PROTOTYPE SAFETY ANALYSIS REPORT – CONSIDERATIONS IN THE DESIGN OF BELOW-GROUND VAULTS

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ABSTRACT

In DOE's Prototype License Application Project, the preliminary design of a below-ground vault (BGV) for low-level radioactive waste (LLW) disposal was prepared. Based on the preliminary design, a Safety Analysis Report (SAR) was prepared. A major subject addressed by the SAR was the design of the disposal facility, which is addressed in this paper. The BGV disposal facility is designed so that there were at least two principal design features which contributed to the performance of the 11 required functions. All waste disposal units exceed the NRC structural design requirements because of the greater attention paid to watertightness of the structures.

The BGV LLW disposal facility is designed to accomplish all the performance objectives of 10 CFR 61, Subpart C and to perform the 11 functional requirements of 10 CFR 61.12(b).

The principal design features provided to accomplish these functions include Class A vaults, Class B/C vaults, disposal unit cover systems, the surface water drainage system, and the percolating water drainage system.

GENERAL

The disposal facility is assumed to be located at a site whose characteristics satisfy the requirements of 10 CFR 61.50. The disposal facility is sized to dispose all LLW delivered to the site over its thirty-year operational life, with a total disposal capacity of 7,050,000 ft3 (199,600 m3). Only commercial low-level radioactive waste for which states are responsible for providing disposal capacity is intended to be accepted at the facility. It is assumed that no mixed waste or waste classified as greater-than-Class C would be accepted(1).

The general layout of the disposal facility is shown in Fig. 1. There are four major areas within the site boundaries; administrative area, buffer zone, general support area, and the disposal area.

PRINCIPAL DESIGN FEATURES

The principal design features provided to perform the required functions are the Class A vaults, Class B/C vaults, disposal unit cover system, the surface water drainage system, and the percolating water drainage system. The contributions of these principal design features to the performance of the required functions listed in 10 CFR 61 are summarized in Table I. In all cases except the buffer zone, each of the 11 required functions is performed by more than one principal design feature. The Receiving and Storage Building and the buffer zone are not discussed in this paper.

Class A Disposal Units

There are three Class A disposal units. Each such disposal unit consists of a single broad excavation, in which are constructed ten Class A vaults. Each vault is comprised of five structurally independent groups of nine disposal cells, making 45 disposal cells per vault.

The construction sequences and waste disposal are depicted in Fig. 2. Spaces between adjacent vaults are backfilled prior to waste placement to provide working surfaces and limit worker exposures.

The major steps in the construction and disposal sequence of a single vault are:

Extend excavation as necessary for current construction.

- Construct percolating water drainage system.
- Construct mat foundation.
- Construct walls.
- Delay for concrete curing.
- Backfill space between current and previous vault.
- Delay while previous vault is filled with waste.
- Backfill space between current and subsequent vault.
- Fill with waste and backfill current vault.
- Construct roof.
- Place interim cover system.
- Monitor structural stability.
- Place final cover system.

The design of all structural members satisfies conditions specified in ACI 224R-80 (2), ACI 318-83 (3), and ACI 350-83 (4) and accounts for all loading conditions required, including abnormal events. Allowances for degradation of concrete and the corrosion of steel were made to assure that Class A vaults would have the intended life of not less than 100 years.

The vaults may be more conservatively designed than required by NUREG-1200 (5) and NUREG/CR-5041 (6) due to more extensive consideration of the need for watertightness and long-term durability than that suggested by these NRC documents.

All structural members of the Class A vault are of steel-reinforced concrete in which Portland Type II cement is used. Each cell is provided with two drains which

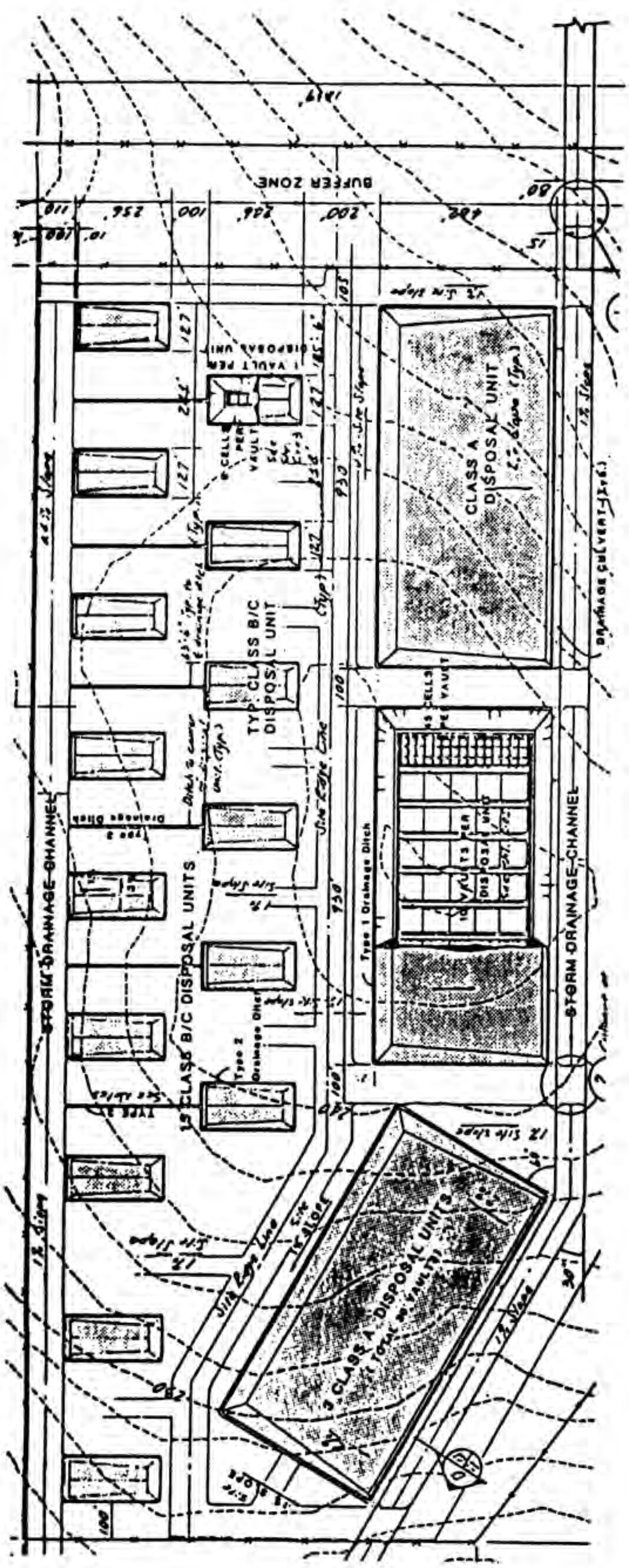

Fig. 1. Disposal Site Layout.

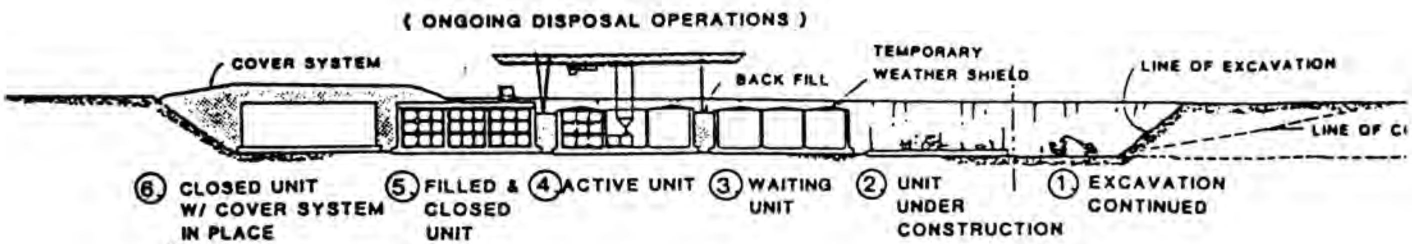

Fig. 2. Construction Sequence for Class A Disposal Units.

TABLE I

Required Functions Performed by Principal Design Features

Required Function	Class A Vaults	Class B/C Vaults	Disposal Unit Cover System	Surface Water Drainage System	Percolating Water Drainage System	Receiving and Storage Building	Buffer Zone
Water Infiltration		•	•	•			
Disposal Unit cover Integrity		•	•				
Structural Stability		•	•				
Contact with Standing Water		•	•	•	•	•	
Site Drainage			•	•	•		
Site Closure and Stabilization		•	•	•			
LongTerm Maintenance		•	•	•	•		
Inadvertent Intruder Barrier		•	•				
Occupational Exposure		•	•	•			
Site Monitoring		•	•		•		•
Buffer Zone							•

function to allow any water which may enter the cell to escape from the cell with little resistance. The primary drain is the floor drain and the secondary drain is made up of perforations at the bases of cell walls.

Each group of nine filled and backfilled disposal cells is provided with a steel-reinforced concrete roof. The roofs are sloped (1 percent) away from the vault center line toward the side walls. Water stops, waterproofing materials, and moisture barriers are provided at all construction joints and on all exterior faces (except the mat foundation), as appropriate, to limit the passage of water into the disposal cells.

The vaults are provided with an interim earthen cover system within two years after the vault has been filled with waste. Once the structural stability and adequate environmental performance of each vault have been demonstrated by surveillance for at least five years, the top portion of the interim cover system is removed and the final cover system is placed.

Class B/C Disposal Units

As shown in Fig. 1, there are 15 Class B/C disposal units. Each such disposal unit contains one Class B/C vault. Each vault is comprised of two structurally independent groups of three disposal cells, making six disposal cells per vault.

The key steps in the construction and disposal sequence for Class B/C disposal units are similar to those for Class A disposal units except that there is no need to delay while the previous vault is filled, and the backfill outside the vault walls has no relationship to activities associated with adjacent vaults.

The design of all structural members satisfies conditions specified in ACI 224R-80, ACI-349 (7) (as modified in NUREG/CR-5041), and ACI 350-83, and accounts for all loading conditions required. Allowances for concrete degradation and the steel corrosion were made to assure that Class B/C vaults would have the intended life of 500 years.

As with class A disposal units, the vault design may be more conservatively designed than required by NUREG-1200 and NUREG/CR-5041 due to more extensive consideration of the need for watertightness and long-term durability than the guidance provided by the NRC.

All structural members of the Class B/C vault are of steel-reinforced concrete, where Portland Type V cement is used. Each cell is provided with two types of drains as with Class A disposal units.

Once waste containers have been placed in a cell, and before the cell is ready to be closed, the top of the cell is covered with concrete shielding blocks and the temporary weather shield during inactive periods. The weather shield and blocks are removed as necessary to permit disposal of additional waste containers.

Each group of three filled and backfilled disposal cells is provided with a steel-reinforced concrete roof. The roofs are sloped (1 percent) away from the vault center line toward the side walls to promote effective drainage of percolating water. Water stops, waterproofing materials, and moisture barriers are provided at all construction joints and on all exterior faces, as appropriate, to limit the passage of water into the disposal cells.

The interim earthen cover system and the final cover system are constructed as described above for Class A disposal units.

Disposal Unit Cover Systems

As soon as possible, but within two years after the Class A and one year after the Class B/C vaults have been closed by the construction of the vault roofs, the earthen interim cover system is placed over the vault. After structural stability and acceptable environmental performance have been demonstrated through monitoring and surveillance, the top portion of the interim cover system is removed, and the final cover system placed. The maximum permeability of the cover system at the time of installation is 1×10^{-6} cm/sec for Class A vaults and 1×10^{-7} cm/sec for Class B/C vaults.

Infiltration through the cover system was estimated using the HELP model(8), while stability of the cover system was evaluated using the Universal Soil Loss Equation(9), the gully erosion model(10), and the Wind Erosion Equation(11).

Surface Water Drainage System

The surface water drainage system is provided to preclude runon of water which originates in land areas outside the disposal site, to conduct precipitation which falls on the disposal site away from disposal units, to limit the amount of precipitation which can infiltrate into the disposal units, and to limit the potential for erosion caused as the water drains from the site. The four major components of the surface water drainage system are three types of ditches and storm drainage collection channels.

Because of the physical location of the site topographically, there is no need to provide the site with berms to preclude runon. There are minimal upgradient drainage areas which have the potential to shed water that might run onto the site.

Ditches are provided around or adjacent to disposal units where runoff water is expected to be generated. Ditches of greater capacity are used to collect runoff water from ditches which surround the disposal units. The essential differences between the ditches are their widths and depths.

Where ditches are provided adjacent to the disposal units, they are constructed to receive discharge from the disposal unit cover systems, without the potential for water in the ditches to move into the cover systems. All ditches are sized to conduct all runoff water resulting from the 100-year, 6-hour rainfall event without overflowing. In the event a more intense rainfall event occurs, runoff may be greater, and water may overflow the bounds of these drainage ditches. Excess runoff will continue to drain away from the disposal units because of the natural slopes at the disposal site. The site slope is 1 percent generally in all directions away from the center ridge line of the disposal facility. Furthermore, disposal units are placed onsite in such a way that there is little, if any, potential for water overflowing ditches serving an uphill disposal unit to inundate downhill disposal units. Rather, such overflow will drain away from all disposal units and discharge to the storm drainage collection channels.

All components of the surface water drainage system were sized using the conditions described above and the Manning Formula for open channel flow(12). Values for the Manning roughness coefficient were determined by the materials assumed to line drainage ditches and channels.

Percolating Water Drainage System

Even though the surface water drainage system and disposal unit cover system are properly designed and function as intended, there may nevertheless be water which percolates into the disposal cells. Infiltration through the cover system reaching the upper vault roof surface could amount to 10 in. (25 cm) and 1.6 in. (4 cm) of water per year for Class A and Class B/C vaults respectively. This water could over time percolate through the concrete roof and then enter the vault. Each disposal unit is, therefore, provided with a percolating water drainage system. The principal components of the percolating water drainage system are sand layers, floor drains, perforations in all cell walls, closed drainage collection, French drains, sumps, and vault subgrade drainage layers.

Each vault (constructed of relatively impermeable concrete walls and roof) is provided with moisture barriers (coal tar and impermeable membranes) to limit the amount of water that may percolate into the disposal cells. Immediately on top of the moisture barriers is a layer of fine gravel which is considered part of the cover system. However, this fine gravel layer performs a function in the percolating water drainage system, by providing a path for percolating water to migrate preferentially away from the disposal cells toward other components of the percolating water collection system.

A column of sand is provided adjacent to the exterior wall of each vault. Water released from the fine gravel layer on top of the roof is received by this vertical column and conducted to the French drains.

Each disposal cell is provided with floor drains which allow water collecting on the floor of the disposal cell to move away from the waste. Water will flow under influence of gravity to the floor drains. The floor drains discharge to a confined collection system and associated sump. During operations these sumps can be monitored for water and pumped if required. Although the water may not be actively removed, either during operations or after closure, there is little potential that water will remain in contact with waste since overflow from the sumps will enter the French drains and the vault subgrade drainage layer and will continue to percolate through the undisturbed natural soils below.

Percolation rates were estimated using Darcy's law(13), environmental conditions, and design information. Drainage components were sized using the Manning Formula for open channel flow.

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