SKI Report 2006:31

Research

An Applied Study on the Decontamination and Decommissioning of Hot Cell Facilities in the United States and Comparison with the Studsvik Facility for Solid and Liquid Waste

Dr. Geoff Varley
Director Commercial Consulting

Chris Rusch
Senior Consultant

July 2006

ISSN 1104-1374
ISRN SKI-R-06/31-SE

SKI perspective

Background

Under the Act on the Financing of the Management of Certain Radioactive Waste etc. (1988:1597), sometimes referred to as the “Studsvik Act”, the Swedish nuclear power utilities make contributions to the Swedish Nuclear Waste Fund at a present rate of 0,2 öre per kWh generated by nuclear power (approximately 0,02 Euro cents per kWh). The Swedish parliament decided that the fund ultimately shall cover all expenses for the decontamination and decommissioning of Swedish non-commercial nuclear installations and research reactors, including disposition of the associated historic wastes. It is extremely important to ensure that the rate of contributions to the Swedish Nuclear Waste Fund reflect the future authentic costs of performing the planned and defined decommissioning and waste disposal tasks over the relevant future time period. To achieve this, it is essential that the cost estimates associated with the relevant decommissioning projects are assessed in terms of the correctness of the basic plans and assumed methodologies, as well as the prudence of the calculated costs.

Purpose of the project

The primary aim of this applied study has been to analyse the cost estimate for decontamination and decommission of the Facility for Solid and Liquid Waste.

A secondary aim has been to derive results that add to current knowledge on decontamination and decommissioning methodologies and costs, so as to enhance the basis for preparing high quality forecasts of future costs related to other facilities. This in turn will enhance the level of confidence in the assessed fees collected from the nuclear utilities, which of course are determined in direct relationship to the overall forecast/estimated costs for the planned future decontamination and decommissioning activities. The comparative study undertaken in this project contributes to the establishment of progressively greater understanding of the level of accuracy and the soundness of the principles used for calculations/estimations of future costs.

Results

The study demonstrates very clearly that the approach of comparing Swedish cost estimates with feedback from actual decommissioning projects completed for similar facilities in other countries, enhances and extends the knowledge basis as to how future cost estimates can be improved. The present report is to be seen as part of an active learning process within a context of collective learning.

The presented applied study reinforces earlier findings in terms of how best to develop reliable and defensible estimates of cost for decontamination and decommission. In this regard, the design of the SVAFO study and cost estimate report does not make sufficient information visible, it has a tendency to rely too much on mechanical reproduction of data used in other estimates (rather than looking afresh at this specific project) and leaves some important questions unanswered. Careful attention to the characterisation of an individual facility is highlighted once again as a fundamental and crucial first step in developing a good quality estimate. This is an important area where the SVAFO estimate could be improved. Hence, a number of significant uncertainties remain.

Continued work

This study demonstrates a clear need for ongoing work to develop a comprehensive platform of decontamination and decommissioning cost information.

Effects on SKI work

SKI can use the present report to draw inferences for analysis of the ongoing evaluation of the yearly cost estimates that are presented by the company AB SVAFO. The study will therefore support the present review process regarding estimated dismantling costs of the Facility for Solid and Liquid Waste.

Project information

At SKI Staffan Lindskog has been responsible for supervising and co-ordinating the project. Geoff Varley at NAC International has been responsible for the information gathering and analyses as well as the final preparation of the report.

SKI reference: 2005/1204/200509053

SKI Report 2006:31

Research

An Applied Study on the Decontamination and Decommissioning of Hot Cell Facilities in the United States and Comparison with the Studsvik Facility for Solid and Liquid Waste

By
Dr. Geoff Varley
Director Commercial Consulting

Chris Rusch
Senior Consultant

July 2006

Prepared for
SKI
May 2006

NAC INTERNATIONAL

Atlanta Corporate Headquarters
3930 East Jones Bridge Road
Norcross, Georgia 30092
770-447-1144
Fax 770-447-1797

32 Bell St
Henley on Thames
Henley-on-Thames RG9 2BH
Oxfordshire
United Kingdom
44 1491 636 284
Fax 44 1491 413 023

2-7-10, Sakura-Machi
Mail No. 184
Koganei, Tokyo, Japan
81-423-87-6758
Fax 81-423-87-6740

22/25 Bolshoi Strochenovsky Pereulok
Office 509
113054 Moscow
Russia
7-095-230-6832
Fax 7-503-230-6844

Stoller Nuclear Fuel
A Division of NAC International
1 Baltic Place, Suite 201-A
Croton-on-Hudson, New York 10520
914-741-1200
Fax 678-328-1591

C-2006-14

ABOUT THE AUTHORS

GEOFF VARLEY

Dr. Varley has 30 years of experience in the nuclear industry, more than 17 years as a consultant and manager with NAC and, before that, more than 12 years with U.K. nuclear fuel services company British Nuclear Fuels plc (BNFL). Since joining NAC in April 1988, Dr. Varley has applied his experience and expertise to a wide range of consulting activities, serving clients worldwide. In June 1993 he became general manager of NAC's Zurich operations. In this capacity, he was responsible for all consulting, database and sales activities performed at NAC's European hub. In July 1996 he opened NAC's London office and in mid-2004 he was appointed as Director of Commercial Consulting for NAC, a function that he fulfils from a base close to London.

Dr. Varley's consulting expertise is applied to all nuclear fuel cycle sectors, with a special focus in the enrichment, fuel fabrication and back end (reprocessing, plutonium and uranium recycle, waste management, spent fuel transport and decommissioning) market sectors. Since April 1988, Dr. Varley has visited numerous reactor and fuel cycle service facilities throughout the world.

CHRIS RUSCH

Mr. Rusch has more than 30 years of experience in the nuclear industry. In his position as a Senior Consultant, he utilises his great versatility to participate in a wide range of consulting activities, spanning all fuel cycle segments from the front end through waste management and decommissioning.

Before joining NAC, Mr. Rusch was the manager of nuclear fuel at Portland General Electric and was responsible for all phases of nuclear fuel procurement, including strategic and tactical planning, bid preparation, supplier and proposal evaluations, contract negotiation, contract administration, and economic analysis. Significant experience includes management of major projects, technical professionals (in-core fuel management and safety analysis personnel) and annual operating and capital budgets of $1 million and $25 million, respectively.

Mr. Rusch managed the procurement of nuclear fuel for a nuclear plant that consistently ranked among the top 10 plants in the United States with the lowest fuel costs. He organised and directed the evaluation and negotiation teams for the procurement of nuclear fuel fabrication services and directed a multi-department, four-year project to establish a new supplier of nuclear fuel fabrication services.

Mr. Rusch has broad utility experience as his assignments required interfacing with accounting, rates and revenues, finance, legal, power analysis and power operations departments and nuclear plant staff, including reactor engineering, licensing, quality assurance and nuclear engineering groups.

Contents

Tables

Figures

Glossary

ANLArgonne National Laboratory located near Chicago, Illinois, USA

DOEU.S. Department of Energy

DOE-EMU.S. Department of Energy - Environmental Management

DOHSState of California - Department of Health Services

DSSIDiversified Scientific Services, Inc., Kingston, Tennessee

EnvirocareEnvirocare of Utah, Inc., Salt Lake City, Utah

GAGeneral Atomics

GA SiteGeneral Atomics Torrey Pins Mesa Facility, San Diego, California

HCFHot Cell Facility at the GA Site

HEPAHigh Efficiency Particulate Air

HLWHigh Level Radioactive Waste

HTGRHigh Temperature Gas-cooled Reactor

IFMIrradiated Fuel Material

INELIdaho National Engineering Laboratory

LLWLow Level Radioactive Waste

NACNAC International

NRCU.S. Nuclear Regulatory Commission

NTSNevada Test Site LLW Facility, Nevada

NWPFNuclear Waste Processing Facility at General Atomics

ORISEOak Ridge Institute for Science and Education

Perma-FixPerma-Fix Environmental Services, Inc., Gainesville, Florida

PIEPost Irradiation Examination

RERTRReduced Enrichment Research and Test Reactor

SSISwedish Radiation Protection Authority

SSASoil Staging Area

Executive Summary

Overview

This report presents the plans, processes and results of the decontamination and decommissioning of the Hot Cell Facility in Building 23 at the General Atomics Torrey Pines Mesa Facility (HCF) and compares the program and cost of decommissioning HCF with the Swedish cost estimate for decontamination and decommissioning of the HM hot cell and wastes treatment facility at Studsvik in Sweden.

Construction of the HCF was completed in 1959 with laboratories and remote operations facilities covering a total area of 690 square metres. The HCF had three main hot cells and was licensed to:

- Receive, handle and ship radioactive materials;
- Remotely handle, examine and store irradiated fuel materials;
- Extract tritium (engineering scale);
- Support new reactor production development;
- Develop, fabricate and inspect UO_2 - BeO fuel materials.

The HM facility in Studsvik was constructed to handle and package medium-active solid and liquid wastes, prior to disposal. Central to the facility is a conventional hot cell including three work stations, serviced by master slave manipulators. Other parts of the facility include holding tanks for liquid wastes and slurries, a centrifuge room, as well as an encapsulation station where drummed wastes can be encapsulated in cement, offices, laboratories and workshops and so on, as well as building and cell ventilation systems.

HCF Decontamination and Decommissioning

Decontamination and decommissioning of the HCF took place during 1993 through 2001. The objective was to obtain regulatory release of the site so that it could be used on an unrestricted basis. Based on data from extensive hazardous and radiological materials characterization, GA evaluated four decommissioning options and selected dismantling as the only option that would satisfy the decommissioning objective.

The decontamination and decommissioning scope included the following actions.

1. Remove the legacy waste that consisted of radioactive wastes stored at the HCF consisting of 21.434 kgHM of irradiated fuel material (IFM) that was owned by the U.S. Department of Energy and store the waste in temporary storage set up at the GA site. This activity was accomplished during Phase I of the project which also included planning, preparation and characterization of the facility.
2. Actual Decontamination and Dismantlement occurred during Phase II. The activities included:
    a. Dismantlement of the building structure surrounding the hot cells and then finally dismantlement of the hot cell block
    b. Soil remediation
    c. Handling and disposal of decommissioning wastes
    d. Confirmatory surveys
3. Final site release occurred during Phase III.
4. The final activity which occurred substantially after Phases II and III were complete was the shipment of the IFM to a DOE facility.

Cost Comparison

The overall decommissioning costs for HM (estimated) and HCF (actual) are MSEK 43.9 (2001 money values) and $35.5 million (1998 money values) respectively. Normalizing to 2001 SEK, the HCF equivalent value is approximately MSEK 392.

The HCF and HCF structures are approximately the same size on a volumetric basis. The volume of the HM hot cells is about 12 percent greater than at HCF but the HCF had 27 percent more surface area due to the existence of three separate cells. Of potential importance is that the contamination levels on the hot cell surfaces were not equal. The HCF facility was highly contaminated from such activities as band-sawing irradiated high temperature gas cooled reactor fuel, which produced aerosols of fuel and graphite particles that spread throughout the hot cells. On these grounds it might be expected that the HCF actual costs would be higher than HM estimates. However, a factor of almost nine times higher seems to be exceptional.

The very large difference in fact stems from a number of special circumstances at HCF that need to be backed-out of a cost comparison in order to make it meaningful. One special requirement was the removal and safe management of irradiated fuel material, including high enriched uranium, the costs for which were considerable. Another cost related to maintenance of the building, including substantial repairs and replacement before decommissioning could commence. The costs of waste disposal also vary substantially, in terms of unit costs and the proportion of dismantling waste that needs to be sentenced to a radioactive waste repository. Finally, the HCF decommissioning project was funded largely by the U.S. Government. This added significant cost to the planning and preparation of the project including voluminous reports (for example the characterization report was 680 pages). The cost of project management and compliance also were increased enormously because of government oversight. Government involvement also resulted in a very conservative approach to managing dismantling wastes.

Concerning the actual labour resources expended on decontamination and dismantling efforts, the HM and HCF projects are quite comparable.

Main Conclusions

The available information for HM has been evaluated and compared, to the extent possible, with the HCF decommissioning costs and other selected NAC derived decommissioning cost benchmarks. In summary the main conclusions for the HM decommissioning cost estimate are as follows:

Planning and Institutional Support

Theoretical estimates of planning and other support activities can have a tendency to assume optimal circumstances and tend not to account for potential changes of circumstances in, for example, the regulatory environment and requirements. It therefore may be prudent to review in general the cost allowances for efforts in this category. In any event, based on advice from SKI, SKI and SSE (Swedish Radiation Protection Authority) oversight will apply to the HM decommissioning project, with attendant costs.

Decontamination, Dismantling and Waste Disposal

The estimate for decontamination and dismantling overall appears to be reasonable. Areas where additional costs could occur (e.g. hot cell concrete) have been identified in this report. Additional cost for waste disposal would be the main consequence if such contamination were found. One of the big differences between the plan and the outcome at HCF was the amount of dismantling waste that had to be disposed of as active waste. Due to the government funding of the HCF project, the determination between clean concrete and radioactive concrete was made very conservatively. The HM facility appears to be in much better radiological condition overall than HCF but it cannot be discounted that surprises are found and/or regulatory requirements change regarding the dumping of waste. If an engineered solution (concrete cutting) were required to dismantle the hot cell, a substantial additional cost could apply.

CHARACTERISATION

Following on from the above comments, the HM estimate does not include any significant allowance for characterisation/radiological mapping of the facility prior to designing and planning the decontamination and dismantling work. The development of an accurate picture before proceeding with the work normally is a prudent and beneficial step to take. An additional estimated cost of up to MSEK3 could apply for such an exercise.

UNCERTAINTIES/CONTINGENCIES

The treatment of uncertainty in developing the HM cost estimate seems to have followed the pattern of other cost estimates analysed by NAC, whereby a round percentage number has been added to certain base estimates. As recommended in reference 4, a more focused approach based on identifying the main potential cost sensitivities and then dealing with them in a more individual manner would be preferable.

1. Introduction

Statenskärnkraftinspektion (SKI) charged NAC International with the task of conducting an applied research study into methods and costs relevant to the decontamination and decommissioning of the Studsvik Facility for Solid and Liquid Waste (HM). To fulfil this task, NAC has focussed on analysis of the plans, processes and results of the decontamination and decommissioning of the Hot Cell Facility at the General Atomics Torrey Pines Mesa Facility, located about 21 kilometers north of San Diego, CA (hereafter referred to as the HCF). The study includes a comparison of this information with the decommissioning plan and cost estimate for the Studsvik Facility for Solid and Liquid Waste (HM) in Sweden (hereafter referred to as the HM). The HM cost estimate is contained in report SEP 01-320, rev 0 prepared by Westinghouse Atom AB for AB SVAFO under order number A.106306.

Additional insights and benchmarks, to the extent possible, are presented based on the analysis of decommissioning project information available for the following facilities:

- the hot cells at Building 324, Hanford Reservation in Washington State;
- the hot cells that were located in Building 200 at the Argonne National Laboratory (ANL) located about 40 km from Chicago, Illinois, USA;
- Storage tanks located in Building 310 also at ANL

Relevant benchmarking information is available for the Building 200 project. More general information is included on the other two projects for completeness, as one or more of these are expected to be decommissioned in the relatively near future and could provide information of interest to SKI at a later time.

This report presents the conclusions of NAC's analyses and comparisons. It includes a full analysis of the HCF, the derivation of relevant benchmarking results from that decommissioning program and a prudence review of the HM cost estimate, looking at the reasonableness of the cost estimate as well as the completeness of the estimate and related logistics.

.

2. General Atomics Hot Cell Facility Description and Decommissioning Scope

2.1 General Atomics Hot Cell Facility Description

2.1.1 Site

The HCF was located at the GA Site which is about 21 kilometres north of the center of San Diego, CA, USA. The HCF was situated at the north central sector of this facility, about 100 metres above sea level and 1.6 kilometres from the Pacific Ocean. Figure 2.1 through Figure 2.4 indicate the location of the GA Site and Building 23 (HCF) and the HCF floor plan. The climate at the site is characterized as Semi-Arid Mediterranean with an average annual rainfall of 26.4 cm.

Figure 2.1 Location of the GA site

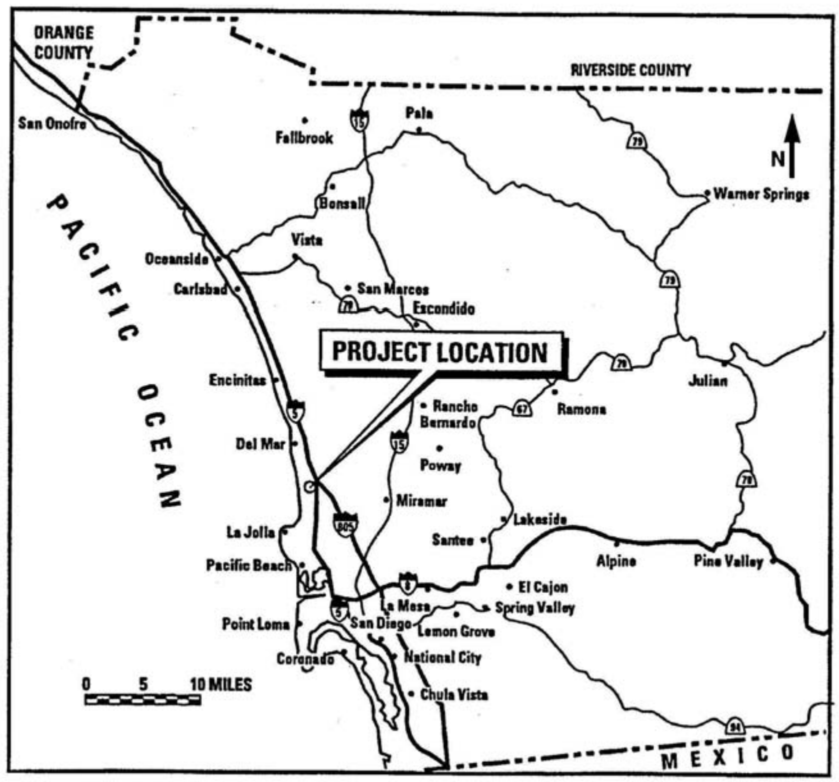
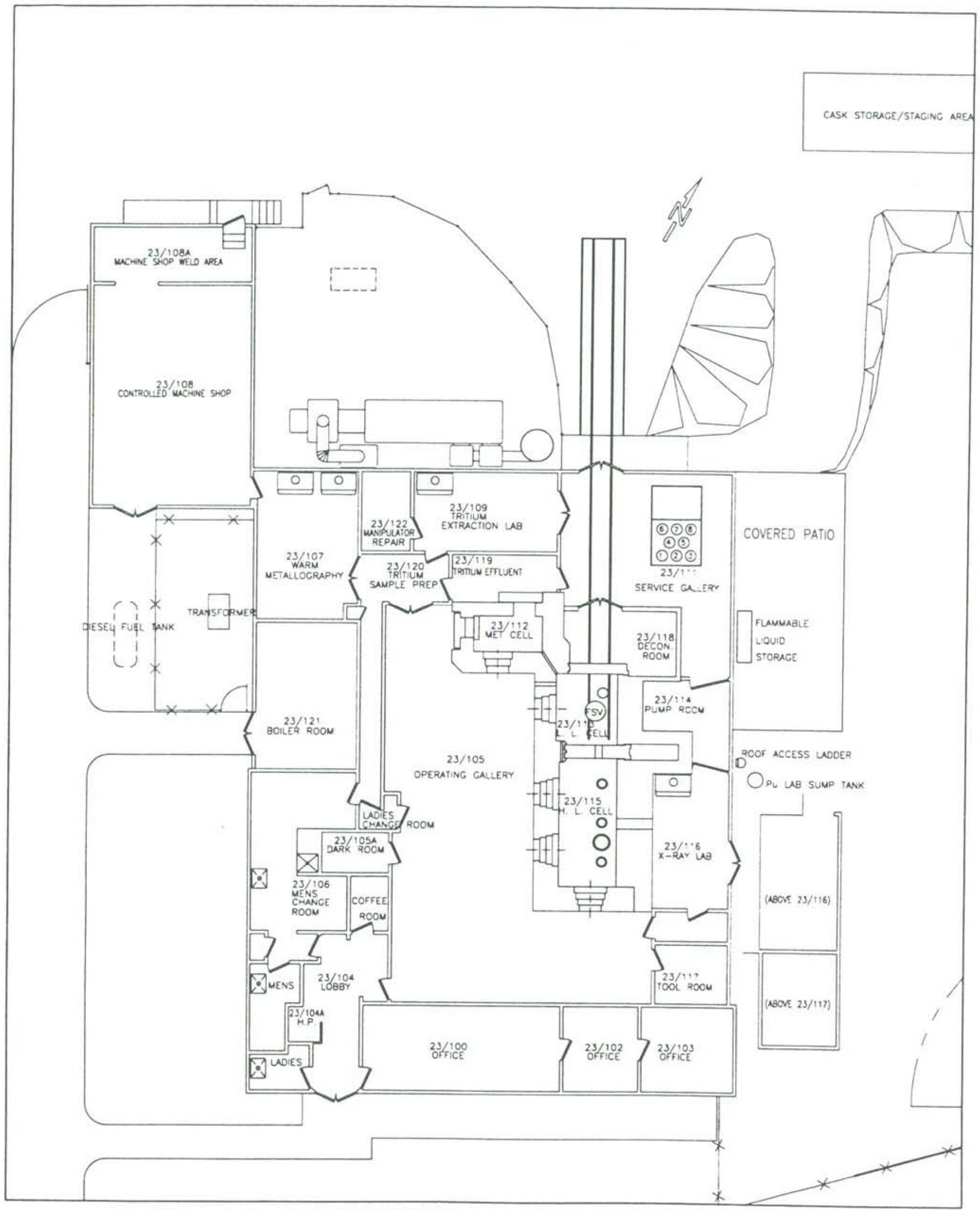


Figure 2.2 Aerial Photo of the GA site

Figure 2.3 Aerial Photo of the HCF

Figure 2.4 Floor Plan of HCF



2.1.2 HCF Description

The HCF was designed and built by Bechtel Corporation. Construction of the HCF was completed in 1959 with laboratories and remote operations facilities covering a total area of 690 square metres. The HCF is surrounded by a fenced service yard with a total area of 4,340 square metres that included concrete pads for staging heavy equipment and material transfers in and out of the HCF.

The HCF had three main hot cells and was licensed to receive, handle and ship radioactive materials; remotely handle, examine and store irradiated fuel materials; extract tritium (engineering scale); support new reactor production development; and develop, fabricate and inspect UO_2 - BeO fuel materials.

Table 2-1 provides a description of the HCF hot cells.

Table 2-1 Description of the HCF Hot Cells

Name of Cell	Length (m)	Width (m)	Height (m)	Wall Thickness (m)	Wall Concrete Type	No. of Operating Stations
High-Level	5.49	2.44	4.57	1.07 – 1.52	Magnetite	3
Low-Level	3.05	2.59	4.57	0.81 – 0.91	High-density	1
Metallography	2.74	1.52	3.51	0.86 – 0.91	High-density	1

2.1.3 *Physical Condition Prior to Decommissioning and Current Status*

Prior to the decommissioning project, the HCF was maintained in a shutdown, safe, surveillance and maintenance mode. Specifically,

- Utility services (water, electricity and natural gas) were connected and functional.
- Building air ventilation and HEPA-filter systems, instrument air supply compressors, and criticality and effluent monitoring systems were operational.
- Manually actuated and automated fire alarm/suppression systems were operational.
- Radiological and security alarm systems were normal.
- Remote handling systems and auxiliary support equipment were operational or available for activation and use.

About five years elapsed between the time that research and development activities stopped in 1991 until actual decommissioning work commenced in May 1996. Figure 2.5 (Operating Galley) indicates that the facility was generally in good physical condition at the commencement of decommissioning work.

Figure 2.5 HCF Operating Gallery

In 1994, the HCF and surrounding fenced service yard were characterized for radiological contamination, hazardous materials contamination and asbestos. The characterization included the collection of 206 soil samples, 405 concrete samples, 38 asphalt samples, 28 vegetation samples, 41 asbestos samples, 90 hazardous material constituent samples and 211 miscellaneous samples (floor tiles, plaster, etc). The HCF and surrounding yard were contaminated with radioactive elements and isotopes including Cobalt-60, Cesium-137, Europium-156, Strontium-90, Uranium and Thorium.

The results of the characterization were as follows:

- Seventy-nine percent of the building floor area and 50 percent of the wall area were radiologically contaminated. Based on results from concrete samples, Cs^{137} contamination was in the range of between 0.00274 and 321.2 Bq per gram and Co^{60} contamination was in the range of between 0.00352 and 11.4 Bq per gram. Many hot particles (fission products in fuel fragments [typically microscopic] from destructive examination of irradiated fuel and containers) were located. General radiation levels associated with these contaminated surfaces are listed in Table 2-2.

- Core drilling verified subsurface contamination. However, the deepest cores that were 9.1 metres below grade level discovered no ground water contamination. Based on results from soil samples, Cs^{137} contamination was in the range of between 0.00296 and 0.179 Bq per gram and Co^{60} contamination was in the range of between 0.0033 and 0.04 Bq per gram.
- Hazardous constituent surveys indicated that 23 percent of the floor and wall area was contaminated with low levels of PCBs, semi-volatile organic compounds and metals. Core sampling indicated subsurface contamination at low levels in areas where oils were used.
- 21 of 41 samples tested for asbestos a tested positive
- A majority of the fenced yard surface had radiological contamination. Subsurface cores collected up to 1.0 metre in depth indicated detectable radioisotope levels.

Floor materials with both hazardous material and radiological contamination were classified as mixed waste and handled accordingly.

Table 2-2 Radiation Levels Associated with Contamination of the HCF (u Sv per hour)

Location	Radiation Level - General Area	Radiation Level - Peak Reading
Corridor near Room 120	2.0	
Decontamination Room – general area	200.0	1,000.0
High-Level Cell	Very high due to storage of HLW	
Low-Level Cell	500.0 to 1,000.0	10,000.0
Machine Shop	2.0 to 4.0	
Manipulator Repair Room	150	1,000.0
Metallography Cell	50,000.0	
Pump Room	<1.0	
Service Gallery Room – general area	20.0	1,000.0
Tritium Effluent Room	2.0 to 5.0	
Tritium Extraction Room	3.0 to 18.0	
Tritium Sample Preparation Room	2.0 to 10.0	
Warm Metallography Room (cold side of to Manipulator Repair)	15.0	

The current status of the facility is as follows:

- All HCF equipment was removed.
- The HCF was completely dismantled.
- The yard area was remediated to radiation and contamination levels less than the release standards for future industrial land use.
- Irradiated fuel material (IFM) has been shipped to INEL for interim storage.

The Department of Health Services (DOHS) and the Nuclear Regulatory Commission (NRC) released the site for unrestricted use.

2.1.4 Wastes Stored

In early 1993, at the time that HCF was accepted by DOE-EM for decontamination and decommissioning, the principle radioactive wastes stored at the HCF consisted of 21.434kgHM of IFM that was owned by DOE. The IFM were collected and retained at the HCF as part of a succession of hot cell PIE projects in support of a number of DOE-sponsored fuel development programs. The IFM was separated by fuel types into two packaging groups including HTGR IFM and RERTR IFM.

The HTGR IFM was consolidated in a single fuel mass comprised of three fuel forms - coated fuel particles, fuel compacts and fuel pebbles. The uranium enrichment of the HTGR IFM varied from 10.0 to 93.15 w/o U^{235}. The total weight of the HTGR IFM was 10.668 kg. The forms are described a follows:

- ***Coated Fuel Particles*** – consisted of solid, spherical sintered ceramic fuel kernels composed of UC_2, UCO, UO_2, $(TH,U)C_2$, or $(Th,U)O_2$, substrate, isotopically coated with discrete multi-layered fuel particle coatings, composed of pyrolitic carbon (PyC) and silicon carbide (SiC).
- ***Fuel Compacts*** – coated fuel particles bound in solid, cylindrical, injection-moulded, high-temperature heat-treated compacts, the binding matrix of which consists of carbonized graphite shim, coke and graphite powder.
- ***Fuel Pebbles*** – coated fuel particles bound in solid, spherical, injection-molded, high-temperature heat-treated pebbles, the binding matrix of which consists of carbonized graphite shim, coke and graphite powder.

The RERTR IFM were comprised of 20 irradiated TRIGA elements consisting of a uranium-zirconium hydride fuel matrix clad in Inconel 800H tubing. The elements were

1.3 cm in diameter and 56cm in length. Thirteen of the elements were intact while seven had been sectioned for PIE. The elements had three distinct uranium enrichments of 20, 30 and 45 w/o U^{235}. The total weight of the RERTR IFM was 10.766 kg.

The enclosures that contained the IFM material and some non-fuel element components were included in the IFM packaging and weighed 45.47 kg.

2.2 Outline of Decommissioning Plan Scope

2.2.1 Objectives

The objective of the HCF decommissioning project was to obtain regulatory release of the site so that it could be used on an unrestricted basis. Prior to establishing the Decommissioning Plan, GA performed extensive hazardous and radiological materials characterization of the HCF and associated site. Based on the characterization data, GA evaluated the four decommissioning options identified in NRC Regulatory Guide 1.86 to determine and select the option(s) that would satisfy the decommissioning objective. The four NRC options are as follows:

- Leave in Place – under this option, the HCF would have been maintained in a secure shutdown mode. This option was evaluated as being unacceptable because the decommissioning objective would not be met due to the extensive contamination in the HCF.
- Entombment – under this option, the HCF would have been entombed, thereby entirely securing the hazardous and radioactive contents of the structure. This option was evaluated as being unacceptable because the decommissioning objective would not be met due to the contaminated soil surrounding the HCF not being dealt with.
- Decommissioning in Place – under this option, the HCF would have been decontaminated and decommissioned but the structure would be left in place. This option was evaluated as being unacceptable because access to decontaminated areas would have required extensive building dismantlement such that the building would have been unusable after the project was complete.
- Dismantlement – under this option, the HCF equipment and structure would be dismantled, the surrounding soil remediated and the site cleared for unrestricted use through NRC and State of California final inspections. This option was selected because it met the decommissioning objective.

2.2.2 Original Planned Scope

As a result of the evaluations described in section 2.2.1, the dismantlement option was selected. The principle tasks included the following actions.

1. Site Characterization,
2. Assessment of Alternatives
3. Relocation of Legacy Waste (IFM) to another facility at the GA Site
4. Site Preparation for Decommissioning
5. HCF Decommissioning Operations
6. Soil Remediation
7. Handling and Disposal of Decommissioning Wastes
8. Confirmatory surveys
9. Final Site Release
10. Shipment of IFM to a DOE facility

2.2.3 Actual Scope

The program of work was carried out in three main phases; preparatory work, actual decontamination and dismantling and closeout work. Several events or situations caused significant changes to schedules or waste quantities and to the scope of the HCF decommissioning project.

- Hot particles were found in the soil staging area, which caused a 13-month delay in the completion of Phase 3 of the project. Over 1,400 cubic metres of soil that was originally determined to be "clean" was disposed of as LLW. This was the major factor in the increase of the quantity of contaminated soil discussed below.
- LLW from dismantlement debris was four times the projected quantity but, in terms of cost, there was no impact because the final quantities of other waste categories were lower than projected (see Table 3-1).
- The volume of contaminated soil was 14 times the projected volume. This caused a significant increase in the scope of soil waste handling and disposal.

2.2.4 Principle Assumptions

The entire decontamination and decommissioning project was contingent on acceptance of the HCF into the DOE-EM Surplus Facility Management Program. After DOE-EM acceptance was secured, a cost-sharing agreement was established.

A significant portion of the utilization of the HCF had been devoted to DOE-sponsored hot cell examinations of spent nuclear fuel. Based on this utilization, DOE and GA agreed to a cost sharing plan in which DOE would be responsible for 76 percent of the decontamination and decommissioning costs and GA the remainder.

This agreement lead to the disposition plan for the IFM. Owing to the fact that the waste was related to DOE-sponsored projects, it was agreed that the IFM eventually would be transferred to a DOE facility. However, the decontamination and decommissioning of the HCF could not proceed until IFM was removed from the HCF and so the IFM initially was moved to a temporary location.

2.3 Outline of Planning and Institutional Requirements

2.3.1 General Planning

With the decline in nuclear fission research and increasing development surrounding the GA Site, GA management made the decision to decontaminate and decommission the HCF and associated fenced service yard. Accordingly, in early 1993, GA submitted a request to DOE that the HCF be designated a candidate site under the Surplus Facility Management Program and the request was accepted in the same timeframe.

On December 14, 1994 GA formally notified the NRC of its intent to “cease” principal activities at the HCF. A Decommissioning Plan was then prepared.

As noted in section 2.2.4, DOE and GA reached a cost-sharing agreement for the decommissioning project. After the cost-sharing agreement was reached the DOE Oakland Project Office awarded contract DE-AC03-84SF11962 to GA for the Phase I scope of work outlined in section 3.1.

Subsequently, in January 1996, another contract, DE-AC03-95SF20798 was awarded for the Phase II and III scope of work also outlined in section 3.1.

2.3.2 Institutional Requirements

The HCF was regulated under the GA Special Nuclear Materials License SNM-0696 issued by the NRC and the Radioactive Materials License 0145-80 issued by the Radiological Health Branch of the DOHS. Release criteria for soil, building materials, concrete, and asphalt were based on criteria in these licenses. The final release guideline values were calculated specifically for the site and represented incremental concentrations above background values. NRC's ***Manual for Conducting Radiological Surveys in Support of License Termination*** (NUREG/CR-5849) provided guidelines for calculating isotopic concentrations in soil that corresponded to maximum permissible gamma exposure rates and dose rates.

There were a number of plans, reports and approvals required for the project. The plans and reports are listed in section 3.1. The documents that required regulatory approvals are listed below along with the government organization granting approval.

1. Environmental Assessment (NRC Finding of No Significant Impact [FONSI])
2. Draft and Final QA Program Plans (DOE)
3. Draft and Final Health and Safety Plans (DOHS)
4. Operational Readiness Reviews to Conduct Phase I, IFM transfer and Phases II and III (DOE)
5. IFM and HCF Characterization Reports (approved by DOE)
6. Decommissioning Plan (approved by DOHS and NRC)
7. Draft and Final Closure Reports (NRC)
8. Request to Release HCF for Unrestricted Use (approved by DOHS and NRC)
9. Contaminated Soil Shipment Approval (DOHS and NRC)
10. Licensing Applications, Notices, Plans, Reports and Approvals (INEL, DOE and NRC) for shipping IFM to INEL

3. Overall Work Program at HCF

This section presents a summary of activities carried out in the three phases of the actual work program. Additional details are provided for selected parts of the program, including on characterisation, transfer and storage of irradiated fuel materials and the management of decommissioning wastes. Items that significantly affected the project cost also are discussed.

3.1 Program Outline

The work scope included the following phases:

- Phase I (April 1993 – October 1995)

    1. Remove the DOE irradiated fuel from the HCF
    2. Remove other radioactive waste from the HCF (Figure 3.1)
    3. Assure that the HCF meets DOHS and NRC health and safety standards
    4. Characterization of the site with respect to contamination from hazardous materials, radioactive isotopes and asbestos.
    5. Define the overall scope of the decommissioning project based on characterization data
    6. Establish project management documentation, project documentation and project controls required by DOE, DOHS and NRC.
    7. Prepare and obtain approvals of the Decommissioning Plan
    8. Complete the following documents and reports:

        a. Project baseline

        b. Inventory reports on legacy waste including IFM

        c. IFM Characterization and Site and Facility Characterization Plans and Reports

        d. Hazards Analysis

        e. Asbestos Surveys

        f. Project Plan/Project Management Plan for Phase I

        g. Concrete and Soil Sampling and Testing Plan

        h. Decommissioning Plan

i. Low Level Waste Certification Plan

j. Waste Minimization Plan

k. Safeguards and Security for IFM

l. Environmental Assessment - Decontamination and Decommissioning

m. Environmental Assessment – (IFM relocation)

n. Procedures for Decontamination and Decommissioning

- Phase II (August 1995 – June 2001)

1. Remove building equipment (Figure 3.2)
2. Recycle cell operations equipment to the extent possible
3. Asbestos remediation
4. Remove non-load bearing walls
5. After 1 - 4 were complete, dismantle the HCF building
6. Characterize, package, and ship radioactive waste
7. Treat mixed waste at the NWPF to separate hazardous waste from radioactive waste or, if separation is not possible, ship mixed waste to an appropriate facility
8. Package and ship contaminated soil to one of two facilities depending on contamination levels
9. Complete the following documents and reports:

a. Operational Readiness Review for Phase II and III

b. Draft and Final QA Program Plans for Phases II and III

c. Project Plan/Project Management Plan for Phases II and III

d. DOE Matrix Analysis Report

e. Draft and Final Health and Safety Plan

f. IFM Transfer Operational Readiness Review Report

g. IFM Transfer and Storage Procedures

h. Progress Reports involving costs, labor, schedules, trends and waste minimization and shipping

- Phase III (January 2000 – September 2001)

1. Confirmatory Survey

2. Final Site Certification activities
3. Complete the following documents and reports:
    a. Final Radiological Survey Plan and Report
    b. Draft and Final Closure Reports
    c. Final Project Closeout Report
    d. Release from SNM and By-product Licenses
4. Shipment of IFM to INEL (August 2002 - September 2003)

Figure 3.1 Removal of Radioactive Waste from the HCF under Phase I

Figure 3.2 Removal of HCF Building Equipment under Phase II

3.2 Decontamination and Dismantling Implementation

3.2.1 Phase I

Phase I consisted of three main activities including characterization of the HCF and surrounding yard; preparation of plans and reports, receipt of regulatory approvals; and removal of IFM and other waste stored at the HCF.

3.2.1.1 Characterization

The purpose of characterization activities was to provide the information necessary to accurately define the extent and magnitude of HCF contamination. The information gathered was used to:

- determine decontamination and decommissioning techniques,
- establish project schedules,
- estimate project costs,
- estimate waste volumes,
- establish health and safety requirements

The HCF and surrounding fenced service yard were characterized for radiological, hazardous materials, asbestos and soil contamination. The characterization included the collection of 206 soil samples, 405 concrete samples, 38 asphalt samples, 28 vegetation samples, 41 asbestos samples, 90 hazardous material constituent samples and 211 miscellaneous samples (floor tiles, plaster, etc). Section 2.1.3 provides the results of the characterization. In addition, visual and radiological surveys were conducted.

The three hot cells were highly contaminated and had high general area exposure rates (see Table 2-1). Therefore, characterization was limited and was based on knowledge of the processes carried out in the cells and limited measurement. A committee of GA experts spent two months examining the HCF operations log books to document the materials brought into the cells in an effort to aid the characterization of the cells.

3.2.1.2 Plans, Reports and Approvals

After the contracts were awarded to GA, preparation for mobilisation on the project was accomplished through a planning process that required a number of plans, reports and regulatory approvals that are outlined in sections 2.3.2 and 3.1. Reference 1 contains a detailed chronology of the project including the dates of issuing the plans, reports and approvals.

3.2.1.3 IFM Transfer to Temporary Storage

In order to dismantle the HCF (Phase II), the IFM and other waste stored in the hot cells at the HCF had to be transferred to a location away from the HCF and surrounding service yard. Section 2.1.4 describes the IFM that was separated by fuel types into two packaging groups, including HTGR IFM and RERTR IFM. The IFM was then loaded into two separate shipping casks.

The casks were transported from the HCF to temporary storage facilities at the GA site. During December 1995 through August 2003, the casks were moved three times and stored at three separate locations at the GA site. In September 2003, the IFM was loaded into an NAC-LWT shipping cask and shipped to INEL in Idaho, USA.

3.2.2 Phase II

This phase dealt primarily with building and hot cell dismantlement and packaging and shipping of (1) wastes from dismantlement, and (2) contaminated soil. Section 3.3 discusses waste disposition; therefore, dismantlement is the focus of this section.

The dismantlement task was accomplished in five steps as follows:

1. For rooms surrounding the main hot cell structure, the tasks were to:
   a. remove equipment and materials,
   b. decontaminate walls, floor and ceiling using a number of possible techniques[1] (essentially state-of-the-art) evaluated in the Decommissioning Plan (Figure 3.3 and Figure 3.4 show blasting and application of strippable paint), and
   c. remove non-load bearing walls.
2. For hot cells, the main tasks were to:
   a. remove equipment and materials,
   b. remove steel liner, and
   c. decontaminate concrete walls, floor and ceiling using remotely operated cleaning methods followed by abrasive cleaning
3. Following decontamination of the HCF, a health physics survey was performed to verify preparations for shutting down the HEPA system.
4. Following shutdown of the HEPA system, dismantlement[2] continued with removal of the:
   a. HCF roof
   b. walls of the rooms surrounding the hot cells and associated slab
   c. ceiling, walls and floors of the hot cells (Figure 3.5)
   d. hot cell foundation, pits and wells
5. Soil remediation consisting of removing “clean” soil to the SSA and packaging and shipping contaminated soil.

At one point in the dismantling sequence, only the hot cell structure was left intact, see Figure 3.6 (last photo on Page Photo 4 of PBS VL-GA-0012).

---

1. Examples of these are: Vacuum cleaning, damp cloth wiping, strippable coatings, hydro blasting, steam cleaning, abrasive blasting, scabbling, spalling, complexing agents/solvents/acids/caustics or CO_2 blasting.
2. This involved concrete cutting. Holes were drilled in the concrete about 2.5 cm apart and the remaining concrete was cut using concrete saws, so the technique was standard.

Figure 3.3 Decontamination Work at HCF

Figure 3.4 Further Decontamination Work at HCF

Figure 3.5 Hot Cell Dismantling

Figure 3.6 Hot Cell After Dismantling of the Surrounding Facility

3.2.3 Phase III

Following removal of all contamination, a final radiation survey was conducted by GA. In addition, independent surveys of the yard were conducted by the Environmental Survey and Site Assessment Program of the Oak Ridge Institute for Science and Education (ORISE) and the NRC and, to a more limited degree, DOHS. Based on the GA survey and the independent surveys, in 2000, the NRC and DOHS released the HCF site for unrestricted use.

3.3 Management of Decommissioning Wastes

There were five main waste types generated from the project including asphalt, concrete rubble, construction material debris, facility equipment and soil. Table 3-1 lists these waste types, associated quantities and the name of the organization that received shipments of the waste.

All waste shipped for burial was in solid form. With the exception of a small amount of mixed waste sent to Diversified Scientific Services Incorporated (DSSI) for incineration, the liquid waste generated during the project was solidified or treated at the Nuclear Waste Processing Facility (NWPF) to yield a solid waste form.

With the exception of the bulk soil shipments to Envirocare, all waste was packaged[3] in metal boxes (1.2m x 1.2m x 2.1 m) or 208-liter metal drums and shipped by truck. The bulk soil waste was wrapped in heavy plastic, transported by truck to rail facilities in Los Angeles, loaded on flatbed rail cars and transported by rail to Envirocare.

Table 3-1 Waste Form and Disposition (cubic metres)

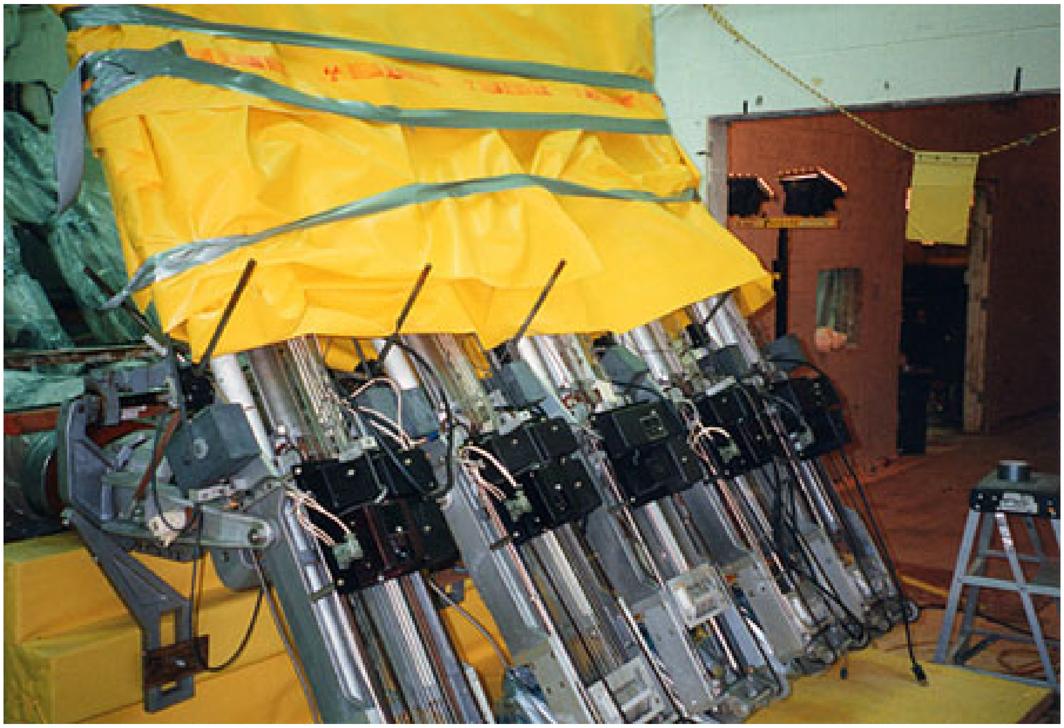
Source	Waste Type	Baseline Plan Projected Volume	Actual Volume	Actual / Projected	Organization Receiving Waste
Concrete and building debris and equipment	LLW	648.46	2,674.20	4.1	U.S. Ecology (Hanford)
Debris including contaminated Pb	Mixed LLW	26.05	13.76	0.5	DSSI, Envirocare, SEG-Duratek, Alaron & Perma-fix
Building debris	Clean	625.81	311.49	0.5	Miramar Landfill[a]
Soil	Radioactive[b] particles in soil	235.03	1,682.71 1,632.73	14.1	Envirocare NTS
Soil	Mixed	65.13	0.00	0.0	None
Asphalt	Clean	379.45	28.32	0.1	Miramar Landfill
Asphalt	Radioactive particles	65.13	31.15	0.5	Envirocare

a. This is landfill owned and operated by the City of San Diego.
b. The total projected contaminated soil was 235.03 cubic metres. The actual quantity of contaminated soil was (1,682.71 + 1,632.73) = 3,315.44 cubic metres.

Manipulators (Figure 3.7) and lead glass windows from the HCF were recycled by shipping this equipment to GE facilities.

3 The packaging criteria are specified in section 3.6 of Reference 2.

Figure 3.7 HCF Manipulators Shipped to GE Facilities



3.4 Milestones and Dates of the Decommissioning Program

Significant milestones and dates regarding the HCF decommissioning are listed below:

- Early 1993 – GA proposed and DOE-EM accepted the HCF as a candidate facility for the Surplus Facility Management Program.
- May 1994 - Site and Facility Characterization Plan completed and issued.
- November 1994 – Facility sampling and soil coring for characterization evaluation were completed.
- January 1995 – Radiological waste shipments begin.
- December 1995 – Irradiated fuel materials transferred to Building 30 at the GA Site.
- May 1996 – Interim NRC approval of the GA Hot Cell Facility Decommissioning Plan and decommissioning activities commenced.
- January 1997 – Final NRC approval of the GA Hot Cell Facility Decommissioning Plan.
- March 1997 – Shipment of equipment including manipulators, periscope, metallograph to GE for reuse.
- December 1997 – Building decontamination activities completed.

- October 1998 – Dismantlement of HCF completed.
- September 1999 – Soil and debris shipments to Envirocare (LLW waste facility in Utah) completed (174 shipments).
- March 2000 – GA confirmatory radiological surveys and independent verification surveys of the HCF site completed.
- August 2000 – HCF site released to unrestricted use.
- May 2001 – contaminated soil and asphalt shipments to the NTS completed (100 shipments).
- June 2001 – all radiological waste disposal activities completed.
- September 2001 – HCF decommissioning activities completed.

3.5 Key Cost Drivers and Sensitivities

3.5.1 Subsurface Characterization Under the HCF Building

Although some coring was conducted under the building during characterization, the number of samples was not sufficient to characterize the extent of soil contamination. The depth of building vaults and pits precluded detailed investigation of the soil beneath the vaults and pits. The quantity of contaminated soil could only be determined after the building was dismantled and debris removed. As noted in Table 3-1, the volume of contaminated soil was approximately 10 times greater than expected, partially due to this characterization difficulty. An estimated 1,250 cubic metres of the difference can be attributed to this problem.

3.5.2 Quantity of Hot Particles

Over 1,410 cubic metres of soil was removed from the yard area and placed in the Soil Staging area (SSA) as clean material. Subsequently, sampling results indicated that this soil was contaminated with hot particles.

GA staff could not identify with certainty the mode(s) of transport that resulted in the hot particles being in the soil. Hot particles from projects involving HTGR coated particle fuel were known to be present at the HCF. Spills, including a flooding incident caused by a hose failure and other activities over the years, provided the transport modes that allowed migration of hot particles into the service yard. Even with these known circumstances and spills, the quantity and pervasiveness of the hot particles in the soil was unexpected. It is possible that some of the hot particles could have been buried in the top soil during decommissioning activities, including digging, transporting and packaging of various waste products. Other hot particles were found on old surfaces not identified in drawings and which had been covered with asphalt or dirt. Some hot particles could not be detected until the background radiation levels were low.

When considered as a bulk quantity, this contaminated soil was below release limits. However, to avoid a long and uncertain regulatory review with DOHS and the NRC, DOE and GA made the decision to disposition the soil as radioactive waste. As noted in Table 3-1, the volume of contaminated soil was much greater than expected, partially due to this characterization difficulty. Over 1,410 cubic metres of the difference can be attributed to this problem.

A GA representative commented that, in his experience, the largest cost uncertainty associated with any decommissioning project is the extent to which radioactivity and hazardous materials have contaminated a facility and the surrounding environment.

3.5.3 Quantity of Low Level Waste from Decommissioning Debris

The actual volume of construction debris was four times more than the estimated volume. A partial explanation could be that characterization of the hot cells was based on limited measurement and a review of information regarding the various projects carried out in the hot cells over the years of operation.

3.5.4 Characterization versus Total Phase I Costs

At $11.788 million, the cost of Phase I represented a significant portion of the HCF decommissioning. Characterization, packaging, transport and temporary storage of IFM represented about 43.6 percent of the Phase I cost, see Table 4-1, representing the biggest single cost contributor for this phase. The cost of waste disposal for this phase represented another 11.4 percent. As a result, site characterization and project mobilization, the tasks usually associated with the initial phase of a decommissioning project, accounted for less than half (45.0 percent) of the Phase I cost. The cost of site characterization and compilation of the associated report represented only 8.9 percent of the Phase I costs.

3.5.5 Dismantlement versus Total Cost of Phases II and III

The direct cost of waste disposition (32.7 percent), materials and services (16.8 percent) and maintenance (14.4 percent) were the biggest contributors to the cost for these phases. Labour for dismantlement nominally was only 5.2 percent of the cost. However, a large portion of the materials and services cost was for external contractors involved in concrete cutting, which was a dismantling activity, and at least some of the oversight effort would apply to this as well. If the entire cost for site supervision, project management and materials and services were attributed to dismantlement, then the cost of dismantlement becomes 31.9 percent of the total cost.

For the HCF decommissioning project, the direct cost for the key task of characterization was significant in absolute terms (~ $1million) but relatively small as a percentage of the total project cost.

4. HCF Decommissioning Cost Analysis

4.1 *Program Cost Breakdowns*

4.1.1 *General*

All costs referred to in this section are stated in terms of 1998 U.S. dollars. The cost of decommissioning the HCF was approximately $35.5 million. Table 4-1 breaks down this total cost by work category and then by project phase.

As noted in section 3.1, the HCF decommissioning consisted of four phases. The shipment of IFM to INEL was not officially defined by project management as "Phase IV" but in effect it was a separate phase of the project.

Table 4-1 HCF Decommissioning Cost Breakdown (1,000s, US$1998)

Work Breakdown Structure Category	Phase 1	Phases 2 & 3	Ship IFM to INEL	Total	% of Total
Waste Disposal	1,340	7,182	0	8,522	24
Package/Transfer IFM to Temporary Storage	5,144	410	0	5,554	15
Structural Decontamination & Dismantlement					
Labour	0	1,151	0	1,151	-
Materials & Services	0	3,689	23	3,712	-
Subtotal	0	4,840	23	4,863	13.7
Maintenance	952	3,156	0	4,108	12
Project Management	511	1,540	436	2,487	7
Compliance	367	1,109	264	1,740	5
Plans, Procedures & Training	1,398	390	0	1,788	5
Characterization	1,052	0	0	1,052	3
Operations & Site Supervision	322	633	0	955	3
Quality Assurance	196	1,231	0	1,427	4
DOE Requirements & Requests	303	655	0	958	3
Final Surveys	0	673	0	673	2
Other	203	167	981	1351	4
Total	**11,788**	**21,986**	**1,704**	**35,478**	**100**

In addition to noting the individual status of expenditure on IFM handling and waste disposal, there are several large expenditures listed in Table 4-1 that require further explanation. These include the “Plans, Procedures and Training” in Phase I; and “Maintenance” and “Materials and Services” under Phase II.

First, consider “Plans, Procedures and Training” in Phase I. Due to the nature of the government finding, considerable efforts were required to gather information and compile it into extensive reports, four examples of which were the Project Plan / Project Management Plan; Environmental Assessment for the Decommissioning and Decontamination of the GA HCF; Hazards Analysis for the GA HCF; and GA HCF Decommissioning Plan. In addition, extensive written procedures were compiled and training was required on those procedures prior to performing actual work.

Second, under Phase II, the “Maintenance” category requires further definition. Several projects had to be completed in order to prepare the HCF for decommissioning including repairing the roof. Evidence of leakage existed and the repairs were required to prevent in-leakage of water during the decommissioning efforts. The roof also was externally contaminated, which complicated the roof repair project. In addition, some of the ventilation ductwork had to be re-routed and the stack monitoring system had to be replaced.

The cells had to be kept in a state of operational readiness until the cells were sufficiently decontaminated to allow access by personnel. In 1993, the HCF decommissioning project was officially designated a project under the Surplus Facility Management Program and government funding for the project began. As a result, during 1993 to about 1997, personnel involved in maintaining the operational readiness of the HCF were charging time to the “Maintenance” category under the project.

Third, under Phase II, the “Materials and Services” expenditures provided tools and equipment for the GA personnel as well as contractor services for HCF dismantlement and other Phase II activities. The large majority of this category was for services provided by two contractors. One contract was let to a concrete cutting company for an estimated $2.25 million. The other contract was let to an organization with a permanent presence at the GA Site that provided labourers, millwrights, equipment operators, etc.

4.1.2 *Man-hour Distribution for Phase I - III*

The man-hours devoted to major project tasks for Phases I - III are listed in Table 4-2. Note that the time required to characterize the facility was greater than the time devoted to actually dismantling the HCF.

Table 4-2 HCF Distribution of Man-Hours Expended and Related Costs (1,000s, US$1998)

Phase I Tasks	Man-hours	U.S. $	%
Plans, Procedures & Training	21,678	1,398	26.4
Characterization	16,313	1,052	19.8
Maintenance	14,762	952	17.9
Project Management	7,924	511	9.6
Compliance	5,691	367	6.9
Operations & Site Supervision	4,993	322	6.1
DOE Requirements & Requests	4,698	303	5.7
Other	3,148	203	3.8
Quality Assurance	3,039	196	3.7
Sub Totals Phase I	***82,246***	***5304***	***100.0***
Phase II and III Tasks	**Man-hours**	**U.S. $**	**%**
Maintenance	45,358	3,156	29.5
Project Management	22,133	1,540	14.4
Quality Assurance	17,692	1,231	11.5
Structural Decontamination & Dismantlement	16,542	1,151	10.8
Compliance	15,938	1,109	10.4
Final Surveys	9,672	673	6.3
DOE Requirements & Requests	9,414	655	6.1
Operations & Site Supervision	9,097	633	5.9
Plans, Procedures & Training	5,605	390	3.6
Other	2,400	167	1.6
Sub Totals Phases II and III	***153,851***	***10,705***	***100***

4.1.3 *Waste Handling and Disposal*

Section 3.3 and Table 3-1 provide detailed information regarding the disposition of the waste forms generated from the HCF project. Table 4-3 provides the cost of packaging, transportation and disposing of the waste forms. The cost per truck shipment to the

Hanford Site and NTS in 1998 money value was about $2,340 and $630, respectively. This is based on a rate of $1.0536 per kilometre. There were a total of 301 and 100 shipments respectively to the Hanford Site and NTS; therefore, the costs of truck transportation to the Hanford Site and NTS were $704,340 and $63,000, respectively.

Table 4-3 Waste Volumes (m^3) and Costs of Packaging, Transportation and Disposal for All Waste Forms Excluding Non-Active Waste (1,000s, US$1998)

Waste Form	Waste Type	Quantity (m^3)	Disposal $ per m^3	Total $ per m^3	U.S. $
Concrete and building debris and equipment	LLW	2,674.20	1,557.37	2,263.85	6,054.0
Soil and Asphalt to Envirocare	Radioactive particles in soil	1,713.86	619.77	781.39	1,339.2
Soil to NTS	Radioactive particles in soil	1,632.73	not available	463.90	757.4
Debris including contaminated Pb	Mixed	13.76	not available	26,958.17	371.0

The shipments to Envirocare involved intermodal (truck and train) transport and the costs were not specified separately.

4.2 Derived Benchmarking Results

As mentioned previously, the HCF decommissioning project costs were highly influenced by the requirements of U.S. government funding; therefore, there are a limited number of meaningful benchmarks that can be derived for application to other projects. The preceding quantitative information in this section has been used to derive unit costs for specific project categories. Section 4.1.3 outlines unit costs suitable for benchmarking waste disposition. This section briefly addresses benchmarking for other tasks.

4.2.1 Characterization

As indicated in Table 4-1, the total cost for Phase I was $11.788 million while the cost of characterization was only 8.9 percent of this total. The characterization task included the collection of samples, analyzing the samples and writing a characterization report. The cost of characterization was $1.052 million and required about 16,300 hours. This however is probably a misleading number in terms of benchmarking and requires adjustment for comparison with other projects, for the following reasons.

FACTORS AFFECTING CHARACTERISATION COST

- The effort needed for characterization prior to starting decommissioning to some extent will depend on the extent of routine surveys during the operational life of a facility. If no routine surveys are conducted then characterization would be more involved, requiring more surveys and different types of surveys (e.g. asbestos, chemicals, LLW, etc).
- The characterization effort depends on the radiological condition of the facility. For example, cells can be so "hot" radiologically that conventional sampling cannot be performed directly by personnel, due to the radiation exposure that would be received. At HCF specifically, destructive examinations of fuel and graphite were conducted causing the facility to be extremely contaminated. A committee of GA experts spent two months examining the HCF operations log books to document the materials brought into the cells in an effort to aid the characterization of the cells.
- The extent to which contamination is contained impacts the characterization effort. HCF had microscopic "hot particles" (very small fuel fragments) both outside and inside the facility. A hot cell flooding incident (see section 3.5.2) spread hot particle contamination. The extent of the hot particle contamination was much more than expected so more samples were required during the characterization process.
- The type of waste (HLW, ILW, LLW, mixed, chemical, asbestos, etc) will determine the characterization effort.
- The materials used for facility construction can impact the characterization effort, depending on whether or not they are materials absorbent, or if the materials present a boundary to the spread of contamination.
- The objectives of the D&D effort also affect the level of characterization needed e.g. whether or not some structures will remain in place or if the site will be returned to "green field" status.
- The fact that the HCF was funded by the government made a significant difference in the overall cost of the project and the characterization effort was impacted in several ways, including:
  - Voluminous reports were compiled by staff costing $60 to $80 per hour. These reports included the "Site and Facility Characterization Plan" and the "General Atomics Hot Cell Characterization Report" the latter of which has 680 pages.

  - As with other portions of the project, the characterization effort was compounded because of the need to be very conservative to avoid cost over runs that otherwise might have resulted due to improper characterization of the facility.
- Compared to the items above, the size of the facility is assessed to be a less important factor affecting cost.

A review of the characterization efforts for the Map Tube Facility at the ANL (ref 3) indicates that this required 1,440 hours over six weeks at total costs of $53,100 for direct labour and $146,900 for equipment. The hourly implied labour rate is about $36.90 per hour. If the same hourly rate were used for the HCF characterization, the total cost would decrease from $1.052 million to about $600,000.

IMPACT ON BENCHMARKING RESULT

NAC has considered what reasonably would need to be accomplished to characterize a facility like HCF and the adjustments that might reasonably apply to the HCF actual cost to provide a meaningful basis for deriving a helpful benchmark to apply to similar projects elsewhere, as follows:

- Reviewing other characterization efforts (the ANL Map Tube facility is one example), it is NAC's judgment that a calendar duration of not more than about two to three months would be typical and representative for characterisation, rather than the four months needed at HCF. It appears reasonable on this basis that the HCF cost might be reduced by 25 percent if a less conservative approach were required.
- The hourly rate was high for the HCF project. Other decommissioning projects analysed by NAC suggest that rates in the order of about $40/hour would be more usual for this type of work, versus the $60 to $80/hour indicated for HCF..
- The level of contamination was high at the HCF. A more moderate level of contamination could lead to an estimated time saving of 10 percent
- The spread of contamination required more surveys. Estimated 10 percent time reduction if contamination can be more contained.
- The log book review committee spent two months (assumed three people for three man-months) reviewing the operation logs of the facility. This function generally would not be required.
- At least two very extensive reports were compiled. Normally the reporting function would be expected to be less rigorous, saving up to two man-months.

Making adjustments for these factors, NAC derives an adjusted, more representative labour resource needed of about 7,700 hours. If a normal rate of about $40/hour were to apply, this would give a little more than $300,000 in cost. If routine surveys and decontamination efforts have occurred during the operational life of the facility, the estimate could even be less. It is of interest to compare this estimate with the actual cost of $310,000 for characterizing the Building 200 hot cell at ANL (see section Table 5-1 in section 5.1.5).

4.2.2 Dismantlement

As with characterization, the actual dismantlement was only a fraction of the cost of conducting Phases II and III. Table 4-1 shows that the total cost for Phases II and III was $21.986 million while the task entitled "structural decontamination and dismantlement" was only $1.151 million or 5.2 percent of this total. The interpretation of this number is not entirely clear but appears to correspond to 15,933 man hours of labour expended specifically on decontamination and dismantlement. However, as noted in section 4.1.1, at least a portion ($2.25 million) of "Materials & Services" should also be included in the actual cost of dismantlement. This increases the direct cost of dismantlement to $3.401 million, or $1,134 per m^3 of demolition debris produced. On top of this it may be appropriate to allocate some of the site supervision/project management costs (see also section .

4.2.3 Waste Volume

The volume of concrete and building debris was 10 to 11 times the volume of concrete that formed the hot cells. This is in line with general experience of these types of facility.

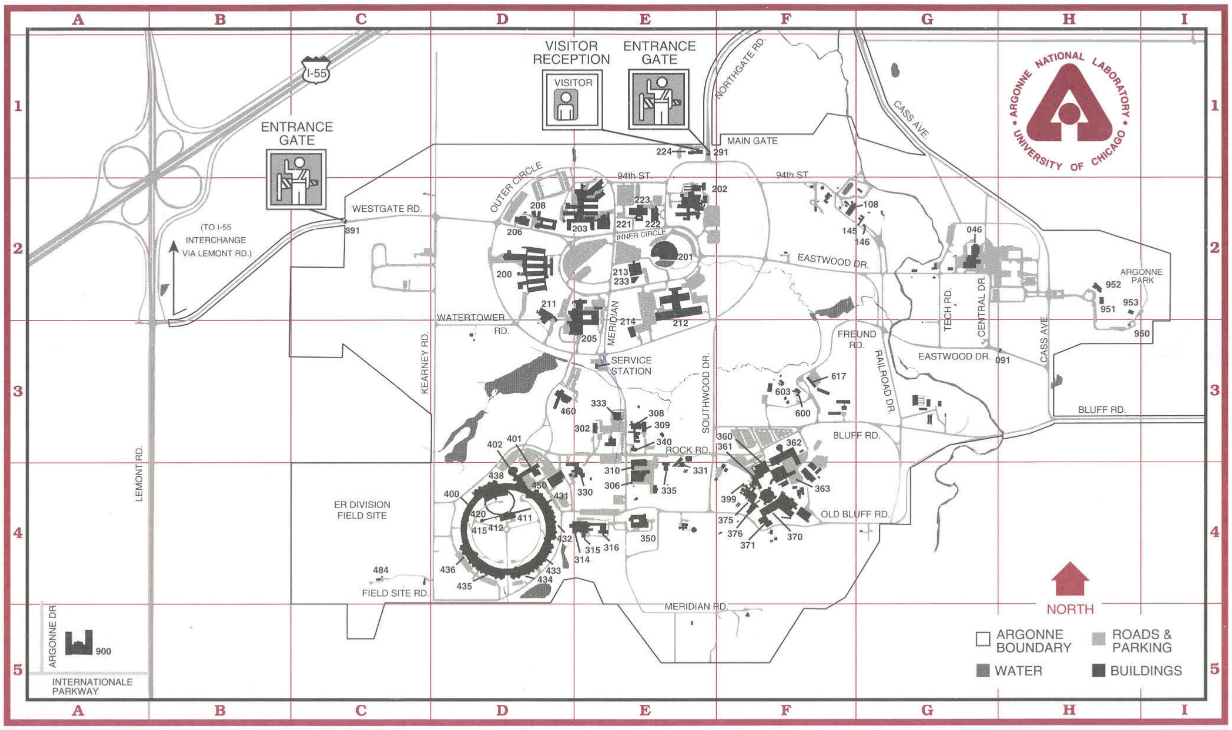
5. Description of Decommissioning Plans for Hot Cells at the Argonne National Laboratory and the Hanford Reservation

The information presented in this section is included mainly as qualitative background to illustrate approaches and experiences in decommissioning projects for other hot cell facilities. Also some additional quantitative benchmarks are derived for potential use in future cost estimating exercises.

5.1 Decontamination of the Building 200 M-Wing Hot Cells at Argonne National Laboratory

The Building 200 Hot Cells are located in the 200 Area of the Argonne National Laboratory (ANL) located about 40 kilometres from Chicago, Illinois, USA. The 200 Area is situated in the north central portion of the ANL site, see sector D2 of Figure 5.1.

Figure 5.1 Site Map of Argonne National Laboratory



BUILDING LOCATOR (Building Number – Grid Location)

East Area	100 Area	200 Area		300 Area		360 Area	400 Area		600 Area	800 Area	Offsite	ANL Park
046 – G2	108 – F2	200 – D2	212 – E2	302 – E3	316 – E4	360 – F4	400 – D4	433 – D4	600 – F3	891 – C2	900 – A5	950 – H3
091 – H3	145 – G2	201 – E2	213 – E2	306 – E4	330 – E4	361 – F4	401 – D4	434 – D4	603 – F3			951 – H2
	146 – G2	202 – E2	214 – E3	308 – E3	331 – E4	362 – F3	402 – D4	435 – D4	617 – F3			952 – H2
		203 – E2	221 – E2	309 – E3	333 – E3	363 – F4	411 – D4	436 – D4				953 – H2
		205 – E2, E3	222 – E2	310 – E4	335 – E4	370 – F4	412 – D4	438 – D4				
		206 – D2	223 – E2	314 – E4	340 – E3	371 – F4	415 – D4	450 – D4				
		208 – D2	224 – E1	315 – E4	350 – E4	375 – F4	420 – D4	460 – D3				
		211 – D2	233 – E2			376 – F4	431 – D4	484 – C4				
			291 – E1			399 – F4	432 – D4					

ANL-624

5.1.1 Building 200 M-Wing Hot Cells Description

In 1961, a wing of hot cells was added to Building 200 for isotope separation and research on heavy radioactive isotopes, see Figure 5.2 and Figure 5.3. The addition, referred to as “M-Wing,” consisted of three so-called megacurie cells and a waste processing cell on the service level of the wing. Each hot cell is 5.5 metres long, 4.3 metres wide and 3.7 metres high. The walls are 1.2 metres thick.

Figure 5.2 Plan View of Building 200 Service Floor Showing Location of the Megacurie Hot Cells

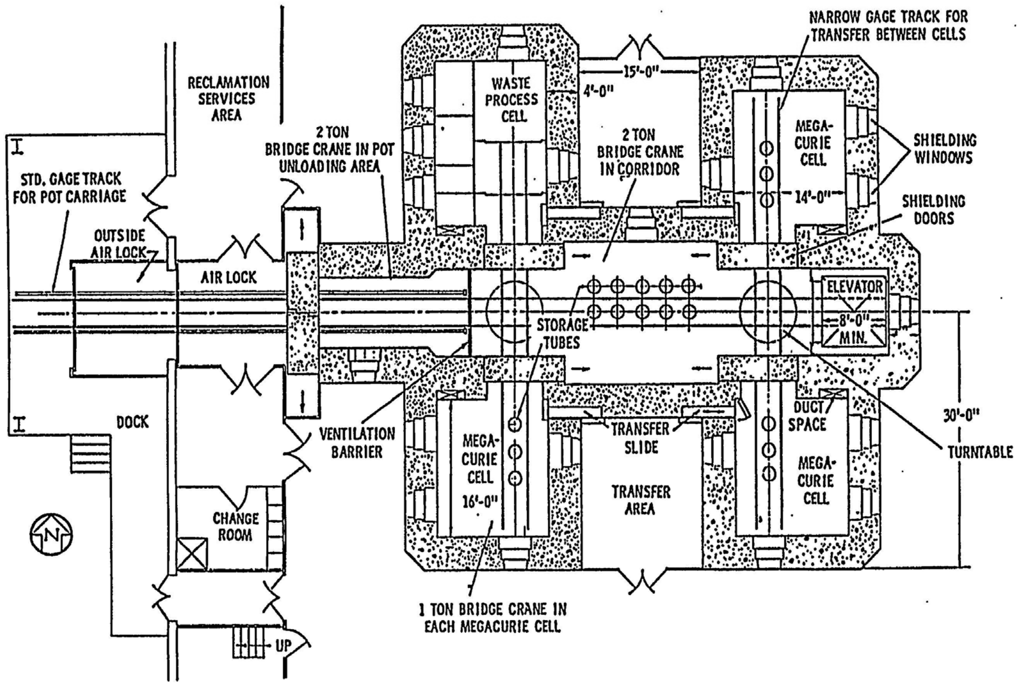
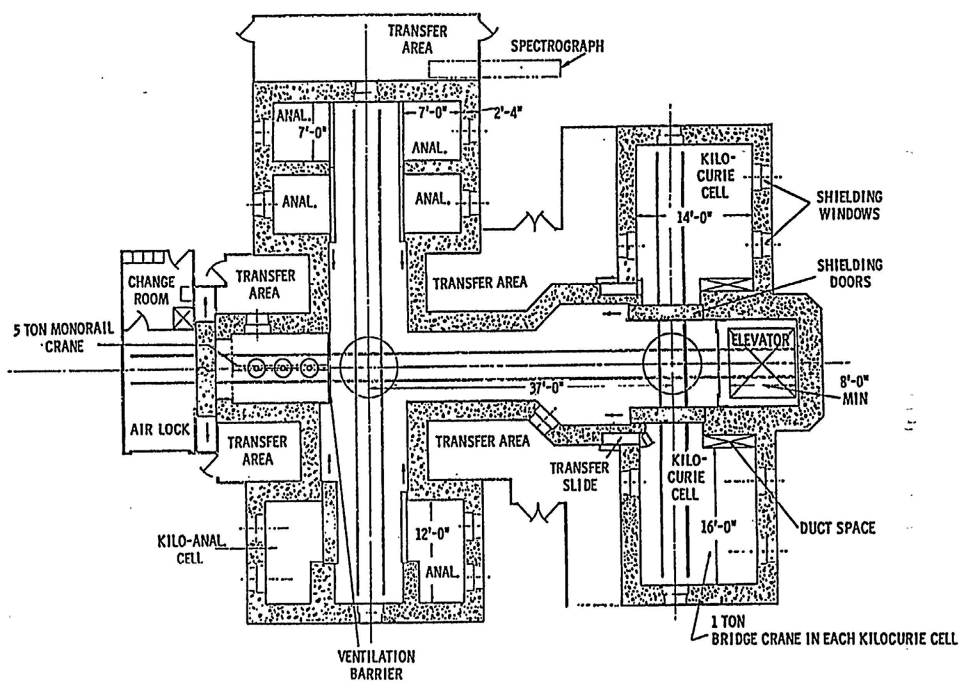


Figure 5.3 Plan View of Building 200 Main Floor Showing Location of the Kilocurie Hot Cells



On the main level of the wing, there are a total of eight hot cells, two of which are designated as kilocurie cells and are the same dimensions as the megacurie cells but with thinner walls (0.7 m). The other six cells are designated as analytical cells and are considerably smaller than the kilocurie cells but have the same wall thickness.

Two of the megacurie cells (M-1 and M-3) and both kilocurie cells (K-1 and K-3) were used for research on the breeding of fissile isotopes in irradiated thorium rods from the U.S. Navy's Shippingport Nuclear Plant. The research involved precise shearing of the rods in Cell M-3, dissolving of the samples in concentrated acids in Cell M-1, preparing dissolver solution samples for radio assay in Cell K-3, and pumping the waste dissolver solution to waste cementing stations in Cell K-1.

Cell A-1 was used for pulverizing irradiated reactor fuel specimens from the Zion Nuclear Plant (Zion, Illinois, USA) for analyses to quantify breeding of fissile isotopes.

5.1.2 Decontamination Project Scope

The purpose of the Building 200 M-Wing Hot Cells Decontamination Project was to practically eliminate the radioactive emissions of Rn-220 to the environment and thereby reduce the source term at ANL and restore the hot cells to a restricted use-condition. Before project initiation, about 96.2 TBq per year of Rn-220 was being emitted from the radioactive contamination left in the hot cells at the end of the breeder program studies in 1985.

After decontamination, the objective was to maintain the hot cells for future use and actively pursue projects to support the facility.

5.1.3 Decontamination Project Implementation

Prior to protected entry by project team members, the first step of the project consisted of remote disassembly of equipment and remote decontamination work. This step included surveying, HEPA vacuum cleaning, wet wipe cleaning, dismantling of equipment, and packaging and segregating radioactive waste. Two pairs of heavy duty manipulators were procured to facilitate the remote tasks. An existing radio-controlled rail cart system was used for moving remote-handled (>2,000 μ Sv per hour) radioactive waste.

The second step involved additional decontamination by protected entry of project team members into the hot cells. An entry into a hot cell by two technicians was supported by five additional personnel. Decontamination techniques included HEPA filter vacuuming, wiping with cotton rages or wiping with absorbent paper wipes wetted with an aqueous detergent solution. Strippable paint was used in repeated steps. Scabbling was used to remove fixed contamination if the other techniques were unsuccessful.

A final survey was conducted to confirm the results of the decontamination project.

Upon project completion, the hot cells were emptied and decontaminated for restricted use. The goal of practically eliminating radioactive emissions from the five hot cells was achieved.

5.1.4 Waste Volumes

Extensive equipment and structures in the hot cells needed to be removed as radioactive waste. The waste forms and associated disposition were as follows:

1. Ten 208-liter drums with a total volume, weight and activity of 2.1 m^3, 1.028 metric tons, and 3.79 TBq. Due to the activity these drums were handled remotely and sent to a DOE LLW radioactive waste site.

2. 146 miscellaneous-sized containers with a total volume, weight and activity of 76.97 m^3, 22.468 metric tons, and 0.283 TBq. Of this total, 7.1 m^3 was classified as mixed waste. This waste was sent either to a DOE LLW radioactive waste site or mixed waste facility.

3. Contaminated lead shielding bricks with a total volume of 0.68 m^3 and weight of 7.7 metric tons were taken to ANL Waste Management for decontamination and recycling.

5.1.5 Project Schedule and Cost

The project was carried out by ANL personnel during 12 September 1991 through 2 March 1996.

The project was completed at a total cost of $5.8 million. Table 5-1provides a breakdown of the project costs.

Table 5-1 Building 200 M-Wing Project Cost Breakdown (1,000s US$1994)

Category	Cost	% of Total
Characterization	310	5.3
Engineering and Procedures	730	12.6

Equipment Procurement	466	8.0
Project Management	725	12.5
Surveillance and Maintenance	923	15.9
Decontamination by Cell		
Hot Cell A-1	101	1.7
Hot Cell K-1	573	9.9
Hot Cell K-3	285	4.9
Hot Cell M-1	874	15.1
Hot Cell M-3	502	8.7
Repackage Orphan Waste	311	5.4
Total	**5,800**	**100**

5.1.6 Key Sensitivities

Several lessons-learned were recorded at the end of the project.

1. Establish effective procedures and controls to prevent the spread of radioactivity when manipulators and other remote devices are removed.

2. Decontaminating the least contaminated cell first and continuing with other cells until the most contaminated cell was last proved to be an effective process.

5.1.7 Derived Benchmarking Results

DECONTAMINATION

The M-Wing Decontamination Project provides a basis for separately estimating the cost of decontaminating a hot cell.

First, a spectrum of unit costs can be derived as follows:

1. Highly contaminated hot cell (radiation levels in the range of 100 to 1,000 mGy per hour) - about $7,300 per square metre.

2. Moderately contaminated hot cell (radiation levels in the range of 10 to 100 mGy per hour) - about $4,500 per square metre.

3. Lightly contaminated hot cell (radiation levels in the range of 1 to 10 mGy per hour) - about $2,400 per square metre.

Based on activity removed, the unit cost of decontaminating the five cells was about $600 per TBq.

WASTE FROM DECONTAMINATION

The amount of waste arising from hot cell decontamination and the associated cost of packaging it is not something that is specifically identified in the HM cost estimate report. For completeness and in case the HM report might be refined in the future, the data available for the highly contaminated hot cells in Building 200 results in the following:

Weight of waste from decontamination of 5 hot cells	Decontamination cost per kg waste
23,496 kg	$99.38

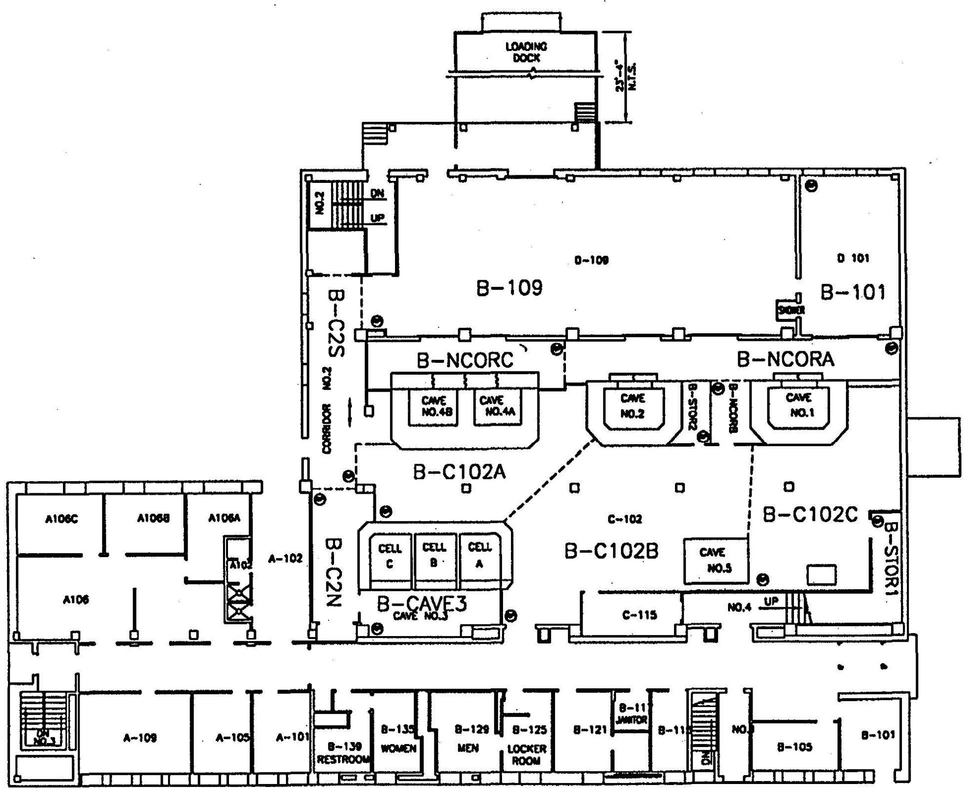
Volume of decontamination waste	Decontamination cost per m^3 waste
79.07 m^3	$29,530

5.2 Characterization for the Building 301 Hot Cells at Argonne National Laboratory

5.2.1 Building 301 Facility Description

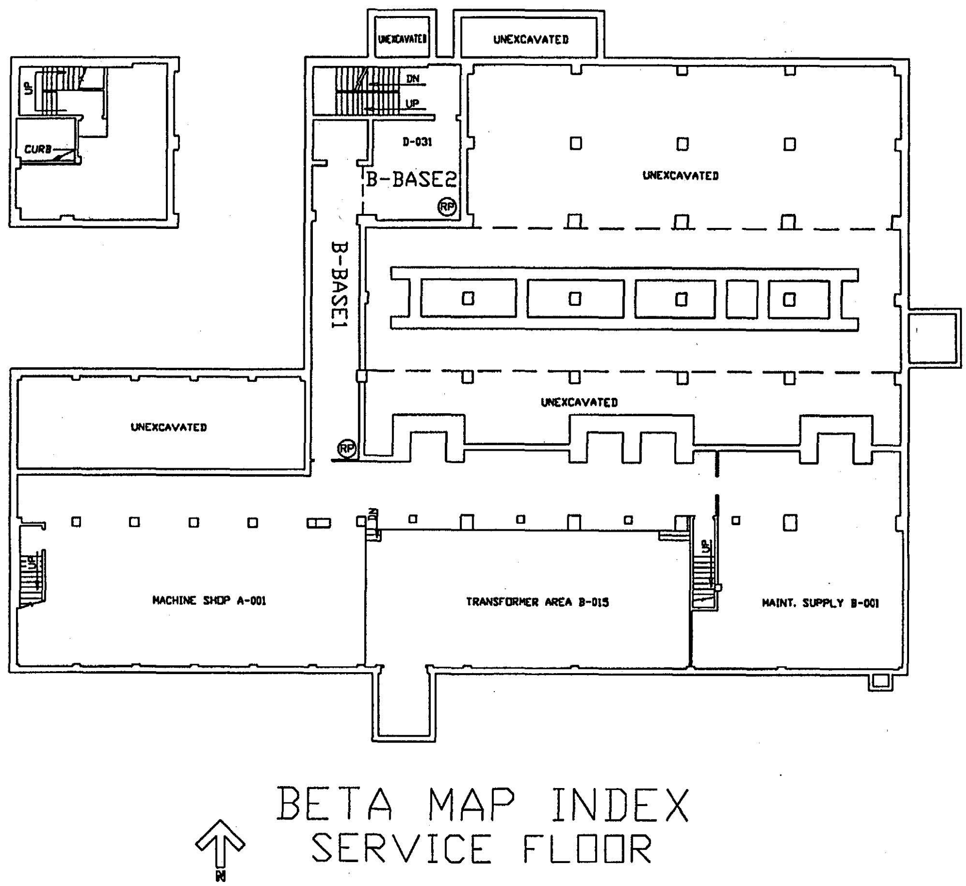
The Building 301 facility is located in the 300 Area of the ANL, see sector E3 of Figure 5.1. The building covers an area of 986.7 square metres with two main floors, a basement service floor and a sub-basement retention tank room. The facility has eight hot cells, see Figure 5.4 and Figure 5.5. This hot-cell facility was completed and became operational in the early 1950s to perform a variety of radiological research and development experiments for DOE on nuclear reactor fuel components and materials. Radioactive operations of the hot cells ceased in 1971 because the cells were obsolete and deteriorating. From 1971 until it was taken out of active use in 1992, the facility was used for projects that did not involve radiation or contamination. In 1974, paint was applied to the interior of the cells to fix contamination to minimize the risk of personnel contamination.

Figure 5.4 Main Floor: Beta/Gamma Survey Units Locator Map



BETA MAP INDEX
MAIN FLOOR

Figure 5.5 Service Floor: Beta/Gamma Survey Units Locator Map



5.2.2 Characterization Project Scope

Originally, building characterization was based on defining the contamination that had to be removed in order to return the building to its original use. Characterization tasks were performed during October 1997 through March 1998. While primary emphasis was placed on radiological evaluation, the presence of non-nuclear hazardous and toxic material was also included in the scope of the characterization.

Work records were largely nonexistent for the early history of the building so assumptions about the extent and type of contamination could not be undefined in the survey planning process. The primary contaminant was found to be Cs-137 embedded in the concrete floors (85.84 MBq), although a variety of other radionuclides consistent with hot cell projects were found in smaller quantities. Due to leakage through the floor, a relatively modest amount of soil contamination was found in the service trench under the building, not penetrating deeply. Two contaminated, disconnected drain lines leaving the building could not be traced by site records and remain a problem for remediation. Location of where the lines run probably will have to be determined through metal detection or direct excavation.

Subsequent to the completion of the characterization of Building 301, ANL management decided that the facility would not be returned to restricted use and should be completely dismantled and the site returned to green field. Currently, additional characterization is being conducted so that an estimate can be compiled for the decontamination and dismantling of the facility.

ANL management is awaiting funding for the decontamination and dismantling project.

5.3 Building 324 Radiochemical Engineering Cells and Vaults at the Hanford Site

5.3.1 Building 324 Facility Description

The Building 324 Hot Cells are located in the 300 Area of the 1,450 square kilometres, Hanford Site which is located north of Richland, Washington, USA. The 300 Area is situated in the southeast corner of the Hanford site, see Figure 5.6. The 300 Area included a number of facilities where significant research was conducted regarding special nuclear materials. Building 324 is located in the northeast corner of this area, see Figure 5.7

Figure 5.6 Hanford Site

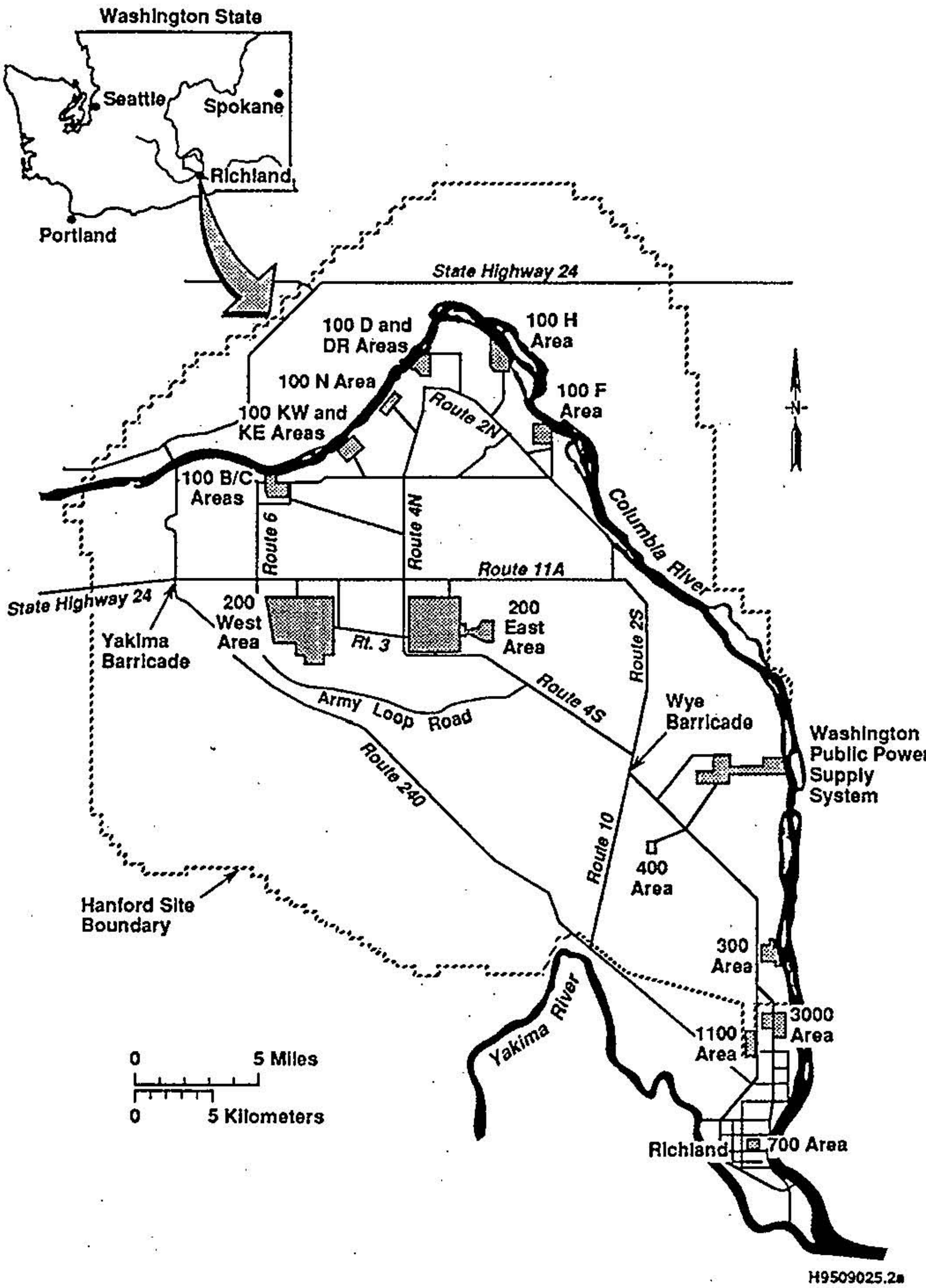
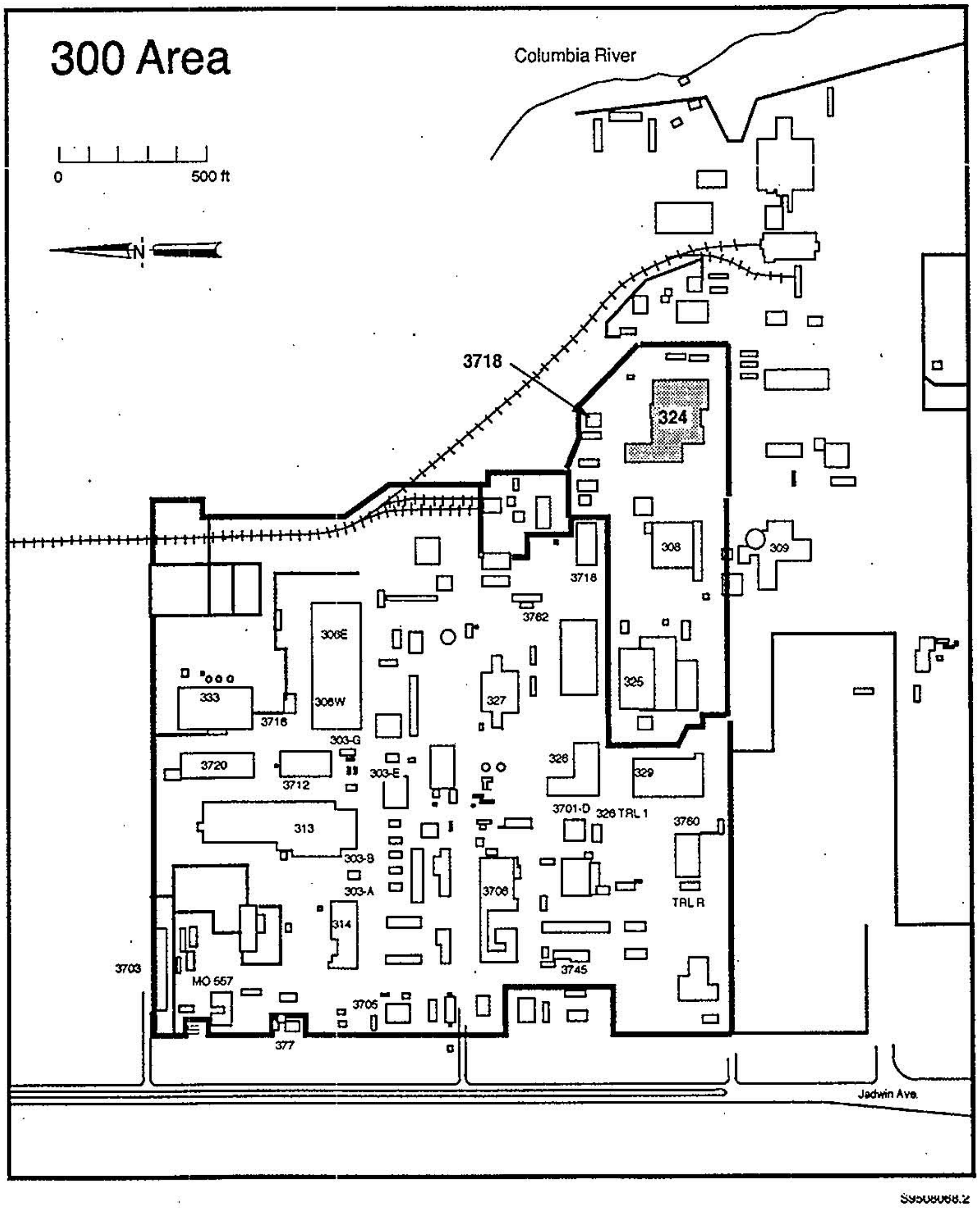


Figure 5.7 Area and Location of 324 Building



Building 324, known as the Waste Technology Engineering Laboratory, is a concrete and steel structure that was constructed during 1964 – 1965. The building footprint is 4,475 square metres and has a partial basement, two full floors and a partial third floor with a combined accessible floor area of 9,450 square metres. The facility is divided into four primary work areas that have a total of 6,164 square metres. The work areas include the:

1. Engineering Development Laboratory – 102 (non-radioactive) used for studies of waste immobilization processes for non-radioactive materials, uranium and thorium.

2. Engineering Development Laboratory – 146 (radioactive) used to house unshielded and mildly shielded glove boxes for studies with extremely toxic materials, tracer level fission products and/or plutonium.

3. Radiochemical Engineering Cells (four hot cells designated A through D) used for numerous studies with radiation levels up to 10,000 Sv.

4. Shielded Materials Facility (Two hot cells for feed preparation and fabrication) used for research and fabrication studies on metallic and ceramic fuel materials with radiation levels up to 10,000 Sv.

Two shielded vaults (high level and low level) contain stainless steel tanks for temporary segregation and hold-up of radioactive liquid feedstocks, or waste, from chemical processing or cleaning operations in the hot cells.

Figure 5.8 through Figure 5.12 provide a detailed view of the facility.

Figure 5.8 Cut-away of the 324 Building Showing the High-Level Vault, Low-Level Vault, and the Radiochemical Engineering Cells

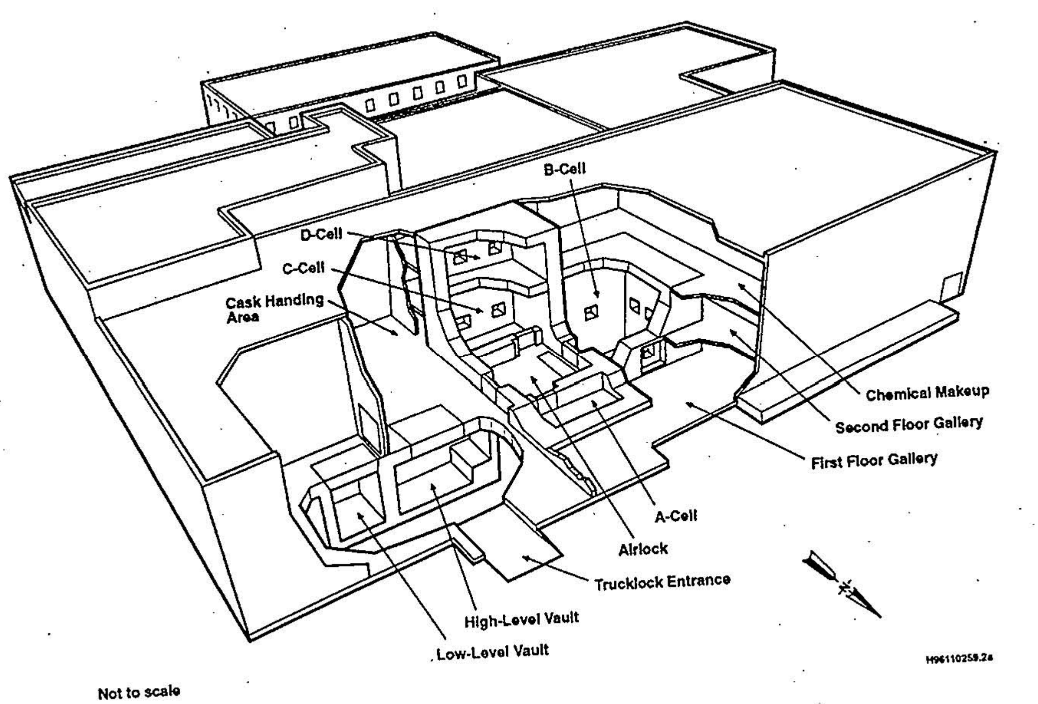


Figure 5.9 324 Building Basement Plan

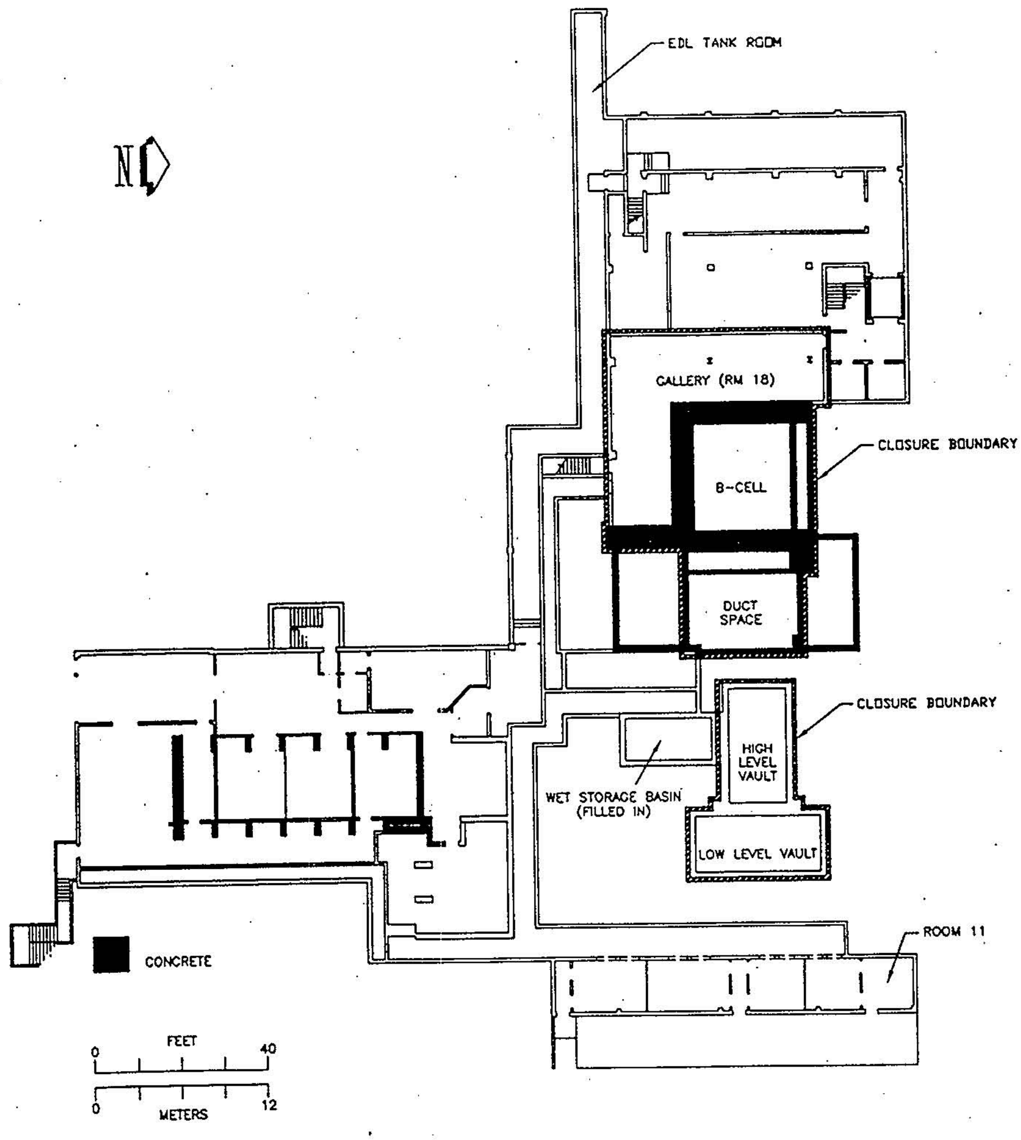


Figure 5.10 324 Building First Floor Plan

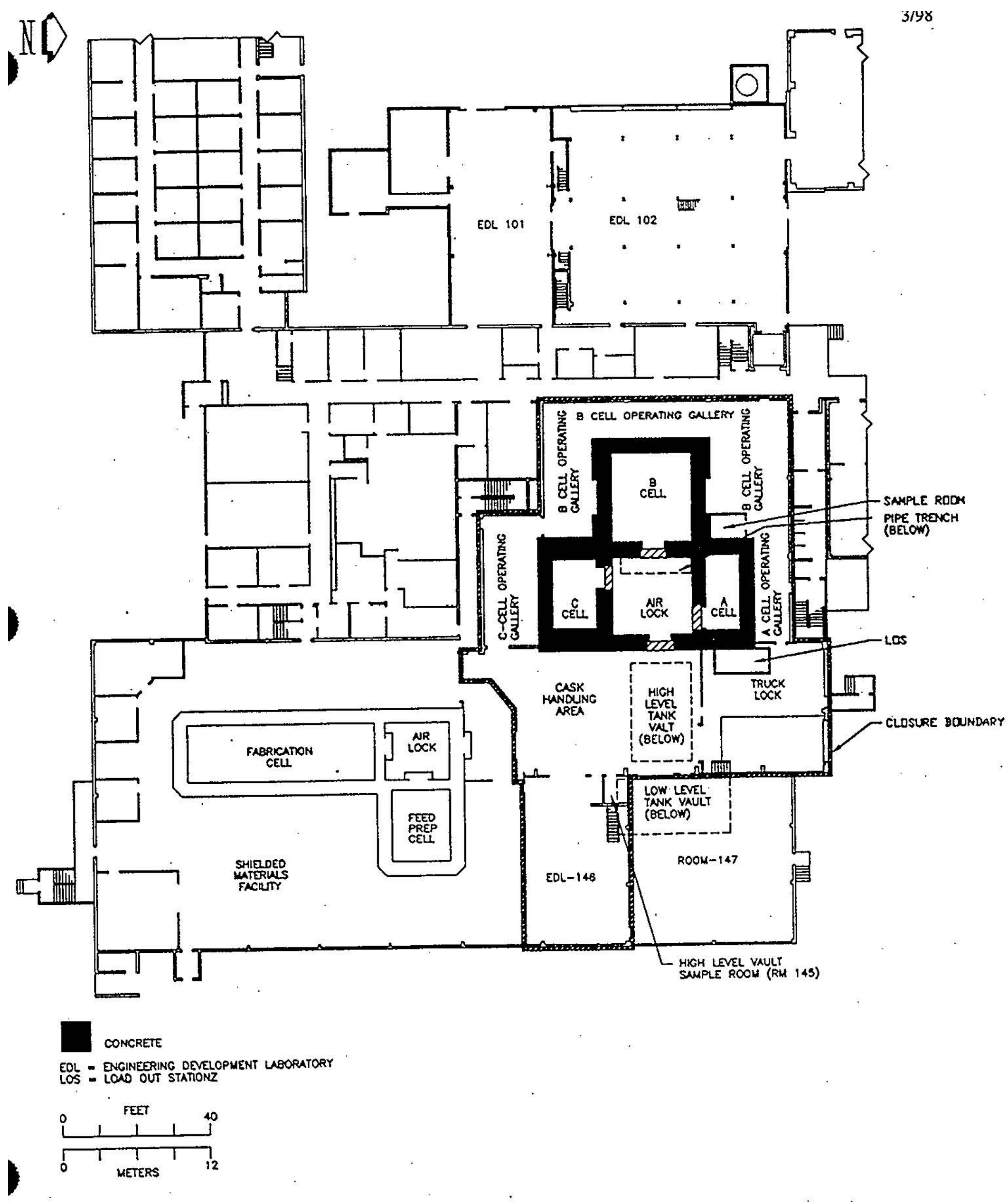


Figure 5.11 324 Building Second Floor Plan

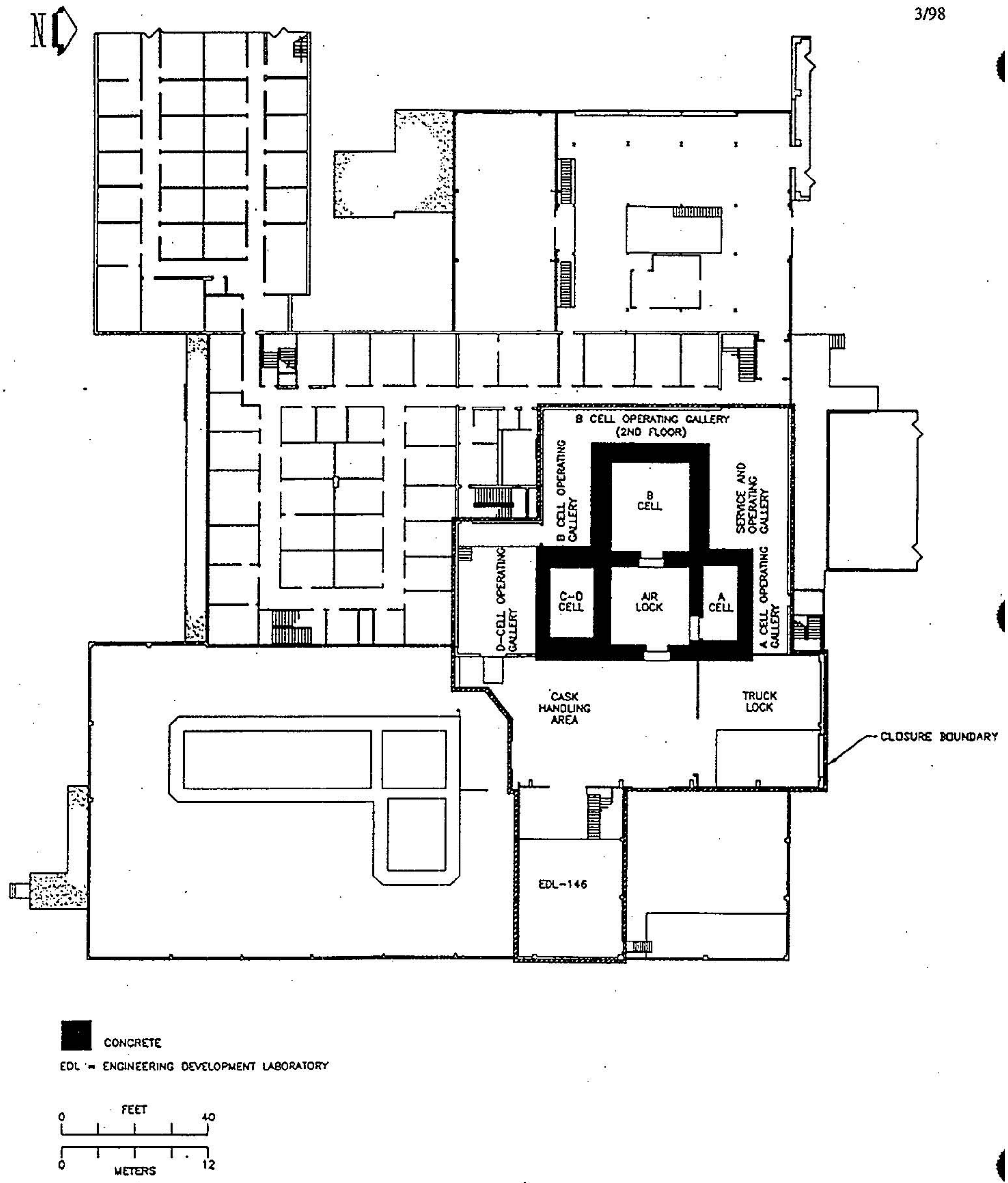
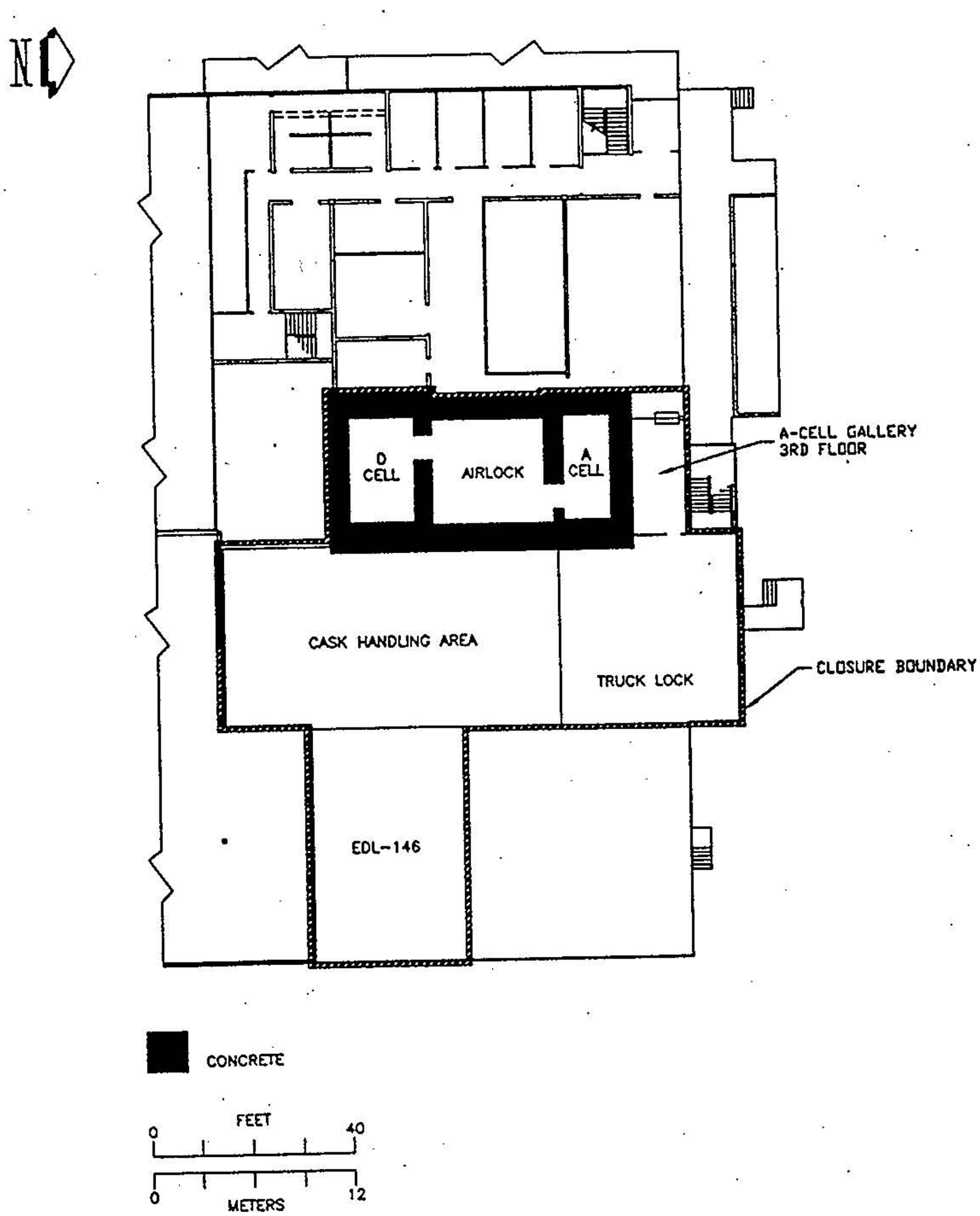


Figure 5.12 324 Building Third Floor Plan



5.3.2 *Decommissioning Project Scope*

As with most of the buildings in the 300 Area, the objective is to completely dismantle Building 324. As of the end of 2002, the last of the spent fuel segments, pieces and fragments had been removed from Building 324, packaged in a GNS-12 cask and transported to the Central Waste Complex at the Hanford Site. Therefore, the radioactive waste from the dismantling task will only be associated with loose or fixed contamination.

Currently, the building is being characterized so that decommissioning plans, cost estimates and schedules can be compiled. In addition, a contract for the engineering work for the dismantling project will soon be concluded.

The dismantling needs to be complete by 2010 in order to meet the schedule objective between the State of Washington and the U.S. Government so the project is focusing on completing building dismantlement by 2009 to ensure that the schedule is met.

6. Comparison of the GA Hot Cell Facility with the Studsvik HM Facility

6.1 HM General Information

The HM facility was constructed to handle and package medium-active solid and liquid wastes, prior to disposal. The facility is constructed on three floors, set into sloping ground on the Studsvik site. Central to the facility is a conventional hot cell including three work stations, serviced by master slave manipulators. Other parts of the facility include holding tanks for liquid wastes and slurries, a centrifuge room, as well as an encapsulation station where drummed wastes can be encapsulated in cement, offices, laboratories and workshops and so on. On the third floor, within the roof structure, is the ventilation equipment, including banks of HEPA filters for the removal of radioactivity from building and cell ventilation streams.

Man access to the hot cell is feasible and a radiological survey of the building is conducted twice per year. In the past there have been overspill events in the drum conditioning room but these have been cleaned up. Operating staff at HM believe that there may be some plutonium contamination in the hot cell but details are not available.

6.2 HM Physical Details

HM is approximately 50m long by 20 to 30m wide and 10 to 13m in height. Figure 6.1 through Figure 6.9 show the general layout of the facility, as well as selected photographs of the hot cell operating room, over cell accesses and the ventilation room equipment. The building has a mixture of heavy concrete walls, including the 1m thick hot cell walls, as well as lighter wall construction. As can be seen from the photographs presented in Figure 6.5 through Figure 6.9, HM is in generally good condition, tidy and clean.

The overall building volume is quoted as 11,900m^3 gross. However, for the purpose of the dismantling study a lower volume of 11,070 m^3 is relevant. The decommissioning plan estimate assumes that about 830m^3 of the basement volume will be left in place and backfilled with inactive dismantling debris, prior to being covered over with soil. The hot cell itself has internal dimensions of 8.6m x 3.5m x 4.2m high, giving an internal volume of 125.7m^3 and a surface area of 161 m^2. The hot cell has a steel lining.

Figure 6.1 Cut-Away View of HM[4]

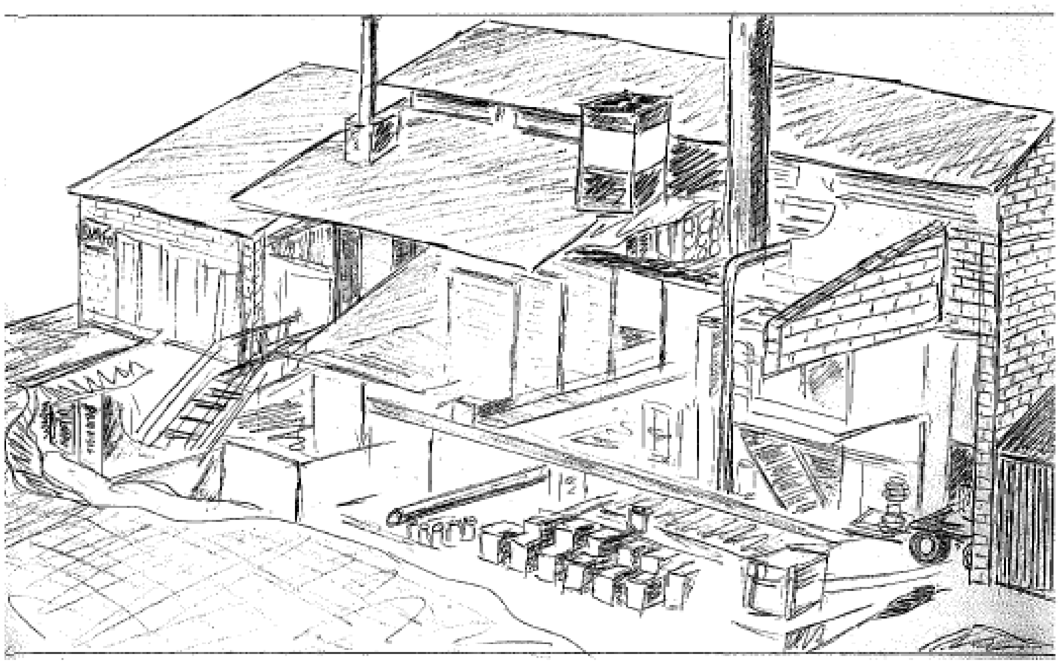


Figure 6.2 Cut-Away Schematic of HM Tank Rooms

This figure was provided to SKI but has been redacted from the final report at the request of AB SVAFO, on grounds of physical security.

Figure 6.3 Cut-Away Schematic of HM Hot Cell, Operating Room and Hot Cell Waste Accesses

This figure was provided to SKI but has been redacted from the final report at the request of AB SVAFO, on grounds of physical security.

[4] This figure is a substitute outline sketch of the facility, prepared by NAC based on an original provided by Studsvik. The original is not included at the request of AB SVAFO, on grounds of physical security.

Figure 6.4 Cut-Away Schematic of HM Hot Cell Drum Transfer Arrangements and Cementing Station

This figure was provided to SKI but has been redacted from the final report at the request of AB SVAFO, on grounds of physical security.

Figure 6.5 Photograph of Hot Cell Operating Room

Figure 6.6 Photograph of Drum Transfer Port Above HM Hot Cell

Figure 6.7 Photograph of Additional Accesses Above HM Hot Cell

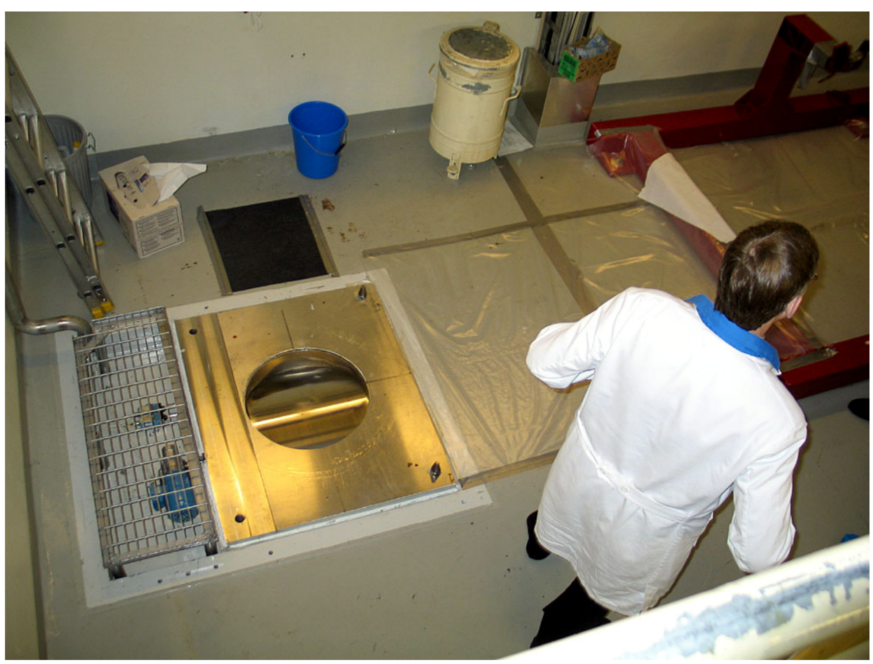
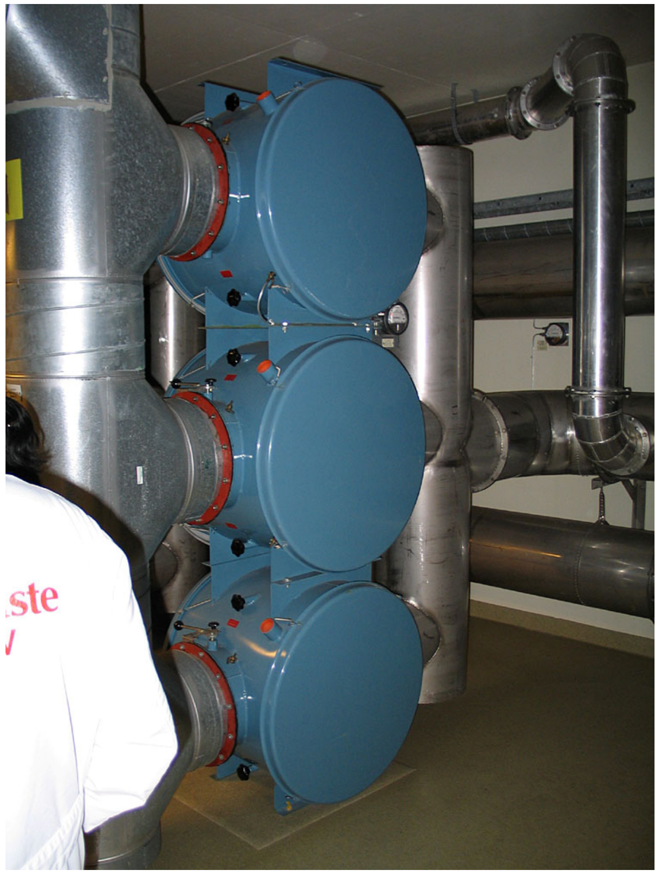


Figure 6.8 Photograph of HM Ventilation Room

Figure 6.9 Photograph of HM HEPA Filters in Ventilation Room



HM therefore is broadly similar to the HCF but some notable differences exist, as follows:

- HCF was more heavily contaminated, having conducted operations such as band saw cutting of hexagonal graphite high temperature reactor fuel elements.
- Substantial concrete vault structures existed below grade, underneath the hot cells and other rooms at HCF and, importantly, access for demolition of these parts required extensive excavation.
- Good as-built drawings of HCF were not available to the team planning the decommissioning exercise. This meant that some of the pits and vaults underneath, for example, were not well characterized.
- Some leakage and migration of radioactive particles into the surrounding soil was discovered, resulting in extensive excavation and removal of soil.

6.3 Decommissioning Scope and Methodology

6.3.1 Overview

The end goal for HM is to dismantle the whole facility except for part of the basement area that will be backfilled with dismantled building waste and then covered over with soil. This contrasts with HCF where everything had to be removed. The general approach to decontamination and dismantling appears to be similar but some activities at HCF have been carried out in a different way at the detailed level e.g. specific decontamination and removal techniques for the steel liner of the hot cell. The choice of decontamination techniques inside the hot cells at HCF avoided the use of sand blasting because this would have caused problems with the fine mechanism of the manipulators, which were sold to GE for use offsite.

Table 6-1 presents a global comparison of HM versus HCF in terms of significant physical characteristics and calendar time associated with decommissioning. The general similarity between HM and HCF is visible, yet the time needed for decommissioning HCF was about three times longer than projected for HM. The main reasons for this appear to be the requirement to excavate a lot of soil and, especially, the institutional demands of the DOE. An NAC source involved directly with the HCF decommissioning program commented very strongly to the effect that DOE reporting and compliance requirements were very demanding and time consuming. In addition, DOE dictated a very conservative approach for public perception reasons. For this reason, if there was any doubt about the classification of a waste stream it was categorised as low level wastes and not released for general dumping.

Table 6-1 Global Comparison of HM and HCF

		HM	HCF	Ratio HM/HCF
Building Volume Before Dismantling (m^3)		11,070	10,300	1.075
Estimated/Actual Building Volume After Dismantling (m^3)		2,648	3,000 [(a)]	0.88
Hot Cell Internal Volume (m^3)		125.7	112	1.12
Hot Cell Internal Surface Area (m^2)		161	205	0.79
Actual/Estimated Calendar Time for D&D (months)	Ph I	5	30	0.17
	Ph II	20-21	58	0.35
	Ph III	3-4	1	3-4
	Total	30	89	0.34

a. Excludes excavated soil

6.3.2 *HM Waste Volumes*

Ultimately the disposal of wastes and the related costs are specific to an individual country situation. However a comparison of the nature of the wastes generated and the volumes is of interest. The estimated waste volumes to be generated in the decommissioning of HM are shown in Table 6-2.

Table 6-2 Projected Dismantling Wastes from HM Decommissioning (nominal excluding contingency)

Type of Waste	Status	MT	m^3	Destiny
	Contaminated	41	75	Disposal in SFL
Process Equipment	Non-active	143	213	Released for Dumping
		1,764	706	Backfilling at HM
	Non-active	2,577	1,383	Released for Dumping
Building Material	Contaminated	10	4	Disposal in SFL

The estimated total volume of dismantled waste at HM of 2,648 m^3 including contingencies is about 12 per cent lower than actually achieved at HCF. The biggest difference to HCF is that almost 97 percent of the waste by volume is expected to be non-active and suitable for dumping. It is assumed that the concrete behind the steel liner of the hot cell will not be contaminated. This may or may not be a valid assumption. At HCF contamination was found and it was compounded by the technique selected for removal of the steel liner.

At HCF full cell decontamination was performed in 1978 – believed to include steam cleaning after powder aerosols had been created from band saw cutting of graphite fuel elements. It seems that some of the liner welds anyway had been compromised and the decontamination efforts increased the extent of activity that leaked through into the underlying concrete. In addition, the HCF decommissioning project may have compounded the problem further by using torches to cut the steel liner away, which tended to transfer and fix more activity into the concrete. Notes in the HCF project report suggest that it highly probable that up to 2.5 cm of walls, floors and ceiling concrete behind steel plates of a hot cell will need to be removed, using methods such as scabbling, and disposed of as active waste. The report suggests that this has been a common experience at other hot cell facilities in the past. If any penetrations have been added after initial construction, this also tends to exacerbate the potential problem. All of the steel liner at HCF was disposed of as active waste.

The quality of the steel liner at HM is not known, nor is the detailed radiological and decontamination history. It would however be prudent to note the above observations regarding HCF. HM certainly has handled lower activity materials in general and also a different dismantling technique is proposed. Rather than using torches as at HCF, HM would use a milling cutter to cut the steel plates into strips that can be removed. This method offers the potential for less transfer of activity onto the concrete during dismantling.

In the event that the underlying concrete at HM is contaminated, potentially a surface layer approximately 2.5 cm think may have to be removed as active waste before general demolition. The extra volume of active concrete for disposal on this basis would be about $4m^3$, adding about 0.5 MSEK to the transport and disposal costs. In addition there would be extra cost associated with scabbling the concrete – approximately 1 MSEK based on the HM estimate for $4m^3$. In addition the under side of the steel liner may need additional decontamination work. It is easy therefore to see how an additional 2 MSEK could be added to the decommissioning project cost in this way.

7. Cost Comparisons

7.1 Overall Estimate

The overall decommissioning costs for HM (estimated) and HCF (actual) are MSEK 43.9 and $35.5M respectively. The Swedish figure is in 2001 money values and the U.S. figure in 1998 money values. Normalising to 2001 SEK equivalent values by applying an escalation rate of 2-2.5 percent per annum to the HCF cost and using the historical exchange rate for 2001 of 10.33 SEK/$, the HCF cost becomes about MSEK 392 – higher than HM by almost a factor of 9. An analysis and explanation of this difference follows.

7.2 IFM, Waste Removal and Maintenance Costs

A special requirement at HCF was the removal of IFM (Irradiated Fuel Materials), the costs for which should be taken out before comparison with HM. Equally, it makes sense to take out on both sides the cost for waste disposal, since this is a cost related to local circumstances and they are what they are governed largely by fixed rates. In addition, the exceptional maintenance costs, explained in section 4.1.1, also are not relevant to HM and must be taken out of the HCF cost for comparison purposes. These adjustments reduce the difference to a factor of 5.5 approximately.

	HCF	HM
Base Cost	$35,478k	MSEK 43.9
Subtract IFM removal	-$7,258k	N/A
Subtract Waste Transport and Disposal Cost	-$8,522k	-MSEK 12.588
Subtract Exceptional Maintenance Costs	-$4,108k	N/A
Balance in Local Currency	$15,590k (1998)	MSEK 31.312
Balance in 2001 MSEK	MSEK 172.2	MSEK 31.3

7.3 Planning and Institutional Costs

The next thing to consider is the costs associated with planning, preparation, compliance, DOE requests, site supervision and QA. As stated, for HCF these were relatively high as a result of this being a DOE project and amounted to about $6.6M. In fact this is very similar to the actual cost experienced in the decommissioning of the Westinghouse Test Reactor ($6.297M).

For HM the cost including a 20 percent contingency is approximately MSEK 7.6 i.e. about 9 times lower. The reasonableness of the HM estimate in this regard is difficult to define. The estimates for facilities at Studsvik including AM, AT, R2/R0 and HM all lie within a range of approximately MSEK 6-8. Undoubtedly institutional demands in the U.S. under a DOE sponsored program are more demanding, although this does not necessarily imply any better safety or better end result. It does however mean that substantially more effort is required. The HM cost estimate specifically states that an application to SKI for the HM decommissioning project would not be required and preparation of a safety report also would not be required.[5] Further discussion of requirements is included in Section 7.7.1.

For the purpose of this global comparison, subtracting these planning and institutional related costs gives a new balance is as follows, with a ratio down to about 4 times higher for HCF.

	HCF	HM
Cost Carried Forward	$15,590k	MSEK 31.3
Subtract Planning and Institutional Costs	-$6,604k	-MSEK 7.564
Balance in Local Currency	$8,986k (1998)	MSEK 23.736
Balance in 2001 MSEK	MSEK 99.2	MSEK 23.7

5. Based on advice from SKI (private communication S. Lindskog [SKI] to G. Varley [NAC], 30 March 2006), this is not the case. SKI and SSE oversight will apply with attendant costs.

7.4 Actual Decontamination and Dismantling

The resources needed for actual decontamination and dismantlement may be summarised as follows.

	HCF	HM
Base Decontamination and Dismantling Labour Cost	$1,151k	MSEK 19.128 (incl. 20% contingency)
External Contract for Hot Cell Concrete Cutting	$2,250k (est)	N/A
Allocation of External Supervisory Contractor Hours	$600k (est)	N/A
Base Decontamination and Dismantling Labour Hours	16,542 @ $69.58/hr (1998)	34,423 @ SEK 450/hr
Approximate Equivalent Labour Hours for External Cost [a, b]	24,000 @ $100/hr (1998)	N/A
Building Volume Dismantled	10,300 m^3	11,070 m^3
Unit Cost in Local Currency	$388.45/$m^3$ (1998)	SEK 1,728/m^3
Unit Cost in 2001 SEK	SEK 4,290/m^3	SEK 1,728/m^3

a. Assumes 80 per cent labour and 20 per cent equipment
b. $100/hr rate is an estimate only

The end result in terms of cost is not close, with HM being about 40 percent of the HCF cost on a unit basis. Of most interest is the number of labour hours involved, with HCF being about 18 per cent higher than the HM hours for the real dismantling work. Based on conversation with one of the HCF project staff, the estimated effective working time (actual productive work on the job) is believed to have been in the order of 50 per cent . This is probably not too different from what would apply at HM. The assumptions in the HM estimate and precise data for the actual HCF project are not available. Based on hours expended, taking into account the extra burden and inefficiency that appears to have been caused by working under a DOE program, the HM estimate appears to be of the right order. Caveats to note are as follows.

The HM estimate refers explicitly to building surfaces decontamination with a rate of SEK 3,600/m^2 including 20 percent contingency. The report acknowledges that this is uncertain but an explanation is not given. Decontamination of the storage tanks is not addressed explicitly, so it is not clear if additional costs might apply to such activity. The estimate states the assumption that there will be no contamination of concrete behind the steel liner of the hot cell. As discussed earlier in this section, it may be prudent to make an allowance for such contamination.

The HM cost estimate clearly specifies a cost of MSEK 1.8 (incl. contingency) for tools and equipment in support of dismantling. The HCF project includes a cost of $3.689M for "materials and services" but a detailed explanation of how these are allocated is not available. As shown above, it was indicated that about $2.25M was for the external contractor engaged on cutting the hot cell concrete, of which NAC estimates perhaps $0.45M was for equipment (approximately MSEK 5), which is about 2.75 times higher than assumed for HM. For convenience in attempting to compare HM and HCF costs, the costs in full are subtracted out in the following summary.

	HCF	HM
Cost Carried Forward	$8,986k	MSEK 23.736
Decontamination and Dismantling Labour Costs	-$1,151k	-MSEK 19.128
Materials & Services/Tools & Equipment	-$3,689k	-MSEK 1.8
Balance in Local Currency	$4,146k (1998)	MSEK 2.808
Balance in 2001 MSEK	MSEK 45.8	MSEK 2.81

7.5 Other Costs

The residual cost difference between HM and HCF is substantial at approximately the equivalent of the total estimated cost for the HM decommissioning program. The breakdown of residual costs for HCF is as follows:

Activity	Cost	Percentage
Project Management	$2,051k	49.6
Characterisation	$1,052k	25.3
Final Survey	$673k	16.2
Other	$370k	8.9
Total	**$4,146k (1998)**	**100**

7.5.1 Project Management

The high project management needs at HCF probably are a result of this being a DOE project. The situation at HM is not the same so there is no specific basis to recommend an extra allowance in this category.

7.5.2 *Characterisation*

The higher level of contamination at HCF and the fact that good as-built drawings were not available probably both contributed to the need for a significant effort in terms of characterisation. DOE reporting requirements also probably were a driver for the extent of this activity.

At HM it is understood that radiation surveys are conducted routinely twice per year. If comprehensive then it is possible that there would be no need for special additional efforts immediately prior to decommissioning. However, it may well be the case that a full radiological mapping of the facility immediately prior to decommissioning would add information that would be helpful in the design, planning and execution of the decommissioning program. Based on benchmarking data from section 4.2.1 the cost for such activities at HM could be in the order of $300,000 as a maximum, or up to about MSEK 3.

7.5.3 *Final Survey*

The final survey effort at HM is very small, which is not surprising given the fact that there will be little left to survey. Only if some surprises in terms of leaks and ground contamination were discovered might this become a more significant activity. At HCF the indicated 9,672 hours for this activity on face value is surprisingly high. However, it is understood that they were not looking for special contaminants, nor was this a special situation regarding unique isotope(s). In fact a source involved with the project has explained that there was nothing special about the survey. However, the GA health physics technicians spent many hours surveying and re-surveying the facility at various intervals in order to confirm that the area was below the release limits. The GA H.P. group was so conservative that they made sure that the facility was 0.1 times the release limits for contamination and radiation. The management philosophy was that there would be no question of meeting the release limits when ORISE, the NRC and the State of California were called in to conduct their own confirmatory surveys.

7.5.4 *Other*

The basis for this miscellaneous category at HCF is not known and is similar to the residual cost of MSEK 2.8 in the HM estimate.

7.6 Cost Information from Argonne Building 200 Decommissioning

This project involved decontamination only and was pursued because the facility was a significant contributor to the overall source term for the ANL-E site. The cells decontaminated at Building 200 clearly were very heavily contaminated by comparison with the HM hot cell and this resulted in comparatively high costs, from $2,400/m^2 for the most lightly contaminated cell to $7,300/m^2 for the most heavily contaminated cell. The HM estimate provides only a total figure of SEK 3,000/m^2 (excl. contingency) for the decontamination of the building surfaces as a whole, of which the interior of the hot cell comprises only about 12 per cent. If the low value from Building 200 were to apply to the HM hot cell, it would take up 89 per cent of the amount included for this activity in the HM estimate.

7.7 Overall Reasonableness of the HM Cost Estimate

Based on the comparisons that have been possible with selected U.S. projects, the HM cost estimate appears to be reasonable. Some additional costs are conceivable however in the following areas.

7.7.1 Planning and Institutional Support

Theoretical estimates of planning and other support activities can have a tendency to assume optimal circumstances and tend not to account for potential changes of circumstances in, for example, the regulatory environment and requirements. It is NAC's impression that the HM cost estimate has been developed in a manner very similar to cost estimates for many other Studsvik facilities and may suffer from 'replication' of tasks and costs based almost entirely on these other estimates, i.e. without a sufficiently fresh approach to the HM facility specifically. For this reason and for the reasons explained in Section 7.3 it therefore may be prudent to review the cost allowances for efforts in this category.

7.7.2 Decontamination, Dismantling and Waste Disposal

The estimate for decontamination and dismantling overall appears to be adequate unless a very different approach had to be adopted involving a more engineered solution to demolishing the hot cell concrete, as in the case of HCF. Potential additional costs associated with possible contamination of hot cell concrete behind the steel liner have been identified. Associated with this would be additional costs for waste management. One of the big differences between the plan and the outcome at HCF was the amount of dismantling waste that had to be disposed of as active waste. The HM facility appears to be in a much better radiological condition overall than HCF but it cannot be discounted that surprises are found and/or regulatory requirements change regarding the dumping of dismantling waste.

For example, if 50 to 100 percent of the dismantled building material that is assumed to be non-active, other than the amount used in backfilling, had to be disposed of in a repository for long-lived intermediate and low level waste (candidates potentially SFL, SFR1, SFR3-5), the associated costs of transport and disposal are estimated to be approximately MSEK 2.5 and MSEK 14 respectively for the 50 percent case, or MSEK 5 and MSEK 28 respectively for the 100 percent case.

The transport cost estimates are based on an assumption of 20 MT of waste per truck and a unit cost for a truck transport derived from information given in item Å14 of the Swedish cost estimate for HM (page 22). The disposal cost estimates are based on an indication[6] of SEK 20,000 per m^3. These estimates are not definitive, they are provided for illustrative purposes only, as the Swedish cost estimate report for HM does not provide much detail about such costs.

The costs already included in the Swedish HM estimate for the transport and disposal of building concrete that is assumed to be declared open for release to dumping/alternative use, are not visible. The total for building demolition is quoted at item R3 to be MSEK 8.3, including inactive transports. The amount for transport and disposal therefore is probably less than half of this total. Subtracting this amount from the above estimates, the financial implication of having to dispose of 50 to 100 percent of all building material assumed in the Swedish estimate to be non-active, would be approximately MSEK 13 to MSEK 24 for the 50 percent and 100 percent cases respectively.

[6] Advise from S.Lindskog [SKI] to G.Varley [NAC] 20 July 2006

8. Summary and Observations

The research and analyses reported herein provide a certain basis for assessing the reasonableness of the HM decommissioning cost estimate. However, in part because of the manner in which the cost estimate has been constructed and presented, a number of significant uncertainties remain. In reference 4 NAC reviewed the approach to preparing and presenting a decommissioning cost estimate and identified a number of areas where the AB SVAFO reports could be improved.

The HM cost estimate report probably pre-dates these recommendations and, as a result, does not follow many of these guidelines offered. For example, uncertainties are not dealt with in a sophisticated way. An estimate is just that but it can be more valuable if its components are presented along with meaningful estimates of uncertainty, especially for those aspect of the work that represent the biggest potential factors that could affect cost.

The report also seems to present a repetitious approach to estimating the requirements for planning and institutional activities, picking up on similar summaries developed in previous estimates for other facilities. In so doing some important aspects may have been missed, not least the fact that SKI and SSE oversight ***will*** apply to the project.

Characterisation of the HM facility prior to commencing decontamination and decommissioning appears to be an activity that has been given little consideration, or at least very little financial provision is made for such activities. This may be short-sighted and ultimately could lead to an underestimate of the overall cost, in part due to the absence of an allowance for this work itself and, secondly, because the effort needed in the actual decontamination and decommissioning may be underestimated.

Some additional benchmarking results have been derived in the course of this study, adding to the collection of benchmarks derived in earlier studies performed for SKI. These benchmarking references collectively still are not so extensive however. Consequently it would be beneficial to expand this base of predictive data by investigating additional Swedish decontamination and decommissioning programs and related cost estimates, including comparisons with pertinent examples of actual decontamination and decommissioning work completed elsewhere.

References

1. "General Atomics Hot Cell Facility Decontamination and Decommissioning Project – Final Project Closeout Report" (PBS VL-GA-0012) dated October 15, 2004.

2. "General Atomics Waste Generator Application" prepared for the Nevada Test Site dated October 1996.

3. SKI 2005:34 An Applied Study on the Decontamination and Decommissioning of the Map Tube Facility 317 Area Argonne National Laboratory, Chicago

4. SKI 2004:11 An Applied Study of the Storage for Old Intermediate Level Waste at the Studsvik Site