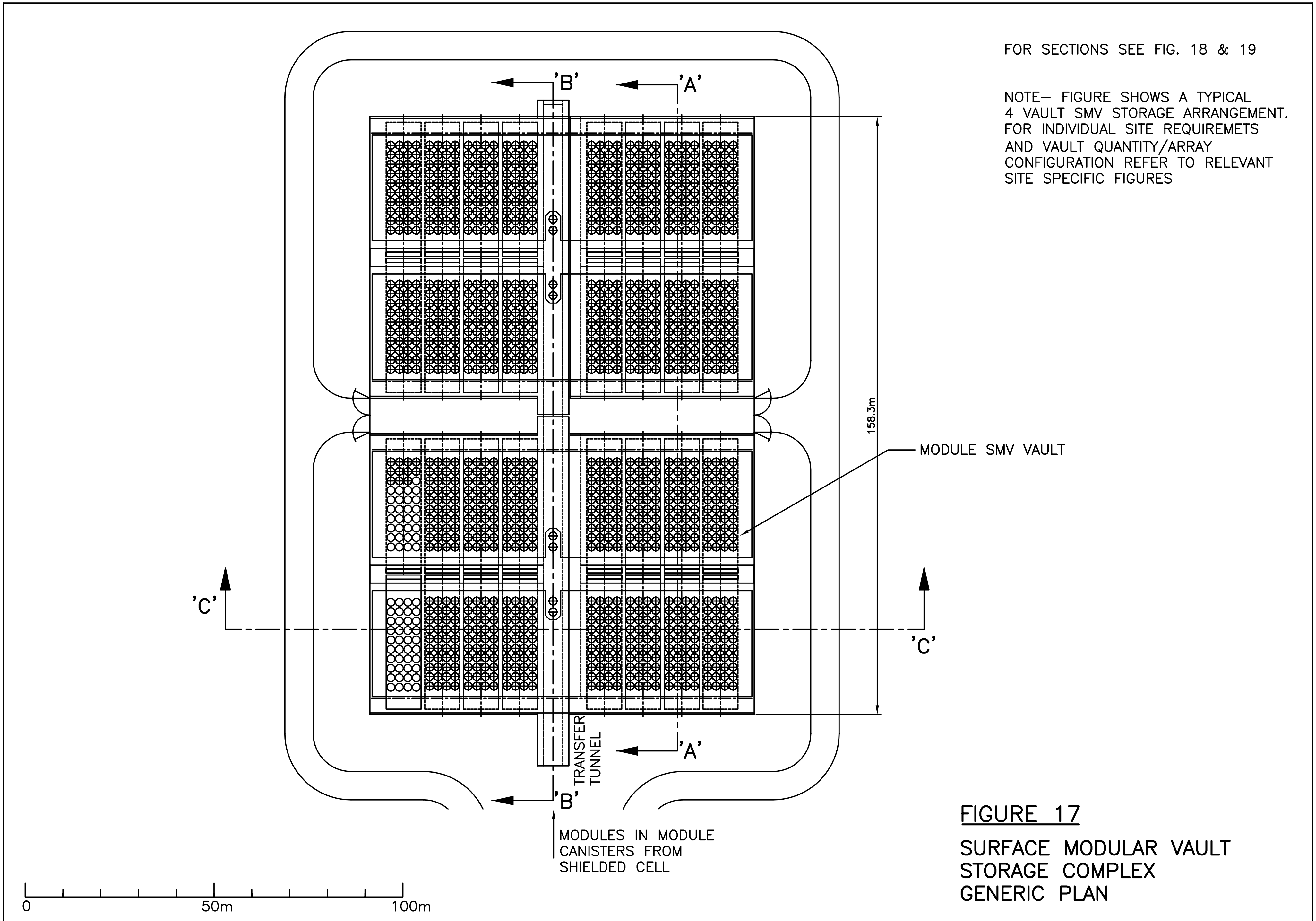
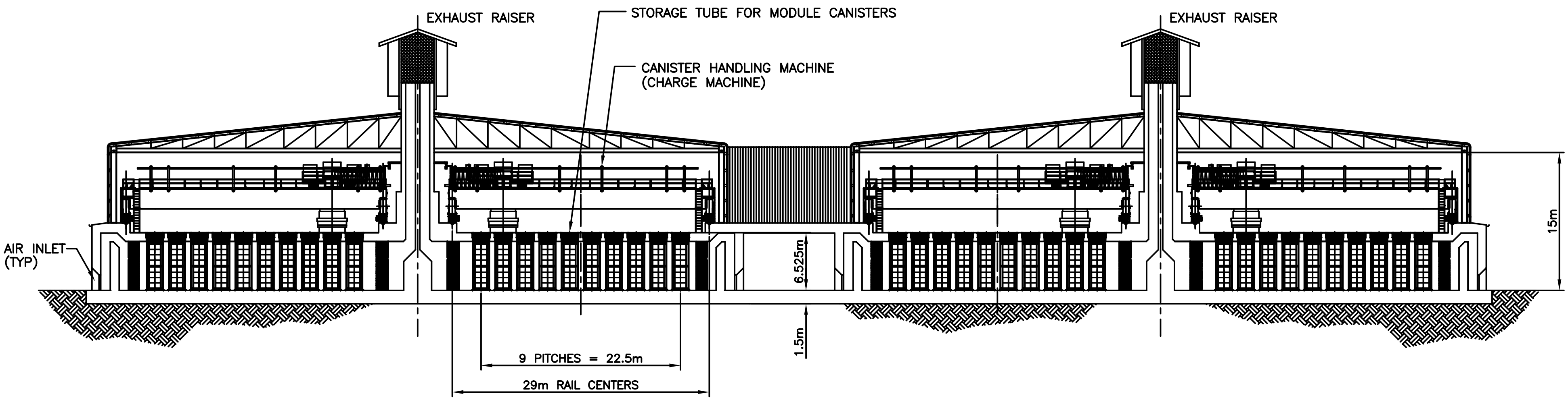
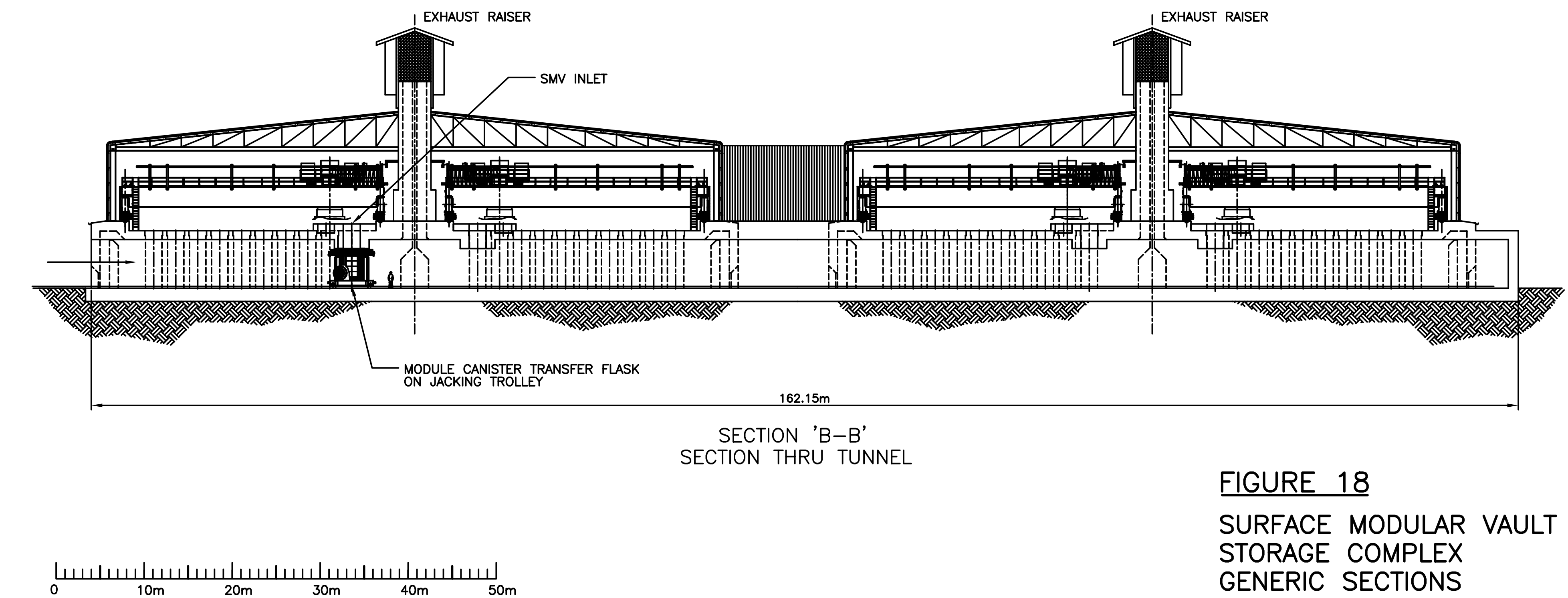


FIGURE 17

SURFACE MODULAR VAULT STORAGE COMPLEX GENERIC PLAN



SECTION 'A–A'
TYPICAL SECTION THRU SMV



SECTION 'B–B'
SECTION THRU TUNNEL

FIGURE 18

SURFACE MODULAR VAULT
STORAGE COMPLEX
GENERIC SECTIONS

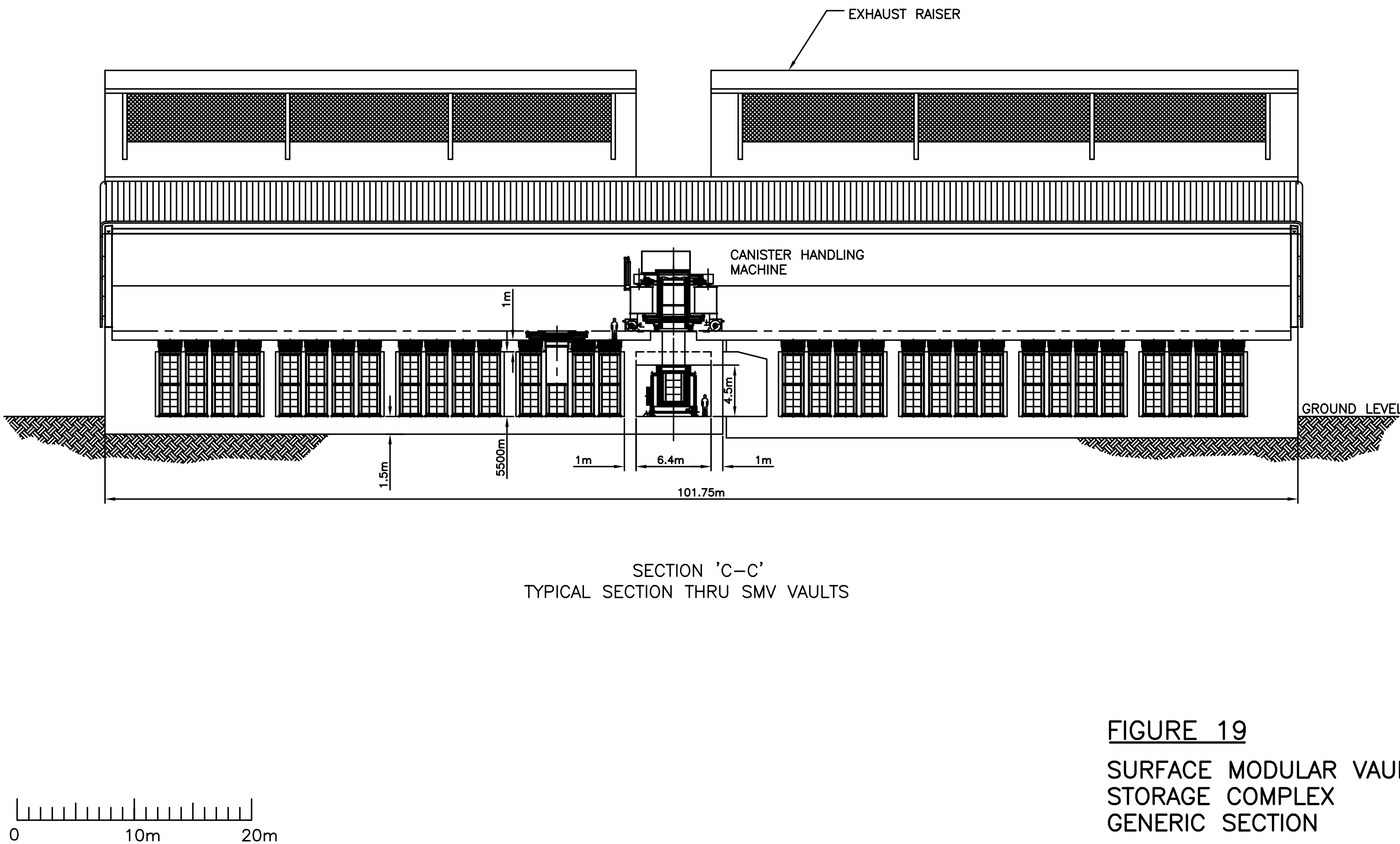


FIGURE 19

SURFACE MODULAR VAULT
STORAGE COMPLEX
GENERIC SECTION

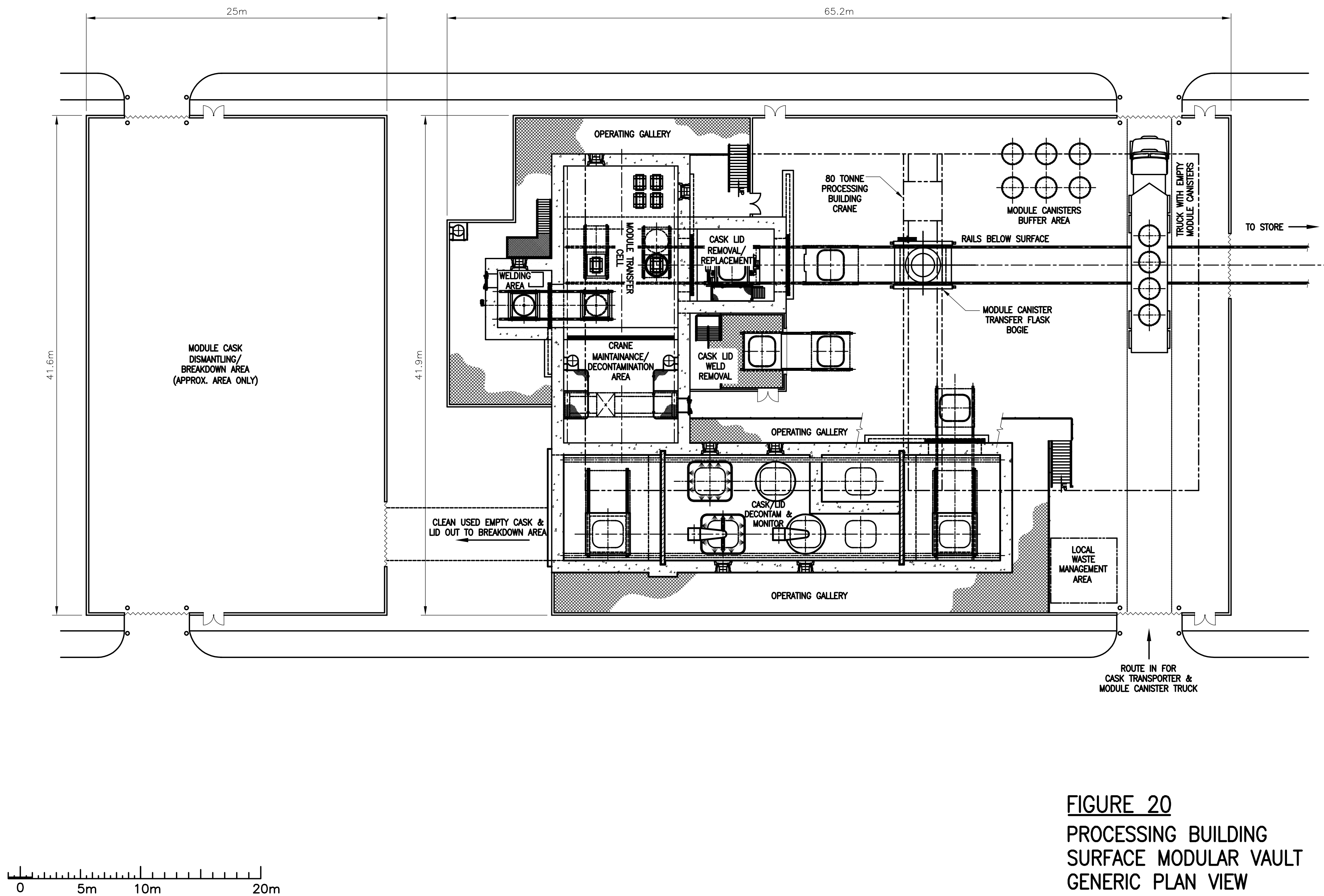


FIGURE 20

PROCESSING BUILDING
SURFACE MODULAR VAULT
GENERIC PLAN VIEW

FOR SECTIONS SEE FIG 22 & 23

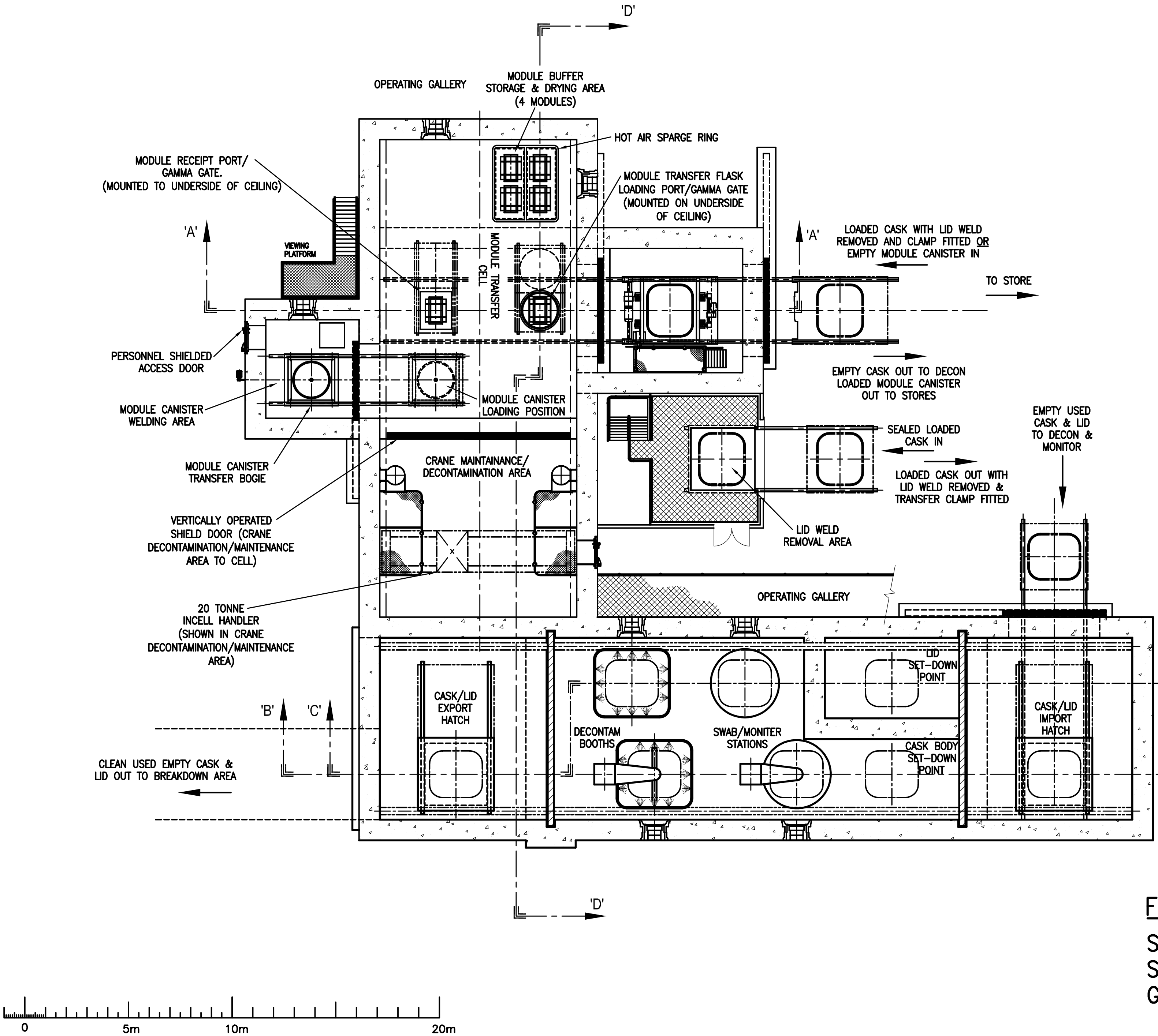
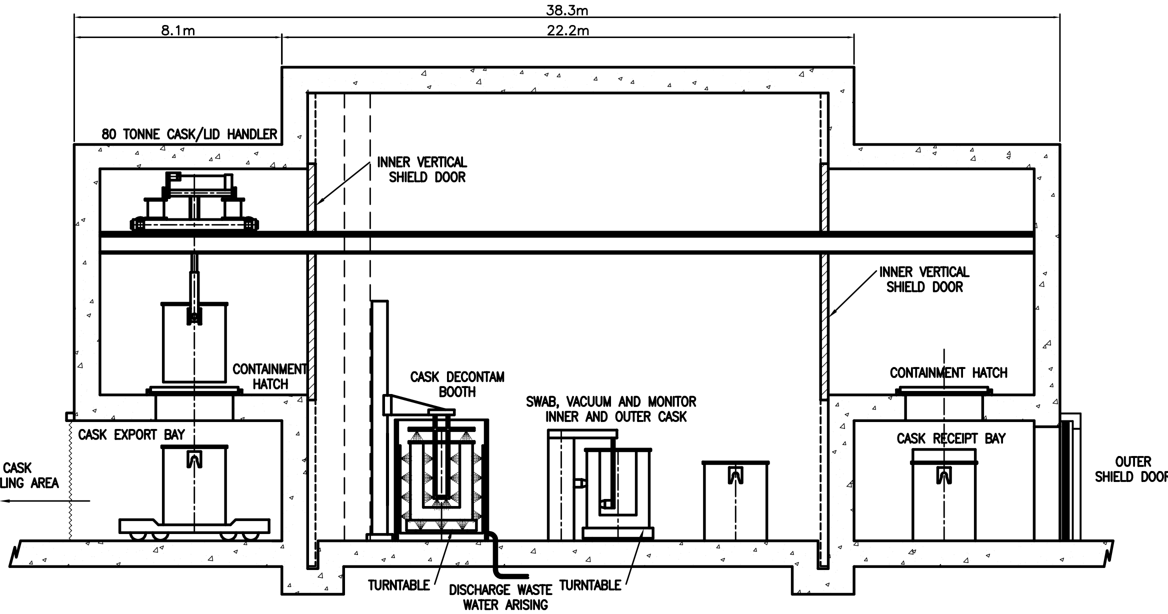
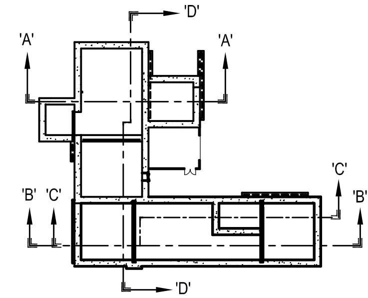


FIGURE 21

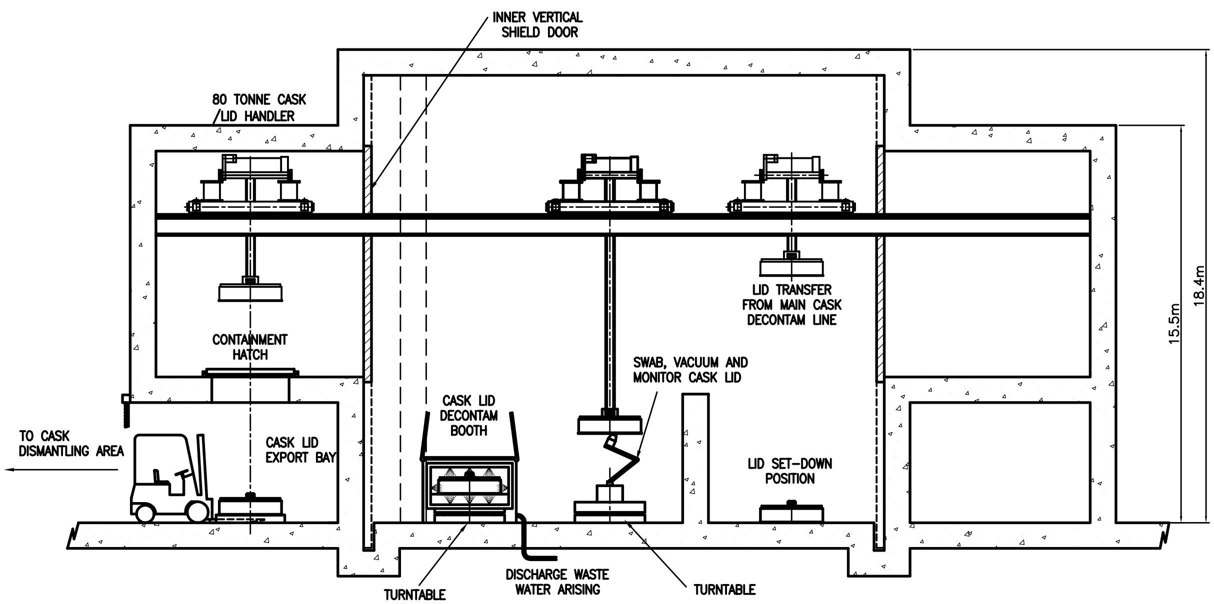
SHIELDED CELL
SURFACE MODULAR VAULT
GENERIC PLAN



SECTION 'B–B' FROM FIGURE 21



KEY PLAN



SECTION 'C–C' FROM FIGURE 21

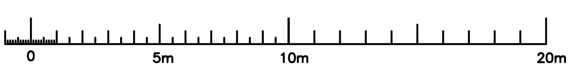
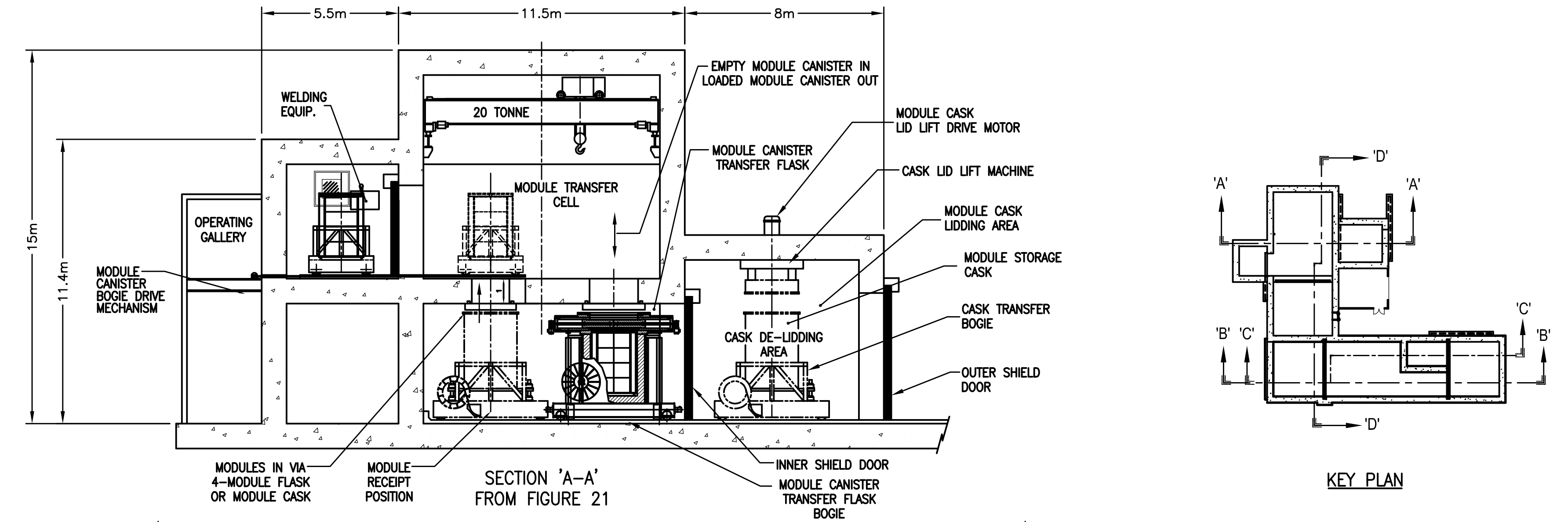


FIGURE 22

SHIELDED CELL
SURFACE MODULAR VAULT
GENERIC SECTIONS



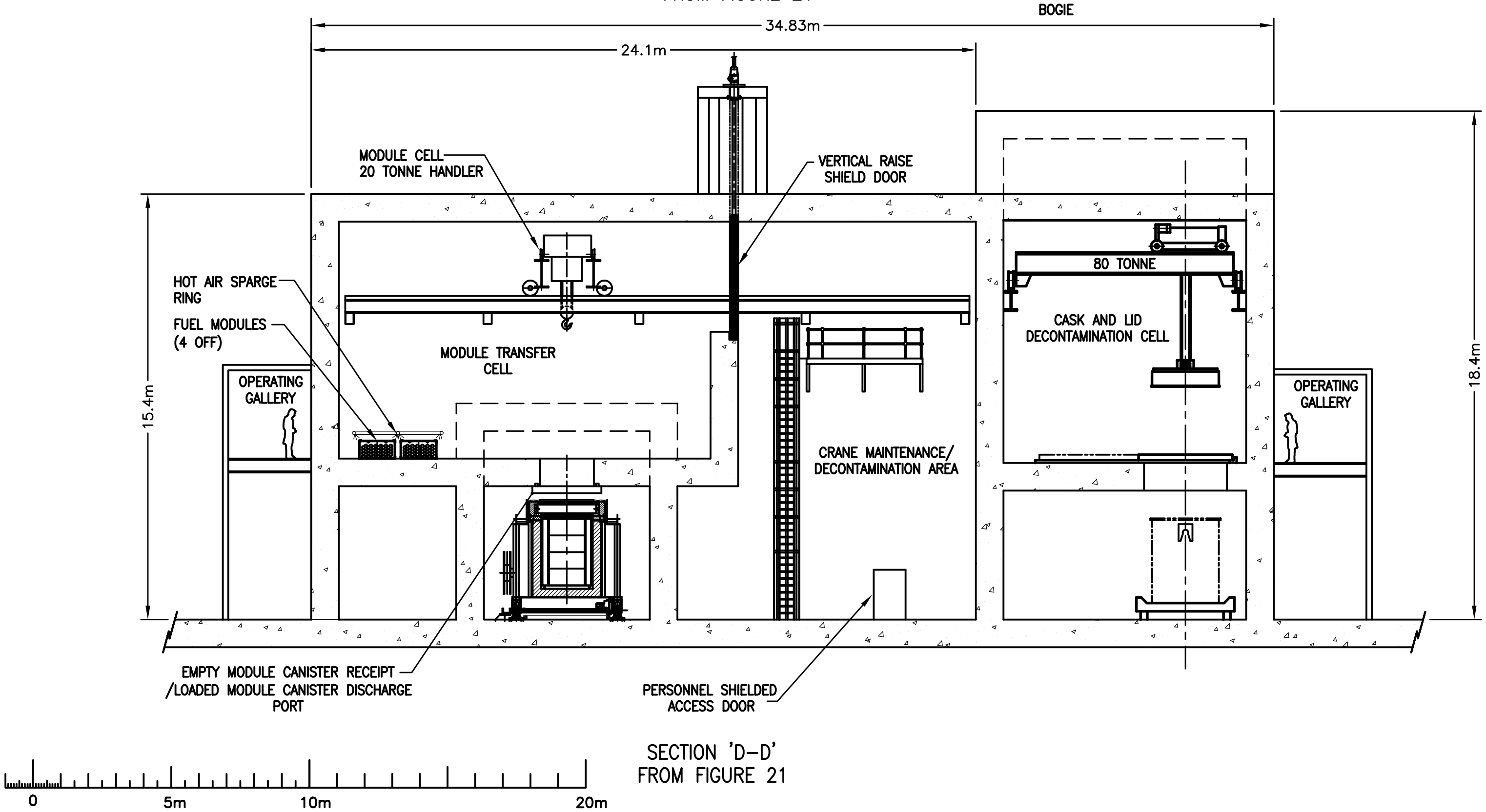


FIGURE 23

SHIELDED CELL SURFACE MODULAR VAULT GENERIC SECTIONS

FOR SECTIONS SEE FIG. 25

NOTE– FIGURE SHOWS A TYPICAL 4 CHAMBER STORAGE ARRANGMENT. FOR INDIVIDUAL SITE REQUIREMENTS AND QUANTITY OF STORAGE CHAMBERS REFER TO RELEVANT SITE SPECIFIC FIGURES.

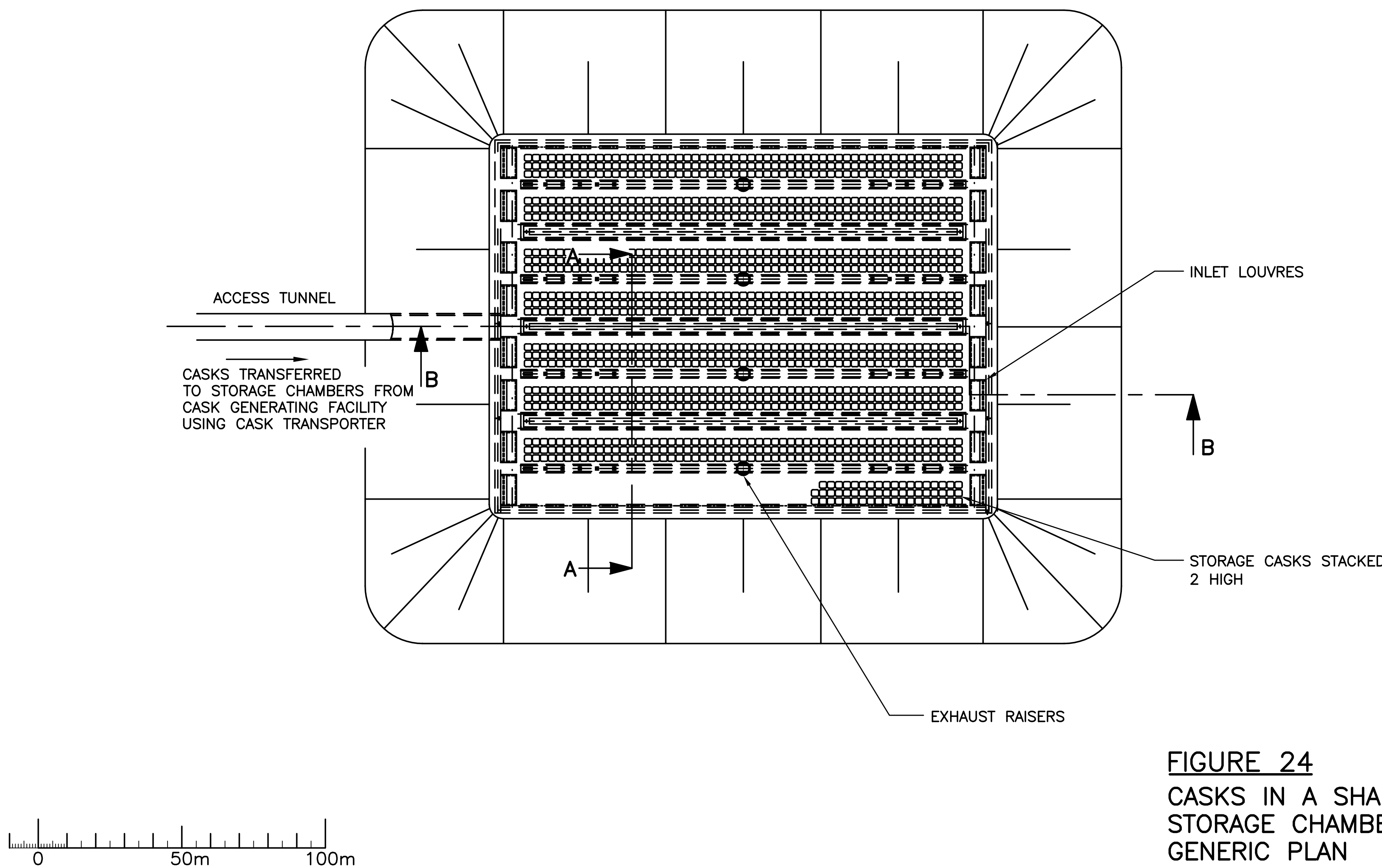


FIGURE 24

CASKS IN A SHALLOW TRENCH STORAGE CHAMBERS GENERIC PLAN

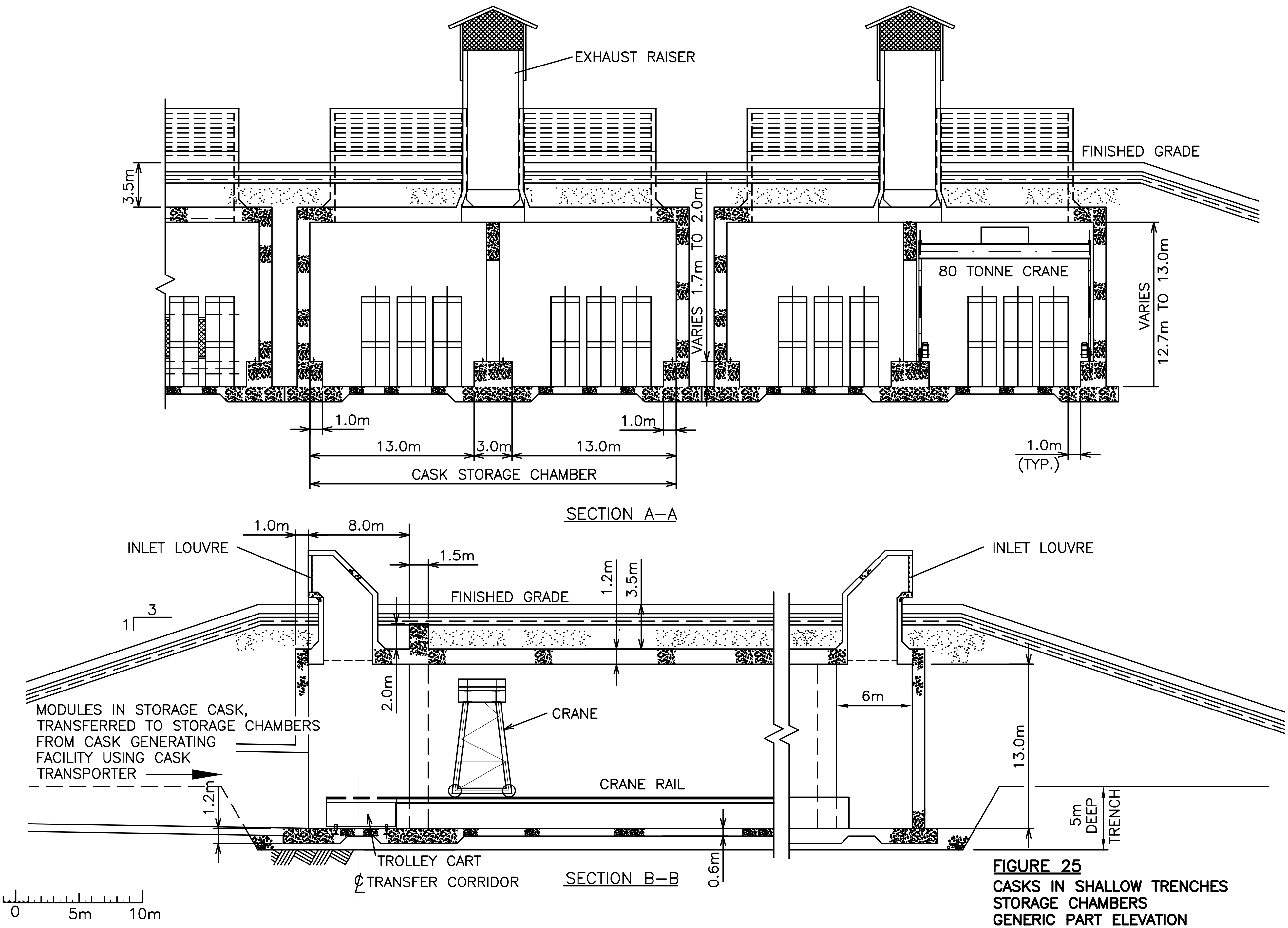


FIGURE 25
CASKS IN SHALLOW TRENCHES STORAGE CHAMBERS GENERIC PART ELEVATION

USED FUEL INVENTORY
AT PICKERING REACTOR SITE :–

2,421 MODULE CASKS

STORAGE SPACE AVAILABLE
FOR 2,600 CASKS
179 SPARE SPACES

FOR SECTION A–A SEE FIG. 16

NOTE– FIGIRE SHOWS STORAGE REQUIREMENTS BUT DOES NOT SHOW ACTUAL BUILDING POSITIONS OR ORIENTATION

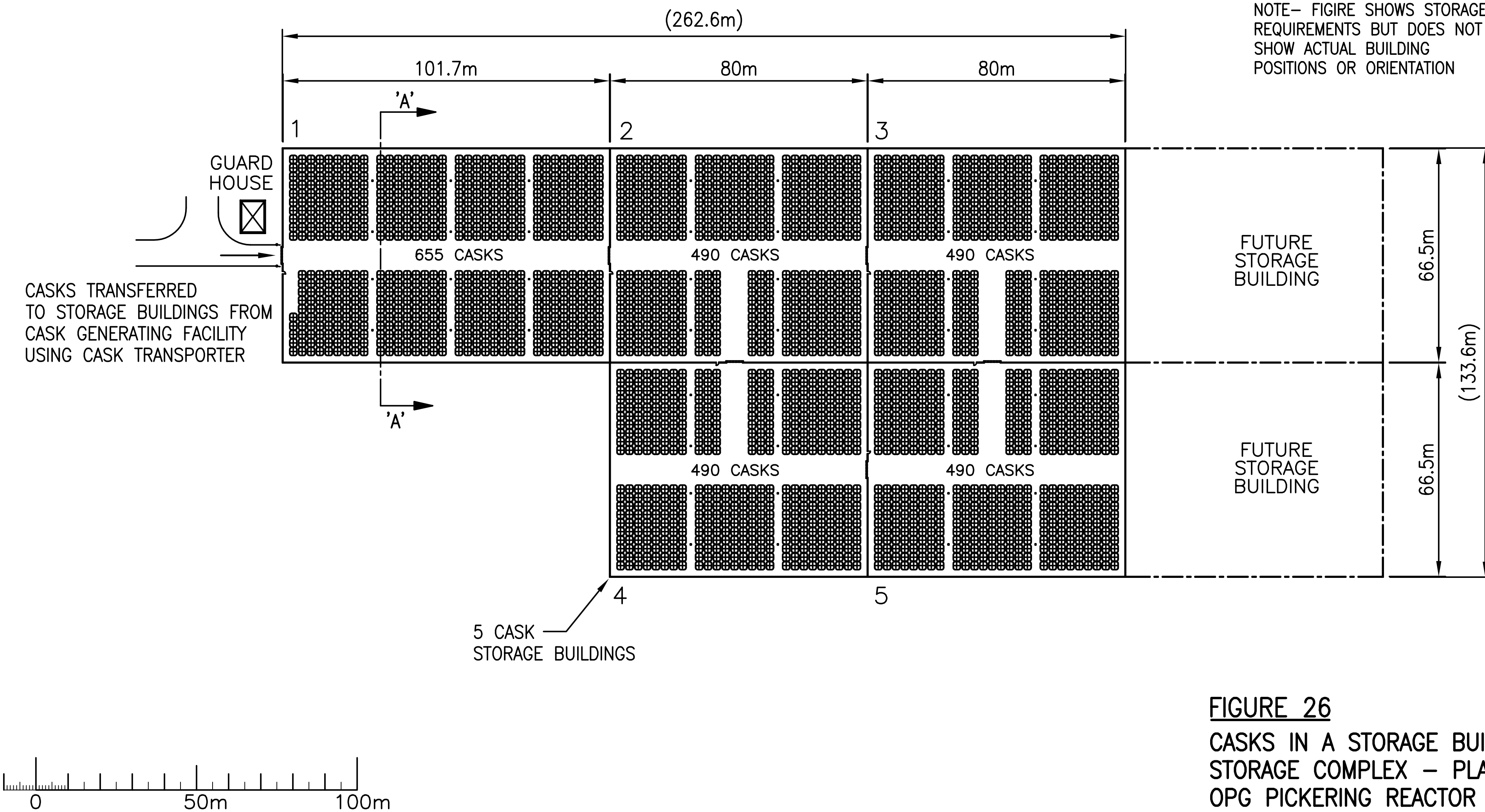


FIGURE 26

CASKS IN A STORAGE BUILDING
STORAGE COMPLEX – PLAN
OPG PICKERING REACTOR SITE

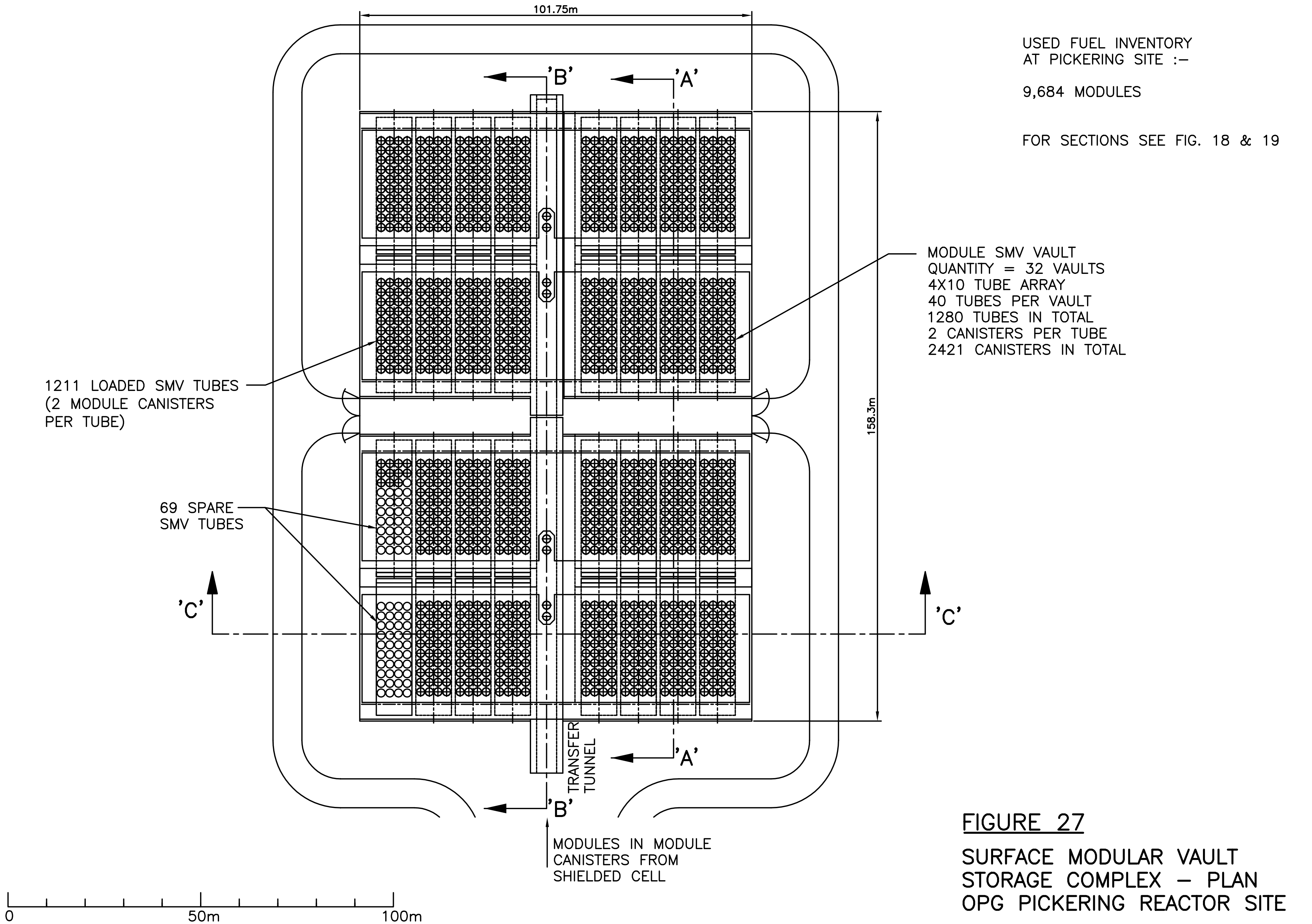


FIGURE 27

SURFACE MODULAR VAULT STORAGE COMPLEX – PLAN OPG PICKERING REACTOR SITE

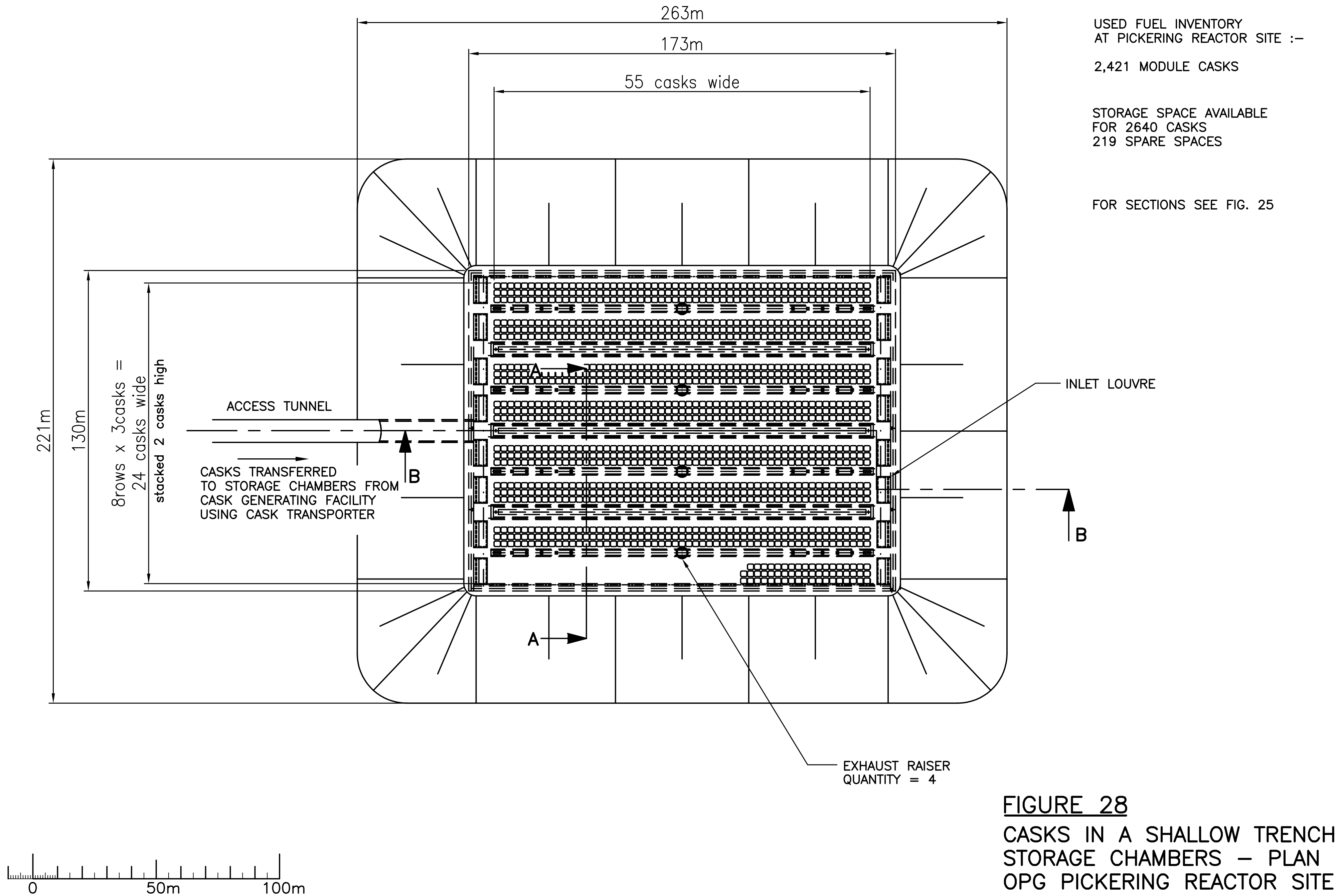


FIGURE 28

CASKS IN A SHALLOW TRENCH STORAGE CHAMBERS – PLAN
OPG PICKERING REACTOR SITE

USED FUEL INVENTORY
AT BRUCE REACTOR SITE :–

3,825 MODULE CASKS

104 BASKET CASKS
(AECL DOUGLAS POINT FUEL)

SPACE REQUIRED FOR 3,929
CASKS IN TOTAL
STORAGE SPACE AVAILABLE FOR
4,160 CASKS.
231 SPARE SPACES

FOR SECTION A–A SEE FIG. 16

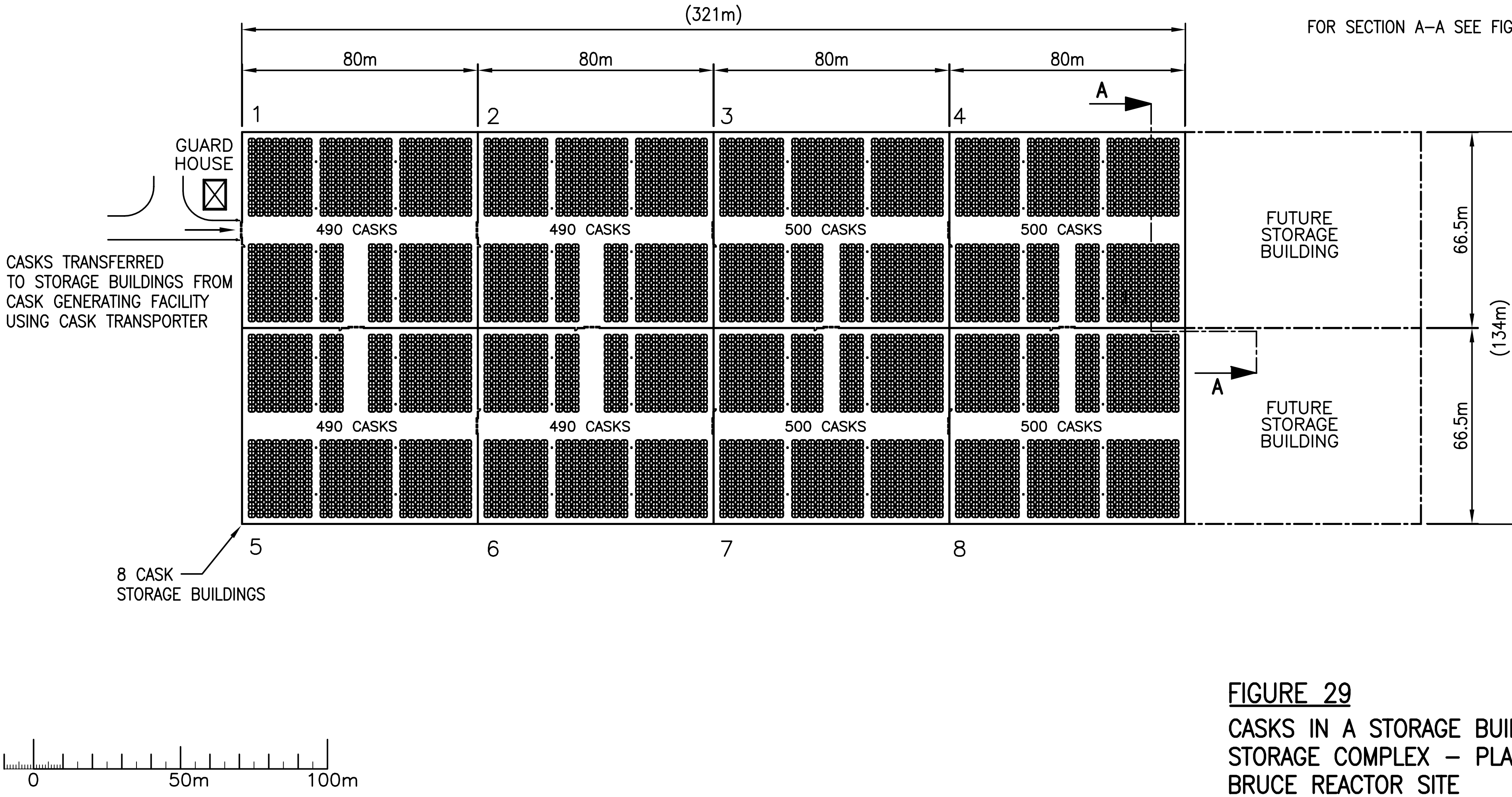


FIGURE 29

CASKS IN A STORAGE BUILDING
STORAGE COMPLEX – PLAN
BRUCE REACTOR SITE

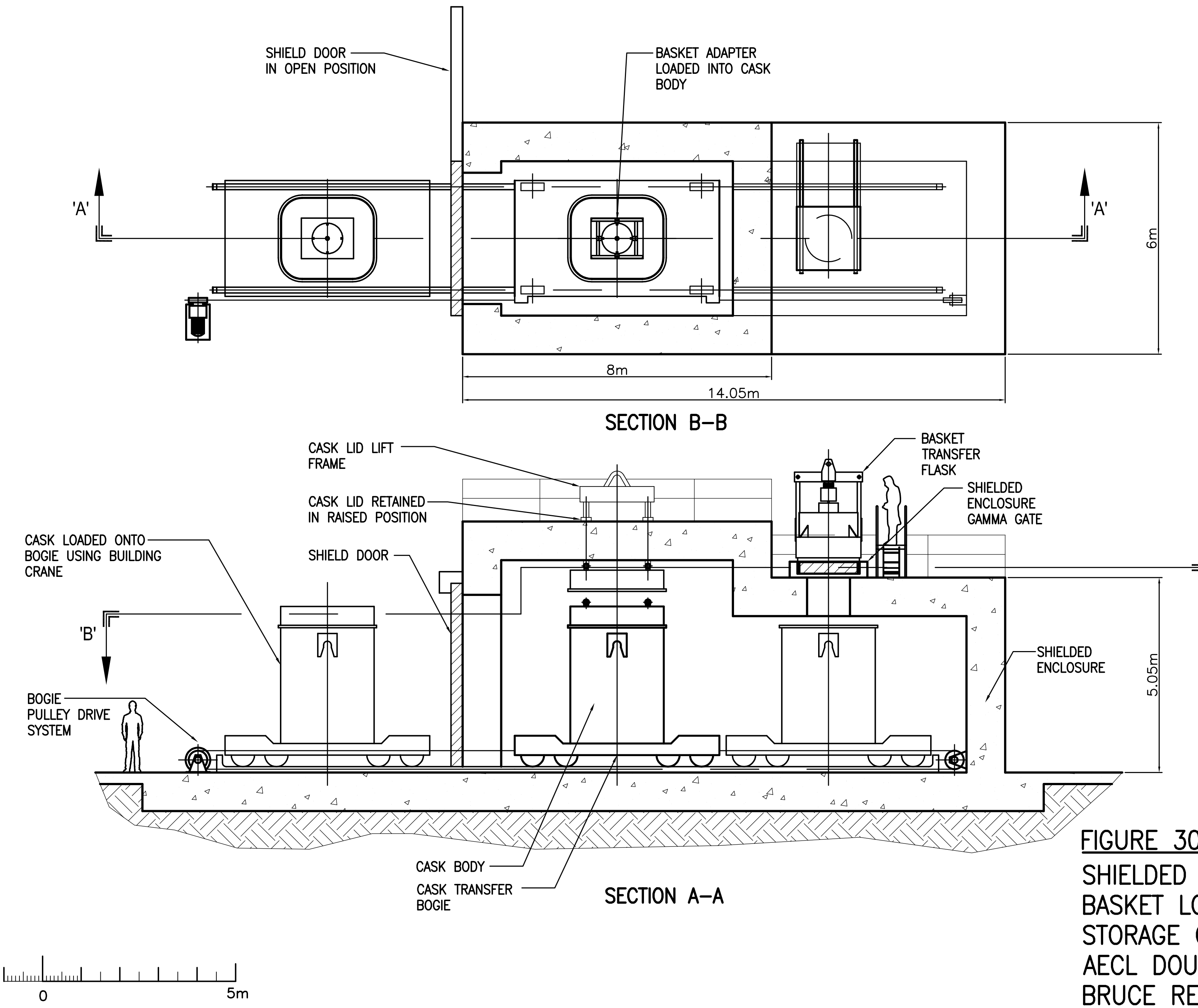
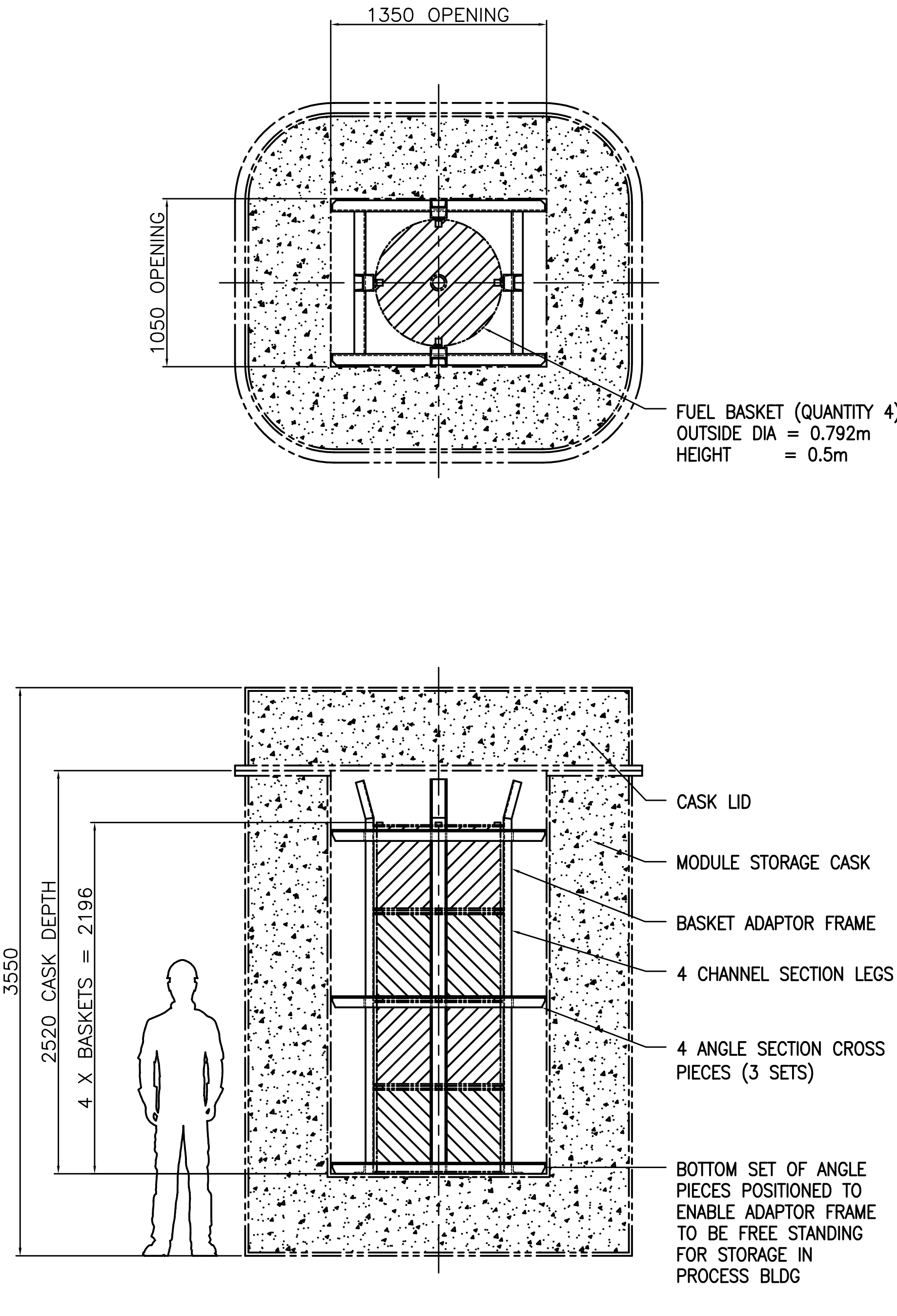


FIGURE 30

SHIELDED ENCLOSURE
BASKET LOADING INTO MODULE
STORAGE CASK – CVSB & CVST
AECL DOUGLAS POINT FUEL AT
BRUCE REACTOR SITE

DETAILS
BASKET ADAPTOR



ASSEMBLY – BASKETS & BASKET ADAPTOR
INSIDE MODULE STORAGE CASK

FIGURE 31 - MODULE CASK BASKET ADAPTOR
(AECL BASKETS INTO MODULE CASKS)
BRUCE REACTOR SITE

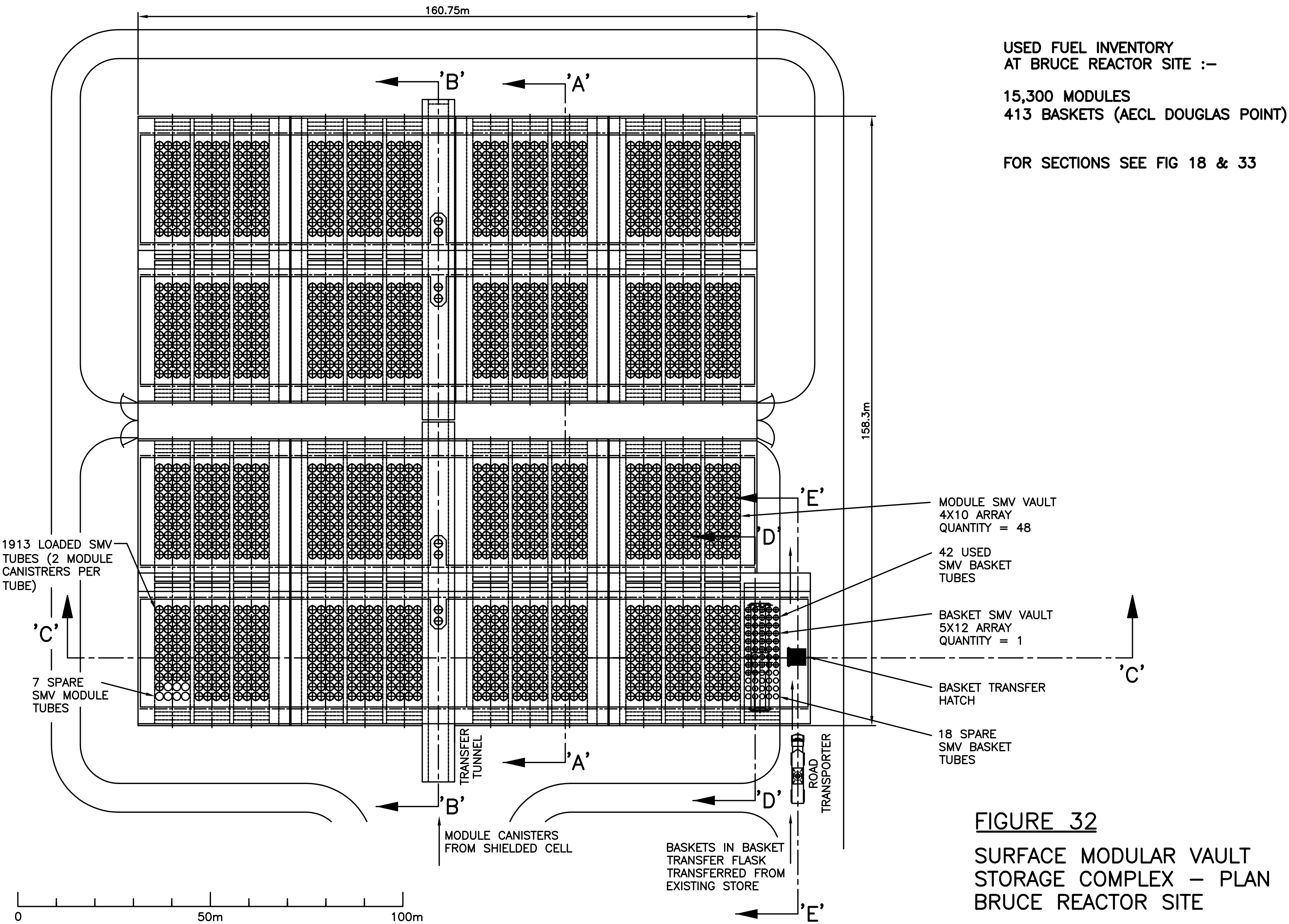
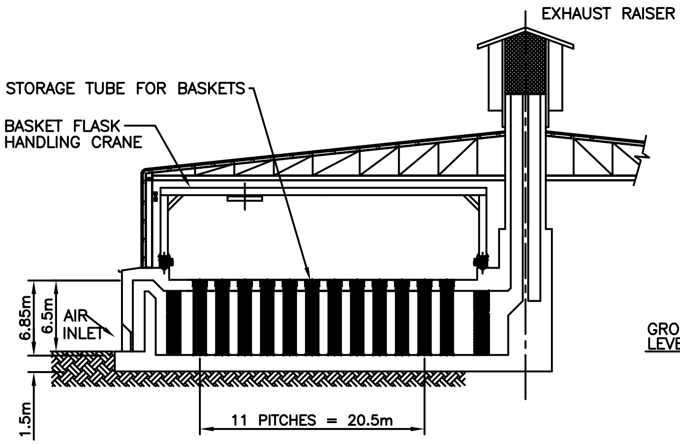
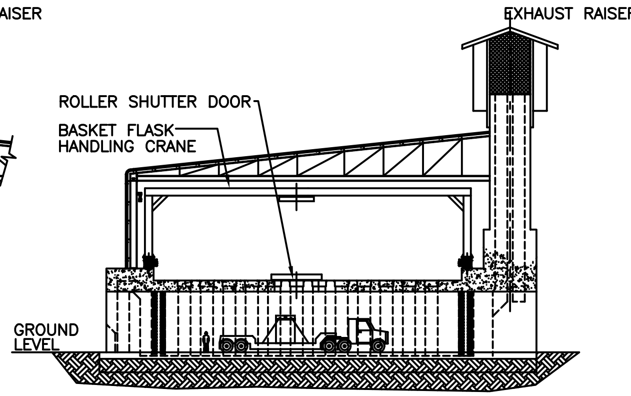


FIGURE 32

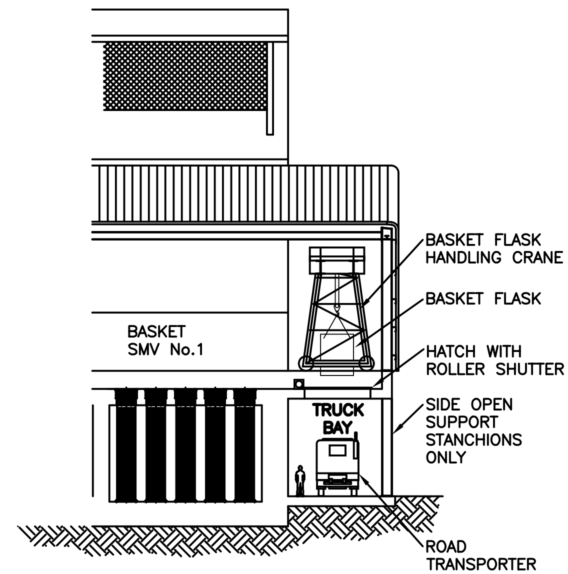
SURFACE MODULAR VAULT STORAGE COMPLEX – PLAN BRUCE REACTOR SITE



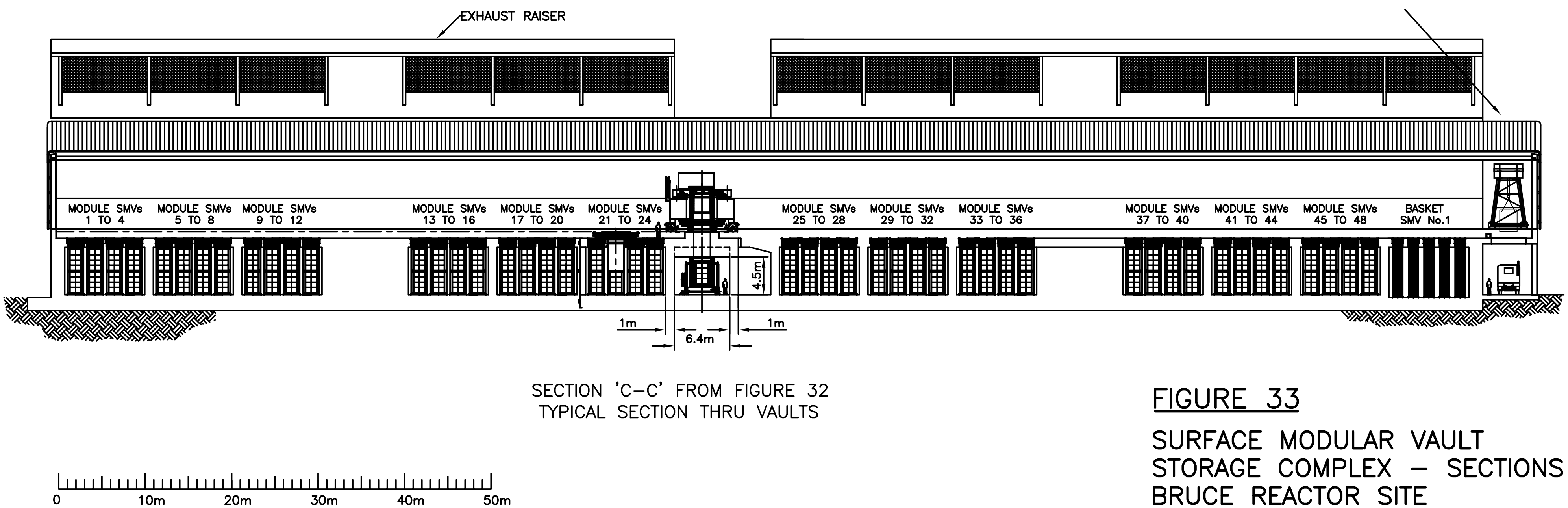
SECTION 'D–D' FROM FIGURE 32
TYPICAL SECTION THRU BASKET SMV



SECTION 'E–E' FROM FIGURE 32
TYPICAL SECTION THRU BASKET LOADING BAY



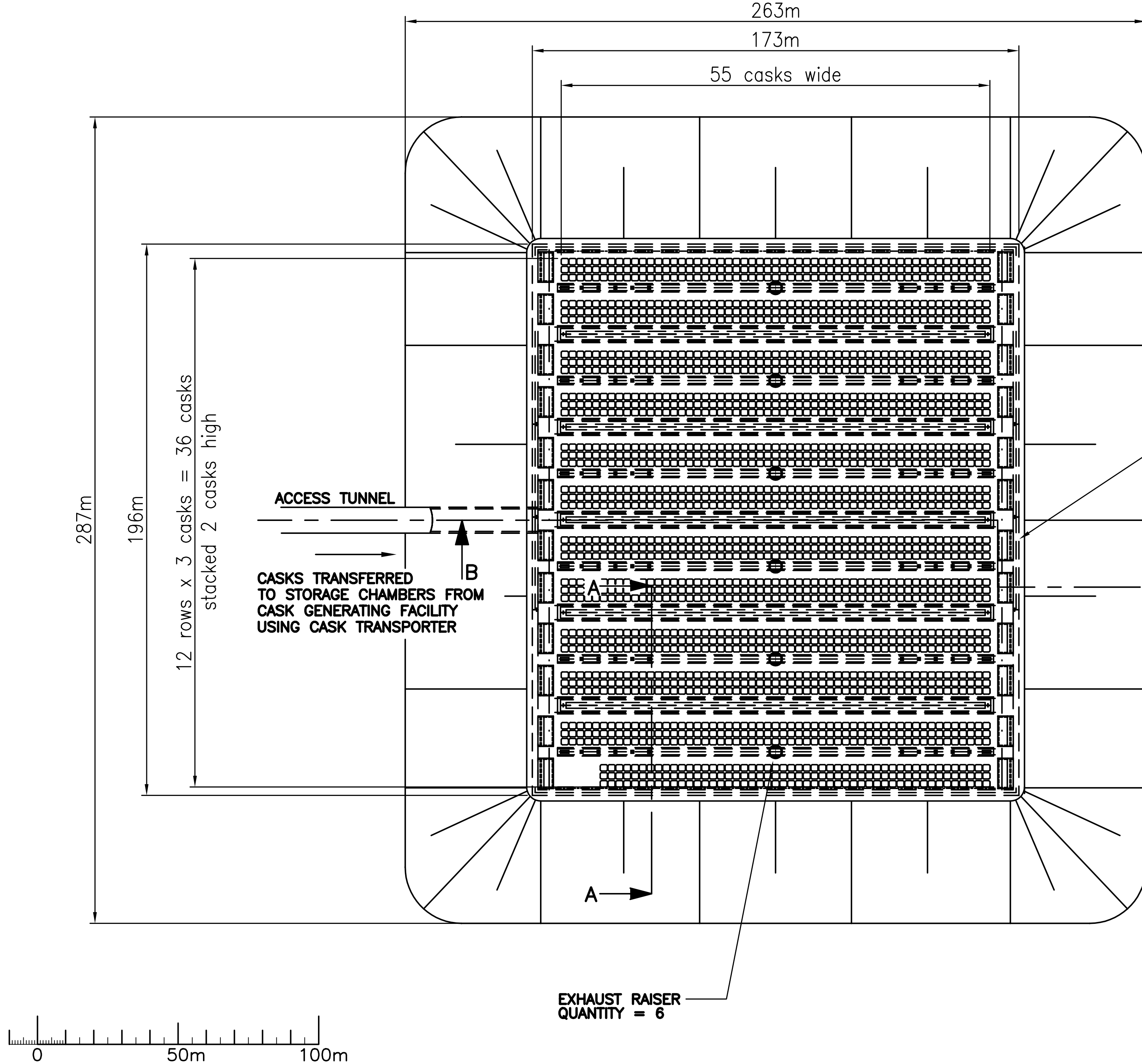
ENLARGED VIEW
OF BASKET FLASK UNLOADING AREA



SECTION 'C–C' FROM FIGURE 32
TYPICAL SECTION THRU VAULTS

FIGURE 33

SURFACE MODULAR VAULT
STORAGE COMPLEX – SECTIONS
BRUCE REACTOR SITE



USED FUEL INVENTORY AT BRUCE REACTOR SITE :–

3,825 MODULE CASKS

104 BASKET CASKS (AECL DOUGLAS POINT)

SPACE REQD FOR 3929 CASKS IN TOTAL.
STORAGE SPACE AVAILABLE FOR 3960 CASKS
31 SPARE SPACES

FOR SECTIONS SEE FIG. 25

FIGURE 34

CASKS IN A SHALLOW TRENCH STORAGE CHAMBERS – PLAN BRUCE REACTOR SITE

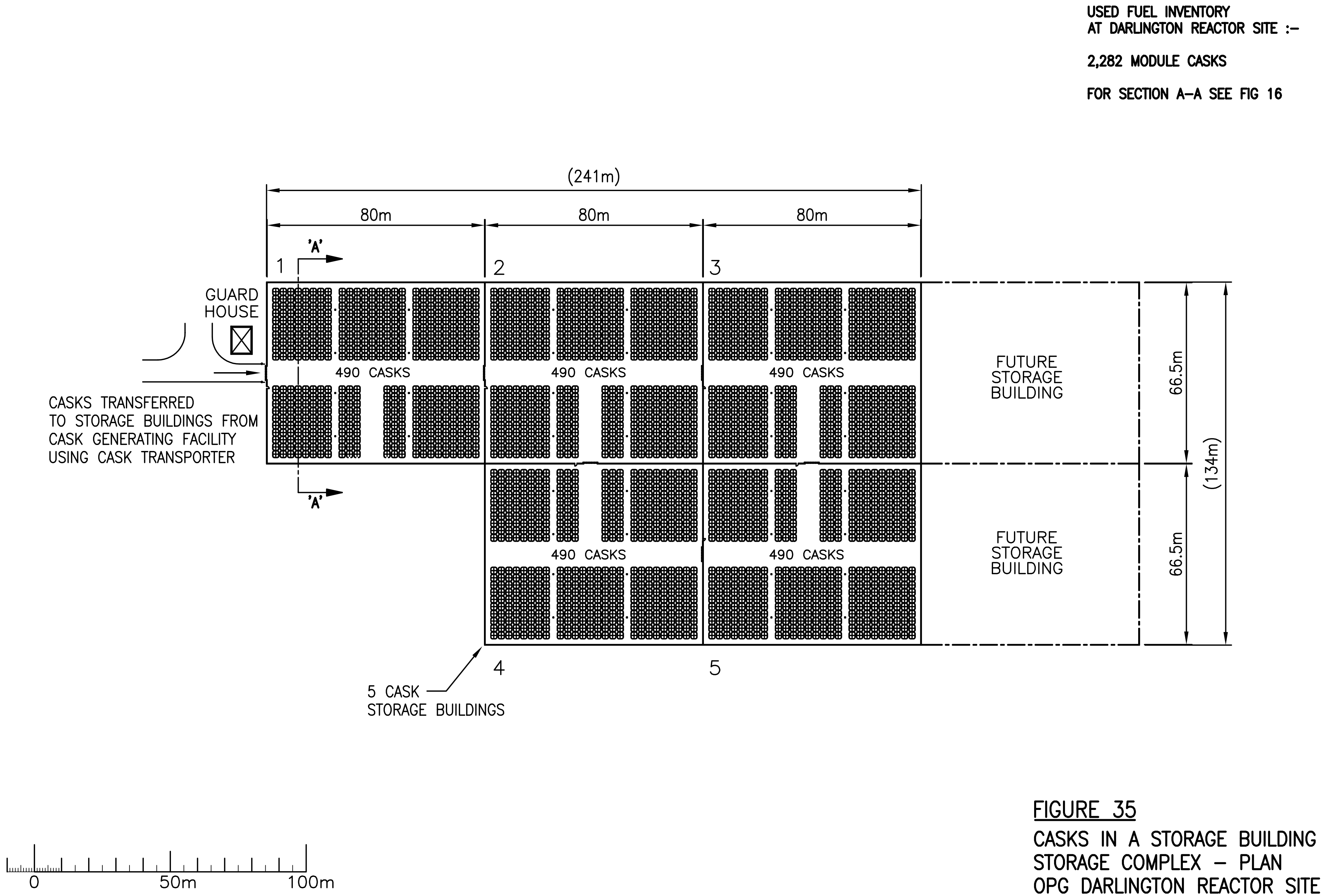


FIGURE 35

CASKS IN A STORAGE BUILDING
STORAGE COMPLEX – PLAN
OPG DARLINGTON REACTOR SITE

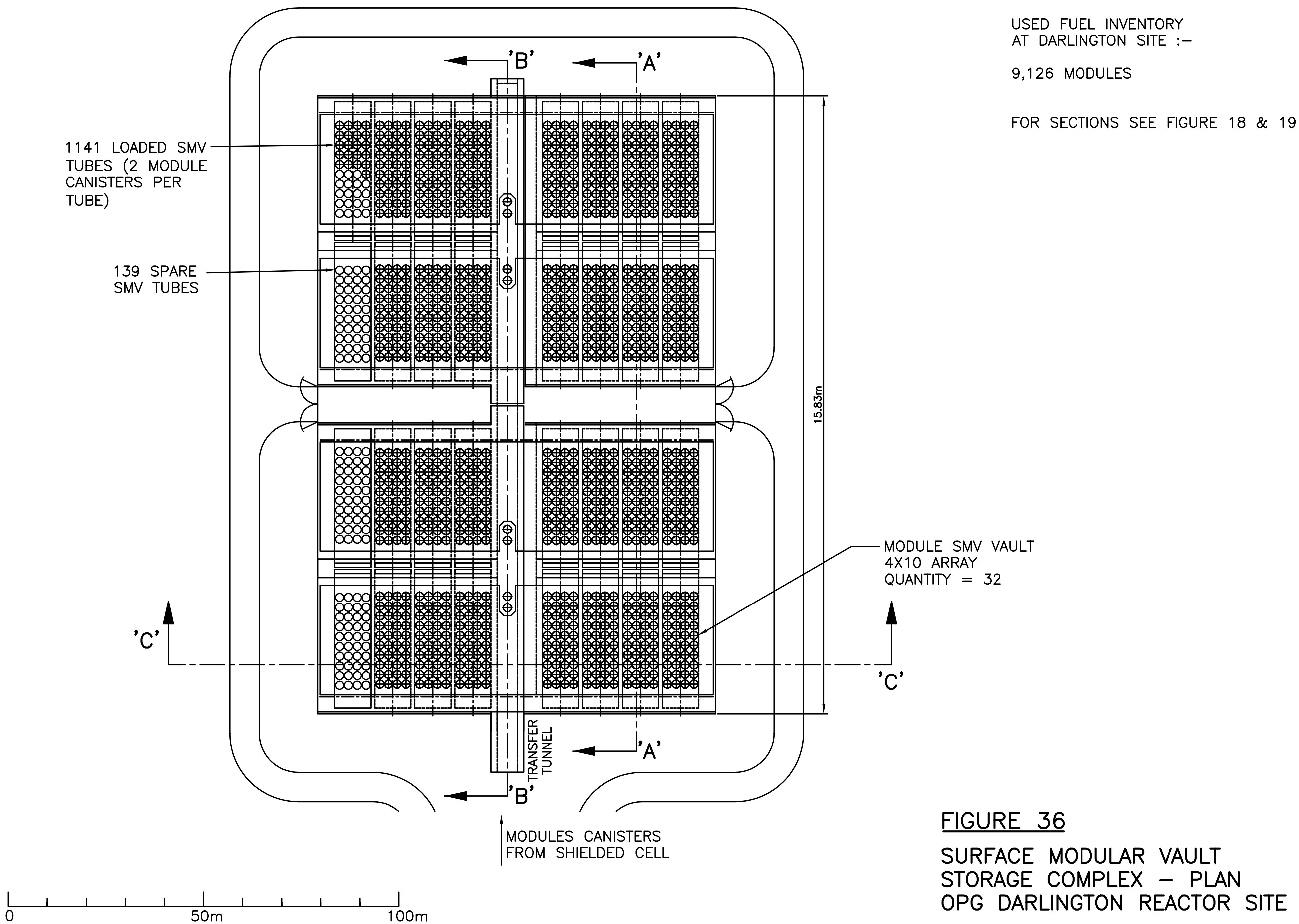
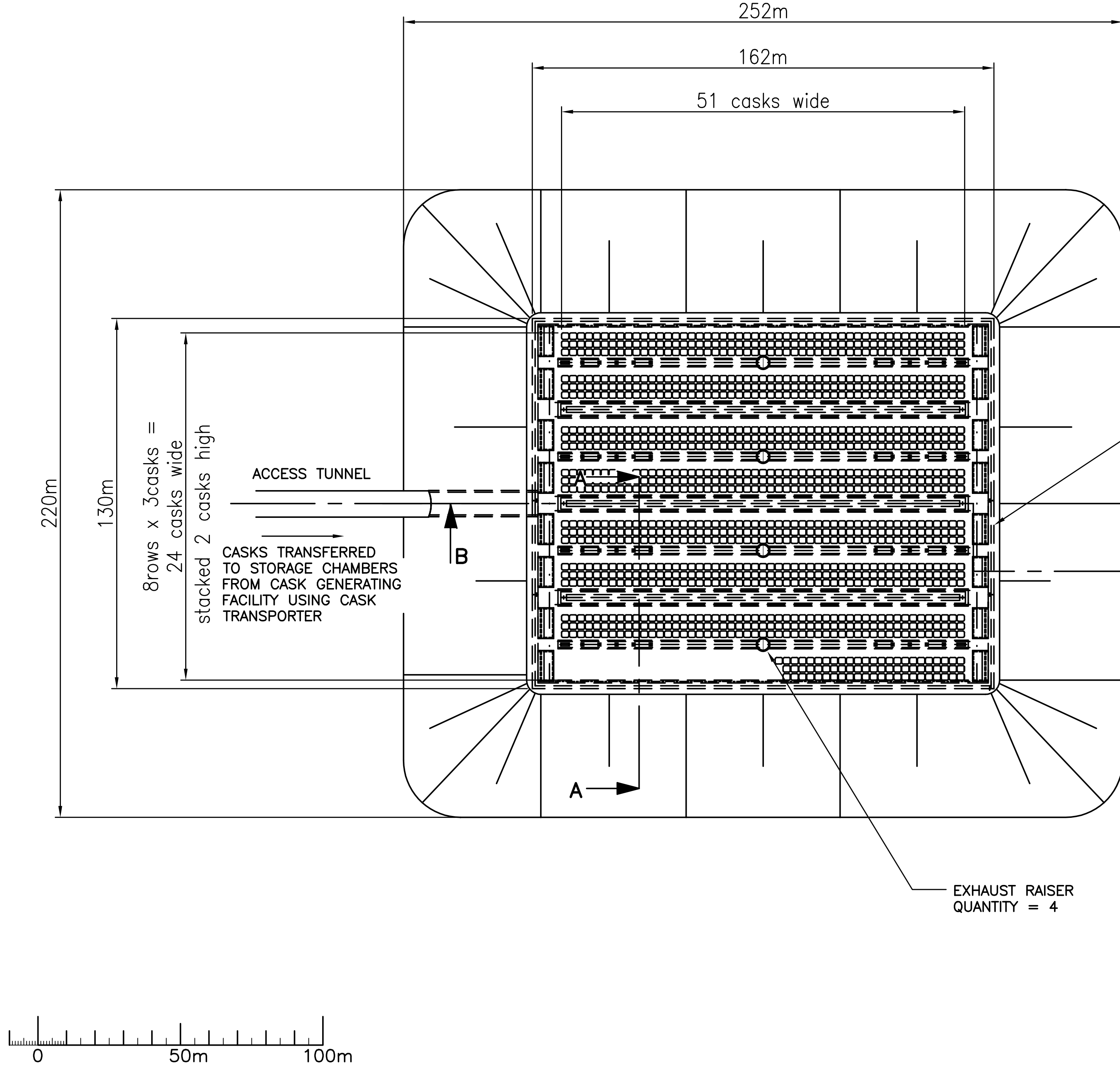


FIGURE 36

SURFACE MODULAR VAULT STORAGE COMPLEX – PLAN
OPG DARLINGTON REACTOR SITE



USED FUEL INVENTORY
AT DARLINGTON REACTOR
SITE :–

2,282 MODULE CASKS

STORAGE SPACE AVAILABLE
FOR 2,448 CASKS
166 SPARE SPACES

FOR SECTIONS SEE FIG 25

FIGURE 37
CASKS IN A SHALLOW TRENCH
STORAGE CHAMBERS – PLAN
OPG DARLINGTON REACTOR SITE