

DEACTIVATING THE N REACTOR BASIN AT THE HANFORD SITE

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ABSTRACT

Deactivation of the 105-N Reactor Fuel Storage Basin (N Basin) at the Hanford Site involved disposition of about 5.3 million liters (1.4 mil gal) of radioactive liquid waste, over 280 m³ (10,000 ft³) of radioactive hardware/debris, about 11 m³ (400 ft³) of sediment, and 295 kg (350 lb) of fuel fragments. N Basin was a major component in the deactivation of the N Reactor complex, which proved to be both technically and physically challenging.

Formal deactivation was initiated in May 1995 after the environmental assessment was completed and a finding of no significant impact was issued. Some of the major issues encountered during the deactivation process included (1) maintaining water clarity during cleanout operations; (2) material identification; (3) hazards analysis development; (4) waste characterization, removal, and disposal; (5) Skyshine dose at the Columbia River; (6) efficient waste shipping/disposal concepts; and (7) the management of multiple interrelated activities/issues while operating in a confined area with limited access.

Deactivation was completed on July 23, 1998, one week ahead of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (1) mandated scheduled completion date. The total radiological exposure for the N Reactor deactivation project was 175 person-rem, which was approximately 33% less than the original estimate of 266 person-rem. The fiscal year 1994 (FY94) approved baseline funding for the total N Reactor deactivation project was \$137 million. The actual cost for completion was \$121 million, or 11.7% less than originally estimated.

INTRODUCTION

Issues

The following issues challenged the U.S. Department of Energy (DOE), Richland Operations Office (RL) Restoration Projects Division management and their Bechtel Hanford, Inc. (BHI)-led Environmental Restoration Contractor (ERC) team in developing, optimizing, and executing deactivation of N Basin:

- An inactive, highly contaminated special nuclear materials storage basin located within 182.8 m (200 yd) of the Columbia River shoreline
- A legally binding mandate to complete deactivation by July 31, 1998

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- Waste containing over 1,500 Ci (consisting essentially of strontium, plutonium, iron, cesium, tritium, and cobalt) of potential source term located primarily on the basin floor beneath 7.3 m (24 ft) of water
- Radioactive waste potentially contaminated with other regulated waste (i.e., polychlorinated biphenyls [PCBs], hydrazine, and methanol)
- 350 pounds (about 2,500 Ci) of spent fuel fragments disbursed about the floor of the basin
- Remotely locating, identifying, and characterizing more than 20 years of accumulated highly radioactive materials, tools, and debris in spent fuel basins, experiencing severe water clarity conditions
- Complying with new/changing directives for assessing hazards and preparing safety basis documentation for deactivating a defueled, non-operational nuclear reactor facility
- A basin superstructure not conducive to deactivation/cleanup operations (limited vertical access restricting use of long-handled tools) combined with 1,100 fuel storage cubicles honeycombing the basin floor.

Requirements

Deactivation of the N Basin was identified as part of the prioritization process conducted under the auspices of the Tri-Party Agreement (1) in deliberation between the three regulatory parties: the DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology). The Tri-Party Agreement is a legally binding agreement addressing both near-term and long-term restoration of the entire Hanford Site (encompassing 1,450 km² [560 mi²]).

While N Basin deactivation was mandated by the Tri-Party Agreement (1), the *National Environmental Policy Act* (2) process was also applicable and deactivation could not proceed until an environmental assessment was completed and a finding of no significant impact (FONSI) was issued. The FONSI, covering all N Reactor deactivation efforts, was issued in May 1995. Deactivation was conducted under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* ([CERCLA] 3). In addition, the EPA required a National Emissions Standards for Hazardous Air Pollutants (NESHAP) application, with the agency issuing a letter of approval. Approval was also required from The Washington State Department of Health (DOH) in the form of a Notice of Construction (NOC).

BACKGROUND

History

The N Reactor was the last operational plutonium production reactor at the DOE Hanford Site, located near Richland, Washington (Fig. 1). The reactor was a 4,000-megawatt (thermal), graphite-moderated, pressurized, light-water-cooled, dual-purpose reactor capable of producing special nuclear materials and steam (for electrical power generation). The reactor operated from 1963 until 1987. All remaining irradiated fuel was removed from N Basin in 1989, followed by the issuance of a cease-preservation directive in 1991 for the entire N Reactor complex.

Between 1991 and May 1995, while the planning, funding, and permitting were being completed, the project performed limited routine activities (room cleanout, shielding installation, routine house cleaning, etc.) under categorical exclusions. In July 1994, deactivation at N Area became more focused subsequent to the awarding of the Environmental Remediation Contractor (ERC) scope of work, separating most remediation activities at Hanford (including N deactivation) from the overall site management contract. With the issuance of the FONSI in May 1995 (see above), deactivation at N Basin was ready to proceed. The DOE, EPA, and Ecology agreed to designate the 100-N Area as a pilot project for achieving coordinated cleanup. This was undertaken as an example of "regulatory streamlining" and emphasizes coordinated implementation of RCRA, CERCLA, Expedited Response Actions (ERAs), deactivation, and decontamination and decommissioning (D&D) activities into a single manageable action plan, at the Hanford complex.



Fig. 1. N Reactor Facilities.

General Description (105-N Reactor Building)

This facility housed the reactor, reactor control/safety systems, and the fuel handling operations. The major components are the reactor core, biological shield, control room, control rod drives, emergency shutdown systems, new fuel handling and loading area, spent fuel temporary holding pools (N Basin), spent fuel loadout area, laboratories, offices, and other support facilities.

The N Basin (Fig. 2) accounts for a major portion of the deactivation activities. It consists of several below-grade, unlined reinforced concrete, interconnected pools (north and south fuel storage basins, north and south loadout pits, transfer pit, segregation pit, and discharge pit) containing about 4.2 million liters (1.1 mil gal) of water and a considerable amount of irradiated hardware and debris.

Objectives

The objectives of deactivating the N Basin included the following:

- Eliminating/minimizing near-term threats to the environment
- Identifying, characterizing, stabilizing (when necessary), and managing existing hazards
- Reducing site overhead costs

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- Providing for safe and cost-effective long-term surveillance and maintenance, and minimal personnel dose exposure during future D&D activities.



Fig. 2. 105-N Fuel Basin Storage.

MANAGEMENT CHALLENGES

Several challenges faced during the N Basin cleanup effort had ERC-wide ramifications and involved how business was to be conducted. These challenges included the following.

Authorization Bases for Cleanup Activities

Relevant authorization bases were needed for the cleanup activities. After the cease-preservation order was issued, the operating reactor safety analysis report (SAR) and its corresponding technical specifications were replaced with a safety assessment for cold shutdown along with defueled technical specifications. These documents focused on the safe storage of spent fuel and environmental monitoring and did not address hazards involved with deactivation or cleanup.

RL and BHI considered that the past approach of using a large, conventional, facility-based SAR with a presupposed nuclear classification was not appropriate for short-term, low-hazard, segmented cleanout and deactivation efforts.

Accordingly, an innovative process was developed that is fully compliant with DOE orders, yet efficiently addresses only the relevant issues for specific deactivation work and accurately determines its classification. This approach is tailored to the way cleanup is performed, addressing a set of activities rather than facilities, and includes the following major steps:

- Identify independent cleanup segments and associated segment activities
- Develop a preliminary hazards classification (PHC) based on gross radionuclide inventory in the segment
- If the PHC shows radionuclide quantities that would result in a classification of Nuclear Category 3 or higher, perform an auditable safety analysis and final hazards classification (ASA/FHC) based on specific activities and quantities actually at risk
- Identify necessary worker safety controls and determine the FHC.

The first segment addressed using this process was the N Basin. Total N Basin radionuclide quantities in the PHC were about 80 times the Nuclear Category 3 threshold; therefore, an ASA/FHC was performed involving detailed accident analyses for eight cleanup activities. The realistic ASA results showed that no planned intrusive cleanup activity could credibly result in an unacceptable exposure to an individual. The bounding FHC results showed that no activity or credible set of activities could lead to an accident scenario resulting in an exposure to an individual in excess of 10 rem at 30 m in a 24-hour event period (with no credit taken for safety equipment or operator responses).

Overall, the worst-case set of coincident accidents led to a total impact of about 38% of the Nuclear Category 3 threshold; on this basis, the FHC was radiological.

Because the ASA/FHC could not anticipate every relevant configuration and work sequence to be used during deactivation, consistent use of a Management of Change process (similar to unreviewed safety question) ensured that changes remained bounded by the authorization basis. This process provides a means to assess potential consequences involved with planned deactivation activities in a more realistic manner that more closely addresses the actual maximum quantity of the total inventory being put at risk.

Team Building with Regulators

The principal regulator for the project was Ecology, whose oversight helped ensure compliance with regulations and Tri-Party Agreement commitments. The state's Department of Health also had important involvement via the issuance of an air permit, allowing cleanup operations to proceed. The project expended significant efforts to both establish and maintain effective relationships with all of the regulatory agencies. Key approaches included the following:

- Taking the initiative to make frequent contact – by phone, invitations to meetings, providing status briefings, conducting plant walkdowns, etc.
- Ensuring appropriate technical, regulatory support, and management personnel attend meetings – questions/issues can be responded to and resolved quickly and efficiently
- Providing early notification when issues or incidents arose – minimizing/eliminating surprises
- Allowing unrestrained access to all project team members – improving flow of information, confidence in and respect between individuals, etc.
- Providing adequate information and documentation to support requested decisions – eliminating requests to merely accept things on faith.

This type of approach was also used when interfacing with other site contractor entities with varying degrees of success.

Managing Multiple Interrelated Issues

Expeditious cleanup of N Basin required the accomplishment of several interrelated tasks and issues simultaneously, leading to a fairly complex set of circumstances. Concurrent activities involving workers could include the following, among others:

- Low dose rate hardware removal, cleaning, and packaging
- High dose rate hardware packaging and monolith grouting
- Sediment relocation (vacuuming)
- Crane maintenance or repair
- Water draindown
- Hydrolasing basin hardware.

To ensure that the work was accomplished safely and efficiently, a variety of measures were employed that are consistent with Integrated Safety Management System concepts:

- **Project Team Approach:** A dedicated team was assigned to the project, including the project manager, field supervision, engineering, and radiological control personnel. This included the DOE project managers co-locating with the project team at the facility.
- **Integrated Schedule:** An integrated, jobhour-loaded schedule was developed showing all work activities, sequencing of activities, and any restraints among them. Special issues, as they arose, were managed via a punchlist and/or an ad hoc schedule or "fragnet."
- **Plan of the Day Meeting:** At the beginning of each shift, the work crew and supervisors were briefed on the planned work and required coordination. Additionally, the department managers reviewed the integrated schedule and/or punchlists at the beginning of each day.
- **Pre-Job Briefing:** Before execution of any new work package, a detailed pre-job briefing was held to review the task, safety limits, other activities that may be impacted, etc. Only those employees who had been briefed were allowed to work on the tasks covered by the work package.
- **Worker Feedback/Process Improvement:** Throughout the task development/design phase, the functional organizations (including craft personnel) were involved in planning, reviews, and walkdowns to take advantage of worker feedback and multi-discipline input to improve the end product inline with Integrated Safety Management System concepts.
- **Limiting Concurrent Major Activities:** It was found that, due to the limited space in and about the basins, and with the necessary level of attention needed for proper supervision, attempting to execute more than two major tasks at the same time overextended resources and led to a noticeable decline in efficiency.

In addition to field work, there were multiple interrelated issues involving budgeting, schedules, project scope, end-point criteria (completion acceptance criteria), interfaces, and regulatory requirements that involved others outside the BHI project team. Key among these are DOE Project Management and the designated regulator under the Tri-Party Agreement (1), Ecology.

Effective coordination among these and other entities was essential to keep the project on track. Success in this area was achieved by providing immediate and full access to the work processes, maintenance of accurate and up-to-date budget and schedule data available to all, and frequent consultation as issues developed.

On-Site Multi-Disciplined Staff

A full-time, multi-disciplined engineering staff with final technical authority was deployed at the site, as opposed to earlier practices of relying on a central, distant engineering organization. This approach allowed direct, daily

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interface between design engineering, the field, and other personnel. Consequently, engineering designs were better suited for their purposes and engineering was able to respond more rapidly and effectively to emerging issues. In addition, technical specialists were brought in, as needed for specific topics, and functioned as members of the site organization.

Craft Task Instructions

Task instructions have normally been written in text format only, using detailed steps. For complex tasks involving many steps in the process, some of which could be done in parallel while others required sequencing, the text could be hard to follow and confusing to those performing the work. To foster better understanding of the intended work process and ensure that safety measures were recognized/implemented, flowcharts and associated graphics were used and found to be effective communication tools for this type of application.

Flowcharts made it easier to visualize steps that needed to be placed together, as well as sections or scope that were independent of other work in the package; where to go when the procedure was repetitive; tasks that could be performed in parallel; or those steps requiring sequential performance. The instructions were kept as simple as possible, using the skill of the craft to complete the details. From the craft worker standpoint, this allowed more freedom to do the job without deviating from the limits that establish a safe work envelope.

Dose Management

The project's measured worker doses were consistently below projections. In addition to reducing doses, measures were also taken to increase worker efficiency and availability without increasing doses. Some of the actions included the following:

- Use of annular kinetic impactors to selectively collect high-density airborne particles associated with plutonium. This approach appreciably reduced the time needed to conduct airborne concentration measurements to support "downposting" from high airborne conditions, minimizing the requirement for respiratory protection, which decreases productivity.
- Use of MSATM-powered air purifying respirator (PAPR) hoods in lieu of standard tight-fitting respirators. The loose-fitting PAPR hoods were cheaper, allowed increased stay times in the basin area (precluded 2-hour work restriction for tight-fitting respirators), reduced heat stress (allows airflow about the head), and allowed for greater visibility and better communication (voices are clearer/louder when not confined by tight-fitting respirators).
- Designating low-dose rate locations in the basin as appropriate waiting areas.
- Installing a dual-purpose concrete shield cover over the basins (Fig. 3) rather than using localized contact shielding and applying a fixative for airborne control; actual worker doses to install the shield cover were one-third those estimated for the original approach.
- Effectively reducing localized hot spots about the periphery of the basin concrete shield (caused by shine from the basin walls/floor) to acceptable levels with the use of sand bags (easy to handle, quick to install, readily available, inexpensive; in addition, sand is available for potential future use as waste packaging material).

Waste Characterization and Disposal

Determining the constituents of the various wastes removed from the N Basin and the resultant packaging needs and acceptable disposal locations was an ongoing challenge.

In addition to radioactivity, N Basin wastes might also include heavy metals, listed wastes, PCBs, and transuranics. Because disposal options are severely limited and/or very costly depending on the waste constituents and their concentrations, inaccurate labeling is unacceptable, requiring very precise waste characterization.

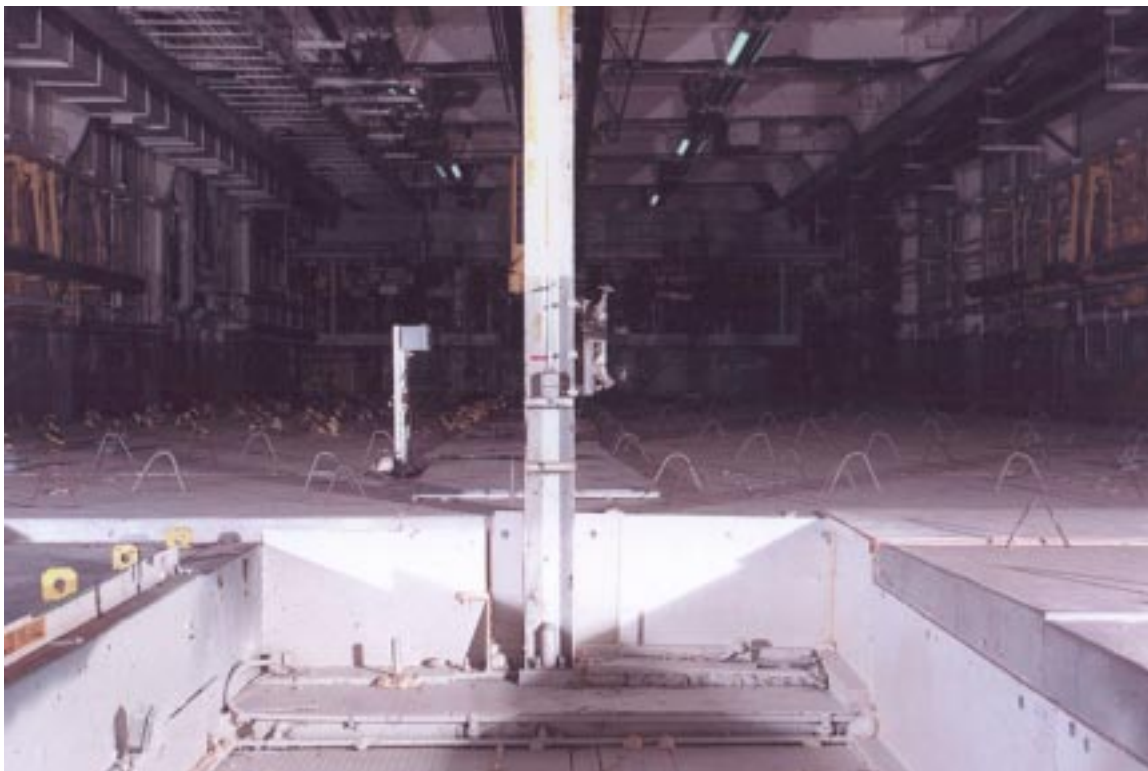


**Fig. 3. Deactivated N Basin.
(~6,000 ft² covered with 1-ft-thick pre-cast concrete panels)**

Project specifications and calculations were prepared to support the characterization of solid waste. These documents addressed waste streams such as low dose rate hardware waste (stainless steel, carbon steel, and aluminum), high exposure rate hardware (HERH) waste (>1 R/hr on contact, primarily irradiated reactor components), and water filters of various types. Calculations were based on computer predictions for the activation of metal hardware, dose-to-curie conversions, analytical results from sampling, and other information, as appropriate. Waste characterizations were formally documented and received independent review prior to issuance. Project-specific conventions for activity averaging and for calculating the concentration of transuranic radionuclides were also prepared.

N Basin cleanup waste is disposed of primarily at the ERC's Environmental Restoration Disposal Facility (ERDF). The ERDF is a large lined facility built mainly to receive large quantities of contaminated soil. An engineering evaluation/cost analysis established that it was cost effective to dispose of N Basin cleanup materials at ERDF as compared to the Hanford Site's Central Waste Complex.

The ERDF can accept radioactive and hazardous wastes, as well as waste contaminated up to 500 ppb PCBs. It cannot accept transuranic waste and will not accept F-listed waste. All non-liquid N Basin waste forms qualified for disposal at ERDF.

N BASIN CLEANUP CHALLENGES

Challenges specific to different cleanup activities are described in the following paragraphs.

Water Clarity

Accurately locating, retrieving, classifying, and packaging waste items 7.3 m (24 ft) underwater requires good water clarity. Table I lists the various challenges to clarity and their accompanying solutions. Different water clarity problems developed at different times as a result of changing cleanup actions. The N Basin water cleanup system used during operation had been out of service for several years and was defunct, which made it necessary to solve the clarity challenges with new equipment. Where prior data may be insufficient or data needs are unclear, the data quality objective method developed by the

EPA is used to establish further data needs. This approach helps ensure that all relevant information is considered, all users of the data are included in the process, all candidate disposition options are covered, and that the decision-makers agree to the data collection/analysis program. Data quality objectives were performed for N Basin sediment and water.

Table I. Water Clarity Problems and Solutions.

Problem	Solution
Algae and bacteria growth	pH control, chlorination, and superchlorination
Suspended sediment	Settling, filtration
Chelated metallic ions	Flocculation
Suspended fine material	Fine filtration (2 micron)

Suspended sediment became a problem as cleanout activities intensified and the layer of sediment on the basin floor became disturbed. Hydrolasing of submerged rusted hardware led to suspension of the chelated metallic ions. Continued operation of circulating pumps and introduction of flyash from grouting operations created fine material that would not settle out or respond to flocculation. Fine filtration with 3M™ filters proved to be very effective compared to other filters of the same nominal size. Final stable control of basin water clarity was achieved using a combination of algae control methods and fine filtration.

Tool Development

The fairly unique conditions demanded that special tools be developed or adapted. For example, accurately and quickly identifying the materials of the many debris items in the basin was necessary. Corrosion and discoloration often make it difficult, especially underwater, to determine composition. Metallic wastes included items made of aluminum, zirconium alloy, carbon steel, and stainless steel.

The primary concern is to ensure that high exposure rate aluminum items are segregated from other HEHR and kept out of the grouted monoliths where they can react with the grout and generate hydrogen. Another need is to identify any potential fuel fragments or pieces, because they require special handling.

The use of an eddy-current tester, held in the proximity of the piece of hardware, was found to be very effective in distinguishing among metals. The hardware's signature on an oscilloscope is unique for each different metal, allowing for very quick and accurate sorting. A conventional eddy-current tester was used, which was modified for an underwater probe. Baseline signatures were established in a clean water tank before the instrument was deployed in the basin.

Another tool development application was the evolution of inexpensive underwater housings that allowed the use of standard security surveillance video cameras (~\$250 each) for viewing basin operations, instead of commercially available underwater video camera systems (\$3,000 to \$8,000 each). The housings were first constructed using aluminum and later refined by using polyvinyl chloride (PVC) fittings to obtain the needed lightweight watertight units. Over the life of the project, the DOE gained about \$95,000 in cost avoidance through this innovation.

This same concept for providing underwater housings was then applied to R07 radiation detection probes, which

previously used commercially available stainless steel housings. The use of off-the-shelf PVC pipefittings not only lowered the cost (estimated \$14,000 cost avoidance), but also provided a more reliable lightweight housing that was easier to manipulate in the deep basin waters. Both the surveillance cameras and R07 probes were key equipment critical to progress/production that were staged on cranes and received rough treatment in a hostile environment. Sometimes the best "hi-tech" solution is a low-tech turn-of-the-century process. This proved to be the case for removing sediment interlaced with significant amounts of small metal debris from the basin floor, including the cubicles. Airlift devices designed in the field to operate within the confinements of the N Basin proved to be the most effective method for removing/separating small debris (mainly consisting of ~5,000 highly irradiated bent metal strips, or "buggy springs", used to separate/position the inner and outer fuel elements). The airlifts were also effective in removing sediment from the floor areas. The airlifts were relatively easy to design/build, and were inexpensive, very reliable, low maintenance and efficient small debris removal/collection apparatus.

Aging Plant Equipment

The cleanup effort had to be accomplished using some of the original 1950's vintage equipment, now some 35 years old and mostly inactive for the previous 8 to 10 years. Reliability problems were encountered with the overhead cranes and 480-V breakers, in particular. Some straightforward steps were taken to cope with these conditions:

- Frequent preventive maintenance was restored.
- Some key components (e.g., breakers) were refurbished.
- Use of certain equipment, such as old water cleanup systems, was avoided in favor of new short-term-use equipment.

When confronted with the necessity to use older and/or equipment that has not been maintained, consideration should be given to locating/stockpiling replacement parts, providing allowances for higher frequency/longer duration repairs, and possibly designing modifications to adapt current components to replace non-available original parts.

Shipping Containers

Efficient packaging of waste for disposal was important in controlling costs and worker exposures, and minimizing packaged waste volumes. Key constraints included container volume, weight, size, dose rate, curie content, transuranic content, waste immobilization, void space avoidance, burial site requirements, and transportation accident survivability. Standard, commercially available containers were used frequently, but on a number of occasions, custom-designed containers were more appropriate. The custom-designed containers are listed in Table II.

Table II. N Basin Special Containers.

Waste Item	Containers
High exposure rate hardware	1.8-m- (6-ft) dia. by 1.8-m- (6-ft) high open-top carbon-steel cylinder containing stacked fuel baskets, grouted underwater in the basin
Large low dose rate hardware	6.1-m (20-ft) open-top Conex™ box, grouted at burial site
Aluminum cubicle guides (very high contamination levels)	Reinforced conventional 1.2-m (4-ft) by 1.2-m (4-ft) by 2.4-m (8-ft) wood box with sand as the void-space filler

The removal of HERH required containers (Fig. 4) that could be filled and grouted while sitting at the bottom of the N Basin (for ALARA), then removed and placed in a shipping cask (for additional shielding during handling and shipping). This was accomplished with 1.8-m- (6-ft) diameter capped pipe with internal-mounted lifting bails (to fit

inside shipping cask) that could be remotely engaged/disengaged under 7.6 m (25 ft) of water. The lifting bails were boxed in to ensure that grout did not flow into the lifting hook engagement region. The grout provided adequate waste containment, alleviating the need for a welded lid.

For large, cumbersome hardware with significant smearable contamination, it was determined to be cost effective to use inexpensive, used top-loading ConexTM boxes modified with hose attachments to allow for grouting at the burial site (required for void fill and structural stability).



Fig. 4. Removal of HERH Containers.

Skyshine Doses at the Columbia River Shoreline

Previous restrictions on access to the Columbia River within the confines of the Hanford Site have been removed, allowing public access to the shoreline adjacent to the N Reactor facility. The total allowable dose to a member of the public at the shoreline is 25 mrem/year. Working with Ecology, it was determined that a reasonable public occupancy time was 888 hours/year for the model person (a person fishing from a boat directly adjacent to the facility). To ensure that the dose contribution from the N Basin would not result in exceeding the total dose allowable at the shoreline, the potential incremental increase from basin deactivation could not exceed 2 mrem over an 888-hour period. Draining the N Basin would increase the shoreline dose rate as the shielding water is removed from the heavily contaminated basin surfaces.

A computer model was developed that predicted the added dose from the N Basin changes at all of the 13 existing receptor sites (corresponding to existing fixed thermoluminescent dosimeter sites) along the shoreline. The model predicted that, unmitigated, the removal of the shielding water would increase the doses well above the allowable limit at several receptor sites.

Shoreline doses were maintained below the allowable limits by the addition of shielding covers over the N Basin (0.3-m-thick concrete panels). The calculated average incremental dose rate increase from the N Basin for the 13 receptor sites is 0.6 mrem over an 888-hour period, well below the 2 mrem allowable.

The aluminum cubicle guides (used to guide fuel canisters into the cubicles) were typically highly corroded and awkward to handle; however, they were small enough to fit into standard plywood burial boxes. However, the void space required filling with sand, substantially increasing the load. The bottom of the box required stiffing to support the additional load when being lifted by a forklift.

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