ADVANCED DISPOSAL TECHNOLOGIES FOR NEW LOW-LEVEL WASTE DISPOSAL COMPACT SITES

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ABSTRACT

A number of low-level radioactive waste disposal sites will start operation in the 1990's. Typically, these sites will employ advanced disposal technologies. These technologies will increase confidence in the safe disposal of waste for hundreds of years following site closure. The disposal procedures will utilize engineered barrier technology in addition to the protection offered by the waste form and the disposal site itself. This paper presents an overview of the disposal technology being used by Chem-Nuclear Systems, Inc. (CNSI) in the design and development of three of the largest U.S. commercial LLW sites. Specific discussion is included on design philosophy, materials of constructor, and special safety features. The CNSI approach is representative of the advanced LLW disposal technology that will be practiced in the U.S. over the next 20-50 years.

INTRODUCTION

The federal government and the individual states designated as hosts for the disposal of Low-Level Radioactive Waste (LLRW) have made the requirements for disposal more stringent than in the past. As a result, advanced technologies employing multiple engineered barriers are being developed to supplant the existing practice of shallow land burial. In these advanced facilities, typically the first engineered barrier consists of concrete containers. These containers are used to dispose of the waste in above ground, closed concrete structures (barrier number 2). The concrete structure is then covered with an engineered earthen cap (barrier number 3). The purpose of the engineered barriers is to provide maximum assurance that the waste constituents are passively isolated from the environment and possible intruders for as much as 300 to 500 years following waste disposal.

This paper discusses aspects of the technologies Chem-Nuclear Systems, Inc. (CNSI) proposes to use for three of the larger LLW compact sites. The proposed designs, while not identical, do have common features. These are representative of LLW disposal technology to be used in the U.S. for the foreseeable future. Detailed design of these facilities is now in progress.

Our current projection is that these sites will become operational in 1993 to 96. The focus of this paper is to highlight the design of these features and to show how they lead to higher confidence levels for safe disposal.

ENGINEERED BARRIER TECHNOLOGY

The key waste disposal goal is to isolate the waste from contact with the environment. In particular, contact with ground or surface water must be precluded. An additional purpose is to prevent inadvertent intrusion into the waste until a period of time has elapsed when the waste is rendered essentially harmless by radioactive decay. The current practice is for all waste to be received in a solid form prior to disposal. Hence, concern with gaseous or liquid release of radioactivity from disposed waste is lessened. Existing waste handling and monitoring procedures adequately ensure safe disposal during the operational period. The function of the new engineered barriers is to enhance disposal operations and also provide a passive means of safe disposal following site closure.

Table I shows the specific barriers to waste isolation which are employed in advanced LLW disposal. The first two barriers are part of current practice and will also be employed at future sites. Specifically:

- Site Characteristics - The disposal site geology and hydrology, in its natural form, must prevent environmental contact with the waste.
- Waste Form - The waste generators must prepare the waste in a solid form suitable for secure disposal.

TABLE I
LLW Disposal Site-Waste Isolation Barriers

- Site Characteristics
- Waste Form
- Engineered Barriers
  - Earth Cap
  - Concrete Module
  - Concrete Overpack

The engineered barriers are illustrated in Figs. 1 to 3.

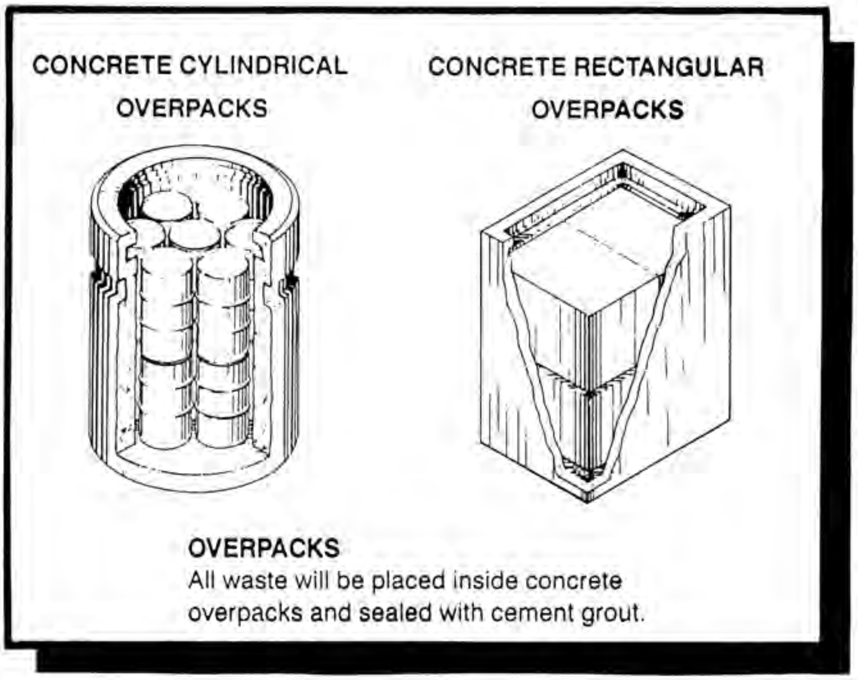

Fig. 1. Overpacks.

These functions are as follows:

- Concrete Overpacks (Fig. 1) - The waste containers are placed within thick walled, reinforced concrete containers. A fluid concrete grout is used to encapsulate the waste container within the overpack. Each overpack contains 100-400 cubic feet of waste. Two types of overpacks are used which are cylindrical and rectangular in shape. The intent is to maximize the waste packaging efficiency within the modules.
- Concrete Modules (Fig. 2) - Individual concrete overpacks are closely packed within thick walled, reinforced concrete modules. Each module is closed after being fully loaded with overpacks, and typically contains 50,000 - 100,000 cubic feet of waste. The modules are isolated from ambient conditions during the loading operations and sealed immediately after loading.
- Earth Cap (Fig. 3) - Typically 40-50 modules (in two rows) are grouped and covered with a multi-layered engineered earth cap. The earth cap soil layers passively divert surface water from the concrete modules. The earth cap is composed primarily of natural materials (clay, sand, vegative soil) obtained from the disposal site or nearby. The modules are completely covered with the earth cap with a cap height extending above the module roof of 7 to 10 feet.

The primary function of the earth cap and concrete module is the diversion of surface and ground water from the waste. The concrete overpacks serve as a barrier in the unlikely event that any water penetrates the waste module. The concrete overpacks, due to their smaller size, greatly facilitate individual inspection and retrievability (if that is ever needed).

The requirements for the engineered barriers in providing long term, passive, waste isolation is shown in Table II. Long term experience with the materials comprising the individual barriers does not incontestably prove that any single barrier can provide the requisite isolation function for 300-500 years. For example, concrete as an engineered construction material has a history of less than 200 years. However, as the logic chain shows in Table II, waste isolation for the required period can be readily proven when the system is taken as a whole --- just considering the engineered barriers. Current estimates, using actual waste disposal records, show that the total curie content of the disposed waste is only about 0.001-0.002 of the initial inventory after 300 years (1). Longer lived isotopes (generally found in Types B, C waste) which comprise most of the remaining

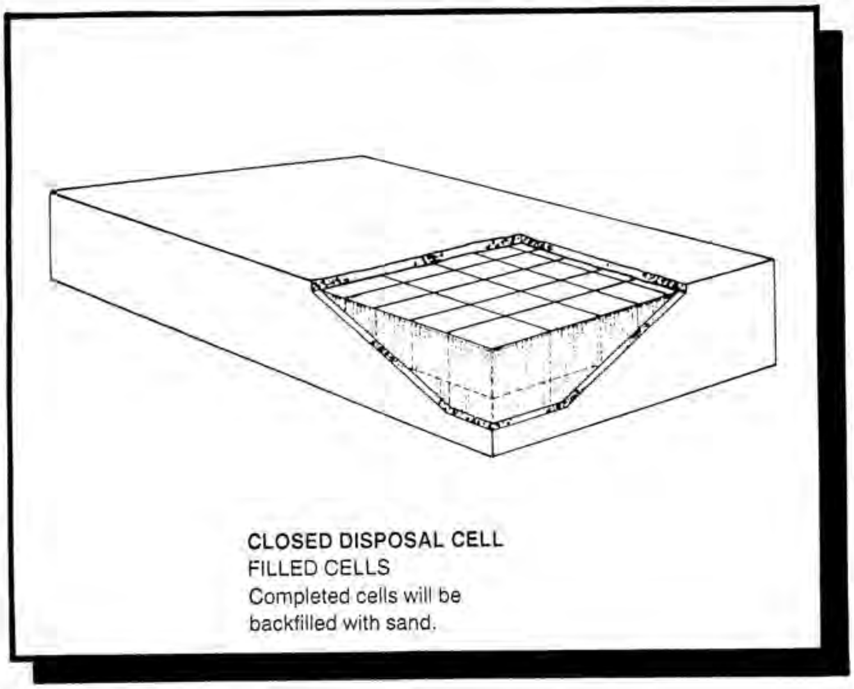

Fig. 2. Closed Disposal Cell.

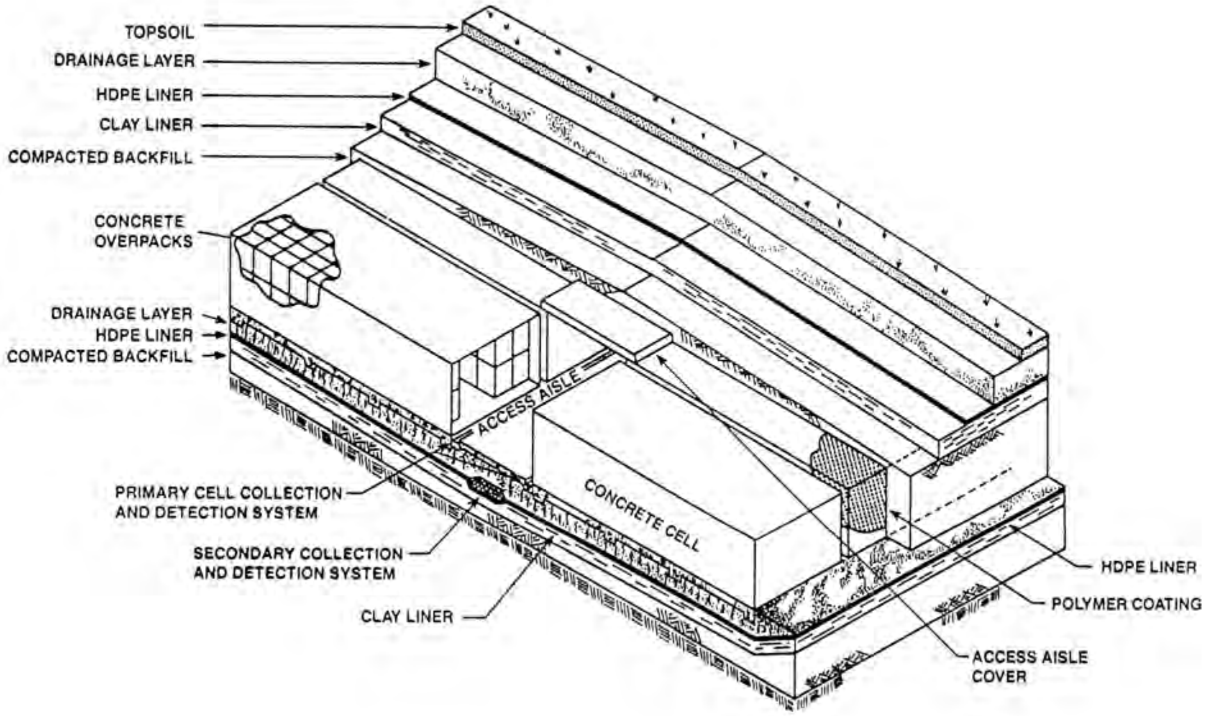

Fig. 3.Disposal Vault Cut-Away.

TABLE II
Performance Appraisal Methodology Conservative Licensing Basis

	OPERATION — 50 yrs.; ACTIVE MAINTENANCE/ CLOSURE — 10 yrs.	ACTIVE INSTITUTIONAL CONTROL — 100 yrs.	PASSIVE INSTITUTIONAL CONTROL — 200 yrs.	INTRUDER CONTROL PERIOD — 200 yrs (WATER INFILTRATION ONLY ABOVE GRADE DESIGN)
INTERVALS	50 yrs. / 10 yrs.	100 yrs.	200 yrs.	200 yrs.
SCHEDULE / CUMULATIVE	0 yrs. – 60 yrs.	60 yrs. – 160 yrs.	160 yrs. – 360 yrs.	360 yrs. – 560 yrs
COVER SYSTEM	LIMITED & CONTROLLED WATER INFLT. (MONITORED)	WATER INFILTRATION ACTIVE STATE MAIN (MONITORED)	NO CREDIT FOR WATER CONTROL	NO CREDIT FOR WATER CONTROL
VAULT	VAULT REMAINS DRY (MONITORED)	NO SIGNIFICANT WATER PENETRATION ACTIVE STATE MAINT. (MONITORED)	POTENTIAL FOR SIGNIFICANT WATER PENETRATION	CREDIT AS INTRUSION BARRIER ONLY
(OVERPACK) RECTANGULAR CLASS A WASTE	NO WATER PENETRATION	NO WATER PENETRATION	POTENTIAL FOR WATER PENETRATION/LEACHING	CREDIT AS INTRUSION BARRIER ONLY POTENTIAL FOR VAULT RELEASE
(OVERPACK) W/LINER CYLINDRICAL CLASS B & C	NO WATER PENETRATION	NO WATER PENETRATION	NEGLIGIBLE POTENTIAL FOR WATER PENETRATION/LEACHING	CREDIT AS INTRUSION BARRIER ONLY POTENTIAL FOR VAULT RELEASE
CONCLUSION	NO VAULT RELEASE	NO VAULT RELEASE	POTENTIAL FOR LIMITED VAULT RELEASE CLASS A ONLY RADIONUCLIDE TRANSPORT ANALYSIS REQUIRED	POTENTIAL FOR LIMITED VAULT RELEASE CLASS A, B, C, & MIXED ONLY RADIONUCLIDE TRANSPORT ANALYSIS REQUIRED

TABLE III
Evolution of LLW Disposal

	PAST	PRESENT	FUTURE
TECHNOLOGY	SIMPLE LANDFILL	ADVANCED LANDFILL	MULTIPLE ENGINEERED BARRIER
POSITION	BELOW GROUND	BELOW GROUND	ABOVE GROUND
WASTE RECEIPT RATE	1 - 2 MILLION CU-FT/YEAR	1 - 2 MILLION CU-FT/YEAR	50 - 500 THOUSAND CU-FT/YEAR
HANDLING	"KICK & ROLL" -- OPEN AIR	CRANE -- OPEN AIR	CRANE -- ENCLOSED
RECORD KEEPING	SIMPLE	DETAILED / COMPUTER	ON-LINE COMPUTER
CONTAINERS	WOOD BOXES / 55 G DURMS	METAL / HIC'S	METAL / HIC'S ENCAPSULATE

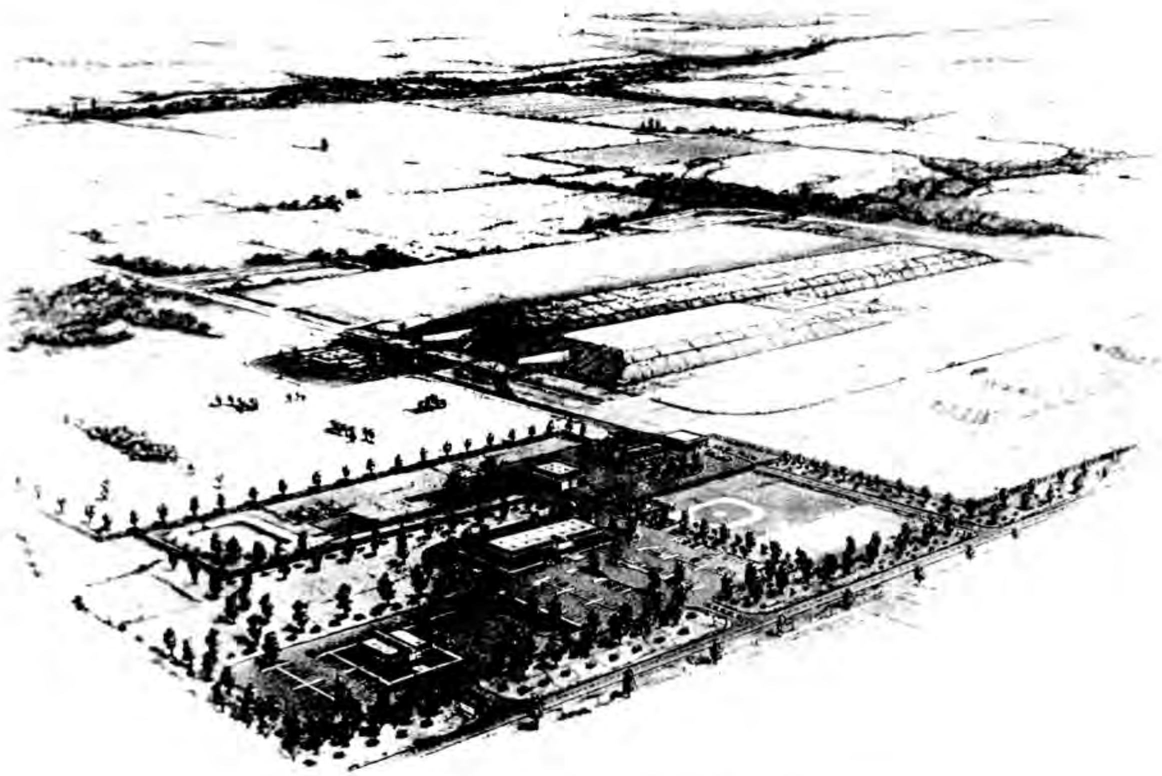

Fig. 4.Design of a typical advanced disposal site.

inventory, are placed in special, thicker walled - polyethylene lined, concrete overpacks.

OVERVIEW OF ADVANCED LLW DISPOSAL SITE

A conceptual design of typical advanced disposal site is shown in Fig. 4. The site can be divided into three general areas:

- Disposal Area - This restricted area contains the waste disposal modules and the waste handling building.
- Administrative Area - This area contains the administrative building, laboratories, maintenance buildings, and the waste receipt building, visitor center, site utilities, etc.
- Buffer Zone/Borrow Area - This area segregates the disposal area from the site boundary. It also is used for storage of borrow materials used for the formation of the earth cap. Retention ponds are situated for temporary storage of surface water diverted from the disposal area.

These generic regions are common to all such sites and do not specifically identify advanced features. Table III presents a comparison of the evolution of the design of LLW disposal sites over the last 25-30 years and specifically highlights the technology advancements. Of key interest is the current requirements for engineered barriers which makes possible above-ground disposal (well above the natural water table), and the smaller annual quantities of disposal waste. The result of increased confidence in long term waste isolation and a development of a number of disposal compact sites is increased cost. Typical disposal costs at present average $40-50 per cubic foot. Disposal costs in the 90's (constant dollars) for the new sites are projected at $100-500 per cubic foot (2). The actual cost will correlate closely with the annual volume of disposal waste. Sites with small volumes of disposal waste will have higher unit costs due to the fixed cost associated with the large capital investment required to develop a new site.

MATERIALS OF CONSTRUCTION

The effectiveness of the engineered barriers is primarily dependent upon the long term reliability of the materials of construction, quality construction practices, and the incorporation of these materials into an effective design. As noted, the design makes considerable use of natural and locally available materials. The primary construction material is reinforced concrete. This material has considerable experience in the U.S. and worldwide. It provides considerable strength and resistance to environmental factors at reasonable cost. It can be constructed using recognized standards for quality control and testing. This permits the design to be constructed in a consistent manner and in full accord with the intent of the approved design. Key elements of the reinforced concrete material must be specified:

- CONCRETE FORMULATION - Current research on concrete (3,4) show the importance of low water-cement mixtures in ensuring both strength and longevity. Pozzolanic cementitious materials such as flyash are blended with portland cement resulting in both increased strength and increased resistance to chemicals found in surrounding soils, they also provide resistance to the erosion forces of flowing water and freeze-thaw cycles.
- REINFORCEMENT - The steel reinforcement bar will not experience harmful corrosion when fully encapsulated in an alkaline cement mixture (5). As a precautionary measure, the reinforcement will be epoxy coated to provide increased corrosion protection.

The design also makes judicious use of artificial materials (primarily plastic films and coatings) where they will have maximum effectiveness against the effects of possible hostile chemicals and also provide erosion protection. These materials primary polyethylene, are also commonly used in hazardous waste disposal sites. Plastics typically contain additives for UV protection and are buried or otherwise shielded from sunlight. Plastic materials are employed for the following applications.

- High Density Polyethylene (HDPE) Liner - The drainage and clay layers of the earth cap are separated by a 2-3 mm (0.080-0.120 inch) liner. This liner is applied in wide sheets and welded at the seams to effect an almost impermeable boundary through the earth cap.
- Module Coating - The external concrete surfaces and inner floor of the module is coated with a plastic coating (typically polyurethane) to provide further protection against water erosion.
- Overpack HDPE Liner - The concrete overpacks used for class B, C waste incorporate a 10-12 mm internal liner between the poured concrete and grout layers (refer to Fig. 1).

The natural materials selected for construction have engineering properties which are important to their function. These materials are mostly used in the earth cap (see Fig. 3) which covers the disposal modules and the foundation upon which the module rests. Properties of particular importance are.

- Permeability - The vegative layer and draining layer must have relatively high permeability (10^0 - 10^{-2} cm/sec range) to permit lateral movement of surface water. The clay layer must have a low permeability

(10^{-7} cm/sec or less) to minimize vertical movement of surface water.

- Chemical Constituents - The soil directly abutting the concrete modules will have low chloride and sulfate ion concentrations to minimize chemical interaction with concrete.

As with all nuclear projects, LLW disposal components will be constructed in accordance with a qualified quality assurance program. The preceding discussion highlights the importance of proper specification of materials and quality control during construction in ensuring that design objectives are met.

SPECIAL DESIGN FEATURES

There are a number of other design features which enhance the operation of new LLW disposal sites. The design and function of these features are as follows:

- Waste Handling Systems - The waste containers are moved from the shipping vehicle, inspected, placed within concrete overpacks, and positioned within the concrete modules. All operations are performed in a closed environment under a negative pressure (as noted in Table II). As a result, there is no direct means of surface water entering the waste modules during and following loading operations or of any possible radioactive contamination exiting from the handling spaces. The module air is filtered, and monitored. Some sites employ a waste processing building (see Fig. 1) while others employ a movable building which directly covers the waste module. The loaded concrete overpacks are handled with forklift trucks and overhead gantry cranes. The waste containers are encapsulated by grouting the overpack. This occurs within the handling building.

- Test Cells - Each site will have a representative disposal module designated as a test cell. The cell will have special test instrumentation and inspection areas to monitor concrete performance, waste stability and other technical parameters of interest. The test cell will be loaded during the initial operational period. It will be available for frequent inspection during the entire operational and closure period.

  Monitoring of cell performance during this period will provide a base line of actual performance. Special areas of concern can be tested to ensure that comparable considerations can be implemented in future operations. In the event that a system design correction is needed, the test cell will serve as precursor of future system performance.

- Waste Monitoring Systems - As is current practice, the entire disposal site will have site radiological monitoring systems. These will monitor for radioactivity in the air and soil at selected locations throughout the site. In addition, monitoring the actual performance of the waste modules will occur on a continuous basis during the operational closure and active maintenance period. Each module will have a gravity drain system (see Fig. 5) which will collect possible liquid infiltration to the module in a local collection tank. The tanks will be interconnected with piping and directed to a larger monitoring/collection tank. The monitoring tank will be utilized for an entire row of modules. Full manned inspection access will be provided to both the local and the larger tanks. All collected fluid will be tested for radioactivity. This system provides a direct means of testing the system of earth cap, waste modules, and overpacks for integrity. Fluid flow is by gravity head and the system is totally passive.

- Site Drainage Systems - These systems serve to divert rainwater from the waste modules. Subsequently, the system collects the diverted water which is then tested and eventually released off-site. The system consists of rain gutters on the module's roofs with concrete culverts. These culverts direct the water to multi-acre retention ponds located in the site buffer zones. The retention pond(s) are lined and have means of sampling for radioactivity and other chemicals. Tested liquids emanating from the waste monitoring systems would also be released to the retention ponds following testing.

- Waste Tracking System - All existing LLW disposal sites have required and maintained extensive records for waste receipt and disposal. The new LLW sites will expand these record systems further to ensure that all required data on the waste is tracked from the time it leaves the generators site to its ultimate emplacement in the waste module. This computerized system will permit real time assessment of the on-site isotopic inventory, including the contents within each waste module. Extensive use will be made of bar code technology to track the waste containers as they are handled and moved on-site. The proposed systems will not only be beneficial for meeting regulatory requirements but will also assist in planning site operational and construction schedules.

CONCLUSION

Each of the LLW site designs will not only meet the federal requirements of 10 CFR 61, but also the unique requirements prescribed by the host state. We believe that this will provide the local population with more than adequate assurance that disposal operations are being conducted in a safe and prudent manner. Not only will most of the site operating force be comprised of local residents, but