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105-F Fuel Storage Basin Excavation ALARA II Review

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ACRONYMS

ALARA	as low as reasonably achievable
CWC	Central Waste Complex
DAC	derived airborne concentration
ERDF	Environmental Restoration Disposal Facility
FSB	fuel storage basin
ISOCS	In Situ Object Counting System
ISS	interim safe storage
LARADS	Laser-Assisted Ranging and Data System
RCT	radiological control technician
SNF	spent nuclear fuel
TRU	transuranic

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	0.037	becquerel	becquerel	27	picocuries

1.0 INTRODUCTION

The following as low as reasonably achievable (ALARA) review was performed to demonstrate that the Reactor Interim Safe Storage (ISS) Project has evaluated the radiological considerations in preparation for the Stage II cleanout of the 105-F fuel storage basin (FSB). Overviews of the engineering and administrative controls used to manage personnel exposure, contamination levels, and airborne radioactivity areas are provided. The Stage II scope of demolition work will remove the bottom 0.8 m (30 in.) of basin fill material with the assumption that fuel elements and high-dose-rate items will be found. High-dose-rate items will be defined as non-spent nuclear fuel (SNF) material having a radiation dose equivalent rate greater than 500 mrem/hr at 30 cm (11.8 in.). Based on this assumption, processes will be in place to allow for the safe management and disposal of SNF and high-dose-rate items. Other materials will be excavated and packaged for disposal at the Environmental Restoration Disposal Facility (ERDF) and the Central Waste Complex (CWC), as appropriate.

2.0 DESCRIPTION OF PROJECT

2.1 FUEL STORAGE BASIN AREA

The FSB area, located on the south side of the 105-F Building, served as an underwater collection, storage, and transfer facility for the irradiated fuel elements discharged from the F Reactor. The FSB area consists of the fuel element discharge pickup area, which is located adjacent to the reactor's rear face; the fuel storage area, which is in the basin proper; the fuel transfer area, which includes the fuel transfer pits; and the wash pad area, which was used to decontaminate fuel-handling equipment. The storage basin is approximately 22 m by 25 m by 6.1 m (72 ft by 82 ft by 20 ft) deep. The transfer bay is located west of the FSB and served as a railcar cask loading area for the transfer of fuel from the FSB.

The deactivation of the FSB at the 105-F Building occurred in 1970. Deactivation of the FSB involved pumping the water until 0.6 m (2 ft) of water remained. Debris materials (e.g., fuel buckets, fuel spacers, process tubes, tongs, wooden floor decking, handrails, and monorail pieces) were placed into the basin and the basin was then filled with fine streambed sand. It is also possible that SNF may have remained in the basin at the time of deactivation.

3.0 SCOPE OF WORK

The basin cleanout will be performed in two stages. Stage I excavation (completed in early February 2001) involved removing and characterizing the upper fill material of the basin. The upper fill material was removed to approximately 4.3 m (14 ft) below grade and will be used as backfill material following the completion of Stage II. Fill removed between 4.3 m (14 ft) and 5.3 m (17.5 ft) was processed for disposal at the ERDF in accordance with the site-specific waste management plan. Stage II excavation will remove the remaining 0.8 m (30 in.) of fill material. This area contains debris and possible SNF that remained in the basin during deactivation of the reactor.

3.1 OVERVIEW OF PLANNING FOR STAGE II FUEL STORAGE BASIN CLEANOUT WORK

The following subsections provide an overview of the planning for Stage II FSB cleanout work.

3.1.1 Radiological Mapping of the Fuel Storage Basin

Mapping of the FSB will be performed using the In Situ Object Counting System (ISOCS) and the GammaCam. The GammaCam will be used to generate a radiological map of the high-dose-rate locations within the basin. The ISOCS will then be used to determine if the high-dose-rate locations contain the appropriate mixture of radionuclides that would indicate the possible presence of SNF. A Laser-Assisted Ranging and Data System (LARADS) radiological survey was performed in early February 2001 to locate areas of focus for the ISOCS and GammaCam.

3.1.2 Setup of Spent Nuclear Fuel Processing Station

A fuel processing station will be set up inside the FSB to segregate and process suspect SNF that is located or identified during the radiological mapping of the FSB. The fuel processing station will be placed in a low-radiation area as determined from the radiological mapping step. The SNF processing station will keep worker exposure ALARA during SNF removal and processing procedures. The SNF holding container will be located next to the fuel processing station that will be used to transport the SNF to K Basins.

3.1.3 Excavate Spent Nuclear Fuel and Dispose High-Dose-Rate Items

The radiological mapping will determine locations for potential SNF and high-dose-rate debris. The SNF and high-dose-rate items will be excavated with a remotely operated excavator called the Brokk. The Brokk is equipped with excavation tools that include a bucket, a grapple for grasping and retrieving large and small objects, and a shear for cutting and breaking wood and metal items. The use of the Brokk excavator will reduce personnel exposure by eliminating the need for personnel entries into the below-grade FSB during high-dose-rate material removal activities.

3.1.4 Excavation of the Transfer Pit

The transfer pit was not excavated during Stage I because of the dewatering activities. A heavy equipment excavator will be the primary means of excavation and demolition of the transfer pit structures and will be similar to that used in Stage I. After excavated to 5.3 m (17.5 ft), the transfer pit will be radiologically mapped similarly to the mapping step above, and any identified high-dose-rate items will be removed using the Brokk.

3.1.5 Characterize Sludge/Fill Mixture for Disposal

Before excavation or shipment of the sludge/sediment material to the ERDF can begin, the sludge/sediment characterization must be performed and samples must be analyzed. Sampling of the material and loading the samples into containers will be performed using the Brokk. If it is not possible for the Brokk to perform the sampling, other remote equipment (e.g., an excavator) or long-handled tools will be used. Samples will be sent offsite for analysis.

3.1.6 Dispose of Remaining Materials in the Fuel Storage Basin

After all SNF and high-dose-rate items have been removed, a heavy equipment excavator will be used to remove the remaining sludge/sediment material in the FSB. Sediments that meet the criteria for transuranic (TRU) waste will be segregated and package for disposal at the CWC. All other waste will be packaged for disposal at the ERDF. If unexpected high-dose-rate debris is located during this process, the Brokk will be used to excavate the materials.

3.1.7 Demolish and Backfill Fuel Storage Basin

The FSB concrete structures and 0.6 m (2 ft) of underlying soils below the FSB floor will be demolished, removed, and shipped to the ERDF. Sampling of the underlying soils will be performed in accordance with the *Sampling and Analysis Plan for the 105-Phase IV Fuel Storage Basin* (DOE-RL 2000) to meet the interim closure requirements. Material from Stage I overburden and the FSB side slope will be used to backfill to grade.

3.2 OTHER SEDIMENT REMOVAL METHODS CONSIDERED

Two methods were considered for the removal of sediment/sludge material in the F Reactor FSB. While the engineering decisions focused on Stage I activities, Stage II activities were also evaluated. The primary criterion used in the evaluation and selection of removal methods was the overall protection of human health and the environment.

3.2.1 Guzzler/Vacuum System

A mock up demonstration was performed to determine efficiencies, production rates, and handling characteristics when removing sediments similar to those expected during the excavation of the basin. This mock-up tested the ability of the equipment to remove these materials from depths up to 6.1 m (20 ft). It was determined that it would be difficult to remotely maneuver the vacuum during excavation, to prevent the vacuum hose from becoming kinked and causing blockage, and to control the type material that was excavated. The guzzler/vacuum system alternative was summarized in the *105-F Fuel Storage Basin Stage I Fill Removal Engineering Evaluation* (Griffin 2000).

3.2.2 Heavy Equipment

The use of large heavy equipment is an advantage in that it has the capability to remove large volumes of material quickly without a person coming in direct contact with the material. However, this type of equipment does not have the capability to process/package SNF, excavate between stem walls, and grapple small high-dose-rate items. The heavy equipment alternative was also summarized in the *105-F Fuel Storage Basin Stage I Fill Removal Engineering Evaluation* (Griffin 2000).

4.0 CONTAMINATION LEVELS EXPECTED

High levels of contamination are expected to be encountered during Stage II excavation. Preliminary estimates indicate that contamination levels up to 1.5 mrad/h per cubic centimeter could be encountered with undiluted sludge, and levels of up to 0.2 mrad/h per cubic centimeter could be expected in sediments that have sludge permeated into them. Surface contamination levels on equipment or items removed from the FSB are expected to be in the high-contamination-area range for both alpha and beta/gamma radioactivity. Table 1 summarizes the expected activity concentrations in the sludge.

Table 1. Expected Contamination Levels.[a]

Radionuclide	Activity (pCi/g)
Ni-59	1.57E3
Co-60	4.31E3
Ni-63	1.69E5
Sr-90	3.00E4
Cs-137	3.51E4
Eu-152	2.29E4
Eu-154	3.63E3
U-238	2.83E1
Pu-238	8.21E2
Am-241	3.81E3
Pu-239/240	8.18E3
Pu-241	1.55E4

[a] Derived from BHI-01151, Table 4-3 (BHI 1998a). Based on 3.18E5 kg of sediment/sludge. Decayed to January 2001.

5.0 AIRBORNE RADIOACTIVITY LEVELS EXPECTED

The estimated sediment inventory outlined in Table 1 and the requirements contained in BHI-RC-03, *Radiological Control Procedures,* Procedure 4.2, "Estimating Airborne Radioactivity Levels," show that the average calculated airborne radioactivity levels that could be encountered is 1.3 composite derived airborne concentration (DAC). The composite DAC is a total of the DAC fractions for each isotope listed in Table 1. These values are based on the assumption that the sediments contain the isotopic distribution and quantities listed in Table 4-3 of the *Final Hazard Classification and Auditable Safety Analysis for the 105-F Building Interim Safe Storage Project* (BHI 1998a). The sediments remaining on the bottom of the basin have permeated throughout the bottom 0.3 m (12 in.) of clean fill materials that were added during stabilization. Appendix A summarizes the estimated DAC levels with sediment material permeating through the bottom 0.3 m (12 in.) of back fill sand.

In an effort to verify the assumptions and calculations that will be used in this air sample plan, the following initiatives will be undertaken:

- At the beginning of the Stage II excavation, in situ radiological surveys (e.g., using ISOCS and the LARADS) will be performed to locate/identify high-dose-rate items and potential SNF. These measurements can also be used to estimate the cesium-137 activity in the sediments. The results of these surveys will be used in conjunction with the available sediment characterization data, and an approximation of the sediment activity will be determined prior to personnel entries into the below grade areas during the Stage II activities. Appropriate scaling factors will be developed using the isotopic ratios contained in the *Final Hazard Classification and Auditable Safety Analysis for the 105-F Building Interim Safe Storage Project* (BHI 1998a).

- During Stage II work, the high-dose-rate items and potential SNF will be excavated and removed remotely using the Brokk system. During this stage of excavation, air sampling will be performed in the below-grade area of the basin to monitor airborne contamination while disturbing the soils and sediments. The results of these air samples will be used to validate the calculations and estimates performed to support the ALARA planning for this task.

- Additional sediment sampling will be performed after the removal of all high-dose-rate items from the bottom 0.8 m (30 in.) of soil to support waste designation. The isotopic results of the waste designation samples will be used to validate the calculations and estimates performed to support the ALARA planning for this task.

6.0 EXPOSURE CONTROL METHODS EMPLOYED TO REDUCE EXPOSURE

6.1 AMP-100

The AMP-100, which is a Geiger-Mueller tube detector, is a state-of-the-art microprocessor-based instrument. It is designed for accurate exposure rate measurements from 0.005 R/hr up to 1,000 R/hr, gamma radiation. Radiation measurements are read on a hand-held digital display up to 91.5 m (300 ft) away and can also be transmitted (i.e., wireless) to a computer terminal. The connections and probe for the AMP-100 probe are water-tight to allow for use in underwater or wet applications. The AMP-100 also allows for an alarm to sound when dose rates exceed a programmed radiation dose rate.

The Reactor ISS Project will use these features to control and minimize personnel radiation exposure. The AMP-100 will be attached to the boom of the heavy equipment excavator and the Brokk while removing lower FSB fill material. A dedicated radiological control technician (RCT) will be assigned to the computer terminal to monitor radiation levels. The heavy equipment excavator and the Brokk operator will be trained to cease excavation activities when the AMP-100 alarms.

6.2 MGPI WIRELESS REMOTE MONITORING SYSTEM

The MGPI wireless remote-monitoring system consists of an electronic dosimeter with a digital display, transmitter for the dosimeters, receiver, and computer. The dosimeter is placed into a transmitter, which allows data on the dosimeter to be transmitted to a receiver. The receiver is connected to a computer terminal that displays radiation exposure rates and accumulated radiation exposure. A dedicated RCT will monitor the computer terminal. The transmitter is capable of transmitting data to a distance of up to 915 m (3,000 ft). In the event that data from the dosimeters are not detected by the receiver/computer after a pre-set time interval, the computer will alert the RCT that contact has been lost. The RCT will then ensure that the work in the FSB is shut down until alternative actions can be taken to adequately monitor individuals in the work areas.

Personnel working in the FSB during excavation will be required to wear alarming electronic dosimetry. Electronic dosimeters will be set to alarm when exposure and exposure rates reach a programmed decision level as prescribed on the radiation work permit. Personnel will be instructed to stop work, shut down equipment (if possible) and immediately leave the area when the dosimeter alarms.

6.3 BROKK

The Brokk is a small excavator that can be remotely operated away from the FSB. The Brokk is designed so it can excavate between the basin stem walls, remove high-dose-rate items, and process (i.e., wash, measure, and weigh) and package SNF. The Brokk will be equipped with video cameras so a trained operator can perform these functions without entering the basin. The use of the Brokk will result in a preliminary estimated dose equivalent saving of 1.2 rem. The use of the Brokk eliminates the need for personnel to handle SNF and high-dose-rate items.

7.0 ENGINEERING CONTROLS

Engineering controls are used to minimize the spread of contamination, control airborne radioactivity, and reduce the level of personnel radiation exposure. Controls that will be implemented in the Stage II FSB cleanout will include the use of remotely operated equipment, water for dust suppression, and in-basin holding canister's for SNF. Long-handled tools will be used if there should be a failure of remotely operated equipment.

8.0 SPECIAL TRAINING REQUIREMENTS

Personnel assigned to work on the 105-F FSB are required to attend daily pre-job meetings and to receive training on identifying items that may be encountered in the FSB. Personnel must be current in the following training: Radiation Worker II, General Employee Training/ Hanford General Employee Training, Facility Orientation, 40-Hour Hazardous Worker Training, and Respiratory Training (if required).

Additional mock-up training is required for personnel that will operate the Brokk and package the SNF for transportation. Operators of the Brokk will demonstrate proficiency in processing (i.e., weighing, measuring, and washing) SNF and in performing excavation. Riggers that will enter the FSB to lock and tie-down the SNF transportation cask will receive mock-up training to ensure readiness for the required activity.

9.0 EXPOSURE ESTIMATE

The total estimated dose equivalent for the Stage II excavation is 2.4 person-rem. Table 2 summarizes the dose equivalent for Stage II FSB cleanout. Dose equivalent estimates are identified by task.

Table 2. Exposure Estimate.

Task	Person-hours	External Exposure Estimate (mrem)	Internal Exposure Estimate (mrem)[a]	Total Exposure (mrem)
Level backfill using the Brokk	112	10	0	10
Basin mapping preparations	1,320	130	0	130
Remove identified fuel elements and package	1,120	230	0	230
Load out conex boxes	48	96	2	98
Remove fuel buckets/deck plating and bottom 0.9 m (3 ft) of soil	2,422	1670	12[b]	1,682
Excavate around outside walls	224	20	0	20
Demolish walls to –38.1 cm (–15 in.) and load out	2,320	230	0	23
Total estimated dose for this activity				2,400

[a] Internal exposure estimates are based upon projected airborne concentrations of 1.3 composite DAC and the use of respiratory protection (PF= 100) during entry into the below-grade areas of the FSB.
[b] Internal exposure estimate is based on the heavy equipment operator working inside the basin for 372 hours.

10.0 CONCLUSION

The decontamination and decommissioning of the 105-F FSB uses sound ALARA practices and principles. The incorporated engineering controls, contamination area controls, airborne radioactivity controls, and the application of new technologies should ensure that all exposures are controlled and maintained ALARA. Implementation of the engineering and administrative controls result in an estimated total effective dose equivalent of 2.4 person-rem.

11.0 REFERENCES

BHI, 1998a, *Final Hazard Classification and Auditable Safety Analysis for the 105-F Building Interim Safe Storage Project*, BHI-01151, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

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BHI-RC-03, *Radiological Control Procedures*, Bechtel Hanford, Inc., Richland, Washington.

DOE-RL, 2000, *Sampling and Analysis Plan for the 105-Phase IV Fuel Storage Basin*, DOE/RL-2000-54, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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APPENDIX A

FUEL STORAGE BASIN INVENTORY

FUEL STORAGE BASIN INVENTORY (BHI-01151, Rev.0, p 4-13)

Nuclide	Activity (Curie)	Half Life (Years)	Current Activity (Ci) January 11, 2001	Radionuclide Concentration	Airborne Estimate	DAC value (835)	DAC
Ni-59	0.50	7.60E+04	0.50	1.57E+03 pCi/gram	3.14E-13	3.00E-06	1.05E-07
Co-60	1.99	5.27E+00	1.37	4.31E+03 pCi/gram	8.63E-13	7.00E-08	1.23E-05
Ni-63	54.80	1.00E+02	53.74	1.69E+05 pCi/gram	3.38E-11	1.00E-06	3.38E-05
Sr-90	10.20	2.88E+01	9.53	3.00E+04 pCi/gram	5.99E-12	2.00E-09	3.00E-03
Cs-137	11.90	3.01E+01	11.15	3.51E+04 pCi/gram	7.01E-12	7.00E-08	1.00E-04
Eu-152	8.40	1.35E+01	7.27	2.29E+04 pCi/gram	4.57E-12	1.00E-08	4.57E-04
Eu-154	1.45	8.59E+00	1.15	3.63E+03 pCi/gram	7.26E-13	8.00E-09	9.07E-05
U-238	0.01	4.47E+09	0.01	2.83E+01 pCi/gram	5.66E-15	2.00E-11	2.83E-04
Pu-238	0.27	8.77E+01	0.26	8.21E+02 pCi/gram	1.64E-13	3.00E-12	5.47E-02
Am-241	0.49	4.33E+02	1.21(a)	3.81E+03 pCi/gram	7.61E-13	2.00E-12	3.81E-01
Pu-241	5.64	1.44E+01	4.92	1.55E+04 pCi/gram	3.10E-12	3.00E-10	1.03E-02
Pu-239/240	2.60	2.41E+04	2.60	8.18E+03 pCi/gram	1.64E-12	2.00E-12	8.18E-01
			Total activity	2.95E+05 pCi/gram		**Total DAC**	1.27E+00

Assumptions:

* Radionuclide concentrations have been decayed from March 1998 to January 2001.
* Assuming that all activity has permeated into the bottom 12" of the soil column (based on a total sludge/soil mass of 3.18E8 grams)
* Area of the Fuel Basin is 5,409 sq. ft, and the assumed density of the sediment/soil is 1.9 g/cm3.

(a) Assumes .72 curies of ingrowth from the decay of Pu-241

*Airborne estimation based on formula contained in BHI-RC-03, Procedure 4.2 , "Estimating Airborne Radioactivity Levels"
Formula: 0.2 x Specific Activity x 1E-15

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