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FISCAL YEAR 1998 YEAR-END REPORT

For the November 1997 to October 1998 Period

IDENTIFICATION OF DOE'S POST-CLOSURE MONITORING NEEDS AND REQUIREMENTS

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MONITORING NEEDS AND REQUIREMENTS**

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LIST OF ACRONYMS

AE/MS	acoustic emission /microseismic
ANDRA	Agence Nationale pour la Gestion des Déchets Radioactifs (National Agency for the Disposal of Radioactive Waste)
APSF	Actinide Packaging Facility
BfS	Bundesamt für Strahlenschutz (Federal Office for Radiation Protection)
CDI	Canyon Disposition Initiative
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMST-CP	Characterization, Monitoring Sensor Technology – Crosscutting Program
COC	Constituent of Concern
CPP	CERCLA Past Practice
CSM	Centre de Stockage de la Manche (Storage Center at la Manche)
DBE	Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (German Company for Building and Operating Repositories)
DOE	Department of Energy
DOE/RL	Department of Energy, Richland Operations Office
EM	Environmental Management
EPA	Environmental Protection Agency
EPD/EMS	Environmental Protection Department/Environmental Monitoring Section
ER	Environmental Remediation
ERC	Environmental Restoration Contractor
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FDH	Fluor Daniel Hanford Company
FEMP	Fernald Environmental Management Project Facility Effluent Monitoring Plans
FFA	Federal Facility Agreement
FRG	Federal Republic of Germany
FRL	Final Remediation Level
FY	Fiscal Year
GC/VOA	Gas Chromatographic Volatile Organics Analyses

GMA	Great Miami Aquifer
GWMP	Groundwater Monitoring Program
HDPE	High Density Polyethylene
HEPA	High Efficiency Particulate Air
HEU	Highly Enriched Uranium
HLW	High Level Waste
IAEA	International Atomic Energy Agency
I&C	Instrument and Control
IFIA	Institut für Instrumentelle Analytik (Institute for Applied Informatics)
ILW	Intermediate Level Waste
IRM	Interim Remedial Measure
JAERI	Japan Atomic Energy Research Institute
JNFL	Japan Nuclear Fuel Limited
KHG	Kerntechnische Hilfsdienstst GmbH (Nuclear Technology Help Service Co.)
LCS	Leachate Collection System
LDS	Leakage Detection System
LLRWDF	Low Level Radioactive Waste Disposal Facility
LLW	Low Level Waste
LTS	Leachate Transmission System
M&I	Maintenance and Inspection
MCL	Maximum Concentration Limit
MW	Mixed Waste
MWMF	Mixed Waste Management Facility
MZCL	Mixing Zone Concentration Limit
NEA	Nuclear Energy Agency
NMS	Nuclear Material Stabilization
OAC	Ohio Administrative Code
OECD	Organization for Economic Cooperation and Development
OEPA	Ohio Environmental Protection Agency
ORWBG	Old Radioactive Waste Burial Ground
OSDF	On-Site Disposal Facility
PFP	Plutonium Finishing Plant

PHMC	Project Hanford Management Contractor
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion ($\mu\text{g/L}$)
ppm	parts per million (mg/L)
PPP	Past Practice Processes
PQL	Practical Quantitation Limit
PTB	Physikalisch-technische bundesanstalt (Physical-technical federal institute)
PUREX	Plutonium Uranium Extraction Plant
RCRA	Resource Conservation and Recovery Act
RFI/CMS	RCRA Facility Investigation/Corrective Measures Study
RI/FS	Remedial Investigation/Feasibility Study
RPP	RCRA Past Practice
ROD	Record of Decision
S&M	Surveillance and Maintenance
SAMCONS	Surveillance, Monitoring, and Control System
SCDHEC	South Carolina Department of Health and Environmental Control
SCK-CEN	Studiecentrum voor Kernenergie - Centre d'étude de l'Energie Nucléaire (Belgium Nuclear Research Center)
SFR	Final Repository for Radioactive Operational Waste (Sweden)
SKB	Swedish Nuclear Fuel and Waste Management Company
SRS	Savannah River Site
TPA	Tri-Party Agreement
TRU	Transuranic
TSD	Treatment, Storage and Disposal Facilities
VLLW	Very Low Level Waste
VOC	Volatile Organic Compounds
UI	Uranium Institute
UIC	Uranium Institute Centre, Ltd.
WAC	Waste Acceptance Criteria
WIDS	Waste Information Data System
WSRC	Westinghouse Savannah River Company

EXECUTIVE SUMMARY

Inadequate planning for postclosure monitoring and lack of appropriate monitoring technologies will prevent closure of contaminated sites after remediation. To aid CMST-CP in guiding its postclosure technology development and deployment efforts, the purpose of this project is to determine, document and track the current and evolving postclosure monitoring requirements at different DOE-EM sites. The postclosure needs of each site will then be compared to determine the most pressing postclosure needs for DOE-EM.

The postclosure requirements of the Hanford, Fernald, and Savannah River sites have been reviewed and documented in FY98. The postclosure activities and plans of other nations with advanced nuclear programs have also been reviewed to aid DOE-EM with the lessons they have learned and the technology they have developed. FY99 activities include reviewing and documenting the postclosure requirements of the Oak Ridge and Rocky Flats sites and determining the most pressing postclosure needs based on these five sites.

The post-closure needs found for Fernald, SRS and Hanford can be summarized as

- groundwater monitoring for different radioactive and hazardous constituents,
- site inspections to verify condition of lands used for waste disposal,
- verification of the operability and operation of monitoring wells and of the leachate/liquid collection system underneath repositories,
- institutional controls such as deed and access restriction , and
- monitoring of buildings/facilities that have been deactivated and are waiting to be fully decontaminated and dismantled.

Current postclosure monitoring activities, on-going or planned, can be accomplished with existing technology. However, these activities would benefit from approaches and technologies that are more efficient (less expensive and/or faster) and reduce personnel exposure to possible hazardous conditions.

The review of the postclosure activities and plans of other nations revealed that most of their postclosure plans are vague or not yet determined. Only two sites are in the postclosure phase and these are placed on the site of active nuclear facilities. The technology planned to be or being used is the same as that used for monitoring of active sites.

1.0 INTRODUCTION

The 2006 plan sets an ambitious agenda for the U.S. Department of Energy (DOE), Office of Environmental Management (EM) and the remediation of sites contaminated by decades of nuclear weapons production activities. The plan's primary objective is to reduce overall clean up costs by first eliminating the environmental problems that are most expensive to control and safely maintain.

In the context of the 2006 Plan, closure refers to the completion of area or facility specific cleanup projects. The cleanup levels are determined by the planned future use of the site or facility. Use restrictions are still undecided for most sites but are highly probable to exclude residential or agricultural activities. Most of the land will be remediated to "industrial use" levels with access restrictions and some areas will be closed-off through containment. Portions of the site will be reserved for waste disposal, either as a waste repository or the in-situ immobilization of contaminated soil and groundwater, and land use will be restricted to waste disposal only.

The land used for waste disposal will require monitoring and maintenance activities after closure. Most of the land used for industrial use may also require such postclosure activities. The required postclosure monitoring and maintenance activities will be imposed by regulators and stakeholders. Regulators will not approve closure plans without clearly defined monitoring methods using approved technologies. Therefore, among all other more costly and labor-intensive closure-related activities, inadequate planning for monitoring and lack of appropriate monitoring technologies can prevent closure.

The purpose of this project is to determine, document, and track the current and evolving postclosure monitoring requirements at DOE-EM sites. This information will aid CMST-CP in guiding its postclosure technology development and deployment efforts.

1.1 FISCAL YEAR 1998 ACCOMPLISHMENTS

A comprehensive review of the postclosure monitoring and maintenance requirements and needs of Fernald, Savannah River Site (SRS), and the Hanford site have been completed. The information was obtained from current, relevant documents and by interviews with site personnel. The review of each site is discussed in further detail in subsequent sections of this annual report. A review of the postclosure programs and plans of nations with advanced nuclear programs (Western Europe and Japan) has been completed. The nations of most interest are Germany, France, and Japan.

1.2 PLANNED ACTIVITIES FOR FISCAL YEAR 1999

Comprehensive reviews of the postclosure needs of Oak Ridge and Rocky Flats will be completed in FY99. The same methodology will be used for these reviews as was used for Fernald, SRS, and Hanford. The requirements of each site reviewed will be compared to each other to determine the most pressing postclosure needs for EM.

1.3 SUMMARY OF RESULTS

The typical length of required postclosure monitoring is 30 years. The postclosure needs found for Fernald, SRS, and Hanford can be summarized as

- groundwater monitoring,
- site inspections to verify condition of lands used for waste disposal,
- verification of the operability of monitoring wells and of the leachate/liquid collection system underneath repositories,
- institutional controls such as deed and access restriction, and
- monitoring of buildings/facilities that have been deactivated and are waiting to be fully decontaminated and dismantled.

Groundwater monitoring is for certain constituents of concern (COCs). The COCs chosen depend on the contamination, waste characteristics if a waste disposal unit, remediation results, and regulatory issues. Unfortunately, most of the operable units have a vague or no postclosure plan, and it is not possible to determine the COCs that might require monitoring for such sites.

Current postclosure monitoring activities, on-going or planned, can be accomplished with existing technology. Trained personnel will perform facility and site inspections. Groundwater monitoring will be performed by analyzing the groundwater, retrieved using a well, in an analytical laboratory. The lack of personnel on site to report any unusual events, such as tornadoes or vandalism, will be resolved by agreements with weather services and the local sheriff's department.

Wells and the leachate/liquid collection systems of a repository will be verified by a camera survey down the well and through the pipes of the collection system. Such surveys are required to verify that the pipes are not clogged and that the well is not damaged. The pipe network is designed to facilitate any necessary maintenance (such as the prior construction of a redundant pipe that can be used if the primary pipe is irreparably clogged).

Postclosure monitoring activities would benefit from approaches and technologies that are more efficient (less expensive and/or faster) and reduce personnel exposure to possible hazardous conditions. Such technologies would include remote surveillance of facilities and sites and in-situ groundwater monitoring. The technology used for postclosure monitoring must be identified in the permit document. Therefore, any new technology must be approved by the regulators.

The review of the postclosure activities and technology of other nations with advanced nuclear programs showed that these nations have only vague postclosure plans. The technology currently used for monitoring of active sites is the technology currently used in postclosure monitoring or planned to be used.

2.0 FERNALD SITE

The postclosure requirements for the entire Fernald site have not yet been formalized in a document. However, the current plans indicate that the main postclosure requirements are monitoring and inspecting the On-Site Disposal Facility (OSDF) after closure. These requirements and plans are contained in a document (FEMP 1997c) that was designed so that it could be expanded to include the whole of the Fernald site if needed (FEMP 1997c, prologue)(Strimbu 1998). The OSDF will contain the contaminated soil and construction debris generated from on-site clean up activities.

Site remediation and decommissioning activities are planned to be completed in 2005. The postclosure phase for the OSDF will begin when the last cell is closed and the cover installed in 2006. The duration of the postclosure care phase is thirty years after closure (DOE 1998c, exhibit E-44 and E-45) (FEMP 1997c, sections 1.0 and 1.1). The postclosure requirements for the OSDF include

- continued ownership of the OSDF site by the DOE or a successor federal agency,
- property use restrictions on the deed,
- restricted access (i.e. fence and warning signs),
- environmental monitoring of groundwater,
- maintenance of the cover and cap system, and
- point of contact information that is to be kept current (FEMP 1997c, section 4.1).

Outside of the OSDF, the Fernald site will be returned to public use but will still be owned by the federal government. Institutional controls will include land use restrictions, deed restrictions, fences, and warning signs. The specific use of the site after remediation has not yet been decided except to exclude residential and agricultural use. The end state will be decided by the Stakeholders: the Fernald Citizens Advisory Board and the Community Reuse Organization. No plans for postclosure activities have been decided yet, but at a minimum, they will include groundwater monitoring of the OSDF (FEMP 1995a, section 9.2) (FEMP 1995b, section 9.1) (FEMP 1996a, sections 8.1 and 8.1.5) (FEMP 1994, sections 9.1 and 9.2.1)(FEMP 1996b, section 9.1.7) (DOE 1998c, exhibit E-44).

The current postclosure care program may be modified if deemed necessary based on remediation and OSDF operation experience and results. Additional postclosure requirements may be necessary for the Fernald site (outside the OSDF) such as additional institutional controls and environmental monitoring to provide data for CERLA-mandated five-year reviews. Additional media may be selected to be monitored for the OSDF such as surface water, vegetation, or sediment (FEMP 1997c, section 12).

2.1 DESCRIPTION OF THE ON-SITE DISPOSAL FACILITY (OSDF)

2.1.1 Hydrogeology

Underneath the site is glacial till which has the properties of an aquitard. Groundwater flow through the till is mostly downward. Below the glacial till are sand and gravel deposits which comprise the Great Miami Aquifer (GMA), a sole source (according to the Safe Drinking Water Act) and a high-yield aquifer. Butler and Hamilton counties obtain a significant quantity of water (potable and industrial) from the GMA. An unsaturated zone of sand and gravel 20 to 30 feet thick separate the bottom of the glacial till from the GMA (FEMP 1997a, sections 2.2 and 2.3).

2.1.2 Repository Design

The OSDF is a modular design with the number of cells (maximum of nine) dependent on the waste volume generated by clean-up activities. The OSDF will consist of eight individual cells (700' x 400') with each cell constructed when needed. Eight cells are sufficient to house the predicted waste volume of 2.5 million cubic yards. An area of land will be set aside for the construction and operation of a ninth cell if a greater waste volume is generated (FEMP 1997a, section 1.1)(FEMP 1997c, section 3.1). The footprint of the OSDF, including the capped area extending beyond the disposal area, will be about 70 acres (FEMP 1997a, section 2.1).

At the end of a cell's loading phase, a multi-layer composite cover will be placed over the cell. This cover is designed to protect the OSDF and minimize the required monitoring and maintenance by diverting precipitation run-on and run-off to designated diversion channels and discharging surface water to existing watercourses (FEMP 1997c, section 2.3). The 2,000-year, 24-hour storm event was the design criterion for the facility as is required for DOE performance category 2 facilities (FEMP 1997c, section 2.4). This cover will consist of (from top to bottom) a topsoil layer stabilized with vegetation, a subsoil layer, a granular filter layer, a bio-intrusion barrier, a geotextile filter, a cover drainage layer, the primary composite cap (geotextile cushion, geomembrane, bentonite geocomposite and compacted clay) and a contouring layer (FEMP 1997a, section 4.3.1).

Underneath each cell will be a composite liner system consisting of (top to bottom) a soil cushion layer, a leachate collection system (LCS) drainage layer, a primary composite liner, a leak detection system (LDS) drainage layer, and an underlying secondary composite layer (FEMP 1997a, section 4.3.1).

The OSDF was designed, and the maximum contaminant concentration that will be allowed to be disposed inside was chosen, such that the waste will be contained (at a level that protects human health and the environment) for 200 to 1000 years. This safety analysis of the OSDF's lifetime includes the scenario that no active maintenance and postclosure care is provided, that the synthetic liner material in the cover and the base system fail, that the leak detection and leachate collection system fail, and that the cover degrades over time. Since the OSDF is an underground structure, events such as human intrusion and tornadoes should have a minimal impact (FEMP, 1996b, pages A.3-30 and A.3-56).

2.1.3 Leachate and Leakage Surveillance Systems

The leachate and leakage surveillance systems (LCS and LDS) (FEMP 1997c, section 6.0) for the OSDF are designed to provide early detection of a leachate release into the environment. The purpose of the LCS is to collect infiltrating water and leachate and prevent it from entering the environment. The purpose of the LDS is to verify the containment integrity of the OSDF by detecting any leachate leaks from the LCS through the primary composite liner. If a leak is detected, then an analysis of the liquid found in the LDS will help determine the impact of the leachate release on the groundwater.

The documents describing the LCS and LDS are concerned primarily with the active operation phase of the facility and only secondarily with postclosure monitoring. Data collected from monitoring these systems during operation will help determine the performance of the OSDF containment and if any amendments to the postclosure monitoring plan are necessary (FEMP 1997a, section 4.4.3).

A three-tier strategy of detection, assessment, and corrective action is required by regulations. Detecting a leak is the first tier and as long as no leachate release into the environment is detected, the facility will remain in the first tier. The second and third tiers are activated if a leachate leak is detected; in such a case, the quality of the groundwater will be assessed (tier 2) and, if necessary, corrective action will be performed (tier 3) (FEMP 1997a, section 4.1).

The design of both the LCS and LDS are similar. Liquid drains toward the western edge of the cell liner into a manhole via an extraction pipe. Inside the LCS manhole, the liquid flows directly from the LCS extraction pipe to a Leachate Transmission System (LTS) gravity line. The LCS manhole is a closed system in which no liquid should accumulate. A submersible liquid level sensor with a logic controller and alarm light will be installed in the LCS manhole. The alarm will be activated at a 2" liquid level.

Liquid in the LDS drains into the manhole's primary containment vessel (the manhole is the secondary containment vessel). The liquid in the LDS manhole will then be pumped through a discharge pipe to the LTS gravity line of the adjacent LCS manhole. A level transmitter will monitor the liquid level in the primary and secondary containment vessels of the manhole. The transmitter will activate an alarm (strobe light and radio signal) if the liquid level is 6" below the top of the primary containment vessel and 2" above the bottom of the secondary containment vessel. A monitoring port within the manhole will be installed to verify the absence of liquid in the space between the carrier and containment pipe. A cleanout will be installed adjacent to the LDS manhole for maintenance on the carrier pipe.

The pipes are high-density polyethylene (HDPE) and double-walled: the inner pipe is the carrier pipe and the outer pipe is for containment. The outer pipe is connected to the manhole wall. A redundant carrier pipe will be installed which will have a HDPE solid-wall spool in the closed position that can be easily opened if needed. The carrier and the redundant pipes will have a monitoring port installed to allow leachate samples to be obtained and to verify the absence of any liquid in the outer pipe.

2.1.4 Leachate Transmission System

The LTS gravity line (FEMP 1997c, section 6.0) runs through the LCS manhole of each cell toward a lift station. At the lift station, the liquid is pumped through a permanent double-wall forcemain to either a sump or an extra tank for periodic removal. After closure, leachate may be pre-treated onsite and disposed off-site or treated and disposed off-site. Information concerning these aspects of the LTS has not yet been decided or documented.

The LTS gravity line is a double-walled HDPE pipe with a 6" inner diameter and a 10" outer diameter. The outer pipe is continuous only between manholes and is connected to the manhole wall. A vent will be installed in the LTS gravity line to prevent a pressure build-up. A 4" diameter quick-connect hose connector will allow pressure tests and cleaning of the line by jetting water. Maintenance of the line will be facilitated by installing cleanouts on the upgradient end of each manhole.

The permanent lift station will have a secondary containment that can be monitored for leakage. The station will be designed with a capacity of one week's leachate volume generated during the waste-loading phase. The volume of leachate is expected to drop significantly once the cell is closed and the cover installed. The volume estimate is an average of 1,145 gallons per acre per day during the initial phase of operation and drops to an average of 0.002 gallons per acre per day after closure (FEMP 1997a, section 4.4.2.1). If the liquid level rises too high, an electrical short may occur and damage the equipment. To prevent this occurrence, the inflow valve will be motor-operated and close automatically in case of a power failure or if monitors detect that the liquid level is above a preset alarm level.

2.2 MONITORING REQUIREMENTS OF THE LEACHATE AND LEAKAGE SURVEILLANCE SYSTEMS

2.2.1 Leachate Collection System

During the postclosure phase, the LCS will initially be monitored monthly. If the liquid level at the LTS permanent lift station sump stays below the "pump operating level" for two consecutive months, then the LCS will be monitored quarterly. If the liquid level is below this value for two consecutive quarters, then the LCS will be monitored semi-annually. However, if the liquid level is over the pump operating level, then the frequency will return to monthly. The pump operating level will be calculated to avoid backup of liquid into the LCS drainage layers and to minimize head in the LTS permanent lift station sump (FEMP 1997a, section 4.4.2.1).

This periodic monitoring will

- determine the quantity of liquid,
- measure the concentration of certain indicator analytes,
- evaluate the condition of the shutoff valve and of the submersible level sensor system of the permanent lift station, and
- check for liquid in the LCS containment pipe and the redundant LCS carrier pipe.

If liquid is found in the redundant carrier pipe, the spool will be opened to allow drainage into the LTS gravity line. Liquid in the containment pipe indicates a leak in the LCS carrier pipe and

will require a video inspection of the pipe to find the leak. Any inspection equipment will be decontaminated within the OSDF perimeter (FEMP 1997c, section 6.0).

2.2.2 Leak Detection System

During the postclosure phase, the LDS will initially be monitored monthly. If the liquid level stays below the "action leakage rate" for two consecutive months, then the LDS will be monitored quarterly. If the liquid level is below this value for two consecutive quarters, then the LDS will be monitored semi-annually. However, if the liquid level is over the action leakage rate, then the frequency will return to monthly. The action leakage rate is not yet decided (FEMP 1997a, section 4.4.2.1).

This periodic monitoring will

- determine the quantity of liquid in the manhole,
- measure the concentration of indicator analytes,
- check for leakage from the primary containment vessel of the manhole,
- check for liquid in the LDS containment pipe (if liquid is present, then a video inspection of the pipe will be done to determine the source of the leakage)
- confirm that all the required signage of the manhole is visible,
- confirm that manhole covers are not cracked or broken (repair/replace if necessary),
- check the condition of the leaking seal on the cover,
- check the general condition of the containment vessel, and
- check for any odors and bacterial growth in the containment vessel. (if bacterial growth is detected, then the manhole will be flushed or sprayed with sodium hypochlorite).

Liquid found in the LDS can be from sources other than a leachate leak from the LCS. An analysis and comparison of the analyte composition and quantity of the liquid from the LCS and LDS will determine if the liquid in the LDS is from the LCS (FEMP, 1997c, section 6.0).

2.2.3 The LTS Gravity Line

The LTS gravity line (FEMP 1997c section 60) will be inspected (frequency to be determined) for

- liquid in the containment pipe,
- visible warning signs,
- the condition of the equipment (such as the valves and hoses),
- any temperature extremes in the manholes,
- pulsating flow, overpressure or underpressure,
- confirmation that the pump is operating,
- the condition of the manhole cover (repair/replace if necessary), and

- the condition of the concrete slab.

2.2.4 Annual Pipe Inspection

Annually, the LCS, LDS, and LTS carrier pipes will be inspected (FEMP 1997c, section 6.0) by video camera (and other equipment) for any obstructions that are clogging the pipe. These instruments must be able to fit inside the inner carrier pipe, monitor its position, and move along the entire length of the pipe. If the carrier pipe is obstructed, flushing with water using the cleanout adjacent to the manhole will be attempted to clear the pipe. If unsuccessful, other methods include blowing out the obstruction with air, vacuuming, jet rodding, inserting a snake, fishtape, or other. If the pipe obstruction can not be dislodged, options include opening the redundant LCS or LDS pipe, inserting a smaller diameter pipe within the obstruction or crushed pipe or replacing the pipe.

2.3 GROUNDWATER MONITORING

2.3.1 Groundwater Monitoring in Glacial Till

Horizontal wells are preferred to vertical wells because of regulations that prohibit installing wells within 200 feet of the waste (to avoid damaging the cap) and the lack of a significant lateral flow (no upgradient and downgradient monitoring is possible). EPA and OEPA regulations both require that the area where leachate would first enter the environment (glacial till) be monitored. The DOE, EPA, and OEPA all agree that the site-specific approach to monitoring the first-entry leakage point would be a horizontal well directly beneath the LDS sump. The sump is the point where the extraction pipe penetrates the clay of the composite liner system (FEMP 1997a, section 3.2.1.1).

Each cell will have a horizontal monitoring well for the glacial till installed during the construction phase before any waste is placed in the facility. The wells will be placed beneath the bottom of the composite liner under the LDS sumps (FEMP 1997a, section 4.3.3). A 6" pipe will connect the horizontal well with the glacial till beneath the sump (FEMP 1997a, Figure 4-3).

A sufficient quantity of liquid for analysis may not be collected due to the clays low transmissive properties and discontinuous nature (FEMP 1997a, sections 2.2 and 2.3). If insufficient volume is collected from the well, then the monitored parameters will be reduced (FEMP 1997a, section 4.3.3).

2.3.2 Great Miami Aquifer

After closure, up to 20 vertical wells (if all 9 cells are built and loaded with waste) will monitor the up- and downgradient groundwater (as required by regulations) from the GMA for the whole OSDF (FEMP 1997a, sections 2.2 and 2.3). The wells will be placed at the closest practicable location where a release from the facility will enter the aquifer but outside the OSDF footprint to avoid damaging the composite cap configuration. The locations of the wells are based on the anticipated groundwater flow and particle tracking analysis using the SWIFT aquifer simulation model.

2.3.3 Baseline

To be able to successfully detect a leachate release, the monitoring system must have the capability of distinguishing contaminants in the groundwater from a leachate release and those from pre-existing contamination. Therefore, an understanding of the background contamination is necessary. FEMP plans to determine the baseline by taking monthly samples for a year before any waste is placed in the OSDF to determine seasonal fluctuations (the range of variability). This is more than the four samples required by regulations (FEMP 1997a, section 4.4.1).

If a comparison of the upgradient and downgradient results shows a statistically significant difference, a leachate release from the OSDF into the GMA is considered possible.

2.3.4 Well Monitoring and Maintenance

Maintenance and inspection (M&I) (FEMP 1997b, section 3.6.2.5) plans for groundwater monitoring wells are documented only for the clean-up and waste loading phase. However, any well M&I activities after closure will be similar to the procedures currently being followed. The current well M&I activities are checking for

- the ID number, which should be clearly painted or welded to the lid,
- depressions or channels around the wells that may direct surface water toward the well,
- rust on and ease of use of the lids and padlocks,
- corrosion or cracking on the well casing,
- cracking or settling of the concrete surface seals,
- sediment on the well screen or accumulated in the well, and
- turbidity of sample.

A camera survey down the well may also be needed.

Sediment in the well can be determined by measuring the well depth at each inspection or by having a dedicated packer for each well. If sediment accumulation is a problem, then the sediment will be removed or the well redeveloped. Furthermore, minerals may precipitate on the well screen, which will reduce the monitoring ability of the well. The use of chemicals to remove these sediments are limited (chlorine, HCl) and are to be used only as a last resort.

2.4 INDICATOR ANALYTES

Analyzing for every possible contaminant that may be present in the OSDF (FEMP 1997a, section 4.5) is unnecessary, difficult, and costly. Therefore, only certain indicator (primary) parameters will be monitored. These constituents were chosen (see section A.6) either because they are the best indicators of a containment failure or are RCRA constituents of concern (COC) present in the OSDF in concentrations close to their waste acceptance criteria (WAC). Pre-existing contamination requires that indicator parameters also be distinguishable from background contamination. The primary parameters are

- technetium-99,

- total uranium,
- boron,
- mercury,
- bromodichloromethane,
- carbazole,
- alpha-chlordane,
- bis(2-chlorisopropyl)ether,
- 1,1-dichloroethene,
- 1,2-dichloroethene,
- 4-nitroaniline,
- tetrachloroethene,
- trichloroethene, and
- vinyl chloride.

Groundwater properties that change quickly and detectably if the chemical composition changes will also be measured. These supplemental parameters are

- the pH,
- specific conductance,
- total organic halogens, and
- total organic carbon.

The parameters chosen will be reconsidered after the aquifer remediation is completed and again after the final cell is capped. These reevaluations might result in the removal of some parameters or the inclusion of extra parameters. A parameter may be removed if it is not detected in the leachate samples collected during the operation phase or if its baseline concentration is high or fluctuates significantly over the year (making any leachate release of this constituent difficult to distinguish from the background).

2.5 AIR MONITORING

The air monitoring program for remediation and closure activities (currently in progress) might be continued during a portion of the postclosure phase. Decisions concerning postclosure air monitoring are still to be finalized and will be documented in a future integrated environmental monitoring plan (FEMP 1997c, section 5.2). The current air monitoring program (see section A.5) consists of

- radiological particulates measured by high-volume air monitors (sampled biweekly),
- radon measurements using
 - * alpha track-etch radon cups (sampled semi-annually) and

- * alpha scintillation continuous radon monitors (current radon concentration), and
- the radiation field in the air measured by thermoluminescent dosimeters (TLD) (FEMP 1997b, section 6.4).

2.6 INSPECTIONS

After closing the last cell, the OSDF will be scheduled for routine inspections at years 1, 2, 3, 4, 5, 7, and 9 of the postclosure period. The inspection will be a visual inspection of several items (see Table 2.6.1) that indicate possible performance problems such as erosion or human intrusion. A CERCLA review is scheduled every five years, which allows the DOE to change this routine inspection schedule (pending EPA and OEPA approval) based on the results of inspections and the maintenance required during the previous five years (FEMP 1997c, section 7.2.1).

Table 2.6.1
Postclosure Inspection Tasks for the OSDF

Category	Tasks
Security system	<ul style="list-style-type: none"> • Condition of fences, gates, locks and warning signs • Any evidence of vandalism, damage, deterioration
Cap	<ul style="list-style-type: none"> • Presence, depth and extent of erosion • Presence, depth and extent of surface cracking (evidence of cap deterioration) • Subsidence (local or over wide area) • Surface settlement and its ability to pond water
Final Cover System	<ul style="list-style-type: none"> • Condition of vegetative cover (such as health, any deep rooted shrubs or trees, density) • Animals burrowing into the cover • Run-on and run-off system (any damage due to erosion, subsidence, settling or other cause) • Are drainage channels free of debris, sediment or excess vegetation
Benchmarks	<ul style="list-style-type: none"> • Integrity of benchmarks • Evidence of benchmark having been disturbed
Maps and photographs	Taken and stored every five years or if changes occur
Leachate	Presence and extent of any leachate seeps

Off-site area	Any changes that might impact the OSDF such as <ul style="list-style-type: none"> • new roads or trails that can change the run-off pattern • changes in the natural drainage pattern • large debris accumulation • man-made or natural constrictions
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Source: FEMP 1997c, section 7.2.2.

Unscheduled inspections may be deemed necessary if reports or information indicate that the site integrity has or may have been breached. These unscheduled inspections may be a follow-up of a specific problem found during a routine inspection or a contingency inspection triggered by news of such events as vandalism, tornadoes or an earthquake. If necessary, corrective action will be performed (FEMP 1997c, section 8.0).

The DOE has signed or plans to sign agreements with the National Weather Service, the Butler County Sheriff Department, and the Hamilton County Sheriff Department. According to these agreements, these agencies will report to the point of contact about any severe weather, unusual occurrence or reports of intrusion or vandalism that may affect the performance of the OSDF (FEMP 1997c, section 11.0).

Maintenance and/or repairs will be done depending on the findings of the inspections. These activities may include, but are not limited to,

- repairing the fence,
- replacing warning signs,
- repairing the final cover (to correct for erosion, dead vegetation, subsidence, settling or other),
- seeding and mulching,
- mowing (each October) to control the growth of woody species (the use of herbicides selective to woody species may also be used),
- burrowing animal control and/or removal,
- removing deep-rooted shrubs and trees (mechanically, chemically or by fire),
- maintaining surface water run-on and run-off drainage systems, and
- reconstruction of the slope or cover (FEMP 1997c, section 9.0).

2.7 REGULATORY DRIVERS

The Ohio regulations either mirror or are more stringent than the federal regulations and are the controlling requirements (FEMP 1997a, section 3.1). The specific regulations are listed in section A.4.

The document that governs the CERCLA response actions at FEMP is the Amended Consent Agreement between the DOE and the EPA Region V, signed September 1991. The DOE is required to implement the postclosure care and inspection plan and is the lead agency responsible for CERCLA activities at FEMP. The EPA is the oversight agency. The DOE Fernald Area Office is ultimately responsible for ensuring that the postclosure care of the OSDF meets all the requirements of the postclosure care and inspection plan (FEMP 1997c, section 1.3).

2.8 REFERENCES

- DOE, June 1998c, "Accelerating Cleanup: Paths to Closure," DOE/EM-0362, DOE/Office of Environmental Management, Washington, D.C.
- FEMP, December 1994, "Final Record of Decision for Final Remedial Action at Operable Unit 4," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, January 1995a, "Final Record of Decision for Remedial Action at Operable Unit 1," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, June 1995b, "Final Record of Decision for Remedial Action at Operable Unit 2," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, August 1996a, "Final Record of Decision for Remedial Action at Operable Unit 3," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, January 1996b, "Record of Decision for Final Remedial Action at Operable Unit 5," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, August 1997a, "Groundwater/Leak Detection and Leachate Monitoring Plan, On-Site Disposal Facility," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, August 1997b, "Integrated Environmental Monitoring Plan," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, July 1997c, "Postclosure Care and Inspection Plan, On-Site Disposal Facility," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- Strimbu, Michael, Environmental Compliance Specialist, Fernald Site, 1998, email dated 3/18/98.

3.0 SAVANNAH RIVER SITE

The Savannah River Site (SRS) was established in 1950 with the mission of producing isotopes for nuclear weapons (e.g., Pu-239 and tritium), medicine, space exploration, and commercial applications (e.g., Cf-252, Pu-238, and Am-241). Since the end of the Cold War, the mission of SRS has changed to the environmental remediation (ER) of the sites contaminated over the last fifty years, disposal of the waste generated from past activities and future remediation, and long-term management of nuclear materials and spent nuclear fuel. The ER objective is to contain known contamination at inactive sites, vigorously assess the uncertain nature and extent of contamination, and then clean up these waste sites while maintaining worker health and safety and protecting public health and the environment. Other SRS activities, such as the recycling of tritium from dismantled nuclear weapons and isotope production, are outside the scope of this report and therefore not discussed.

The closure and postclosure plans for SRS are decided on a site-by-site basis. The number of sites scheduled for assessment or environmental remediation (ER) activities are 487 (WSRC 1998l). However, only a minority of these sites currently have a postclosure plan or are in the postclosure phase. Postclosure needs for the other sites are not discernable since any required monitoring is strongly dependent on the results of the assessment and remediation activities. Postclosure tasks could include, but are not limited to, regular maintenance (mowing, erosion control measures, placement of signs, fence repair, etc.) and monitoring (site condition and groundwater) in accordance with RCRA/CERCLA requirements. Managing and maintaining closed waste sites also includes performing periodic inspections after closure in accordance with the RCRA part B permit renewal application for that particular site (DOE 1998c, section II-3.2).

Other postclosure requirements or needs are generated by required surveillance and maintenance (S&M) activities of deactivated facilities awaiting decommissioning and of the waste that is or will be disposed on-site. Many of these closure plans are currently vague and to be decided in the future; therefore, the postclosure needs are vague at best.

Current projections indicate that all environmental remediation will be complete in FY 2025. The EM mission in environmental restoration will be completed in FY 2038 with completion of the regulatory-driven released sites S&M. During the post FY 2038 period, the DOE will continue to have a stewardship role that will require ongoing monitoring and maintenance. The long-term S&M responsibilities will then be assigned to the site landlord (DOE 1998c). Final disposition of remaining solid waste is scheduled for 2032. Facilities deactivation should be completed by 2026 with long-term S&M for these facilities completed in 2070 (DOE 1998d, p.ES-11 – ES-12).

3.1 REGULATIONS

Due to past operations and disposal practices, SRS was placed on the CERCLA National Priorities List by Environmental Protection Agency (EPA) in 1989. In 1993 SRS entered into a Federal Facility Agreement (FFA)(WSRC, 1998h) with the EPA and the South Carolina Department of Health and Environmental Control (SCDHEC). In addition to the FFA, SRS has also entered into assessment/cleanup of several portions of the site via RCRA permits as required by several settlement agreements.

Specific regulatory agreements define commitments and milestones for the Savannah River Site and are the primary drivers for these programs. SRS is committed to meeting agreements with external agencies such as the SCDHEC and the EPA. The SRS commitment is consistent with the Administration's policy (Executive Order 12088) to comply with regulatory commitments. These include the Environmental Restoration Program and High Level Waste Program commitments cited in the Federal Facility Agreement (FFA) and Resource Conservation and Recovery Act (RCRA) permit and the Waste Management Program commitments in the Site Treatment Plan Consent Order.

In addition to formal regulatory commitments, SRS has made commitments in response to Defense Nuclear Facilities Safety Board recommendations. For the most part, these agreements relate to nuclear material stabilization and spent fuel management. While not subject to formal enforceable action, these commitments are treated with high priority by SRS.

The Federal Facility Agreement (FFA) for the Savannah River Site was established under Section 120 of CERCLA and Sections 3008(h) and 6001 of RCRA (Effective Date of August 16, 1993) between the EPA Region IV, the DOE, and the SCDHEC (WSRC 1998d). The Agreement directs the comprehensive remediation of the Savannah River Site. It contains requirements for (1) site investigation and remediation of releases and potential releases of hazardous substances, and (2) interim status corrective action for releases of hazardous wastes or hazardous constituents. This Agreement delineates the relationship between its requirements and the requirements for corrective measures being conducted under Sections 3004(u) and 3004(v) according to the conditions of the SRS's Federal RCRA permit and the State's Hazardous Waste permit. It expands the site investigation process begun at the SRS under the RCRA permit to address (1) releases at or from units not included in the RCRA permit and (2) releases of hazardous or radioactive substances, or both, not regulated by the RCRA permit. This Agreement also establishes requirements for the prevention and mitigation of releases or potential releases at or from the SRS high-level waste tank system(s) identified in FFA-Appendix B.

The Agreement governs the corrective/remedial action process from site investigation through site remediation and describes procedures for the Parties to set annual work priorities (including schedules and deadlines) for that process. The Parties will coordinate the administrative and public participation processes prescribed by the various statutes (e.g., RCRA and CERCLA) governing the corrective/remedial action process at SRS.

The Westinghouse Savannah River Company (WSRC) Environmental Restoration Division manages the evaluation and remediation of the release sites falling under the purview of the FFA.

3.2 LANDLORD CHANGE

SRS has projected that the environmental management (EM) program's landlord responsibility on the site ends in 2028 and will then be transferred to another DOE entity. Although it is not known what DOE entity this might be, precedent for this type of ownership transfer occurred with the EM program's assumption of certain defense program facilities. The FY 2028 date was selected since that marks the last major commitment dealing with facility operation (i.e., completion of the High-Level waste activities). At that point, remaining EM commitments basically will be limited to surveillance and maintenance. This landlord change is not expected to change any of the postclosure needs and requirements (DOE 1998c, section 4.0).

3.3 POSTCLOSURE REQUIREMENTS FOR ER SITES

Currently, only four sites have final remediation reports in the SRS administrative records. Only these sites are officially closed and in the postclosure phase. FFA- Appendix C.4 lists sixteen sites in the process of closure (including the four closed sites with final remediation reports) which have the agreement of SRS, EPA and the SCDHEC (WSRC 1998h and 1998i). SRS lists an additional 14 units being closed which do not presently have the full regulatory agreement of the EPA and SCDHEC (DOE 1998b). Sites from these three categories were reviewed. The lists of contaminants being monitored for the sites undergoing closure may be reduced during the postclosure phase if they are not detected during closure phase monitoring. Some additional sites are included that currently have no signed record of decisions.

Each site has its own closure and postclosure plan. The site-specific postclosure requirements currently available, either planned or ongoing, can be divided into four different categories:

- 1) no action necessary,
- 2) institutional controls only,
- 3) institutional controls and groundwater monitoring, and
- 4) institutional controls and mixing zone groundwater monitoring

3.3.1 No Action

These sites, listed in FFA Appendix C.4, have no postclosure requirements: Burma Road Rubble Pit (WSRC 1996, p. 14), Central Shops Burning/Rubble Pit (WSRC 1997d, p. 1), , Grace Road Site (WSRC 1997a, p. 1), Gunsite 113 Access Road (WSRC 1997b, p. 1), Gunsite 720 Rubble Pit (WSRC 1997c, p. 1), and M-Area West (WSRC 1997e, p. 37-38). Two additional sites that might have no postclosure requirements but currently have no signed ROD are the Fire Department Hose Training Facility (WSRC 1998k, declaration 1-3) and the Motor Shop Seepage Basins (WSRC 1998i, p. 27-28).

3.3.2 Institutional Controls

Institutional control places restrictions on site access and includes periodic field inspections to ensure that proper precautions are being maintained. The EPA and the SCDHEC must be notified within 30 days if any breach or compromise of these restrictions has been identified.

The typical wording of an institutional controls clause is

Implementation of institutional controls will involve both short- and long-term actions. For the short-term action, signs will be posted at the _____ source OU indicating that this area was used for the disposal of waste material and contains buried waste. Additionally, existing SRS access controls will be used to maintain use of this site for non-residential use only. In the long term, if the property is ever transferred to non-federal ownership, the U.S. Government will create a deed for the new property owner that will contain information in compliance with Section 120(h) of CERCLA. The deed shall include notification disclosing former waste management and disposal activities as well as remedial actions taken on the site. The deed notification shall, in perpetuity, notify any potential purchaser that the property has been used for the management and disposal of radioactive materials and hazardous substances. The deed shall

also include deed restrictions precluding residential use of the property. However, the need for these deed restrictions may be reevaluated at the time of transfer in the event that contamination no longer poses an unacceptable risk under residential use. These deed restrictions are consistent with the RCRA deed notification required at final closure to the RCRA facility if contamination will remain at the site. The restrictions are also consistent with the RCRA permit requirements that ensure protection of human health and the environment by maintaining documentation of property restrictions and institutional control requirements. In addition, if the site is ever transferred to non-federal ownership, a survey plat of the area will be prepared. The plat will be certified by a professional land surveyor, and recorded with the appropriate county recording agency. The _____ source OU is located in _____ County (WSRC 1998d, p 2 and 89).

A typical field inspection checklist has the following questions (WSRC 1998g, p. 9-11).

- 1) Check for potential encroachments (Ensure there is no building on the site).
- 2) Does the site have brush or woody vegetation that needs cutting and disposal?
- 3) Does the grass need to be cut?
- 4) Verify that wells and roads are accessible.
- 5) Are the wells properly locked?
- 6) Is the concrete pad cracked or broken? Is the pad undercut or silted over?
- 7) Is the well properly identified?
- 8) Verify the well's posts and protective covers are in place.
- 9) Verify waste units' signs have correct and legible information.
- 10) Does the site show signs of erosion or subsidence?
- 11) Are there any signs of burrowing animals (holes)?
- 12) Verify that the orange ball markers are in place.
- 13) Verify the fence is locked and in good condition (if applicable).
- 14) Check integrity of drainage ditches (if any) for presence of excessive erosion, sediment buildup, and any debris restricting water flow.
- 15) Does site need general clean up (housekeeping)?

3.3.3 Groundwater Monitoring

The frequency of sampling and the constituents monitored in the groundwater differ from site to site (details for the different sites are listed below). SRS has a general groundwater monitoring program for environmental screening (see section B.3). However, whether this program would be continued when all ER activities are completed is not known.

3.3.4 Mixing Zone Groundwater Monitoring

Mixing zones are appropriate for situations where the source of groundwater contamination has been removed and contaminant concentrations are decreasing by natural attenuation mechanisms

(biodegradation, flushing, volatilization, adsorption, and hydrolysis). The mixing zone is the area where the plume will migrate while it dissipates. Under these regulations (South Carolina Hazardous Waste Regulations R.61-68), certain concentration limits above maximum concentration limits (MCLs), known as Mixing Zone Concentration Limits (MZCLs), are established within the area called the mixing zone. MCLs, which are protective for drinking water, are established at the compliance boundary downgradient of the plume (WSRC 1998b, p. 41-43 and declaration 3).

Only two sites have currently been selected as groundwater mixing zones (Old F-Area Seepage Basin and D-Area Oil Seepage Basin). The MZCL and the MCL values of the Constituents of Concern (COCs) being monitored for the two sites are listed in Table 3.3.4.1

Table 3.3.4.1
MZCL and MCL Values for COCs Monitored at the Old F-Area and D-Area Oil Seepage Basins

Contaminant	MZCL (pCi/mL)	MCL (pCi/mL)	Location
Iodine-129	0.048	0.001	Old F-Area
Strontium-90	0.146	0.008	Old F-Area
Tritium	216	20	Old F-Area
	MZCL (mg/L)	MCL (mg/L)	
Benzene	0.0062	0.005	D-Area
Cis-1,2-Dichloroethene	0.457	0.070	D-Area
Methylene Chloride	0.0095	0.005	D-Area
Nitrate	20.9	10	Old F-Area
Tetrachloroethene	0.085	0.005	D-Area
Trichloroethene	1.150	0.005	D-Area
Uranium (total)	0.083	0.02	Old F-Area
Vinyl Chloride	0.032	0.002	D-Area
1,1-Dichloroethene	0.007	0.007	D-Area
1,2-Dichloroethene	0.070	0.070	D-Area

Sources: WSRC 1998a, p. 26-29; WSRC 1997f, p. 5-1 to 5-4; WSRC 1998b, p. 98

3.4 SITE-SPECIFIC INFORMATION FOR SITES IN THE POSTCLOSURE PHASE

Four sites have officially been closed and are in the postclosure phase. These sites have final remediation reports signed by SRS, EPA, and SCDHEC. The pits have been filled with construction debris and backfill and then covered with a low permeable clayey soil cap. The soil is compacted and mounded to be above ground. Vegetation is planted to stabilize the cap. The Silverton Road Waste Unit was an open dump and was bulldozed, graded, covered with soil, and planted with grass.

3.4.1 K-Area Bingham Pump Outage Pit

Institutional controls only are required, consisting of warning signs, access control, no residential use, and deed restrictions (WSRC 1997g, p. 1-2).

3.4.2 D-Area Burning/Rubble Pits

Institutional controls (consisting of non-residential use restriction) and confirmatory groundwater analysis is required (WSRC 1998g, p. 7). Groundwater sampling frequency is annual and began in the second quarter of 1998. The analytes are arsenic, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chromium, chrysene, 1,2-dichloroethane, endrin, manganese, octachlorodibenzo-p-dioxin, PCB-1260, total radium, 1,1,2-trichloroethane and tritium. Any analytes not detected within five years may be dropped from further monitoring. If no analytes are detected above their MCL values, then SRS will request EPA and SCDHEC to allow groundwater monitoring at this site to be discontinued.

3.4.3 F-Area Burning/Rubble Pits

Institutional controls include signs (declaring that the area was used to manage hazardous waste), access controls and land use restrictions (nonresidential activities), deed notification and field inspections to monitor general site conditions (WSRC 1997i, p. J-1 – J-10). Further characterization of the groundwater has been conducted to determine if these pits are the source of groundwater contamination. The analytes being monitored are carbon tetrachloride, dichloromethane, iron, lead, nitrates, radium, tetrachloroethylene, trichloroethylene, trichlorofluoromethane, tritium, volatile organics, field parameters, and water quality parameters.

3.4.4 Silverton Road Waste Unit

Institutional controls includes deed notification, access controls, identification signs, field inspections to monitor general site conditions, and land use restrictions (WSRC 1998f, p. 8). Groundwater will be monitored semi-annually during the second and fourth quarters of each calendar year. Analytes to be monitored are carbon tetrachloride, 1,2-dichloroethane, dichloromethane, tetrachloroethylene, and trichloroethylene. If any analyte is not detected over background or its MCL value over four measurements (two years), then SRS will request EPA and SCDHEC that this analyte not be monitored for this site.

3.5 SITES UNDERGOING CLOSURE

The sites undergoing closure are discussed since they contain information regarding postclosure plans and what COCs in the groundwater will be monitored. The COCs that will be monitored during the postclosure phase may be less than those monitored during closure activities. COCs not detected in the groundwater during the closure phase may not be monitored during the postclosure phase.

Of these sites, only the old F-area seepage basin is listed in the FFA appendix C.4 (WSRC 1998h) as being in the process of closure. Sites listed in FFA appendix C.4 have been agreed upon and the records of decisions (ROD) signed by the SRS, EPA, and the SCDHEC. The other sites are listed by SRS as being in the process of closure but EPA and/or SCDHEC have not

signed the ROD concerning these sites. The C-, F-, K- and P- area coal pile runoff basins are also included even though no signed RODs concerning them have been signed by SRS, EPA or SCDHEC.

3.5.1 Old F-Area Seepage Basin

The selected remedy for the groundwater medium is a groundwater-mixing zone with institutional controls. Contaminated vegetation and soil in the vicinity will be removed and placed in the basin, followed by in-situ grouting, backfilling, compacting, and installing a low-permeable soil cover. Signs will be posted and the extent of the groundwater contaminant plume will be monitored (WSRC 1998a, p. 26-29).

The groundwater monitoring wells have three classifications: plume wells, intermediate wells, and boundary compliance wells. All wells will be sampled semi-annually for five years. The constituents monitored are for

- plume wells iodine-129, nitrate, strontium-90, tritium, total uranium, lead, radium-226/228, gross alpha, nonvolatile beta;
- intermediate wells iodine-129, nitrate, strontium-90, tritium, total uranium, gross alpha, nonvolatile beta;
- boundary compliance wells iodine-129, nitrate, strontium-90, tritium, total uranium, lead, radium-226/228, gross alpha, nonvolatile beta.

Three plume wells are located within the plume and have exhibited the highest concentrations of COCs. The plume wells will be monitored to ensure that contaminants do not exceed MZCLs. If a MZCL is exceeded during a semi-annual sampling event, all of the plume wells will be re-sampled within 30 days to validate the exceedence. If the MZCL is exceeded again, SRS will submit a plan for corrective action to SCDHEC and EPA within 90 days of the confirmatory data.

The intermediate wells will be located between the plume wells and the compliance boundary wells to validate model predictions. If contaminant concentrations exceed modeled concentrations, the model will be re-calibrated with the new data to redetermine the calculated concentrations at the compliance boundary wells. If the re-calibrated model indicates that the MCLs will be exceeded at the compliance boundary, then SRS will submit a plan for corrective action to SCDHEC and EPA within 90 days of the determination.

The compliance wells will be located near the downgradient plume boundary and monitored to ensure that contaminants do not exceed MCLs. If an MCL is exceeded, all of the plume wells will be re-sampled within 30 days to validate the exceedence. If the MCL is exceeded again, SRS will submit a plan for corrective action to SCDHEC and EPA within 90 days.

3.5.2 A-Area Burning/Rubble Pits and A-Area Rubble Pit

Postclosure requirements are still to be decided, but may include institutional controls and groundwater monitoring for chlorinated solvents and benzo(a)pyrene (WSRC 1998c, p. 100-105).

3.5.3 C-,F-,K- and P-Area Coal Pile Runoff Basins

No further action may be required for these basins. Confirmatory groundwater monitoring will be conducted for five years for the K-area basin, beginning in the second calendar quarter of 1998. The analytes to be monitored are beryllium, bis(2-ethylhexyl) phthalate, chromium VI, gross alpha, radium-226, radium-228, and pH. No institutional controls are planned (WSRC 1998j, p. 35).

3.5.4 D-Area Oil Seepage Basin

A groundwater mixing zone with institutional controls is the remedy selected for this site. Nine new wells will be installed and twelve groundwater wells in total will be monitored. The groundwater will be monitored quarterly for the first year, annually thereafter (subject to review every 5 years). The analytes monitored are benzene, cis-1,2-dichloroethene, 1,1-dichloroethene, 1,2-dichloroethene, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, and indicator parameters. Indicator parameters measured in the field include pH, specific conductance, temperature, turbidity, dissolved oxygen, and oxidation/reduction potential. Indicator parameters measured in the laboratory include total organic carbon, nitrate, iron(2), sulfate, and chloride (WSRC 1998b, p. 98)(WSRC 1997f, p. 5-1 – 5-4).

Institutional controls include controlled access (security gates and perimeter fences), signs (indicating that groundwater in the vicinity has been contaminated by hazardous materials), and deed notification.

3.5.5 F-Area Groundwater

Semi-annual groundwater monitoring is being conducted for lead, nitrate, iodine-129, radium-226/228, strontium-90, total uranium, tritium, gross alpha, and nonvolatile beta (WSRC 1997e, p. 21-22).

3.5.6 F-Area Hazardous Waste Management Facility

Groundwater monitoring is required for the analytes barium, cadmium, chromium, cobalt, copper, cyanide, lead, mercury, nickel, nitrates, tetrachloroethylene (PCE), trichlorofluoromethane, tritium, zinc, gross alpha, gross beta, and total radium (WSRC 1997e, p. 23-24).

3.5.7 M-Area Hazardous Waste Management Facility

Groundwater is monitored monthly for aluminum, lead, nickel, uranium, tetrachloroethylene, and trichloroethylene (WSRC 1997e, p. 35-36). The A/M area groundwater operable unit is included in this groundwater monitoring (WSRC 1997e, p 3-6).

3.5.8 Metallurgical Laboratory Hazardous Waste Management Facility

The basin is currently under RCRA postclosure care. Groundwater monitoring is quarterly for the analytes cyanide, heavy metals, non-halogenated (F003) solvents, tetrachloroethylene, and trichloroethylene. General field inspections are also conducted quarterly (WSRC 1997e, p. 39-40).

3.5.9 Mixed Waste Management Facility

Closure activities of the MWMF were completed in December 1990 (See section 3.5.3). Postclosure activities will continue for 30 years. Groundwater monitoring is monthly for the analytes cadmium, lead, mercury, indicator parameters, volatile organic compounds (VOCs), carbon-14, iodine-129, neptunium-237, plutonium-239, strontium-90, technecium-99, tritium, and uranium-235/238. General field inspections are also conducted monthly (WSRC 1997e, p. 41-42). The MWMF is part of the burial ground complex. Remediation for the groundwater of the burial ground complex is still being planned (WSRC 1997h and 1998e).

3.5.10 Old Radioactive Waste Burial Ground

Groundwater is monitored monthly for cadmium, lead, mercury, VOCs, chlorinated VOCs, gross alpha, nonvolatile beta, and tritium. Final remediation action is still being developed (See Section 3.5.2). Sampling and analysis of the remaining contents of the old solvent tanks is ongoing and will be used to determine waste disposition alternatives. All groundwater associated with the burial complex is being address under the RCRA permit for the mixed waste management facility. General field inspections are conducted monthly (WSRC 1997h, p. 2-19 – 2-32).

3.5.11 Sanitary Landfill

The landfill is closed. The groundwater is monitored quarterly for the full suite of VOCs, tritium and the full range of drinking water characterization (see section B.3). The site is inspected quarterly for general site conditions (Adams 1998).

3.5.12 TNX Area Groundwater

Remediation and assessment activities are ongoing. Groundwater is monitored for chlorinated VOCs, mercury, nitrate, and gross alpha (WSRC 1994, p 2).

3.6 THE SOLID WASTE PROGRAM

The Solid Waste Program's major focus is to manage large volumes of legacy waste, cleanup wastes arising from environmental restoration, and waste from other ongoing site activities (DOE 1998c, p. 55). Waste will be treated and disposed, either on-site or off-site. Activities include

- storage of legacy mixed waste (MW) until treatment and disposal options are identified and implemented (probably beyond FY 2006),
- low level radioactive waste (LLW) storage, treatment, and disposal activities (done in 2030).
- the shipping of all legacy hazardous waste for treatment and disposal (by the end of FY 2002) or re-classified as mixed waste (MW) and handled accordingly,
- receiving, treating, and disposing on-site of approximately 110 million gallons of waste salt solution in Saltstone Vaults (until FY 2024),

- storing tritiated oil until the tritium has decayed sufficiently or until appropriate treatment technologies are developed,
- disposal of naval reactor components, and
- design, develop, and operate new disposal units as necessary for disposal of large volumes of ER waste (design and construction is scheduled to be started in FY 2007).

SRS intends to use all existing LLW disposal capacity. Waste that does not meet SRS performance standards or exceed WAC values will not be accepted. The disposal of waste will include postclosure maintenance and monitoring of groundwater and site condition. However, specific details are not available.

Contaminated soil, debris, and rubble excavated due to environmental remediation will become waste (LLW, MLLW, other) and will need to be disposed. Some contaminated areas do not need excavation but will require immobilization of the waste in-situ. In-situ remediation will require institutional control and groundwater monitoring. The COCs that will be monitored are dependent on the assessment and remediation results and therefore can not be forecasted.

Disposal of mixed waste remains an open issue since specific plans for disposal of these wastes are being addressed at a national level. Subtitle C disposal facilities exist at two DOE locations and potentially two commercial locations. Agreements to use any of these facilities, however, are not in place.

3.7 BURIAL GROUND COMPLEX

The Burial Ground Complex consists of several former or present disposal sites for hazardous and radioactive wastes from SRS activities (DOE 1998c, p. 55). It is divided into two areas: the Old Radioactive Waste Burial Ground (ORWBG) and the Low-Level Radioactive Waste Disposal Facility (LLRWDF) where disposal continues today (DOE 1998e).

3.7.1 Low-Level Radioactive Waste Disposal Facility

The LLRWDF contains underground tanks for radioactive solvent storage, transuranic waste storage pads, and engineered and slit trenches. Five additional areas, totaling 24 acres, of the LLRWDF are being closed in accordance with RCRA regulations in the 1996-99 time frame. The remaining 37 acres of the LLRWDF are solid waste management operations areas (DOE 1998e).

The degree of soil contamination in the complex is unknown. Potential contaminants, however, include chlorinated and organic solvents, toluene, benzene, and components of degreasing agents used to clean metal parts. Metals of concern are lead, cadmium, and mercury. Potential radioactive materials in the soil include alpha-, beta-, and gamma- ray emitting materials. Preliminary groundwater analyses in the complex show contamination from tritium, cadmium, lead, mercury, and chlorinated organic compounds.

3.7.2 Old Radioactive Waste Burial Ground

The ORWBG (see 3.4.10) contains various levels and types of radioactive waste (transuranic waste, LLW, and intermediate-level radioactive waste). Twenty-two underground storage tanks

were used to store organic solvents for incineration in two areas of the unit. The ORWBG was also used for the storage of contaminated equipment, a sandblasting facility for equipment decontamination, and various repair facilities. A low-permeability soil cover was placed over the ORWBG unit with topsoil and vegetation in November 1997 (DOE 1998e).

Final remedial action is still being planned (the signed ROD is scheduled to be submitted in June 2000) (WSRC 1997h, p. 8-1). The immediate threats to groundwater are tritium and VOCs; near-term threats may be Sr-90, C-14, Hg, Cd, and Pb; and future threats include I-129, Tc-99, Np-237, U-235, U-238, and Pu-239 (WSRC 1997h, p. 2-23).

3.7.3 The Mixed Waste Management Facility

The 58-acre MWMF (see section 3.4.9) is three separate areas of the LLRWDF and was closed in accordance with RCRA regulations in 1991. Waste is buried in 20-foot deep trenches. The waste was compacted to minimize any potential for further settling, covered with soil and topped with a 3-foot cap of kaolin clay and a 2-foot layer of topsoil over the cap. Shallow-rooted grasses were planted to hold the soil in place. Concrete drainage structures were constructed around the perimeter of the MWMF to carry rainwater away from the facility.

3.8 FACILITIES DEACTIVATION AND DECOMMISSIONING ACTIVITIES

The deactivation and decommissioning plan for the site's major processing facilities (e.g. reactors and canyons) is still to be decided (DOE 1998c). Deactivation is intended to reduce risks and thereby minimize long-term surveillance and maintenance costs. It is usually implemented through equipment removal, elimination to the extent possible of radiological and hazardous sources of contamination, utility isolation, and similar measures. The goal is to reduce facilities to a "cold, dark, and dry" or "cheap to keep" state in which they could be maintained at very low cost for many years. Decommissioning, on the other hand, is the placement of a facility in its final end state consistent with the site's land use plan.

The end state could be leaving the major processing facilities in a low-cost deactivated state indefinitely, or could be as costly as complete demolition, with any number of variations in between (entombment, for example). Funding for the deactivation of major processing facilities (such as C, K, L, P, and R Reactors and F and H Canyons) has been deferred to FY 2006 in favor of higher priority missions. The last of the deactivation activities is currently scheduled to be completed with the deactivation of the High-Level Waste facilities in FY 2026. Following deactivation, facilities will be placed in a long-term, low cost S&M program through FY 2070 (pending final decommissioning).

3.9 OTHER ACTIVITIES AND WASTE

3.9.1 Transuranic Waste

The majority of the transuranic (TRU) waste is scheduled to be disposed at the Waste Isolation Pilot Plant in New Mexico. Decisions regarding the final disposition of the remaining TRU are still to be decided (DOE 1998c).

3.9.2 High-Level Radioactive Waste

By the end of FY 2027 all high-level waste facilities will have waste removed off-site, services cut and capped, and process vessels filled with grout and turned over for final environmental closure and long-term monitoring. Once all canisters have been shipped from each of the storage buildings, the aboveground buildings will be dismantled, and the foundations covered with a cap. Closing the waste tanks includes removal of the waste, removal of any remaining waste heels, washing the tank, physically isolating the tank from all service piping, wiring and connections, and closing the tank by filling it with grout (DOE 1998c). Long-term monitoring will be required thereafter.

3.9.3 Nuclear Material Stabilization Activities

The nuclear material stabilization (NMS) activities will convert these materials to forms suitable for storage. Nuclear materials include plutonium metals, solids, scraps, and residues; uranium, plutonium, neptunium, americium, and curium solutions; uranium alloys and other materials. These activities will generate LLW, MW, HLW, and TRU waste in unknown amounts.

After stabilization, these materials will be removed from the SRS Chemical Separation Facilities (2 Canyons and 2 B-Lines) and the facilities will enter a minimum S&M mode and be transferred to the Facilities Deactivation Program. The Actinide Packaging and Storage Facility will continue the safe, secure, and monitored (IAEA) storage of these stabilized materials until a decision is made (assumed by FY 2028) on their final disposition.

3.9.4 Spent Nuclear Fuel

The Spent Nuclear Fuel (SNF) Program will continue receiving offsite fuel and manage existing SNF and heavy water inventories for safe storage and disposition. FY 2035 is the scheduled end date for the SNF program. The facilities will be deinventoried and then placed in a demobilized state with low-cost S&M. No decisions concerning the end-state of the facilities and final disposition of the SNF have been documented. The facilities may be decommissioned.

3.10 REFERENCES

- Adams, Karen, DOE engineer in charge of Sanitary Landfill, 1998, personal conversation with Will LaVeille.
- DOE, 1998a, SRS Baseline Disposition Maps;
<http://www.em.doe.gov/closure/mapmenu.html#SR>
- DOE, 1998b, Environmental Restoration Records of Decision; <http://www.em.doe.gov/er.html>
- DOE, 1998c, *Accelerating Cleanup: Paths to Closure [National/Complex-Wide Report]*; DOE/Office of Environmental Management; June 1998; DOE/EM-0362.
- DOE, June 1998d, *Accelerating Cleanup: Paths to Closure [SRS-Specific Report]*; DOE/Savannah River Operations Office.
- DOE, 1998g, ER fact sheets on the Internet,
<http://www.srs.gov/general/srenviro/erd/gen/fsindex.html>
- WSRC, October 1994, *Interim Action Record of Decision, Remedial Alternative Selection – TNX Area Groundwater Operable Unit (U)*; WSRC-TR-94-0375; Rev. 1.
- WSRC, April 1996, *Record of Decision, Remedial Alternative Selection for the Burma Road Rubble Pit (231-4F) (U)*; WSRC-RP-96-101; Rev. 1.
- WSRC, January 1997a, *Record of Decision, Remedial Alternative Selection for the Grace Road Site (631-22G) Operable Unit: Final Action (U)*; WSRC-RP-96-00160.
- WSRC, January 1997b, *Record of Decision, Remedial Alternative Selection for the Gunsite 113 Access Road (631-24G) Operable Unit: Final Action (U)*; WSRC-RP-96-00833; Rev. 1.
- WSRC, January 1997c, *Record of Decision, Remedial Alternative Selection for the Gunsite 720 Rubble Pit (631-16G) Operable Unit: Final Action (U)*; WSRC-RP-96-00832; Rev. 1.
- WSRC, April 1997d, *Record of Decision, Remedial Alternative Selection for the Central Shops Burning/Rubble Pit (631-6G) (U)*; WSRC-RP-96-873; Rev. 1.
- WSRC, June 1997e, *Savannah River Site Five-Year Review of Records of Decision Report*; WSRC-RP-97-403; Rev. 0.
- WSRC, September 1997f, *Groundwater Mixing Zone Application for the D-Area Oil Seepage Basin (631-G)*; WSRC-RP-97-422; Rev. 0, Final.
- WSRC, October 1997g, *Record of Decision, Remedial Alternative Selection for the K-Area Bingham Pump Outage Pit (643-1G) (U)*; WSRC-RP-97-178; Rev. 1.
- WSRC, November 7 1997h, *Workplan/RCRA Facility Investigation/Remedial Investigation Report for the Old Radioactive Waste Burial Ground 643-E, S01-S22 (U)*; Volume I – Text; WSRC-RP-97-00127; Rev. 0.

- WSRC, December 1997i, *Phase II, RCRA Facility Investigation/Remedial Investigation Plan for the F-Area Burning/Rubble Pits (231-F and 231-1F) and Rubble Pit (231-2F) (U)*; WSRC-RP-90-486; Rev. 2.3.
- WSRC, January 1998a, *Corrective Measures Implementation/Remedial Design Report/Remedial Action Work Plan (CM/RDR/RAWP) for Old F-Area Seepage Basin (904-49G) (U)*; WSRC-RP-97-854; Rev. 0.
- WSRC, February 1998b, *Record of Decision, Remedial Alternative Selection for the D-Area Oil Seepage Basin (631-G) (U)*; WSRC-RP-97-402; Rev. 0 Draft.
- WSRC, March 1998c, *Record of Decision, Remedial Alternative Selection for the A-Area Burning/Rubble Pits (731-A/1A) and Rubble Pit (731-2A) Operable Unit (U)*; WSRC-RP-97-142; Redline Draft Rev. 1.
- WSRC, March 1998d, *Record of Decision, Remedial Alternative Selection for the F-Area Retention Basin (281-3F) (U)*; WSRC-RP-97-145; Rev. 0.
- WSRC, March 1998e, *H-Area Retention Basin Treatability Study Work Plan (281-3H) (U)*; WSRC-RP-98-00125; Rev. 0.
- WSRC, March 1998f, *Final Remediation Report for the Silverton Road Waste Unit (731-3A) (U)*; WSRC-RP-97-153; Revision 1.1.
- WSRC, March 1998g, *Final Remediation Report for the D-Area Burning/Rubble Pits (431-D and 431-1D) (U)*; WSRC-RP-97-406; Revision 1.1.
- WSRC, 1998h, *Federal Facility Agreement for the Savannah River Site*; Administrative Document Number 89-05-FF; Effective Date: August 16, 1993 (as modified through 04/13/1998); WSRC-OS-94-42.
- WSRC, April 1998i, *Record of Decision, Remedial Alternative Selection for the Motor Shops Seepage Basin (716-A) (U)*; WSRC-RP-97-840; Rev. 0.
- WSRC, April 1998j, *Record of Decision, Remedial Alternative Selection for the C-, F-, K-, and P-Area Coal Pile Runoff Basins (189-C, 289-F, 189-K, and 189-P) (U)*; WSRC-RP-97-850; Rev. 0.
- WSRC, April 1998k, *Record of Decision, Remedial Alternative Selection for the Fire Department Hose Training Facility (904-113G) Operable Unit (U)*; WSRC-RP-97-171; Redline Rev. 1.
- WSRC, 1998l, Savannah River Site/Environmental Restoration Division Waste Units; Gerry Stejskal, WSRC; personal communication 5/8/98.
- WSRC, May 1998m, The Savannah River Site's Groundwater Monitoring Program, Fourth Quarter 1997 (U); WSRC; ESH-EMS-970491.

4.0 HANFORD SITE

The Hanford Site is located in Southeastern Washington State, approximately 25 miles north of Richland, Washington, and occupying about 560 square miles adjacent to the Columbia River. The mission of the Hanford Site included processing nuclear materials in support of defense, research, and medical programs of the United States. The Hanford Site defense production facilities included nuclear fuel fabrication facilities, nuclear production reactors, separation facilities, product preparation facilities, research facilities, and waste management facilities. The current Hanford Site's mission is to manage waste products; researching, developing, applying, and commercializing technologies; waste management; cleanup and environmental restoration. Engineering, scientific and research programs are conducted on environmental restoration, tank waste remediation, waste management, nuclear energy, and energy research. This assessment does not address non-DOE facilities (Washington Public Power Supply System, U.S. Ecology).

Closure and postclosure plans at Hanford are decided on a site-by-site basis. Many sites/units are in various stages of the remediation process, but few have been closed. Of the facilities that have been closed, most have been clean closed, eliminating the need for postclosure monitoring. After a facility, unit, or site is closed, depending on the conditions of the closure, postclosure monitoring activities are conducted to ensure that there is no further threat to the environment. The postclosure monitoring needs directly relate to the type of closure strategy, facility type, and risk involved.

The Hanford site will remain under the care of the federal government after environmental restoration is completed (DOE 1998c, section 3.2). Postclosure tasks could include, but are not limited to, regular maintenance (erosion control measures, placement of signs, fence repair) and monitoring (site condition and groundwater) in accordance with RCRA/CERCLA requirements. Managing and maintaining closed waste sites may require performing periodic inspections for general site condition, correcting any damage discovered during these inspections, and groundwater monitoring. Surveillance and maintenance (S&M) activities are required for deactivated facilities awaiting decommissioning. Unfortunately, many of the closure plans are currently vague or to be decided in the future; therefore, the postclosure needs are vague at best.

4.1 TIMELINE

The timeline (DOE 1998c, exhibit 3-12) for the environmental restoration of the Hanford site is divided into the different missions required. The environmental management (EM) mission and waste management is scheduled to be completed in 2046. Waste management activities include the spent nuclear fuel program (completed 2046), treating solid waste (completed 2032) and the storage and disposal of solid waste (completed 2046). The deactivation of facilities is scheduled to be completed in 2014 (the facilities then enter S&M mode until decommissioned and dismantled).

Environmental remediation activities are scheduled to be completed in 2043. These activities include 100 Area source remedial action (completed 2011), 200 Area source remedial action (completed 2024), 300 Area transuranic (TRU) waste retrieval (completed 2014), decontamination and decommissioning (completed 2043), and groundwater remediation (completed 2007). The tank waste will be retrieved and the tanks closed by 2046. The high-level

waste (HLW) from these tanks will be disposed and the storage facilities decontaminated and dismantled by 2046.

4.2 REGULATIONS

4.2.1 Governing Regulations

The Hanford Federal Facility Agreement And Consent Order (Ecology, EPA, DOE, 1994) is commonly referred to as the Tri-Party Agreement (TPA). The TPA is the plan for hazardous waste permitting, closure and postclosure requirements, and remedial action under RCRA, CERCLA, and the Washington State Hazardous Waste Management Act (Chapter 70.105 Revised Code of Washington, as amended). The regulatory situation is a complex interaction of state and federal regulations. Cleanup of a given unit may be regulated by any or all of the regulations identified above. The TPA is designed to mitigate conflicts between regulations. In execution, there is still some confusion of regulatory responsibility and applicability.

The Hanford Site is permitted under a single Washington State identification number and is considered a single State Dangerous Waste Program/RCRA facility with numerous unrelated units spread over the site. Since the entire site cannot be permitted simultaneously, the facility is being permitted on a unit/group basis. The Washington State Department of Ecology (Ecology) is generally the lead for permitting activities with the United States Environmental Protection Agency (EPA) having final approval rights on certain conditions. The permit is titled: *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste at the Hanford Facility, Washington State Department of Ecology, Permit Number WA7890008967, Revision Number 4A* (Ecology 1996b).

4.2.2 Postclosure Requirements

Closure at Hanford is primarily regulated through the TPA. The Washington Administrative Code (WAC) Dangerous waste regulations are contained in WAC 173-303 (WSR 1997). Postclosure requirements are specifically outlined in the Part B permit submitted for each facility, unit, or group. WAC 173-303-610, titled Postclosure Care and Use of Property, is the relevant closure and postclosure regulatory section. WAC 173-303-9905 is the list of dangerous waste constituents.

Postclosure care is to begin after completion of closure, continue for a period of thirty years, and must consist of at least:

- groundwater monitoring and reporting and
- maintenance and monitoring of waste containment systems as applicable.

Groundwater monitoring is required to

- consist of enough appropriately located and sized wells that can represent the background quality of water,
- consist of enough appropriately located and sized wells that can represent the quality of water passing the unit boundary,

- allow for detection of contamination where waste may have migrated from the waste management area, and
- use cased wells that maintain the integrity of the borehole and prevent contamination of well samples.

Groundwater monitoring data analysis must use a parametric analysis of variance or an analysis of variance based on ranks. Both methods must be followed by a multiple comparisons procedure. Additional specific requirements apply to detection monitoring, compliance monitoring, and corrective action programs. Reporting times vary by program type and within each permit.

The maintenance and monitoring plan is responsible for maintaining the integrity of the containment structure. Maintenance and monitoring activities are specified in the postclosure plan. The plan must address the specific activities conducted and the frequency that they will be conducted during the postclosure period. Specific requirements apply to the different types of containment structures.

4.3 POSTCLOSURE CATEGORIES

For regulatory purposes in the TPA Action Plan, facilities are classified as:

- Treatment, Storage, and Disposal Facilities (TSD)
- Past Practice Processes (PPP)
 - * CERCLA Past Practice (CPP)
 - * RCRA Past Practice (RPP)
- Facility Decommissioning Process.

Each of the physical facility types described in this report will be subject to a closure process. Facilities not categorized are considered "interim status." Interim status facilities are those without a RCRA Part B permit or closure plan (Ecology, EPA, DOE 1994, section 6.3).

4.3.1 Clean Closure

If all hazardous wastes and constituents can be removed, the unit/group can be closed as a "clean closure" per WAC 173-303 and 40 CFR 270.1. No postclosure activities are required (Ecology, EPA, DOE 1994, section 6.3).

The sites listed in the TPA as clean closed are 300 Area Solvent Evaporator, 2727-S Nonradioactive Dangerous Waste Storage Facility, Simulated High Level Waste Slurry Treatment and Storage Unit, 218-E-8 Borrow Pit Demolition Site, 200 West Area Ash Pit Demolition Site, 2101-M Pond, 216-B-3 Expansion Ponds, Hanford Patrol Academy Demolition Sites, 304 Concretion Facility, and the 4843 Alkali Metal Treatment and Storage Facility (Ecology, 1996b).

4.3.2 Closure as Land Disposal Unit

Units/groups that cannot meet clean closure requirements will be closed as land disposal units per the requirements of WAC 173-303. These units will require a postclosure permit addressing maintenance, inspection, groundwater monitoring, and any necessary corrective actions. The postclosure period is specified as thirty years from the closure certification date, but Ecology can modify this period in accordance with WAC 173-303-610. A closure plan is to be submitted with the Part B permit postclosure permit application. For units that will be closed prior to issuance of a permit for postclosure, an interim status postclosure plan will accompany the closure plan (Ecology, EPA, DOE 1994, section 6.3).

4.3.3 Procedural Closure

Units/groups classified as TSDs but never actually treated, stored, or disposed of hazardous or mixed wastes can be procedurally closed. A certification to this effect must be submitted to Ecology. Following a review and/or inspection, Ecology can either concur or deny. Denied units/groups will follow other options as described above. These units do not need to go through the closure process and require no postclosure activities (Ecology, EPA, DOE 1994, section 6.3).

4.3.4 Past Practice Processes

Past Practice units/groups are designated as CERCLA Past Practice or RCRA Past Practice units. The EPA and Ecology jointly determine which authority (RPP or CPP) will be assigned to each operable unit. In general, CPP will apply to an operable unit consisting of past-practice units and for units where CERCLA-only materials comprise the majority of work to be done. RPP will apply to operable units having significant TSD units and/or lower priority past-practice units (Ecology, EPA, DOE 1994, section 5.4).

A current listing of all operable unit boundaries and priorities site-wide is primarily documented in the Waste Information Data System (WIDS). WIDS is regarded as the primary reference regarding waste sites at Hanford (<http://www.bhi-erc.com/dm/wids/wids.htm>). Each individual operable unit is scoped to support the planning phases of Remedial Investigation/Feasibility Study (RI/FS) or RCRA Facility Investigation/Corrective Measures Study (RFI/CMS). Under most circumstances, CPP and RPP closure approaches will yield similar results.

The Hanford Site is already included in the CERCLA National Priority Listing. Each CPP unit will be subject to the RI/FS process. The RI/FS process examines the unit and develops a treatment option, culminating in a Record of Decision (ROD) that specifies the plan for the unit. Remedial Design, Remedial Action, and Operations and Maintenance phases follow the ROD.

RPP units undergo a similar process to the CPP units. Depending on the information available for a facility, the lead regulatory agency may determine that a RCRA Facility Assessment is necessary to determine whether or not a RFI is required. Where sufficient information is available, effort is focused on the RFI/CMS. RFI/CMS work plans are functionally equivalent to RI/FS work plans. Based on the results of the RFI, the lead regulatory agency may determine no further investigation or corrective actions are necessary. Otherwise, the lead regulatory agency will require a CMS. The CMS will identify and evaluate corrective measure alternatives and justify the recommended alternative. After receiving concurrence from the lead regulatory agency, a Corrective Measures Implementation will initiate and complete the recommended

alternative. Upon completion, the lead regulatory agency will issue a certificate of completion (Ecology, EPA, DOE 1994, section 7.4.2).

4.4 POSTCLOSURE REQUIREMENTS

General postclosure requirements that could be expected for a closed site are listed below. Postclosure environmental monitoring will be less extensive as current environmental monitoring (described in Appendix C.4).

4.4.1 General Postclosure Plans' Requirements

The postclosure plans of TSD units (DOE/RL 1991b, section 11.3) are to include plans for inspections, monitoring, maintenance, and land treatment. The land treatment plan is concerned with the programs and procedures to maintain a vegetative cover (keep out deep-rooted plants and burrowing animals), minimize wind erosion damage, and the management of run-on and run-off systems. The inspection plan concerns inspecting the condition of

- the access control devices
- the cover and the site (if any damage due to erosion, settlement, subsidence and displacement)
- the vegetative cover
- the run-on and run-off controls
- the cover drainage system
- the gas venting system
- the wells
- the benchmark integrity.

The monitoring plan will describe the postclosure groundwater monitoring activities and will include information concerning aquifer identification, contaminant plume description, detection monitoring program, compliance monitoring program and the corrective action program. The maintenance plan will describe the procedures, equipment, and material needs for prevention and corrective maintenance. Maintenance will include

- repairing damage to access and security control devices
- repairing the effects of erosion, settlement, subsidence and displacement
- mowing, fertilization and other activities necessary for the maintaining the vegetative cover
- repairing the run-on and run-off controls
- replacing wells.

4.4.2 Deed Restrictions

Deed restrictions (DOE/RL 1990a, section 8.1; DOE/RL 1990b, section 8.2; DOE/RL 1991a, section 8.1) are also an integral part of postclosure protection. The following is the typical wording for a deed restriction:

"The United States Department of Energy, Richland Operations Office, an operations office of the United States Department of Energy, which is a department of the United States Government, the undersigned, whose local address is the Federal Building, 825 Jadwin Avenue, Richland, Washington, hereby gives the following notice as required by 40 CFR 265.120 and WAC 173-303-610(10) (whichever is applicable):

- a. The United States of America is, and since April 1943, has been in the possession in fee simple of the following described lands: (legal description of the operable unit)
- b. The United States Department of Energy, Richland Operations Office, by operation of the (facility name), has disposed of hazardous and/or dangerous waste under the terms of regulations promulgated by the United States Environmental Protection Agency and Washington State Department of Ecology (whichever is applicable) at the above described land.
- c. The future use of the above described land is restricted under terms of 40 CFR 264.117(c) and WAC 173-303-610(7)(d) (whichever is applicable).
- d. Any and all future purchasers of this land should inform themselves of the requirements of the regulations and ascertain the amount and nature of wastes disposed on the above described property.
- e. the United States Department of Energy, Richland Operations Office has filed a survey plat with the Benton County Planning Department and with the United States Environmental Protection Agency, Region 10, and the Washington State Department of Ecology (whichever are applicable) showing the location and dimensions of the (facility name) and a record of the type, location, and quantity of waste treated."

4.4.3 Well Maintenance

The well is inspected whenever a groundwater sample is retrieved. The groundwater monitoring wells have a locked cap and are surrounded by four steel ground posts to prevent damage to the wells from vehicles and to increase its visibility. The head, cap, protective posts, concrete pad, and pump performance are inspected. Problems, such as excessive turbidity of the groundwater sample, are noted. Any required maintenance will then be performed to rectify these problems.

Each well undergoes periodic maintenance every five years. Maintenance includes the removal of dedicated equipment (such as the pump), pump inspection, cleaning the inner walls of the well's casing and screen by brushing, removal of any sediment accumulation, a video camera survey down the well hole, and the reinstallation of the dedicated equipment (DOE/RL 1997b, section 3.4; DOE/RL 1993, section 8.2; DOE/RL 1998b, section 3.3). If a groundwater monitoring well is no longer suitable for postclosure monitoring, then a new well will be installed (Buckmaster 1998, section 3.2)

4.5 SITE-SPECIFIC POSTCLOSURE REQUIREMENTS

Based on the available documentation, only two facilities have published postclosure monitoring plans. Most of the closures to date have been "clean closures" which do not require postclosure monitoring. The closure plans of some other facilities contain vague information about what the postclosure plans might contain if a clean closure is not obtained.

4.5.1 300 Area Process Trenches Postclosure Plan

The 300 Area Process Trenches (300 APT) received liquid effluent from 300 Area fuel fabrication and research and development activities via the 300 Area process sewer system. The dangerous constituents of concern are trichloroethene (TCE) and dichloroethene (DCE) (DOE/RL 1998, section 3.1).

Groundwater monitoring activities revealed that concentrations of cis 1-2 dichloroethene and uranium exceeded maximum contaminant levels (MCL). This necessitated a change to the permit, the development of a corrective action groundwater monitoring plan, and the issuance of a postclosure plan (DOE/RL 1997a). The corrective action groundwater monitoring plan was not publicly available as of this writing.

Institutional controls are not required to restrict surface activities (i.e., no fences or barriers) but are required to restrict groundwater use. Groundwater use will be restricted through notifications in the Hanford Facility land use master plan and county real property records (DOE/RL 1998a, section 2.1). The facility is part of the 24-hour surveillance of the entire Hanford site by Hanford Patrol protective force personnel (Buckmaster 1998, section 5.1).

4.5.2 183-H Solar Evaporation Basins Postclosure Plan

The 183-H Solar Evaporation Basins (183-H) received liquid wastes from H-Reactor operations. No institutional controls are necessary to restrict surface activities. Current groundwater control activities are sufficient to stop groundwater use for drinking or agricultural use (DOE/RL 1997b, section 2.1).

The primary dangerous waste constituent of concern is hexavalent chromium. Additional waste indicators from the 183-H plume are technetium-99, fluoride, nitrate, and uranium (DOE/RL 1997b, section 3.1). 183-H groundwater is being remediated as part of the 100-HR-3 operable unit. The interim remedial measure (IRM) for the groundwater operable unit is a pump and treat system employing ion exchange. The RCRA corrective action sampling and analysis schedule includes a network of four wells sampled annually (DOE/RL 1997b, section 3.2).

Water samples are analyzed for the constituents of concern along with alkalinity, other metals, and other anions. Samples measurements for pH, temperature, specific conductance, and turbidity are taken. The monitoring is a combined RCRA/CERCLA activity because the 183-H facility is a RCRA closure, but the groundwater is part of a CERCLA operable unit. Because of this, there are RCRA corrective action monitoring schedules, operable unit remedial investigation (RI) monitoring schedules, and operable unit IRM monitoring occurring simultaneously (summarized in Table 4.5.2.1).

Table 4.5.2.1
Analysis suite codes (FY97/98) for 183-H RCRA corrective action, CERCLA RI monitoring, and IRM

Analysis/ Parameter	RCRA Corrective Action		CERCLA RI		IRM
Metals	Aluminum	Iron	Aluminum	Iron	Chromium, Uranium(VI)
	Antimony	Magnesium	Antimony	Magnesium	
	Barium	Manganese	Barium	Manganese	
	Beryllium	Nickel	Beryllium	Nickel	
	Cadmium	Potassium	Cadmium	Potassium	
	Calcium	Silver	Calcium	Silver	
	Chromium	Sodium	Chromium	Sodium	
	Cobalt	Uranium	Cobalt	Vanadium	
	Copper	Vanadium	Copper	Zinc	
		Zinc			
Anions	Chloride	Nitrate	Chloride	Nitrate	Nitrate
	Fluoride	Sulfate	Fluoride	Sulfate	
Radionuclide Screening:	Activity Scan		Gross alpha Gross beta	Activity scan	
Specific Radionuclides	Technetium-99		Tritium		Strontium-89/90 Technetium-99 Tritium
Miscellaneous Parameters:	Alkalinity				
Field Parameters:	PH Specific conductance Temperature Turbidity		pH Specific conductance Temperature Turbidity		pH Specific conductance Temperature Turbidity

Source: DOE/RL, 1997b

4.5.3 Other Facilities

The closure plans for the 4843 Alkali Metal Storage Facility (DOE/RL 1990a, section 8.0), the 303-K storage facility (DOE/RL 1990b, section 8.0), 616 Nonradioactive Dangerous Waste Storage Facility (DOE/RL 1989, section 11.0) and the 3718-F Alkali Metal Treatment and Storage Facility (DOE/RL 1991a, section 8.1) state that a clean closure is proposed and therefore no postclosure plan was submitted. However, if clean closure is not an obtainable option, then deed restrictions will be imposed and a postclosure plan will be written with detailed plans concerning inspection, monitoring, maintenance, personnel training, postclosure contact, provisions to amend the postclosure plan, and provisions to certify the postclosure plan (DOE/RL 1990a, Section 8.2).

4.6 FACILITY DEACTIVATION AND DECOMMISSIONING

Facility decommissioning takes a facility from operational status to its end state condition (final disposition). This is accomplished by the completion of three phases: facility transition, surveillance and maintenance (S&M) and disposition phase (DOE 1994; DOE 1995; Ecology, EPA, DOE 1994, section 8.1.3). Deactivation involves removing hazardous chemicals and bulk nuclear materials. Contamination on surfaces and inside equipment is cleaned or isolated. The heating, ventilation, and other utilities are disconnected and isolated. After deactivation, the unit undergoes surveillance and monitoring and the next step is decommissioning and demolition (DOE/RL 1997a).

4.6.1 Transition Phase

The transition phase will not be considered complete until DOE has either completed RCRA closure and/or implemented a lead regulatory agency approved preclosure work plan. In cases where closure is not completed during the transition phase, the S&M plan for the key facility will address RCRA compliance. It is anticipated that, for such units, RCRA closure will be conducted during the disposition phase; however, Ecology may, at any time, choose to accelerate closure timing and/or initiate final closure in order to assure timely protection of human health and the environment (Ecology, EPA, DOE 1994, section 8.8).

4.6.2 Surveillance and Maintenance

The S&M Plan describes facility-specific activities to address monitoring, maintenance, and operational requirements for the essential systems at a facility. The plan will ensure that the facility is maintained cost effectively and in a safe, stable condition that presents no significant threat of release of hazardous substances into the environment and no significant risk to human health and the environment until final disposition is completed (Ecology, EPA, DOE 1994, section 8.5.4).

Facilities placed in a S&M condition require periodic inspections and examinations. The generally accepted S&M period is on the order of fifty years; for the purposes of this report, these inspections and examinations are considered postclosure monitoring.

During FY1997, S&M activities mainly included maintenance activities. Radiation surveys and visual inspections are conducted to identify releases. Inspection frequencies range from weekly to years depending on the facility. Inspections are mainly walk-throughs to examine:

- condition of physical structures to identify structural defects
- hazardous conditions
- contamination migration
- unidentified hazardous materials
- unidentified friable asbestos
- failed lights
- animal/water/insect intrusion.

4.6.3 Plutonium Uranium Extraction Facility

The Plutonium Uranium Extraction Facility (PUREX) achieved standby condition in September 1992 and is now in the long-term S&M program. PUREX facilities include the 202-A building, ancillary buildings, and associated equipment within the perimeter fence. Operational systems include the heating, ventilation and air conditioning system; the electrical system; the Surveillance, Monitoring, and Control System (SAMCONS) Instrument and Control (I&C) unit; and surveillance lighting (DOE/RL 1998c, section 2.1 & 2.2).

Electricity is not supplied through the original electrical distribution system, which has been isolated and disconnected, but through two new electrical substations and transformers. The lighting has an external disconnect and is energized only during an internal inspection.

The ventilation system consists of the canyon exhaust fan which forces air from non-contaminated areas towards the high contamination areas. Three 200-horsepower fans are installed (two are backup) with only one fan operating at a time. A monthly rotation schedule results in each fan being in operation every third month. If the operating fan fails, the SAMCONS monitoring unit will activate alarms and one of the backup fans (DOE/RL 1998c, section 2.2.4).

The SAMCONS I&C unit monitors and/or controls the air flow (nine differential pressure transmitters), temperature (of the exhaust fans bearings, air tunnel, building and of the SAMCONS I&C unit), liquid levels in catch tanks, humidity and dewpoint of air in the filter, and condition and status of the electrical system (DOE/RL, 1998c, section 2.2.4.3). Surveillance activities include continuous stack particulate sampling, monthly iodine sampling, quarterly surveillance of the interior and exterior condition of the facilities, and routine surveillance of equipment. Routine housekeeping includes removing tumbleweeds and other debris (DOE/RL 1998c, section 2.3).

The quarterly surveillance inspection is to detect

- any structural defects and roof deterioration
- contamination migration
- deficiencies in postings

- the presence of any hazardous materials, unlabeled containers, unidentified friable asbestos
- failed lighting
- water, animal, or insect intrusion (DOE/RL 1998c, section 2.3.2).

Routine surveillance of the equipment includes

- monthly inspection and lubing of the exhaust fans and bearings
- quarterly inspection of the vacuum pumps
- replacing light bulbs as needed
- equipment calibration as recommended in procedures
- high efficiency particulate air (HEPA) filter replacement (frequency is determined by surveillance)
- cold weather protection (whenever cold temperatures occur)
- monthly canyon exhaust fan rotation
- electrical system maintenance when recommended in procedures (DOE/RL 1998c, section 3.4.1).

Cold weather protection requires special attention to frost on inlet areas of the vents, SAMCONS instrument temperatures, and water effects on HEPA filters (DOE/RL 1998c, section 3.18).

Physical access to the building is prevented by fences, locked gates, and signs. Access is limited to trained, authorized personnel. No intrusion alarms or routine security patrols within the perimeter fence are performed; but the area is part of the 24-hour Hanford Patrol surveillance (DOE/RL 1998c, section 10.1).

4.6.4 The 105-C Reactor

The 105-C Reactor was shutdown in April 1969 and was one of the first facilities to be placed in interim safe storage configuration (DOE 1995, chapter 4). Loose contamination, the fuel storage basin, the fuel examination facility, ancillary support buildings, and all building portions outside the shield wall were removed. Deactivation also involved installing steel siding on the exterior, installing a new roof, and closing any penetrations into the shield wall. The objective is to safely store the reactor until it is removed as one-piece and disposed (DOE/RL 1998d, section 2.2).

Electrical power is supplied from a 13.8-kV line with no backup power capability. Permanent lighting is installed inside along the planned surveillance route, but inspectors must carry a spare light source whenever inside. Two temperature sensors (resistance temperature detectors) and a flooding sensor are installed along with spare sensors. If the sensor fails, the spare sensor can be activated from outside the closed facility. The failed sensor will be repaired or replaced during the next scheduled surveillance. The remote monitoring system transmits data via a modem and a dedicated phone line to the operation supervisor workstation. The water supply lines, sewer pipes, pipes to trenches and cribs have been isolated or plugged (DOE/RL 1998d, section 2.4).

An external visual inspection (from the ground, roof access will not be required) will be conducted annually to detect any structural or roof defect. Periodic surveillance of the 105-C Reactor interior will be performed every five years and will include

- structural integrity: any corrosion, aging of materials, water, insect, or animal intrusion;
- barriers and postings: locks, tags, fencing, confined space postings, radiological area postings;
- radiological surveys;
- repair of confinement systems: 2 HEPA filters, sealants, and roof;
- repair of structural components; and
- removal of hazardous substances (DOE/RL 1998d, section 2.3).

Ventilation will be provided by leaving the entrance door open and operating a skid-mounted exhauster. The exhauster is configured with HEPA filters and a beta-gamma monitoring system. Two sheet metal coverings over the building's HEPA filter openings need to be removed for ventilation and reinstalled after the inspection is completed (DOE/RL 1998d, section 2.4.3).

The only access into the facility is through the utility room. The door to the utility room is closed and locked. The door from the utility room to the reactor facility is locked and welded shut (except during inspections). The facility is entered only for S&M activities. No intrusion alarms or dedicated security patrols are required, but the facility is part of the 24-hour Hanford Site security surveillance (DOE/RL 1998d, section 8.0).

4.7 WASTE DISPOSAL

The Central Plateau is located in the 200 area and is reserved for waste disposal for the Hanford site. Waste management facilities to be operated at the Central Plateau include the Environmental Restoration Disposal Facility (ERDF) and two treated effluent disposal facilities. Entry into this area will be reserved for properly trained, authorized personnel only. LLW, mixed and hazardous waste will be disposed (DOE/RL 1996, section 3.3.2; DOE 1998h).

The ERDF will be used for mixed low level waste disposal in trenches. Its location was chosen because of geological stability, it is outside the 100-year flood plain, is more than 7 miles from the Columbia River and is 240 feet above the water table. A double liner (compliant with RCRA requirements) will be installed beneath the waste and will include an effluent collection system. A cover will be constructed over portions of the facility when filled with waste. WAC requires a 30 year postclosure monitoring and maintenance of the ERDF (DOE 1996b). Postclosure monitoring should be similar to that required for the OSDF in Fernald (except for the CUCs monitored): groundwater monitoring, monitoring and maintenance on the effluent collection system and of the cover system.

The treated effluent disposal facilities are an underground drainage field. Current technology can not remove tritium from the effluent, but discharge limits will be observed. The location of the 200 Area Treated Effluent Disposal Facility, which will receive the tritiated water, was chosen to allow sufficient time for the radioactive decay of tritium before migrating to the Columbia River (DOE 1996a).

The Central Plateau is the most contaminated area of the Hanford site (DOE/RL 1996, section 1.3.2.3). Postclosure plans are not available yet. However, postclosure monitoring will probably include groundwater monitoring. However, what COCs will be monitored can not presently be determined since it depends on the characteristics of the waste disposed and the results of groundwater remediation efforts. The presence of a COC in the groundwater due to previous contamination will complicate efforts of detecting this COC from a leak of the waste repository. Other projected postclosure controls will be access and deed restrictions and monitoring and maintenance of the repository facility and cap system.

LLW and MW resulting from ER activities or other activities will be disposed on-site at Hanford. Decisions regarding nuclear materials and spent nuclear fuel are still to be decided. The majority of the TRU on-site will be deposited in WIPP. The ER waste stream is estimated to be

- ERDF disposal of MW, LLW, hazardous debris, and soil: 3.8 million m³
- in-situ disposal of LLW in the 200 area (capped): 20 million m³
- other specific waste, such as asbestos, will be disposed off-site.

HLW sludge, salt, and liquid will go to a geologic repository off-site (Yucca Mountain). Processing of this waste will produce LLW that will be disposed on-site. Closed tanks will also remain on-site (DOE 1998h).

4.8 END STATE DEFINITIONS

Some postclosure requirements may be inferred by the projected end state of the Hanford sites and facilities at the end of ER activities. End states are directly related to the land use alternative selected (Table 4.8.1). The following descriptions are summaries of the end states identified in the plan and do not refer to any single unit or facility. Additional information specific to the facility type is included where available.

4.8.1 Activity Descriptions

Safeguards and security activities restrict access to the facilities (fences, signs, and guards). Institutional control of groundwater controls groundwater use through land use and deed restrictions combined with safeguards and security activities. Groundwater monitoring activities are conducted in accordance with the facility permit. Consolidating the contaminants is simply moving the contamination into a smaller area (i.e., bulldozing smaller piles into one larger pile). A cap is a barrier placed over the waste site to prevent water from permeating through the contaminated area and limit further penetration toward groundwater. The no action alternative is given as a baseline, it is not expected to be chosen (Ecology, EPA, DOE 1994, section 3.0).

Table 4.8.1
End state alternatives and activities

Alternative	Activities
No Action	<ul style="list-style-type: none"> • Continue existing monitoring program (air, water, soil, wildlife, vegetation) of radiological/chemical hazards • Stabilize waste site (consolidate contamination, cover with clean soil, revegetate) • • Maintain safeguards and security
Unrestricted Future Land-Use	<ul style="list-style-type: none"> • Extensive excavation of contaminated soils • Remediation of groundwater (pump & treat systems) • Groundwater monitoring, institutional control of groundwater use
Restricted Future Land-Use	<ul style="list-style-type: none"> • Limited excavation of contaminated soils • Close/remediate facility/unit and treat groundwater OR cap facilities and monitor groundwater • Groundwater monitoring, institutional control of groundwater use • Some residual contamination left in place
Exclusive Future Land-Use	<ul style="list-style-type: none"> • Consolidate contaminants • Cap facility/unit • Maintain engineering/institutional control of land/groundwater use

4.8.2 Reactor Facilities

The reactors (Ecology, EPA, DOE 1994, section 3.0) will be placed in a safe storage configuration for approximately 75 years. The B Reactor is assumed decontaminated, but not dismantled, and is open for access-controlled public viewing. After the safe storage period, the reactor will be removed as a single unit and placed in a disposal facility in the 200-W Area. Uncontaminated areas and adjacent facilities will likely be demolished and placed in a burial ground near the reactor.

Safe storage includes the removal of all areas external to the massive shielding walls adjacent to the reactor core and sealing all penetrations to the building. There will be one access port available for periodic inspections, approximately occurring every five years. In the case of C Reactor, a new roof structure was added to supplement the failing existing roof. Necessary upgrades (structural, security) will be made to support the safe storage period. This process also

includes adding fixatives, significant decontamination, and demolition. Disposal activities will use a large tractor-transporter to transport the reactor to a solid waste burial facility in the 200-W Area. Safe storage activities are managed as part of S&M activities.

4.8.3 Canyon Facilities

The Canyon Disposition Initiative Project is establishing the end-state definition for Hanford's canyon facilities (Table 4.8.3.1). The U-Plant is the pilot facility for this project. Currently the CDI is characterizing these facilities - a preliminary step in determining the preferred end state. The alternative chosen will determine the postclosure requirements (DOE 1993).

**Table 4-8.3.1
Canyon Facilities Alternatives and End State Activities**

Alternative	Activities
Alternative 0	No Action
Alternative 1	Full Removal and Disposal
Alternative 2	Decontaminate and Leave in Place
Alternative 3	Entombment with Internal Waste Disposal
Alternative 4	Entombment with Internal/External Waste Disposal
Alternative 5	Close in-Place – Standing Structure
Alternative 6	Close in-Place – Collapsed Structure

4.8.4 Tank Facilities (Bechtel Hanford, n/a)

Following remediation, closing tank farms under the TSD process (RCRA) involves

- Ensuring that the tanks contain a residual equal to no more than 1 percent of the initial tank inventory
- Tanks (both single and double shelled) would be stabilized by gravel filling,
- Tank farm structures (such as miscellaneous underground storage tanks, pump pits, valve boxes, and diversion boxes) would be stabilized with grout
- Hanford Barriers would be placed over tanks and low activity waste disposal vaults
- Facility decontaminating and decommissioning would involve disposing of non-contaminated facilities on-site (entombed in place) and contaminated material and equipment at an on-site low-level waste burial ground (Ecology 1996a).

The current Hanford Barriers design is a horizontal, multi-layered above grade engineered soil structure used to isolate the waste site from the environment. It is composed of 10 layers, a total of approximately 15 feet thick, extends an additional 30 feet beyond the perimeter of the area to

be protected, and is placed over the top of the facility, site, or unit of interest. Postclosure activities might include inspection and maintenance of the cap and groundwater monitoring

4.8.5 Groundwater

The groundwater under large parts (about 32 square miles) of the Hanford site is contaminated above EPA drinking water standards for several hazardous and radioactive constituents. Remediation to the level of nonrestrictive use is not considered feasible (DOE/RL, 1996, section 3.3.3.1). The main radioactive contaminants are, but are not limited to, tritium, cobalt-60, strontium-90, cesium-137, technetium-99, iodine-129, and isotopes of uranium, plutonium, and europium. The main hazardous contaminants are, but are not limited to, chromium, chloroform, mercury, various inorganic acids, polychlorinated biphenyl, cyanide, nitrate, fluoride, carbon tetrachloride, ferrocyanide, trichloroethylene, uranium and petroleum compounds (DOE/RL 1996, section 1.3.1).

These constituents may be the main COCs monitored during the postclosure groundwater monitoring. However, the COCs that will be monitored during the postclosure phase depends largely on remediation results and may include all or only some of the constituents listed above. Other constituents, not listed above, may also be monitored during the postclosure phase. Further details about the COCs currently being monitored throughout the Hanford site are available in Section C.4

4.9 REFERENCES

- Bechtel Hanford, Inc., no date given, *Richland Environmental Restoration Project*, webpage at <http://www.bhi-erc.com/canyon/canyon.htm>.
- Buckmaster, M.A., March 1998, *Inspection, Monitoring, and Maintenance Plan for the 300 Area Process Trenches*, BHI-01161, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
- DOE, September 16, 1993, Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, WA, Federal Register, Vol. 58, Number 178, Page 48509.
- DOE, 1994, *Decontamination and Decommissioning Handbook*, DOE/EM-0142D, DOE, Office of Environmental Remediation, Washington, D.C.
- DOE, 1995, *Decommissioning Resource Manual*, DOE/EM-0246, DOE, Office of Environmental Restoration, Washington, D.C.
- DOE, 1996a, *Baseline Environmental Report, Volume III: Site Summaries for the 1996 Baseline Environmental Management Report: New Mexico – Wyoming*, DOE/EM-0290, DOE, Washington D.C. (<http://www.em.doe.gov/bemr96/han4.html>)
- DOE, 1996b, *Baseline Environmental Report, Volume III: Site Summaries for the 1996 Baseline Environmental Management Report: New Mexico – Wyoming*, DOE/EM-0290, DOE, Washington D.C. (<http://www.em.doe.gov/bemr96/han3.html>)
- DOE, 1998c, *Accelerating Cleanup: Paths to Closure [National/Complex-Wide Report]*; DOE/Office of Environmental Management; June 1998; DOE/EM-0362.

- DOE, 1998h, *Hanford Baseline Disposition Maps*,
<http://www.em.doe.gov/closure/mapmenu.html#RL>
- DOE/RL, 1989, *616 Nonradioactive Dangerous Waste Storage Facility Dangerous Waste Permit Application*, DOE/RL-89-03, Rev. 2, DOE/RL, Richland, Washington (<http://www.hanford.gov/docs/rl-89-03/rl8903-5.htm#11.0>)
- DOE/RL, 1990a, *The 4843 Alkali Metal Storage Facility*, DOE/RL-90-49, Rev 1, DOE/RL, Richland, Washington (<http://www.hanford.gov/docs/rl-90-49/rl-90-49.htm>)
- DOE/RL, 1990b, *the 303-K Storage Facility Closure Plan*, DOE/RL-90-04, Rev. 2A, DOE/RL, Richland, Washington (<http://www.hanford.gov/docs/rl-90-04/rl90-042.htm#8.0>)
- DOE/RL, 1991a, *The 3718-F Alkali Metal Treatment and Storage Facility Closure Plan*, DOE/RL-91-35, Rev. 2, DOE/RL Richland, Washington (<http://www.hanford.gov/docs/rl-91-35/rl91-358.htm>)
- DOE/RL, 1991b, *Hanford Facility Dangerous Waste Permit Application, General Information Portion*, DOE/RL-91-28, Rev. 3, DOE/RL, Richland, Washington (http://www.hanford.gov/docs/rl-91-28/chp_11.htm#11.3)
- DOE/RL, 1993, *300 Area Process Trenches Closure Plan*, DOE/RL-93-73, Rev. 1, DOE/RL, Richland, Washington (<http://www.hanford.gov/docs/rl-93-73/rl93-731.htm>)
- DOE/RL, 1996, *Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan*, DOE/RL, Richland, Washington www.hanford.gov/eis/hraeis/eisdoc/chap.3/chap3.htm
- DOE/RL, 1997a, webpage document: *Closing the Circle from the War Years to the Future*, DOE/RL, Richland, Washington <http://www.hanford.gov/history/misc/circle.htm>
- DOE/RL, June, 1997b, *183-H Solar Evaporation Basins Postclosure Plan*, DOE/RL-97-48, Rev. 0, DOE/RL, Richland, Washington
- DOE/RL, May 1998a, *300 Area Process Trenches Postclosure Plan*, DOE/RL-98-31, Rev. 0, DOE/RL, Richland, Washington.
- DOE/RL, May 1998b, *Surveillance and Maintenance Plan for the Plutonium Uranium Extraction (PUREX) Facility*, DOE/RL-98-35, Rev. 0, DOE/RL, Richland, Washington.
- DOE/RL, September 1998c, *Surveillance and Maintenance Plan for the 105-C Reactor Safe Storage Enclosure*, DOE/RL-98-44, Rev. 0, DOE/RL, Richland, Washington.
- Ecology, EPA, and DOE, 1994, *Hanford Federal Facility Agreement and Consent Order*, as amended Washington State Department of Ecology, U.S. Environmental Protection Agency, U.S. Department of Energy, Olympia, Washington (<http://www.hanford.gov/tpa/tpahome.htm>).
- Ecology, April, 1996a, *Final Environmental Impact Statement for the Tank Waste Remediation System*, Washington State Department of Ecology, Olympia, Washington
- Ecology, 1996b, *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste at the Hanford*

Facility, Washington State Department of Ecology, Permit Number WA7890008967,
Revision Number 4A, Olympia, Washington
(<http://www.hanford.gov/docs/wa7890008967/index.htm>)

WSR, 1997, WASHINGTON ADMINISTRATIVE CODE, Washington State Register,
Olympia, Washington (http://www.mrsc.org/cgi-bin/om_cgi.exe?clientID=479&infobase=wac.nfo&softpage=Browse_Frame_Pg)

5.0 POSTCLOSURE REQUIREMENTS ACCORDING TO FEDERAL REGULATIONS

State regulations for postclosure monitoring are based on the Code of Federal Regulations, either mirroring the federal regulations or are more stringent. The postclosure monitoring requirements are found in 40 CFR § 264.

5.1 GENERAL REQUIREMENTS

After closure, the owner or operator must submit a survey plat that includes information concerning the location of the waste and the dimensions of the landfill cells or waste units (40 CFR § 264.116). A record of the type, location and quantity of hazardous waste must be submitted 60 days after closing each waste unit. The following information must be included in the deed after closure:

- the land has been used to manage hazardous waste,
- its use is restricted, and
- the survey plat (40 CFR § 264.119).

A postclosure plan must be submitted which includes a description of the activities and their frequencies for monitoring and maintenance. This plan must also include the name, address, and phone number of a contact person or office (40 CFR § 264.118).

Postclosure care begins after closure and is to last 30 years, unless shortened or lengthen by the director (40 CFR § 264.117). A certificate that postclosure care has been completed according to the approved plan must be submitted within 60 days after postclosure care has been completed (40 CFR § 264.120).

5.2 ADDITIONAL REQUIREMENTS FOR TANKS, WASTE PILES, AND CONTAMINATED BUILDINGS

The closure of a tank (40 CFR § 264.197), of waste piles (40 CFR § 264.58), or of contaminated buildings (40 CFR § 264.1102) requires the removal or decontamination of all waste residue and contamination in the system components, soils, structures, and equipment. All such contamination and residue is to be treated as hazardous waste. If not all contamination or waste residue can be reasonably removed or decontaminated, then the postclosure care applicable to landfills is required.

5.3 ADDITIONAL REQUIREMENTS FOR SURFACE IMPOUNDMENTS

To close facilities that use surface impoundments to treat, store or dispose of hazardous waste, all waste residue, contaminated containment system components, subsoils, structures, and equipment must be removed or decontaminated. Free liquids must be removed or solidified. A final cover is to be installed over the impoundment. The final cover must be able to

- minimize the migration of liquids through the impoundment,
- minimize any required maintenance,
- minimize erosion through the use of drainage,
- accommodate settling and subsidence, and
- have a lower or equal permeability than the bottom liner or subsoil

If any waste remains,

- then the waste must be stabilized and be able to bear the final cover,
- the final cover must be maintained to preserve its integrity and effectiveness,
- any damage due to settling, subsidence, erosion, or other events must be repaired if deemed necessary,
- the leak detection system must be maintained and monitored,
- the groundwater monitoring system must be maintained and monitored, and
- run-on and run-off must be controlled to prevent erosion or other damage to the final cover (40 CFR § 264.220).

Postclosure care of land treatment must include

- all operations necessary for degradation, immobilization, and transformation of hazardous constituents,
- a maintained vegetative cover,
- run-on and run-off control systems,
- control of dispersal of hazardous waste due to wind,
- restricted agricultural use of the land, and
- monitoring of the unsaturated zone.

The requirements may be waived if the owner or operator can demonstrate that the level of hazardous constituents is below background (40 CFR § 264.280).

5.4 ADDITIONAL REQUIREMENTS FOR LANDFILLS

A landfill requires the installation of a cover after closure. The final cover must

- minimize the long-term migration of liquids,
- minimize any required maintenance,
- minimize erosion through the use of drainage,
- accommodate settling and subsidence, and
- have a lower or equal permeability than the bottom liner or subsoil (40 CFR § 264.310).

Landfills are to have a leachate collection and removal system above the liner. If it can be demonstrated that an alternative design and the characteristics of the location are sufficient to prevent the migration of hazardous constituents, then the leachate collection and removal system requirement may be waived.

New landfills must have two liners with a leachate removal system above and between the two liners. This leachate removal system will also be a leak detection system (40 CFR § 264.300).

Postclosure care of a landfill includes

- maintenance of the final cover (includes repairing damage due to settling, subsidence, erosion, or other events),
- operating the leachate collection and removal system (may be waived if leachate is no longer detected),
- maintaining and monitoring the leak detection system,
- controlling run-on and run-off to prevent erosion or other damage, and
- protecting and maintaining surveyed benchmarks (40 CFR § 264.310).

6.0 POSTCLOSURE PROGRAMS OF OTHER NATIONS

Other nations with advanced nuclear programs face the same problem as the United States regarding contaminated sites and radioactive waste. The experience gained and the technology used by these countries in their planned or on-going postclosure programs may be applicable to DOE-EM's postclosure needs. Therefore, we reviewed the postclosure programs of Western Europe (focusing on Germany and France) and Japan.

The Internet was first searched for information, followed by contacting key personnel for further, more detailed information. The search included companies and research centers active in remediation and radioactive waste issues, remediation activities and plans of contaminated lands and facilities, and radioactive waste repositories. The purpose of this review is to provide the DOE with information not readily available in the United States. Therefore, this review does not include foreign companies with U.S. branches and/or which are active in the U.S. domestic nuclear industry such as British Nuclear Fuel Limited and Siemens. Also excluded for similar reasons are the results of any joint research projects of U.S. government agencies or national laboratories with foreign companies, research centers, or agencies.

This review showed that these nations have only vague postclosure plans. The technology currently used for monitoring of active sites is the technology currently used in postclosure monitoring or planned to be used.

6.1 LACK OF POSTCLOSURE PLANNING AND EXPERIENCE

Communications with several personnel in Japan and Europe revealed that the monitoring plans for radioactive waste repositories during or after closure were not complete or decided (Chaplow 1998; Schulze 1998; Takeuchi 1998; Decréton, 1998a). Experience in monitoring a site during postclosure is limited since only two radioactive waste repositories (see section 6.4) are being monitored in the postclosure phase. Research and activity in the field of remediation and decontamination has concentrated primarily on the assessment and clean-up aspects. Monitoring, though part of remediation and decontamination, has received little attention (Decréton 1998b).

Reactors that have been decontaminated in Western Europe and Japan have not generated any postclosure monitoring experience. Electricite de France has dismantled the equipment and buildings at the Chinon, Bugey and St. Laurent nuclear power stations, sealed and monitored the reactor core. However, each site has other reactors still in operation, so the shut-down reactors are monitored normally with no cost burden. Germany and Japan choose to decontaminate and dismantle their nuclear facilities completely and quickly. After the decontamination and dismantling of the 100 MWe Niederaichbach nuclear power plant in Bavaria, the German government announced the site safe for unrestricted agricultural use (UIC 1998).

Due to its nuclear weapons program, France also has contaminated lands that need to be cleaned up. However, very little information is available concerning remediation and monitoring activities due to military secrecy similar to the secrecy found necessary by DOE during the Cold War. The release of public information is only currently being debated in the French Senate (Davis 1994; Bataille, 1997).

6.2 HOW REPOSITORY DESIGN MINIMIZES POSTCLOSURE REQUIREMENTS

The European goal in radioactive waste repository design is a repository so safe that postclosure monitoring is not necessary (Decréton 1998a). Many Western European nations (Switzerland, Finland, U.K., Germany and Sweden) are disposing or plan to dispose their low-level waste (LLW) and short-lived intermediate waste (ILW) in deep geologic formations or mines. Postclosure monitoring of such repositories is considered superfluous and therefore is not required (OECD/NEA 1989; Nirex 1997; PTB 1983; Kunze 1998a).

An example is the Swedish Final Repository for Radioactive Operational Waste (SFR). The SFR is built in crystalline bedrock approximately 60 meters below the seafloor (water is approximately 5 meters deep). The geology, hydrology, and the construction of the repository is such that no postclosure monitoring is considered necessary. Groundwater monitoring to insure repository integrity is not required because the groundwater head under the sea is constant, resulting in a groundwater flow equal to zero (SKB na).

German regulations allow postclosure environmental monitoring of a LLW/ILW repository to be stopped if it can be demonstrated that certain radionuclides are not detected in the air or water being discharged from the repository or that the exposure pathways have been closed (BfS 1996, section C.2.3.3).

6.3 POSTCLOSURE PLANNING

6.3.1 Spent Nuclear Fuel Disposal

A repository for spent nuclear fuel (SNF) and/or HLW will be in a deep geologic formation. Normally, such a repository would not require any postclosure monitoring, but the presence of fissionable material requires inspections and monitoring against unauthorized retrieval.

The German monitoring plan of a closed repository containing spent nuclear fuel is observation by satellite, aerial reconnaissance, monitoring of Kr-85 in the exhaust air of the repository mine and visits by international agencies such as the IAEA and Euroatom. Kr-85 release is an indication of an opened spent fuel canister. Inspectors will be looking for any signs that SNF had been removed from the repository and of any undeclared activities related to SNF management or reprocessing in the immediate vicinity (Kunze 1998b and 1998c).

The technology available for the geophysical observation of a possible SNF/HLW repository in Gorleben, Germany was examined in a recent paper. The use of any non-seismic procedures (such as magnetic, electromagnetic, and gravity methods) was found to have an insufficient range and sensitivity to be useful. Long-term monitoring by acoustic emission /microseismic methods (AE/MS) was also found unacceptable. The installation of a sensor network underground while the waste is being loaded would allow the use of AE/MS technology for monitoring purposes; but the failure rate after 10 to 20 years is intolerable for current technology. The use of satellite imagery and aerial photography may detect undeclared shaft sinking (Eilers et al 1997).

This analysis was site-specific for Gorleben and may not apply to other sites. No plans or research on developing more advanced technology for postclosure monitoring for intrusion was found.

6.3.2 Remediation of Contaminated Uranium Mines near Wismut

The Federal Republic of Germany (FRG, "West Germany") inherited contaminated uranium mines near Wismut from the German Democratic Republic ("East Germany") due to reunification. These mines were in operation for 45 years until December 31, 1990. Wismut GmbH's main mission (sole shareholder since May 1991 is the FRG) is the remediation of these mines and the surrounding vicinity. Remediation is expected to be completed in 2010.

Wismut's environmental monitoring program is divided into three categories:

- 1) rehabilitation monitoring is the surveillance needed only during the cleanup and decommissioning period,
- 2) basic monitoring is the periodic environmental monitoring of geomechanical stability (subsidence, tailing ponds, slope surveying, seismic activity) and for radioactive and non-radioactive components, and a
- 3) monitoring program of the foodstuffs and off-site drinking water performed by an independent monitoring authority for the state governments of Saxony and Thurniger (mines are located in these two states).

After closure, rehabilitation monitoring is expected to be continued five years, basic monitoring will continue for 10 to 30 years and any long-term monitoring after 30 years would be assumed by the state governments (Knoch-Weber and Mehner 1997).

Little planning for postclosure monitoring has been done. The cost projection of basis monitoring over the remediation phase and the postclosure phase are conservative estimates based on the technology and methodology currently employed. A cost reduction from 8 million to 6 million Deutsche Marks is calculated during the postclosure phase, which is the result of a reduction in the number of monitors, frequency of monitoring, and number of parameters monitored (Knoch-Weber and Mehner 1997; Wolf 1998).

6.3.3 LLW Repository at Rokkasho-mura, Japan

Japan's LLW repository at Rokkasho-mura, Japan began operation in December 1992. Its design is a concrete vault six or more meters below the surface. Outside the reinforced concrete vault, below the ground, is an inspection tunnel. A drainage pipe network collects liquid inside the repository and drains it to the inspection tunnel (Shimoda and Iimura 1991; JNFL 1993). The details of the monitoring system have yet to be decided (Takeuchi 1998), but some planning on the post-closing monitoring has been done.

Postclosure monitoring is divided into three stages in which the amount of monitoring required is reduced as the hazard of the radioactive waste diminishes. Stage 1 lasts 10 to 15 years after closure, stage 2 lasts 30 years after the end of stage 1, and stage 3 lasts 300 years after the end of stage 1. During stage 3, the site will be opened to the public with the provision that digging and use of the stream water be prohibited (Shimoda and Iimura 1991; JNFL 1993).

Postclosure activities for stage 1 and 2 include

- monitoring drainage water and groundwater for radionuclides,
- measuring the radiation count for the air to calculate the skyshine radiation dose,
- inspecting the site and the cover soil for any damage (repair if necessary), and
- inspecting the underground structure (inside the inspection tunnels) to verify that no leakage has occurred (leakage will be fixed only in stage 1).

After stage 2, the inspection tunnel will be closed. Environmental monitoring and site patrols will continue during all three stages (Shimoda and Iimura 1991; JNFL 1993; Kawanishi 1998a and 1998b).

6.4 ON-GOING POSTCLOSURE MONITORING

Only two repositories were found among the Western European nations and Japan that have been closed and are now in the postclosure monitoring phase. Both sites are on-site of active nuclear facilities, which reduce the need for remote surveillance technology and methodology.

6.4.1 The Very Low-Level Waste Repository at Tokai, Japan

Japanese regulations require that material be regulated as radioactive if only a trace amount of man-made radioactivity is present or possible, resulting in a new category of radioactive waste called Very Low-Level Radioactive Waste (VLLW). The dismantling of the Japan Power Demonstration Reactor produced 1,670 tons of VLLW (mostly construction debris) with an activity of < 0.4 Bq/g and < 40 Bq/cm² for metals. The VLLW was packed in artificial resin bags and buried without any engineered barriers in a demonstration test site within the site of JAERI's (Japan Atomic Energy Research Institute) Tokai Research Establishment. A 2.5 m clay cover was placed over the waste with grass planted on the surface (JAERI 1998; Okoshi et al 1997).

This repository is now in the postclosure monitoring phase. Thirty years after closure, the site will be patrolled, inspected and maintained. Thereafter, it will be released from institutional controls (JAERI 1998; Okoshi et al 1997). Groundwater (the water table is 7 m below the surface) is retrieved manually for monitoring using boreholes located around the repository (Okoshi 1998a). The pH and concentrations of radionuclides and Ca⁺ are measured. The Ca⁺ concentration is used to help calculate an estimated radionuclide migration rate. The accumulated radiation dose on the surface is measured using thermofluorescence integrating dosimeters that are exchanged and read every quarter. The radionuclide concentrations in the soil and pine needles are also monitored (JAERI 1998; Okoshi et al 1997). Every week, a patrol inspects the facilities to insure that the soil cover, signs, fences, and the monitoring instruments are not damaged. Any damage will immediately be repaired (Okoshi 1998b).

6.4.2 Centre de Stockage de la Manche

From 1969 to 1994, France disposed its LLW and short-lived ILW at the Centre de Stockage de la Manche (CSM). The waste was first buried in shallow trenches, but after 1991, a concrete repository concept was employed. The postclosure surveillance and control phase is scheduled

for 300 years and began with the installation of the cover system (from 1991 to 1997) (ANDRA 1997a and 1997b; Han et al 1997).

The CSM is located on the premises of a nuclear facilities site, close to the nuclear fuel reprocessing plant at La Hague. Therefore, any environmental monitoring of the surrounding area is undoubtedly connected with that of the entire site. However, these measurements are planned to be continued through the whole postclosure monitoring period of 300 years. Currently, the air, surface water, river mud and sediment, plants, and milk from cows in the nearby communities are sampled and analyzed for contaminants. Groundwater is monitored from piezometric holes at the site perimeter and the surrounding area. Access restrictions were imposed on the site as part of institutional controls (ANDRA 1997b).

The cover system contains several layers and is designed to be impervious to water. On the surface are run-off channels and a drainage system for precipitation. From top to bottom, the cap layers are topsoil planted with grass, semi-impermeable schist, fine-grain sand, bituminous geomembrane, fine-grain sand, and schistose material designed to shape the cap's slope. The two fine-grain sand layers are drainage layers. The first drainage layer is designed to minimize the hydraulic head on the geomembrane and the second layer as a detector of water penetration through the geomembrane. The design criterion for water infiltration is less than 10 liters per square meter per year. The surface run-off and the two drainage layers each have their own drainage and monitoring systems (Potier 1995).

The run-off water is diverted to the main monitoring station to be analyzed with flow meters, radiation detectors, and pH meters. The main monitoring station also regulates the flow of the water into the Sainte-Hélène stream. Water from the cover's drainage layers flow to the drainage monitoring system, which is equipped with radiation detectors and automated flow meters. Contaminated water will be treated at the water treatment plant on-site. Non-contaminated water will be released to a storm basin for eventual use or release to the environment. The water infiltration data of the cap will be monitored and assessed for 300 years (Potier 1995).

For 10 to 20 years, the cap surface and the engineered structures will be inspected visually for any settlement or subsidence that may reduce cap performance. An internal inspection of the pipes and drainage systems will be conducted by video camera. Aerial photography and topographic surveys will be conducted to monitor for any topographical changes of the site (Potier 1995; ANDRA 1997b).

The number of years for monitoring may change since the French government, in 1996, has accepted recommendations from an independent scientific commission to install a new cap system. The current cap system was declared suitable only if active monitoring continues. A three-stage process was proposed in which there will be five years of extensive monitoring, followed by a period lasting 45 years in which a new cover system will be prepared and installed, and ending with a 200-year period of reduced monitoring. The French agency responsible for radioactive waste disposal, ANDRA (Agence Nationale pour la Gestion des Déchets Radioactifs), is required to write a new proposal for postclosure monitoring which will then go through a public discussion period starting in 1997 (UI 1996).

In 1992, a new repository was opened at the Centre de l'Aube and is expected to operate for 50 years. The repository design is based on the lessons learned from the CSM. Underneath the disposal cells are underground tunnels equipped with drains for any water that may have seeped through the repository. These tunnels are above the water table and should be dry. A weather

station checks the temperature, wind, rain, sunshine, and the radiation level of the air (ANDRA 1996).

6.5 RESEARCH CENTERS

6.5.1 Institute for Applied Informatics – Research Center Karlsruhe

The Institute for Applied Informatics (IFIA) at the Research Center at Karlsruhe (Forschungszentrum Karlsruhe, P.O. BOX 3640, D-76021 Karlsruhe, Germany) is actively researching and developing in-situ monitoring instruments and sensors for organic contaminants. These sensors are not yet commercially available but the institute is working on commercial development of this technology (Bürck 1998).

Optical sensors have been developed that can detect nonpolar organic substances in water. The sensors are composed of coiled optical fibers with a polysiloxance (a hydrophobic polymer) cladding. The interference from solution turbidity and the broad absorption bands of water are eliminated by using near-infrared absorption spectroscopy only on those organic species that penetrate the cladding. Currently, detection limits are in the range of 0.5 to 1 ppm for organic compounds like chlorinated hydrocarbons or BTX aromates. Measuring times range from 2 to 15 minutes (IFIA 1998a). An older version of this sensor was able to detect trichloroethene in-situ at the ppm level in 50 m deep wells in field trials at Savannah River and Livermore (Bürck 1998). Other in-situ trials were successful with a fiber-optic connection between the probe and the spectrometer up to 250 meters long (IFIA 1998a).

Optochemical sensors can also be used to measure pH directly by using immobilized pH-indicators or indirectly by using ions such as ammonium and nitrate, metal ions such as Hg^{2+} , Cd^{2+} and Pb^{2+} (using chelating agents), and gaseous pollutants such as NH_3 and SO_2 . Research and development of nanometer-sized optical probes is ongoing. Nanometer probes would result in a thousand-fold reduction of sample volume and response time (IFIA 1996).

Another project is the development of a robotic system that can detect contaminants below waste sites. A successful demonstration of part of this system included the following: (1) an automated system that can collect soil samples in non-cased drill-holes and bring them up to the surface for analysis and (2) a probe robot that can move itself through a cased drill-hole, open up a buried pipe, collect samples, close the pipe, and return to the surface. One of the goals is to place analytical devices for volatile pollutants directly under the repository (IFIA 1998b). The Karlsruhe Micronose is one of the instruments being developed that has detection limits, for example, of less than 1 ppm for tetrachloroethene, 10 ppm for methane, and less than 0.5 ppm for Xylene (IFIA 1998c).

A gas sensor microsystem has been developed that can detect organic compounds in the air using the sensitivity of the electrical conductivity of semiconductor metal oxide detectors to the composition of the atmosphere. The detector is coated with a selective permeable ceramic membrane chosen to protect the detector from corrosive compounds and to allow a selectivity of compounds to be detected. The chip is equipped with 40 single sensing elements including two temperature sensors and 4 heating elements (IFIA 1998d). The end goal is the ability to produce large number of gas sensor arrays according to ISO 9000 and at low costs (IFIA 1998e).

Many research centers and universities are involved in the research of sensors that could detect contaminants. However, only IFIA was found to be researching and developing sensors especially designed for waste repositories and contaminated sites.

6.5.2 SCK-CEN

The Advanced Instrumentation and Teleoperation group of the SCK-CEN (Belgium Nuclear Research Center, BR3, Boeretang 200, B-2400 MOL, Belgium) is actively researching telerobotic methods in nuclear environments. Their main focus is sensor tolerance in high radiation fields and the data processing methods necessary to compensate for the diminished capability of radiation-hardened transducers. For example, a radiation-resistant sensor is not capable of providing the visual information of a camera but only data concerning the distance from the sensor to various surfaces. They have developed a Kalman filter which transforms this data, which is hard for a human operator to quickly visualize and use, to an image based on basic geometrical forms that creates a crude picture which is useful to a human operator.

Their teleoperations research is also applicable to other instrumentation. Other research includes the radiation tolerance and use of fiber optics in nuclear environments (as a network element or as dose, temperature and stress sensors), degradation of monitoring instrumentation (transducers and processing electronics) by radiation, development of radiation-resistant instruments, and adapting current technology to nuclear standards and restrictions (SCK-CEN 1997 and 1998). In-situ tests in an underground laboratory are planned (Decréton 1998c).

6.5.3 Kerntechnische Hilfsdienstst GmbH

The Kerntechnische Hilfsdienstst GmbH (KHG) was founded in 1977 by nuclear power plant utilities, the fuel cycle industry and research institutes. One of the projects ongoing at KHG is developing remote handling technology for radiation fields and testing for radiation hardness. The systems tested are radio- and cable-controlled vehicles that are equipped with cameras, dose rate probes, and manipulators. Though these systems are designed mainly for nuclear power plants, they could be useful in postclosure monitoring (Boden et al 1996; KGH 1998; Krüger 1998).

6.5.4 Other Research in Progress

Some research of interest to postclosure monitoring of radioactive waste repositories has been initiated but has not yet reached a point where results can be published. The Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (DBE) has work ongoing concerning redundant fiber-optic automated measurement systems for monitoring repositories. This project is to be completed in January 2000 (Jobmann 1998).

The Radioactive Waste Management Center of Japan is studying the monitoring and postclosure management of a radioactive waste repository in a project funded by the Science and Technology Agency. However, this project started in August 1998, so no results are available (Sawada 1998).

6.6 CONCLUSION

The overall conclusion of this review for Western Europe and Japan is that postclosure plans are vague. Existing, commercially available technology and methodology are used or are planned to be used. Little research and development is being performed for advanced postclosure monitoring technology.

6.7 REFERENCES

- ANDRA, July 1996, *Centre de l'Aube Disposal Facility*, ANDRA, France.
- ANDRA, 1997a, webpage of ANDRA (<http://www.andra.fr/fcent.htm>, last updated 11/18/97 France (in French, translated by Rohani Weger).
- ANDRA, December, 1997b, *Centre de la Manche Disposal Facility*, France.
- Bataille, M. C., Député, December 1997, "Rapport N° 179 - l'Evaluation de la Recherche sur la Gestion des Dechets Nucleaires a Haute Activite - Tome II : Les Dechets Militaires" Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques – (French Senate report, translated by Rohani Weger), Paris, France.
- http://www.senat.fr/rap/o97-179/o97-179_mono.html
- BfS (Bundesamt für Strahlenschutz), 1996, *Anhang C zur Richtlinie zur emissions- und Immissionsüberwachung kerntechnischer Anlagen (REI) Brennelementzwischenlager, Endlager für radioaktive Abfälle*, BfS, Bonn, Germany.
- Boden, A., Krüger, W., Martensen, H.J., Müller, Th., Paustian, P., Schmidt, E., and Wagner, H., November 1996, "Abschlußbericht: Stilllegung und Rückbau Untersuchung zur Strahlenhärtung Elektronischer Komponenten", Förderkennzeichen (Report number) 02 S 7544, Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie, Bonn, Germany.
- Bürck, Jochen, Scientist at IFIA, 1998, email from 7/23/98.
- Chaplow, Robert, Nirex, 1998, email from 7/22/98.
- Davis, M.B., 1994, "The French Mess Nucleaire", *Bull. Atomic Scientists*, July/August 1994.
- Decréton, Dr. Marc, Project Manager of the Teleoperations Group of SCK-CEN, 1998a, personal communications, email dated 8/28/98.
- Decréton, Dr. Marc, 1998b, email from 8/5/98.
- Decréton, Dr. Marc, 1998c, email dated 8/5/98.
- Eilers, G., Kranz, H., Scheibe, R., Schultze, E., Seidel, K., 1997, "Evaluation of the applicability of some geophysical techniques for geological repository safeguards in a salt dome," European Safeguards Research and Development Association (ESARDA), Proceedings of the 19th Annual Symposium, Montpellier, France May 11-13, 1997.

- Han, K.W., Heinonen, J., Bonne, A., 1997, "Radioactive Waste Disposal: global Experience and Challenges," *IAEA bulletin*, Vol. 39 No. 1, page 33, IAEA, Vienna (<http://www.iaea.or.at/worldatom/inforesource/bulletin/bull391/bonne.html>).
- IFIA, 1996, from the IFIA webpage at , last updated 7/22/96, Karlsruhe, Germany.
- IFIA, 1998a, webpage located at site of IFIA, Karlsruhe, Germany <http://www-ifa.fzk.de/Buerck/EFAS.htm>.
- IFIA, 1998b, from the IFIA webpage at http://irchsurf5.fzk.de/mox-sensors/PressReleases/PressRelease97_Eng.htm, last updated 9/1/98, Karlsruhe, Germany.
- IFIA, 1998c, from the IFIA webpage at http://irchsurf5.fzk.de/mox-sensors/Information/Specification_ENG.htm, last updated 9/1/98, Karlsruhe, Germany.
- IFIA, 1998d, from the IFIA webpage at http://irchsurf5.fzk.de/mox-sensors/Information/Introduction_Eng.htm, last updated 9/1/98, Karlsruhe, Germany.
- IFIA, 1998e, from the IFIA webpage at http://irchsurf5.fzk.de/mox-sensors/PROXI/Proxi_Eng.htm , last updated 9/1/98, Karlsruhe, Germany.
- JAERI, 1998, *Persistent Quest, Research Activities, 1997*, section 4.4, JAERI, Tokyo.
- JNFL (Japan Nuclear Fuel Limited) March, 1993, *Outline and Safety of Rokkasho Low-Level Radioactive Waste Disposal Center*, JNFL, Aomori-city, Japan.
- Jobmann, M., DBE, 1998, personal communications, email dated 8/18/98.
- Kawanishi, Dr. Motoi, Team Leader of Natural Barrier Team, Nuclear Fuel Cycle Back-End Project, Abiko Research Laboratory, Central Research Institute of Electric Power Industry (CRIEPI), material received from me by mail, received August, 1998a.
- Kawanishi, Motoi, personal communications, email dated 8/20/98.
- KGH, company webpage, http://www.khgmhb.de/english/fe_wir.htm
- Knoch-Weber, J., and Mehner, H.-C., 1997. "Die Umgebungsüberwachung der Wismut GmbH." *Braunkohle Surface Mining*, Vol. 49, No. 2, March/April 1997.
- Krüger, Winfried, Technology Group Leader of KGH, letter dated 8/20/98.
- Kunze, Volker, Department of Nuclear Safety and Transport, BfS, 1998a, email from 8/4/98.
- Kunze, Volker, 1998b, written correspondence received 7/23/98.
- Kunze, Volker, 1998c, personal communications, email dated 9/1/98 (included quotes from Helmut Kranz).
- Nirex, 1997, webpage of Nirex <http://www.nirex.co.uk/nirfx10.htm> last updated 12/15/97.
- OECD/NEA (Organisation for Economic Co-operation and Development/Nuclear Energy Agency), August 1989, "Issue Brief: No. 6 the Management of Low- and Intermediate Level Radioactive Waste", OECD/NEA, Paris <http://db.nea.fr/html/brief/brief-06.html>.

- Okoshi, M., Yoshimori, M., Abe, M., 1997, "Near Surface Disposal of Very Low Level Waste Generated from Reactor Decommissioning and Related Safety Requirements", Proceedings of an international symposium on experience in the planning and operation of low level waste disposal facilities, IAEA, Vienna.
- Okoshi, Minoru, 1998a, Department of Decommissioning and Radioactive Waste Management, Tokai Research Establishment, Japan Atomic Energy Research Institute fax received 8/12/98.
- Okoshi, Minoru, 1998b, personal communication, email from 8/13/98, Japan Atomic Energy Research Institute (JAERI).
- Potier, J. M., 1995, "Centre de la Manche Closure System or Final Closure of a Low Level Waste Disposal Facility," Institut for Nuclear Materials Management (INMM) Proceedings for 1995, INMM_95_449, available on web at http://www.c3.lanl.gov/inmm/cgi/INMMwais/doc-options.cgi?document_name=inmm_95_449
- PTB (Physikalisch-technische Bundesanstalt), 1983, "Info-blatt: Sicherheitskriterien für die endlagerung radioaktiver Abfälle in einem Bergwerk", Section 10, Bonn, Germany.
- Sawada, Shohei, Research Division of Geological Repository, Radioactive Waste Management Center, Japan, personal communications, email dated 8/25/98.
- SCK-CEN, 1998, website of the Teleoperations Group of the SCK-CEN, <http://hades.sckcen.be/dept/br3/teleop/>, last updated 4/21/98, Mol, Belgium.
- SCK-CEN, 1997, *Scientific Report*, 1996 <http://hades.sckcen.be/publications/scr/96/scrrwc/pdr2.htm>, Mol, Belgium
- Schulze, Hartmut, DBE, Radioactive Waste Repository at Morsleben, 1998, email from 8/6/98.
- Shimoda, H. and Iimura, H., 1991. "Shallow Land Disposal of Low-Level Radioactive Waste by Burying in Concrete Vault: Design and Construction of the Facility at Rokkasho Storage Center." Proceeds of the Third International Conference on Nuclear Fuel Reprocessing and Waste Management, RECOD '91, Vol. I, Sendai, Japan, April 1991.
- SKB (Swedish Nuclear Fuel and Waste Management Co.), no date given, *Final Repository for Radioactive Operational Waste - SFR*, SKB booklet, SKB, P.O. Box 5864, S-102 48 Stockholm, Sweden.
- Takeuchi, Dr. Mitsuo, 1998, member of Steering Committee on HLW project in Japan, email dated 8/10/98.
- Wolf, Frank, Wismut, 1998, email from 8/4/98.
- UI (Uranium Institute), July 17-23, 1996, *UI News Briefing 96/29, NB96.29-12*, Uranium Institute Information Service, <http://www.uilondon.org/nb/nb96/nb9629.htm>
- UIC (Uranium Institute Centre, Ltd.), March, 1998, "Nuclear Issues Briefing Paper 13: Decommissioning Nuclear Facilities," <http://www.uic.com.au/nip13.htm>

APPENDIX A

FERNALD

More detailed information is presented here concerning the Fernald site and the OSDF.

A.1 SITE DESCRIPTION

From 1951 to 1989, the mission of the Feed Materials Production Center, located at the Fernald site, included the conversion of uranium ore to uranium metal and the fabrication of uranium target elements for the nuclear weapons program. These activities were limited to a 136-acre lot known as the Production Area. The remaining 914 acres of the site was used for waste storage and disposal, leased for livestock grazing or remained forested. After stopping production in 1989, the DOE used Fernald to store nuclear material (uranium, thorium, and mixed waste) generated at Fernald and other DOE sites. The activities of the last four-and-a-half decades resulted in contamination of a portion of the site's soil and groundwater. The new DOE mission is to clean up the Fernald site, which is reflected in the new name: Fernald Environmental Project (FEMP) (FEMP 1995b, section 1.0).

The land of the Fernald site slopes slightly toward the west and the small intermittent stream Paddys Run (which runs through the western part of the site). The exception is the extreme northwest corner of the site, which drains east toward the Great Miami River. The western portion of the site lies within the north-south corridor of the 100- and 500- year floodplain of Paddys Run. The site contains 8.9 acres of surface water and 35.9 acres of freshwater wetland (FEMP 1997a, section 1.1). The area surrounding the Fernald site consists mainly of agricultural or recreational land. Within five miles of FEMP are 23,000 residents (FEMP 1995b, section 1.0).

Underneath the site is glacial till (dense sandy lean clay) that has the properties of an aquitard. The till is a dense lean clay with sand and gravel lenses. Its upper layer is brown clay and its lower layer is lower permeable gray clay. The glacial till is currently 90 to 100 percent saturated but is expected to drop when the cap and underlying liners of the OSDF are installed. The groundwater flow is predominantly downward at a rate of 6 inches per year (FEMP 1997a, section 2.2 and 2.3).

The Great Miami Aquifer (GMA) is about 45 to 90 feet below the OSDF. The aquifer is 175 feet thick and divided into three zones: uppermost (FEMP's type 2 monitoring wells), middle zone (type 3 wells), and lowermost zone (type 4). The groundwater flow is about 345 feet/year from west to east. Uranium is calculated to migrate about 30 feet/year in the GMA (FEMP 1997a, sections 2.2 and 2.3).

A.2 PLANNED REMEDIATION

The facilities and buildings onsite will be decontaminated and dismantled; the nuclear material stored onsite will be transported to storage or disposal facilities offsite; and contaminated land and groundwater will be cleaned up or removed. The aquifer will be restored down to 20 ppb uranium. Remedial action for the surface, subsoil, and groundwater in the glacial till and the GMA is to be performed wherever final remediation levels (FRLs) are exceeded. The clean-up of the site will be completed by 2005 according to the Ohio Field Office and FEMP. During remediation, an onsite disposal facility (OSDF) for low-level radioactive waste (contaminated soil and debris from decontamination and decommissioning activities) will be built and loaded with waste from on-site that satisfies the waste acceptance criteria. The repository will have a capacity of 2.5 million cubic yards repository (DOE1998c, section E.8).

The remediation of the Fernald site is divided into five units. Unit 1 consists of the Waste Pits 1 to 6, the Burn Pit and the Clearwell. The waste material and contaminated soil will be removed and most of it will be disposed off-site (about 600,000 cubic yards of LLW). Excavation holes will be refilled with backfill and a cover system will be installed over it (FEMP 1995a, declaration statement).

Unit 2 consists of the Solid Waste Landfill, North and South Lime Sludge Ponds, South Field, and the Inactive and Active Flyash Piles. Most of the waste and contaminated soil (about 314,700 cubic yards) will be disposed on-site at the OSDF. The remaining waste (about 3,100 cubic yards) will be disposed off-site. Soil containing lead from the firing range will be treated and sent off-site (FEMP 1995b, declaration).

Unit 3 consists of the former Production Area and the buildings and equipment associated with production. The material will be treated and disposed either on-site at the OSDF or off-site (FEMP 1996a, declaration statement). Material such as nuclear products, process residue, excess supplies, chemicals, and equipment will be sent to the DOE Nevada Test Site for disposal. Over 200 structures such as buildings, storage pads, ponds, basins, and underground utilities will be decontaminated and dismantled (above-grade structure and foundation) (FEMP 1996a, section 1.3).

Unit 4 consists of the concrete storage silos, the site waste storage areas, and their contents. Facilities included in this unit are the decant sump tank, a radon treatment system, and a concrete pipe trench. The waste will be disposed either on-site at the OSDF or off-site at the DOE Nevada Test Site. Excavations resulting from removing contaminated soil will be backfilled with clean soil (FEMP 1994, declaration statement).

Unit 5 consists of the impacted environmental media (such as soil and groundwater) that is not included in the other units. The contaminated media that does not exceed the waste acceptance criteria will be disposed in the OSDF (FEMP 1996b, declaration statement).

A.3 ONSITE DISPOSAL FACILITY

The OSDF will be located in the Northeast section where the gray clay is thickest (FEMP 1997a, section 1.1). The location of the OSDF is based on a 10-year site characterization (including modeling results of the predicted fate and transport of potential contaminants) to be where the site's geology and hydrogeology minimizes the possibility that any leachate release will contaminate the groundwater (FEMP 1997c, section 3.2).

The surface soil in the immediate vicinity of the OSDF is contaminated above FRLs to an approximate depth of 6 inches and is above background but below FRLs for the remaining area within the footprint. The area of the GMA closest to the planned OSDF site that is contaminated and planned to be cleaned up is about 330 feet west of the OSDF. The contamination levels after remediation will be above background but below the FRLs, which will increase the uncertainty in distinguishing between pre-existing contamination and contamination resulting from a small quantity of leakage from the OSDF (FEMP 1997a, section 2.4).

The expected waste stream is 80% contaminated soil and the remainder being demolition rubble, fly ash, lime sludge, municipal solid waste and small quantities of other material (FEMP 1997a, section 1.1; FEMP 1997c, section 3.1). Units 2 and 5 are expected to generate 90% of the

contaminated soil and waste placed in the OSDF and the remaining will be from units 1 and 4. The integrity of the OSDF will be protected by prohibiting the following items: waste from off-site, pressurized gas cylinders, process-related metals, materials containing free liquids, drums that are not empty and crushed, scrap tires, used oils, and transformers that have not been crushed or emptied and filled with grout (FEMP 1996a, section 8.1.5).

A.4 REGULATORY DRIVERS

The postclosure monitoring and inspection plan of the OSDF is shaped by regulatory and other pertinent requirements (see Table A-1).

Table A-1.
Regulations Concerning the Postclosure Maintenance and Monitoring of the OSDF

Regulation	Description
Groundwater Monitoring Program (GWMP)	
OAC 3745-27-10	Sanitary landfills must have a plan for the GWMP, monitoring system, sampling and analysis procedures, and a detection monitoring procedure. The GWMP is to <ol style="list-style-type: none"> 1) be a three-tier program of detection, assessment, and corrective measures, 2) be for all significant zones of saturation at and above the uppermost aquifer, 3) have the number, location and depth of the wells to be sufficient to detect leakage from the landfill at the closest practicable location, 4) measure the groundwater upgradient (not affected by landfill) and downgradient, and 5) have a statistical analysis procedure as described in this rule.
OAC 3745-54-98, 40 CFR 264.98	Owner must monitor for indicator parameters, waste constituents or reaction products that provide a reliable indication of the presence of hazardous constituents in the groundwater. OEPA will specify which parameters and constituents.
40 CFR § 264.303(c)	Owner/operator is required to have a leak detection system and record the amount of liquid from each sump (not in Ohio regulations). During the postclosure phase, these measurements are to be made monthly. If sump liquid level is below the pump operating level for two months, then the frequency is quarterly. If sump liquid level is below the pump operating level for two quarters, then the frequency is semi-annually. If sump liquid level is above the pump operating level, then frequency becomes monthly.

Leachate Monitoring Plan	
OAC 3745-27-08(C)(5)	OEPA may require the monitoring of leachate storage structures.
OAC 3745-27-19(K)(1)	Any leachate detected on the landfill facility surface shall be contained and managed at the facility. The leachate may be collected and disposed according to OAC 3745-27-19(k)(5)&(6). Corrective action shall be taken to minimize, control or eliminate the condition which produced the leachate.
OAC 3745-27-19(K)(3)	An annual inspection of the LCS collection pipes is required to verify that no clogging has occurred.
OAC 3745-27-19(K)(4)	The OEPA can authorize the temporary storage of leachate within the solid waste placement limits pending treatment and disposal.
OAC 3745-27-19(K)(5)	Owner may treat and dispose of leachate on-site at the facility, pre-treat on-site and dispose off-site or treat and dispose off-site.
OAC 3745-27-19(K)(6)	Owner shall have a contingency plan for storage and disposal of leachate. Included in the plan will be the setting aside of land for the building of an on-site treatment facility.
OAC 3745-27-19(M)(4) & (5)	The owner shall submit an annual report on the LCS which shall include the monthly quantity of leachate collected and treated, location of the leachate treatment and disposal, verification that the leachate management system is operable and analytical testing results.
40 CFR §258.61	If the owner or operator can prove that the leachate does not threaten human health and the environment, then the OEPA may allow the leachate management system to cease operation.
Postclosure Care Plans	
OAC 3745-27-14(A) ²	The postclosure care phase period is 30 years. This period can be shortened by the OEPA.
OAC 3745-27-06	Owners must prepare a postclosure, a groundwater detection and monitoring, a leachate monitoring, and a leachate contingency plan.
OAC 3745-27-11(B)	The postclosure plan shall include the name and location of the facility and units, description of the postclosure activities, and contact information (name, address and telephone number) during postclosure phase. OEPA shall be notified of any changes.
OAC 3745-66-18(A)&(C)	<p>The postclosure plan shall</p> <ol style="list-style-type: none"> 1) Identify and describe the monitoring activities and frequency; 2) Identify and describe the maintenance activities and frequency to ensure cap, final cover and other containment integrity and the functioning of monitoring equipment; 3) Provide name, address and telephone number of person or office to contact during postclosure care and inspection period.

OAC 3745-66-18(D)	Owner may amend the postclosure plan during the active and postclosure phases of the facility.
OAC 3745-66-18(G)	Before the postclosure care period, the postclosure plan and length may be amended.
Closure and Postclosure Objectives	
OAC 3745-27-11(H)	Requires <ul style="list-style-type: none"> 1) the grading of all land surfaces where solid waste has been placed to prevent the ponding of water 2) installation of a drainage facility which will divert surface water from the landfill facility 3) installation of a groundwater monitoring system.
OAC 3745-27-11(O)	The facility is to be closed in a manner that minimizes the maintenance and release of leachate to an extent that protects human health and the environment.
OAC 3745-66-11	The facility shall be closed in a manner that <ul style="list-style-type: none"> 1) minimizes the need for further maintenance 2) controls, minimizes, or eliminates the escape of hazardous waste and constituents to the groundwater, surface water or to the atmosphere to an extent that protects human health and the environment 3) satisfies all closure requirements.
OAC 3745-68-10(A) ¹	The landfill final cover must <ul style="list-style-type: none"> 1) minimize the long-term migration of liquids through the landfill 2) maintain its integrity if settling and subsidence occur 3) require minimal maintenance 4) have an equal or lower permeability than either the bottom liner system or natural subsoil.
OAC 3745-27-19(E)(26)	Engineered components of the facility shall be maintained and repaired if damaged or failed.
OAC 3745-27-19(J)(1)&(4)	The facility shall have and maintain surface water control structures that will divert surface water from where the solid waste has been deposited, control run-on and run-off to minimize water infiltration and erosion of the cover material and cap system. Action shall be taken to rectify the source of any ponding or erosion of areas where solid waste is deposited.

Postclosure Care	
OAC 3745-27-14(A)(1)&(2) ²	<p>During the postclosure period,</p> <ol style="list-style-type: none"> 1) a leachate management, surface water management and groundwater monitoring systems are to be maintained and operated 2) the integrity and effectiveness of the cap system is to be maintained, including repairing any damage due to erosion or to prevent run-on and run-off from causing damage or erosion.
OAC 3745-68-10(B) and (D) ¹	<p>The owner or operator shall, during the postclosure phase,</p> <ol style="list-style-type: none"> 1) maintain the final cover's integrity and effectiveness, including repairing any damage due to settling, subsidence, erosion or other events 2) collect and remove leachate (prevent excess accumulation) until leachate is no longer detected 3) maintain and operate a groundwater monitoring system 4) prevent run-on and run-off from eroding or damaging the final cover 5) protect and maintain surveyed benchmarks.
Property Use Restrictions	
OAC 3745-68-10(D)(5)	Owner must restrict access as appropriate for postclosure use.
OAC 3745-27-11(H)(5)(a)	Owner shall file a plat of the unit(s) of the sanitary landfill facility including such data as the area, exact location, depth, volume, and nature of the solid waste deposited.
OAC 3745-66-16	Owner shall have a professional land surveyor prepare and certify a survey plat indicating the location and dimensions of cells and disposal units with respect to permanently surveyed benchmarks. Prominently displayed on this plat, the owner shall state its obligation to restrict disturbance of the waste disposal unit in compliance with regulations.
OAC 3745-66-19(A)	Owner shall submit a record of the type, location, and quantity of hazardous waste which has been disposed within each disposal unit of the facility.

Deed Notification	
OAC 3745-27-11(H)(5)(b)	Owner shall record a notation on the deed for the landfill facility property (or some other instrument which is normally examined during title search) that notifies in perpetuity any potential purchaser that the land has been used as a sanitary landfill and include information describing the acreage, location, depth, volume and nature of the solid waste.
OAC 3745-66-19(B)	The owner shall record a notation on the deed for the landfill facility property (or some other instrument which is normally examined during title search) that the land had been used to manage hazardous waste, its use is restricted and a copy of the survey plat which describes the type, location and quantity of the hazardous waste.
OAC 3745-66-19(C)	If the current or any subsequent owner removes the hazardous waste or waste residue in a manner that satisfies OAC 3745-66-17(C), he may request the OEPA to approve either the removal of the notation on the deed or an addition concerning the removal.

¹ In lieu of 40 CFR §265.310(a)

² In lieu of RCRA Subtitle D

Source: FEMP 1997c, 2.2; FEMP 1997a, Table A-1

The Ohio Administrative Code (OAC) 3745-27 are the Ohio Municipal Solid Waste Rules, OAC 3745-66 are the Ohio Hazardous Waste Interim Standards Rules and OAC 3745-68-10 are the Ohio Hazardous Waste Landfill Rules.

A.5 AIR MONITORING

The current air monitoring plan for site remediation is described below for a general idea of what a postclosure air monitoring plan may entail. In response to DOE orders 5400.1 and .5, air monitors will be located on-site, near the FEMP property border and at several off-property sites during remediation operations (FEMP 1997c, section 5.2). The air is monitored for radiological particulates, radon concentration, and radiation count.

During remediation, the main sources of emissions are from many different activities and potential sources. During postclosure, any emissions would originate from the OSDf (FEMP 1997b, section 6.1). 40 CFR 61 subpart H requires that no member of the public receive more than 10 mrem per year. The receptor site is the point of compliance and therefore the site where the monitors are to be located (FEMP 1997b, section 6.4.2.1).

A.5.1 Radiological Particulates

During remediation activities, 18 high-volume air monitors placed at potential receptor sites will measure radiological particulates (FEMP 1997b, section 6.4.2.1). The potential receptor sites are determined by considering the 16 wind rose sectors measured for the site. If a receptor site is outside the Fernald perimeter, then the monitor will be placed on the site boundary in the path

downwind from the potential source. The filters will be analyzed every two weeks for total uranium and total suspended particulates. The total uranium analysis is relatively inexpensive, easy and reliable. A portion of each biweekly sample will be set aside for a more detailed quarterly analysis for U-238, U-235/6, U-234, Th-232, Th-230, Th-228 and Ra-226. The detection limit for the biweekly total uranium analysis is 2 $\mu\text{g}/\text{filter}$ and for the quarterly analysis is $7.0 \times 10^{-6} \text{ pCi}/\text{m}^3$ for U, $2.3 \times 10^{-6} \text{ pCi}/\text{m}^3$ for Th and $8 \times 10^{-7} \text{ pCi}/\text{m}^3$ for Ra (FEMP 1997b, Table 6-2). The manufacturer recommends that these monitors be inspected and calibrated at least annually (FEMP, 1997b, section 6.5.2.1).

A.5.2 Radon Concentration

During remediation activities (FEMP 1997b, section 6.4.2.2), radon measurements will be performed by using 64 alpha track-etch radon cups and 20 alpha scintillation continuous radon monitors. The radon cups are long-term integrating detectors, have a detection limit of 0.2 pCi/m^3 , are sampled semi-annually, and do not require electricity. The continuous radon monitors measure the current radon concentration, require electricity and have a detection limit of 1.0 pCi/l . The continuous radon detectors are to be checked monthly with a source (FEMP 1997b, section 6.5.3). DOE order 5400.5 prescribes a short-term radon concentration limit of 100 pCi/l and an annual limit of 3 pCi/l for the fence and 30 pCi/l site-wide (FEMP 1997b, section 6.6.2).

A.5.3 Radiation Count (FEMP 1997b, section 6.4.2.3)

During remediation activities, the radiation field in the air will be measured by a network of 37 environmental and thermoluminescent dosimeters (TLD) which have a detection limit of 5 mrem. The dosimeters will be replaced quarterly and read. The TLD reader will be calibrated semi-annually (FEMP 1997b, section 6.5.4.2).

A.6 CHOOSING THE CONSTITUENTS OF CONCERN

The COCs (parameters) chosen to be monitored (FEMP 1997a, section 4.5) should be mobile, persistent, prevalent in the OSDF and potentially able to enter the environment in a detectable amount. Pre-existing contamination adds an additional criteria that the parameter be distinguishable from background contamination. The Ohio Solid Waste and the Ohio Hazardous Waste rules contain a list of monitoring parameters but allow the use of an alternate site-specific parameter list. Waste Acceptance Criteria (WAC) methodology was used along with the regulatory criteria to select the parameters. WACs are concentration and mass-based limitations on the waste to be accepted into the OSDF.

WACs were developed for all groundwater pathway COCs. Fifteen COCs were evaluated to have the potential to contaminate the GMA within 1000 years by transport through the glacial till if not placed for disposal in the OSDF. The rate that contaminants may move through the glacial till to the GMA varies. Uranium is expected to reach the GMA in 210 to 260 years and technetium (FEMP's most mobile contaminant) in 3.6 years (FEMP 1997a, section 2.3).

Among these 15COCs, 11 required a numerical WAC value. These 11 COCs are considerably more mobile and persistent than the other COCs and are prime candidates for indicator

parameters. Only five COCs are expected to approach their WAC concentration (see Table A-2) and the other COCs will have a maximum soil concentration much lower than their WAC.

RCRA regulations required the development of WAC values for 27 additional constituents (RCRA regulated constituents). All of the inorganic and most of the organic COCs in the regulatory default monitoring parameter list have been detected in the subsurface groundwater at several locations at FEMP. The majority of these constituents are not groundwater pathway COCs and have relatively high WAC values. Six of these constituents have numerical WAC values but are not expected to affect any disposal decisions. Four RCRA constituents (see Table A-2) are chosen as primary indicators because their expected maximum soil concentration in the OSDF are reasonably close to their WAC value.

The proposed primary parameter list (see Table A-2) were chosen for two reasons: good detectability if released and/or they are significant RCRA regulated constituents. Examples of constituents not chosen are chloroethane, toxaphene, Np-237 and St-90, which had relatively high WAC values and small expected maximum concentrations in the OSDF.

Table A-2.
(FEMP, 1997a, section 4.5.2.1)

Constituent	FRL in GMA	WAC	C _{max} /WAC ^a	Primary Parameter	Chosen because of	
					Good De- tectability	RCRA COC
RADIONUCLIDES						
Np-237	1 pCi/g	3.12 x10 ⁹ pCi/g	8.43 x 10 ⁻¹⁰	No	Not Chosen	
Strontium-90	8 pCi/g	5.67 x10 ¹⁰ pCi/g	1.14 x 10 ⁻¹⁰	No	Not Chosen	
Technetium-99	94 pCi/g	29.1 pCi/g	1.00	Yes	Yes	No
Total Uranium	20 ppb	1,030 mg/kg	1.00	Yes	Yes	No
INORGANICS						
Magnesium	0.9 ppm	N/A ^b	N/A ^b	No	Not Chosen	
Chromium VI	0.022 ppm	N/A ^b	N/A ^b	No	Not Chosen	
Boron	0.33 ppm	1.04 x10 ³ ppm	1.38 x 10 ⁻²	Yes	Yes	No
Mercury	2 ppb	5.66 x10 ⁴ ppm	2.30 x 10 ⁻⁴	Yes	Yes	Yes
ORGANICS						
Bromodichloromethane	0.1 ppm	0.903 ppm	7.75 x 10 ⁻³	Yes	Yes	no
Carbazole	0.011 ppm	7.27 x10 ⁴ ppm	3.44 x 10 ⁻⁶	Yes	Yes	no
Alpha-chlordane	0.002 ppm	2.89 ppm	1.76 x 10 ⁻³	Yes	Yes	no
Bis(2-chlorisopropyl)ether	0.005 ppm	2.44 x10 ⁻² ppm	1.00	Yes	Yes	no
Chloroethane	0.001 ppm	3.92x10 ⁵ ppm	N/A. ^c	No	Not Chosen	
1,1-Dichloroethene	0.007 ppm	11.4 ppm	3.42 x 10 ⁻³	Yes	No	Yes
1,2-Dichloroethene	0.005 ppm	11.4 ppm	2.98 x 10 ⁻²	Yes	No	Yes
4-Nitroaniline	0.02 ppm ^d	4.42 x10 ⁻² ppm	1.00	Yes	Yes	no
Tetrachloroethene	0.005 ppm ^e	128 ppm	1.25 x 10 ⁻²	Yes	No	Yes
Toxaphene	0.003 ppm ^f	1.06 x10 ⁵ ppm	N/A ^c	No	Not Chosen	
Trichloroethene	0.005 ppm	128 ppm	0.695	Yes	No	Yes
Vinyl Chloride	0.002 ppm	1.51 ppm	1.00	Yes	Yes	Yes

^a C_{max}/WAC is the ratio of the maximum soil concentration expected for the constituent in the OSDF divided by the WAC value.

^b No WAC value was calculated since the constituent is not capable of superceding action level in GMA within 1000 years regardless of amount in OSDF

^c WAC is closed to pure product concentration (10^6 ppm) so C_{max}/WAC ratio was not calculated

^d No FRL was found in the documents and no maximum contamination level (MCL) was found in federal regulations, so the number given is the PQL (practical quantitation limit) which is the lowest concentration that can be reliably determined in groundwater. (40CFR 258, Appendix II, 7/1/97)

^e No FRL was found in the documents, so the MCL allowed by regulations (40CFR 141.61(a), 7/1/97) is given (listed under synonym tetrachloroethylene).

^f No FRL was found in the documents, so the MCL is given (40CFR 141.61(c), 7/1/97)

A.7 REFERENCES

- DOE, June 1998c, "Accelerating Cleanup: Paths to Closure," DOE/EM-0362, DOE/Office of Environmental Management, Washington, D.C.
- FEMP, December 1994, "Final Record of Decision for Final Remedial Action at Operable Unit 4," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, January 1995a, "Final Record of Decision for Remedial Action at Operable Unit 1," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, June 1995b, "Final Record of Decision for Remedial Action at Operable Unit 2," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, August 1996a, "Final Record of Decision for Remedial Action at Operable Unit 3," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, January 1996b, "Record of Decision for Final Remedial Action at Operable Unit 5," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, August 1997a, "Groundwater/Leak Detection and Leachate Monitoring Plan, On-Site Disposal Facility," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- FEMP, August 1997b, "Integrated Environmental Monitoring Plan," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio, 1997.
- FEMP, July 1997c, "Postclosure Care and Inspection Plan, On-Site Disposal Facility," Fernald Environmental Management Project, DOE Fernald Area Office, Fernald, Ohio.
- Strimbu, Michael, Environmental Compliance Specialist, Fernald Site, 1998, email dating 3/18/98.

APPENDIX B

SAVANNAH RIVER SITE

B.1 TIMELINE

Table B-1 presents a summary of the final end states and dates at SRS (DOE 1998d, ES-11 – ES-12). Final end states are based on current technologies and federal and state regulatory requirements. Technology advances, economic feasibility issues, or changes in regulatory requirements may result in changes to the projected end states. The SRS Future Land Use Map is little changed from current use since most facilities will continue to be operational. One item to note is the potential addition of facilities for new missions (e.g., tritium production).

Table B-1.
Key Program End States and Dates at SRS

Key Activities	Final End State	End Date (FY)
Environmental Restoration		
High Risk Release Sites	All Assessments Complete	2013
	All Remediation Actions Complete	2017
Low/Medium Release Sites	All Assessments Complete	2013
	All Remediation Actions Complete	2017
Groundwater Remediation	Water Treatment Systems Operational	2025
Surveillance and Maintenance	EM S&M Transferred to New Landlord	2038
High Level Waste (HLW)		
Vitrification of HLW	All High Level Waste Vitrified	2024
Waste Removal From Tanks	All 51 Tanks Emptied	2024
Storage Tank Closures	All 19 Tanks Closed	2025
Nuclear Material Stabilization		
Nuclear Material Stabilization	Stabilization of Pu, Np, highly enriched uranium (HEU), SNF, Am, and Cm	2004
Actinide Packaging Facility (APSF)	Construction complete	2001
	APSF and stabilized materials transferred to non-EM landlord	> 2028
Spent Nuclear Fuel		
K Reactor & Basin Deinventory	HEU material deinventory completed	< 2006
L Reactor & Basin Deinventory	HEU materials, SNF, and heavy water deinventory complete	2011
SNF in Receiving Basin	Deinventory complete	2011
Transfer and Storage Facility	Operational (receiving off-site SNF) until	2035

Solid Waste		
Consolidated Incinerator Facility	Liquid/solid waste incineration complete	2030
TRU Waste Ready for Shipment	Processing complete	2029
Hazardous, Mixed, and Low Level Waste	Treatment and disposal complete	2032
Facilities Deactivation		
Canyons & B-Lines Deactivation	Deactivation complete	2015
HLW Facilities Deactivation	Deactivation complete	2026
Long-Term S&M	Complete	2070
EM Landlord Responsibility	Transfer to another program	2028

B.2 WASTE STREAMS

Because of the lack of accurate records regarding quantities of wastes disposed in the various burial grounds, basins, seepage pits, etc., it is not possible to estimate with any degree of accuracy the current waste load at SRS nor the amounts of waste that will remain on site after remediation and closure. As part of the complex-wide effort to coordinate waste disposal efforts, however, those wastes that were quantifiable were organized into "Waste Disposition Maps." These, therefore, give the best available picture of what the ultimate disposition of waste material will be (DOE 1998a).

B.2.1 Environmental Remediation Activities

The estimated waste projection for waste due to environmental remediation activities and that will remain on site is

- soil mixing/grouting with cap installed (LLW soil: 453,584 m³)
- in-situ containment with cap (LLW soil/rubble/debris: 848,174 m³, MLLW soils and debris: 445,286 m³)
- chemical stabilization/grout in place (MLLW sludges/soils: 20,526 m³)
- sites requiring only access and institutional controls (LLW soil and debris: 27,799.1 m³)
- bio-remediation (HAZ soils: 119,459 m³, HAZ groundwater: 98,000,000 m³)
- sites requiring compliance monitoring (HAZ groundwater: 136,000 m³, LLW groundwater: 90,100 m³, HAZ soils/sludges: 14,407 m³)
- LLW disposal on-site (LLW soil, rubble, debris, and vegetation: 54,813.8 m³, LLW groundwater: 4,087.5 m³)

B.2.2 LLW Disposal

The projected waste streams for the LLW repositories on-site that are currently or will in the future receive waste are:

- E-Area Low Activity Waste Vault Disposal (low activity compactibles: 109.7 m³, naval fuel/low-level alpha (compact): 10,450 m³, low activity bulk waste : 6,784 m³)
- E-Area Trench Disposal (from the MW Program: 389.3 m³, bulk metal : 37,977 m³, low activity bulk waste : 13,508 m³, contaminated soil/debris : 22,222.9 m³, contaminated large equipment (size reduction): 990 m³, low activity job control waste that was incinerated: 4,780 m³)
- E-Area Dispose in Place (naval reactor components : 2,465 m³)
- E-Area Intermediate Level Vault Disposal (Intermediate Level Waste : 2,625.9 m³)
- Sandstone Vault (process water and LLW from the HLW program)
- national pollutant discharge elimination system outfall (process water).

B.2.3 HLW and NMS Activities

- The projected waste stream for the HLW program is divided into different sources. The sludge in the tanks and from future nuclear material stabilization (NMS) activities are estimated to be
- liquid benzene, which will be incinerated on-site: 1,483 m³
- mercury, which will be sent to Oak Ridge National Laboratory: 4.34 m³
- HLW, which will be disposed in the geologic repository: 3,961 m³
- LLW (salt from tanks, wash water from tank and facilities), which will be disposed as grout at the Saltstone Vault Disposal: 757,453 m³.

B.3 Environmental Screening of Groundwater

The SRS Groundwater Monitoring Program (GWMP) carries out monitoring of the sites at all stages of observation, characterization, remediation, and closure (WSRC 1998m). The Environmental Protection Department/Environmental Monitoring Section (EPD/EMS) is responsible for providing drilling, sampling, and analytical and data management support. Quarterly reports are issued that provide extensive information on the SRS-GWMP activities.

GWMP activities include

- installation, maintenance, and abandonment of monitoring wells
- environmental soil borings
- development of sampling and analytical schedules
- collection and analysis of groundwater samples
- review of analytical and other data

- maintenance of the databases containing groundwater monitoring data
- quality assurance (QA) evaluations of laboratory performance.

New wells designated as screening program wells are scheduled initially for four quarters of environmental screening. Environmental-screening constituents, which include indicator parameters, groundwater quality characteristics, and some drinking water characteristics, are listed below (Table B-2). After the initial four quarters of analyses for new wells, environmental screening is scheduled once every three years for wells identified as environmental-screening program wells. The wells are sampled only for the environmental screening that has not been analyzed within the past three years. Sampling may be more frequent upon request or if a constituent of concern is over a certain limit (see flagging criterion below).

Table B-2.
Environmental Screening Constituents and Field Measurements

Environmental Screening Constituents		Field Measurements
Aluminum	Mercury	Air temperature
Arsenic	Nitrate-nitrite as nitrogen	Date
Barium	Nonvolatile beta	Depth of water
Cadmium	Selenium	Flow rate
Chloride	Silver	pH
Chromium	Sodium	Phenolphthalein alkalinity
Fluoride	Sulfate	Program
Gross alpha	Total dissolved solids	Sampling method
Iron	Total organic carbon	Site code
Lead	Total organic halogens	Specific conductance
Lithium	Total phosphates (as P)	Stabilized (yes or no)
Manganese	tritium	Time
Major ions: calcium, magnesium, potassium, silica		Total alkalinity
		Turbidity
		Volume purged
		Water temperature
		Well condition

EPD/EMS has established two sets of flagging criteria to assist in managing sample results. The flagging criteria do not define contamination levels; instead, they aid personnel in sample scheduling, data interpretation, and trend identification. Since 1991, the flagging criteria have

been based on the EPA drinking water standards and on method detection limits. Analytes in the data tables are assigned flagging levels (0, 1, or 2) depending on their concentrations in a groundwater sample. The flagging levels dictate the scheduling and frequency of groundwater sampling.

The flagging criteria were determined as follows:

- *Flag 0:* Analytical results below Flag 1 and constituents that have no flagging criteria
- *Flag 1:* one-half of Flag 2 criterion
- *Flag 2:* the EPA's final or proposed primary or secondary drinking water standard.

If a constituent did not have a drinking water standard, the Flag 2 criterion was set at 10 times the 90th percentile detection limit obtained by one of the primary laboratories.

Constituents classified as Flag 0 in each well series are scheduled for analyses only by custodian request or as part of the triennial environmental-screening program. If an analytical result for an environmental-screening or gas chromatographic volatile organics analyses (GC VOA) in any well exceeds Flag 2 or Flag 1, the environmental-screening wells in the same monitoring series are sampled and analyzed for that constituent once a year. If a constituent falls below Flag 2 for three consecutive sampling events, the individual well's flag is reduced from Flag 2 status to Flag 1 or Flag 0 status, depending on the results, and the well is scheduled according to the lower flag. If a constituent falls below Flag 1 for three consecutive sampling events, the individual well's flag is reduced from Flag 1 status to Flag 0 status, and the flagging-based sampling ceases.

If an environmental-screening or GC VOA constituent has ever been flagged in a well series, it automatically is flagged for all new wells of that series that are designated as environmental-screening wells. The rules previously referred to also apply to removal of a flag from a new well. When one or more of the five constituents (carbon tetrachloride, chloroform, tetrachloroethylene, 1,1,1-trichloroethane and trichloroethylene) in the GC VOA suite are flagged, the entire suite is scheduled for analysis.

The following constituents are exceptions to the flagging rules:

- Specific conductance and pH have flagging criteria but do not trigger the scheduling mechanism.
- No flags are set for the following indicator parameters and major cations: alkalinity, 5-day biochemical oxygen demand, calcium, carbonate, chemical oxygen demand, magnesium, potassium, silica, sodium, total dissolved solids, total phosphates (as P), and total phosphorus.
- Aesthetic analyses such as color, odor, corrosivity, Eh, turbidity, and surfactants will not be assigned flagging criteria.
- Common laboratory contaminants and cleaners including phthalates, dichloromethane (methylene chloride), ketones, and toluene are not assigned flagging criteria unless they have primary drinking water standards.

B.4 SITE DESCRIPTION

The following sections describe facilities at approximately 100 locations within designated areas at SRS (WSRC, 1998m).

B.4.1 Acid/Caustic Basins

The acid/caustic basins in F-, H-, K-, L-, P-, and R-Area are unlined earthen pits (approximately 50 by 50 by 7 feet deep). These pits received dilute sulfuric acid and sodium hydroxide solutions used to regenerate ion-exchange units in power plant water purification processes at the reactor and separations areas in the center of SRS. The basins allowed mixing and neutralization of the dilute solutions before their discharge to nearby streams.

B.4.2 Burning/Rubble, Rubble, and Metals Burning Pits

From 1951 to 1973, burnable wastes—such as paper, wood, plastics, rubber, oil, degreasers, and drummed solvents—were received and burned monthly in the burning/rubble pits. In 1973, burning was discontinued and the waste was covered with a layer of soil. Rubble wastes—including paper, wood, cans, concrete, and empty galvanized-steel barrels and drums—were disposed of in the pits until they reached capacity and were covered with soil.

B.4.3 Coal Pile Runoff Containment Basins, Ash Basins, and Coal Piles

Electricity and steam at SRS are generated by burning coal. The facilities generally contained a 90-day reserve of coal that was not rotated. During long-term exposure to the environment, chemical and biological oxidation of sulfur compounds in coal resulted in the formation of sulfuric acid. To achieve compliance with the National Pollutant Discharge Elimination System permit issued in 1977, coal pile runoff containment basins were built. The C-, F-, L-, and R-Area coal piles have been removed. In 1991, the K-Area coal pile was reduced to a 2-inch base, and 75 percent of the P-Area coal pile was removed.

Currently, rainwater runoff from the remaining coal piles flows into the coal pile runoff containment basins via gravity flow ditches and sewers. The basins allow mixing of the runoff and its seepage into the subsurface, thus preventing the entry of large surges of low-pH runoff into surface streams. Ash sluice water from the D-Area and K-Area powerhouses has been discharged to the D-Area ash basins and the K-Area ash basin, respectively, since 1951.

B.4.4 Disassembly Basins

The disassembly basins, also called fuel and target storage basins, are concrete-lined, open tanks of water next to the reactor rooms inside the reactor buildings. Irradiated assemblies (reactor fuel and target rods) were rinsed and stored in the basins prior to their shipment to the separation areas. Some radioactivity was transferred to the basin water. Sand filters were used to remove radioactive particulates from the disassembly basin water. The filtered water was circulated through deionizers to remove additional constituents and was purged periodically through regenerated deionizers to the reactor seepage basins.

B.4.5 Seepage and Retention Basins

Seepage, retention, and settling basins have been used at SRS to store or dispose of wastewater from various operations. Closure activities include dewatering, backfilling and covering with a low-permeable clay cap.

B.4.6 Operating Buildings and Facilities

HLW vitrification facilities include

- the Defense Waste Processing Facility (S-Area Vitrification Building or Canyon) where vitrification occurs
- the F- and H-Area Canyon Building where irradiated products from the reactors are dissolved using nitric acid
- the A-Line uranium recovery facility where uranium oxide is produced from uranyl nitrate
- cooling water basins
- the Effluent Treatment Facility (ETF), which removes hazardous and radioactive contaminants from low-level liquid wastes and concentrates them for immobilization as saltstone
- pump pits which collect high-level radioactive sludge from the tanks and also pump it to the treatment facilities
- *monitoring wells*
- hazardous waste storage facilities (hazardous and mixed waste are stored in drums placed on diked concrete floors designed to contain liquid spills)
- Naval Fuel Material Facility (used to produce HEU for naval reactors until 1989),
- Vitrified HLW storage facilities
- holding tanks and pumps for LLW salt solutions
- the Z-Area Saltstone Manufacturing and Disposal Facility (processes and permanently disposes of low-level radioactive salt solution supernatant from the underground storage tanks and from ETF concentrate).

B.4.7 Plume Monitoring

In addition to the groundwater monitoring conducted at specific locations, numerous plume definition wells also monitor a 5-square-mile area to assess the extent of volatile organic contamination. The plume encompasses approximately three square miles and consists primarily of trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane. Additional wells monitor the separations and waste management areas.

B.4.8 RADIOACTIVE WASTE STORAGE AND DISPOSAL FACILITIES (SEE SECTION 3.5)

B.4.8.1 Burial Grounds

The burial grounds have been used for storage and disposal of radioactive solid waste produced at SRS or shipped from other facilities since 1952. The original area, known as the old burial ground, contains low-level alpha and beta-gamma trenches, intermediate-level beta-gamma trenches, and alpha waste trenches. As the trenches were filled, they were covered with soil. When the old burial ground was filled in 1974, operations moved to the adjacent low-level radioactive waste disposal facility (LLRWDF).

The sections of the LLRWDF currently being operated, known as the Solid Waste Disposal Facility, contain trenches for only radioactive waste. Concrete vaults, known as the E-Area vaults, have been constructed east and north of the LLRWDF for disposal of solid radioactive waste. The first waste was placed there in September 1994.

Until 1965, transuranic (TRU) waste was placed in plastic bags and cardboard boxes and buried in earthen trenches. Between 1965 and 1974, lower level TRU waste was buried unencapsulated in trenches, and higher-level TRU waste was buried in retrievable concrete containers or encapsulated in concrete. Since 1974, TRU wastes contaminated with greater than 0.01 Ci/g have been stored in watertight containers on concrete pads with monitoring sumps. TRU waste storage pads 1-19 are on the FFA's list of RCRA-regulated units.

Since mid-1984, newly generated low-level beta-gamma waste has been placed in metal boxes or metal drums. Currently, it is disposed of in engineered trenches and covered with at least 4 feet of soil. Some wastes that do not have forms that are easily placed in containers are disposed of in shallow land-burial slit trenches.

Mixed waste is stored in two buildings that began receiving waste in 1987 and 1995. Mixed wastes stored or disposed of within the old burial ground and portions of the LLRWDF include cadmium, lead, mercury, and tritiated pump oil. Some of the waste is contained in welded stainless steel containers or metal drums and stored within concrete cylinders. Degraded radioactive organic solvents and tritiated pump oil have been stored in 22 underground storage tanks in the old burial ground. In addition, two areas of the old burial ground were used for incineration of solvents.

B.4.8.2 Tank Farms

Liquid radioactive wastes are stored and processed at the tank farms, which comprise subsurface tanks containing high-level aqueous radioactive wastes in the form of sludges, supernatant liquid of varying salt concentrations, and saltcake. Approximately 129 million liters of waste are stored in the tanks.

The high-level liquid waste volume is reduced in the tank farm evaporators. Certain tanks are used for pretreatment of the wastes before they are processed into saltstone (low-level waste) or a glass form (high-level waste). Pretreatment processes at the tank farms include in-tank precipitation and extended sludge processing. Because of restrictions on the disposal of purge water, monitoring wells at the tank farms are bailed and not purged.

B.4.9 SANITARY LANDFILL AND INTERIM SANITARY LANDFILL

The sanitary landfill began receiving waste from office, cafeteria, and industrial activities during 1974. Materials such as paper, plastics, rubber, wood, cardboard, rags, metal debris, pesticide bags, empty cans, carcasses, asbestos in bags, and sludge from the site's wastewater treatment plant were placed in unlined trenches and covered daily with soil or a fabric substitute. The original section of the landfill and its southern expansion, with a total area of approximately 54 acres, have been filled. Operations at the portion of approximately 16 acres known as the northern expansion, or the interim sanitary landfill, were discontinued in November 1994.

Sanitary landfills are intended to receive only nonradioactive, nonhazardous waste. However, until October 1992, some hazardous wastes (specifically, solvent-laden rags and wipes used for cleaning, decontamination, and instrument calibration) were buried in portions of the original 32-acre landfill and its southern expansion.

B.4.10 SLUDGE APPLICATION SITES

These sites originally were the subject of a research program using domestic sewage sludge to reclaim borrow pits and to enhance forest productivity at SRS. In 1980, sludge was applied to various sites. After sludge was applied to the sites, hardwoods and pines were planted to quantify the effectiveness of the sludge as a fertilizer and soil conditioner. Revegetation of the sites is continuing. Monitoring was canceled at some of the sites. In 1989, the K-Area location (now called the K-Area sludge land application site) was declared a RCRA/CERCLA unit because of the presence of chlordane in the lagoon sludge applied to the site.

B.4.11 OTHER SITES

Other sites include

- B-Area Gas Station which has elevated levels of benzene
- wells
- chemical, metal, and pesticide pits which were used to dispose of oil in drums, organic solvents, and small amounts of pesticides and metals (the pits were excavated, contaminated soil and waste moved to the hazardous waste storage facility, two trenches formed, backfilled, and capped)
- oil and chemical disposal basins
- diesel tank spill
- acid/caustic basins
- N-Area Diesel Spill Hazardous Waste Storage Facility (tanks have been filled with inert material and the pipelines disconnected)
- N-Area Fire Department Training Facility (shallow pit surrounded by an 18-inch-high asphalt dike has been excavated and backfilled)
- hydrofluoric acid spill

- Silverton Road Waste Site (waste material is covered with soil and vegetation)
- TNX Burying Ground (although most of the disposed material was excavated and sent to the LLRWDF between 1980 and 1984, an estimated 27 kg of uranyl nitrate remains buried at this location).

B.5 REFERENCES

DOE, 1998b, SRS Baseline Disposition Maps;

<http://www.em.doe.gov/closure/mapmenu.html#SR>

DOE, June, 1998f, *Accelerating Cleanup: Paths to Closure [SRS-Specific Report]*; DOE/Savannah River Operations Office, Savannah River, South Carolina.

WSRC, May, 1998t, *The Savannah River Site's Groundwater Monitoring Program, Fourth Quarter 1997* (U); WSRC; ESH-EMS-970491.

APPENDIX C

HANFORD

C.1 HANFORD SITE DESCRIPTION

The Hanford site is divided into different numbered areas. Activities in the 300 Area include fuel production and research and development for the plutonium production reactors. The plutonium production reactors were constructed in the 100 Areas. The 200 Areas were responsible for extracting the plutonium from the spent reactor fuel, disposing of wastes, and processing the plutonium prior to shipment off site. The 400 Area is home of the Fast Flux Test Facility. The 600, 700 and 1100 Areas provided buffer space, offices, and support facilities.

C.1.1 The Areas

The 100 Areas (100-B/C, 100-D, 100-DR, 100-F, 100-H, 100-K, 100-K) are located along the Columbia River on the northern side of the Hanford Site. These sites were each built around a plutonium production reactor as part of Hanford's defense mission. Extensive contamination exists in some areas of surface soils, subsurface soils, and groundwater. Strontium-90, tritium, nitrate, and chromium are detected at many of the 100 Area operable units (DOE/RL 1996, section 4.10.1.2).

The 200 East Area (200-E) is located in the middle of the Hanford Site and was responsible for chemical reprocessing of nuclear materials. 200-E Facilities include the Plutonium-Uranium Extraction Plant, B-Plant, Waste Encapsulation and Storage Facility, 200 Area Treated Effluent Disposal Facility, 242-A Evaporator, and liquid waste storage in the East Tank Farms. The 200 West Area (200-W) is approximately seven miles west of 200-E. Historically, the 200-W was responsible for chemical reprocessing and plutonium finishing. 200-W Facilities include Plutonium Finishing Plant, S-Plant (Reduction-Oxidation Facility), T-Plant, U-Plant, Waste Receiving and Processing Facility, Environmental Restoration Disposal Facility (ERDF), burial grounds, and the west tank farms. The 200 North (200-N) area is north of the 200-E and 200-W Areas and was used as a storage facility during Hanford's defense production mission. The 200 Area contaminants include extensive groundwater plumes of technetium-99, iodine-129, nitrate, tritium, uranium, and chlorinate hydrocarbons such as carbon tetrachloride, chloroform, and trichloroethylene (DOE/RL 1996, section 4.10.1.3).

The 300 Area is located several miles north of Richland. The 300 Area served as Hanford's reactor fuel fabrication and research and development center. Facilities include laboratories, burial grounds, and the 300 Area Treated Effluent Disposal Facility. The 400 Area is located several miles north of Richland and includes the Fast Flux Test Facility (a sodium cooled test reactor) and the Fuels and Materials Examination Facility (FMEF).

The 700 Area is located in downtown Richland and includes the Federal Building. The 100 Area is located at the northern tip of Richland, several miles south of the 300 Area and includes office buildings and support facilities. The 600 Area is the remainder of the Hanford Site not designated as part of 100, 200, 300, 700, or 1100 areas.

C.1.2 Agencies

United States Department of Energy, Richland Operations Office (DOE-RL) is responsible for the Hanford Site and the Pacific Northwest National Laboratory (PNNL). DOE-RL has overall responsibility for the Project Hanford Management Contractor (PHMC), Environmental

Restoration Contractor (ERC), and PNNL. DOE-RL is ultimately responsible for all activities and external interaction with stakeholders, regulators, and tribal organizations.

The PHMC is the management and integration contractor for the Hanford Site. Currently, the PHMC prime contractor is Fluor Daniel Hanford Company (FDH) and the PHMC team includes six major subcontractors and six enterprise companies. FDH has overall responsibility for all PHMC activities on the Hanford Site. PHMC subcontractors/major projects "own" facilities that will be eventually transferred to the Facility Stabilization Project.

The PHMC is divided into several main projects:

- Waste Management: responsible for waste handling, packaging, and disposal
- Tank Waste Remediation System: responsible for Hanford's tanks, associated systems and the disposition of tank wastes
- Spent Nuclear Fuel: responsible for the disposition of nuclear fuels at Hanford,
- Maintenance and Operations
- Facility Stabilization Project.

Babcock and Wilcox Hanford Company, a major subcontractor to the PHMC, is responsible for the Facility Stabilization Project. The Facility Stabilization Project will characterize facilities, make recommendations for the best remediation action, and eventually transfer ownership of the facility to the Environmental Restoration.

The ERC manages the Environmental Restoration Program. Bechtel Hanford Incorporated (BHI) is the current ERC. The ERC plans, manages, executes, and integrates a full range of activities for the cleanup of groundwater, contaminated soils, and inactive nuclear facilities under DOE's Environmental Restoration Program. The Battelle Memorial Institute operates PNNL. PNNL operates facilities on the Hanford Site that will eventually be transferred to the PHMC and eventually to the ERC.

C.2 FACILITY TYPES

C.2.1 Cribs, Ponds, Ditches, Trenches, Injection Wells, French Drains

Cribs, ponds, ditches, trenches, and injection wells are facilities designed to receive lower-activity radioactive waste and discharge it directly into the ground. Cribs, ponds, and ditches use percolation to discharge waste to the soil in a solution. Typically, waste became concentrated in the soil layer closest to the surface. That soil layer could be retrieved and disposed of in a facility better designed to handle higher-level wastes. Injection wells and french drains direct liquid waste directly underground into the soil. These facilities were used to dispose of radioactive wastes.

C.2.2 Burial Grounds and Landfills

Burial grounds and landfills are used for the disposal of solid wastes. Burial grounds typically received drums and boxes, but waste types, package configurations, and facility types vary

considerably. These facilities were used to dispose of radioactive and hazardous wastes (hexone, transuranics, compactibles solid waste, contaminated vehicles).

Hanford is currently placing all environmental restoration wastes in the Environmental Restoration Disposal Facility (ERDF). The ERDF is a modern disposal facility designed and operated in compliance with current regulations.

C.2.3 Reactor Facilities

Hanford has nine plutonium production reactors located along the Columbia River. Support facilities (warehouses, water treatment systems, effluent disposal systems) were also located near each reactor. The reactors all used graphite block cores. Eight of the reactors were constructed with single-pass cooling systems, and the ninth, N-Reactor, had a recirculating primary coolant system along with several secondary, single-pass systems. With an average life span of twenty-two years, these nine reactors were built between 1944 and 1963, and closed down between 1964 and 1987 (WHC 1993).

At the 100-K Area, fuel is being stored in two basins called the "K-Basins." Reactor fuel was stored in these basins before reprocessing in the Canyon facilities. The basin's integrity is suspect, having leaked during the 1970's and again in 1993 and an effort to move the fuel to a newer and safer facility is underway (DOE/RL 1997a).

Another reactor is the Fast-Flux Test Facility, located in the 400 Area. Contaminants/wastes are beta-gamma emitters from reactor operations, spent nuclear fuels, sodium dichromate, asbestos, and lead.

C.2.4 Canyon Facilities

Canyon facilities are the large-scale chemical processing plants used to separate the radionuclides of interest from reactor fuel. They are called canyon facilities because of their size and interior appearance. The facilities are six hundred to one thousand feet long, approximately sixty feet wide and typically one hundred feet high. Nearly half of the building is below grade. Chemical processing equipment is arranged into a series of "cells" located in the center of the canyon. The cells are surrounded by several feet of concrete and are accessed via cover blocks and overhead cranes. Each facility is serviced by a heavy rail spur and has an attached railroad tunnel. The majority of the process equipment remains in place. B-Plant is unique due to the attached Waste Encapsulation and Storage Facility, a cesium canister fabrication and storage facility. Other facilities include B-Plant, T-Plant, U-Plant, S-Plant, and the Plutonium Uranium Extraction Plant (PUREX). Contaminants/wastes include a wide variety of chemical wastes, transuranics, asbestos, and lead.

Although technically not a canyon facility, the Plutonium Finishing Plant is included here to simplify discussions. PFP is a steel frame constructed building with a series of glove boxes, chemical process equipment, vaults and laboratories. PFP processed plutonium prior to shipment to other DOE sites. Contaminants include chemical wastes, radioactive wastes, and asbestos.

C.2.5 Tank Facilities

Liquid wastes not discharged to a unit described in Section C.2.1 or directly to the river, were typically discharged to underground storage tank facilities. Groups of tanks, called tank farms, are near most major facilities (B-Plant, S-Plant, PUREX, etc.). Hanford has 177 tanks, all 6 to 10 feet below the ground, in 18 clusters or 'farms' on a plateau near the center of the site. Of these, 149 are single shell tanks, which means they are made of a single carbon steel wall encased in concrete. The single shell tanks, all but two of which were built by 1955, range in capacity from 50,000 to 750,000 gallons (DOE/RL, 1997a). The double-shell tanks use two concentric, carbon steel shells separated by an annulus of approximately three feet. Corrosion controls include cathodic protection systems and chemical additions to maintain a caustic environment. Tank facilities include catch tanks, receiver tanks, lift stations, diversion boxes, valve pits, and piping for intra and inter tank farm liquid transfer as well as two evaporator facilities. Sixty-eight of the single shell tanks have, or are suspected to have, leaked waste. Contaminants include a wide variety of radionuclides, organic, and caustic chemicals.

C.2.6 Laboratory and Test Facilities

Hanford's laboratory facilities include facilities in both the 200 and 300 Areas. These facilities included hot cells, test reactors, and laboratories. These facilities handled radioactive materials and most have waste storage systems. In general, these facilities were constructed as part of canyon process development and in support of those processes.

C.2.7 Effluent treatment

Hanford's effluent treatment facilities include the 300 Area Treated Effluent Disposal Facility, and the 200 Area Effluent Treatment Facility and Treated Effluent Disposal Facility. These facilities treat and dispose of liquid effluents, including evaporator condensate. These facilities are currently operating.

C.2.8 Miscellaneous Support Structures

The Hanford Site employs many support structures including, but not limited to fabrication shops, storage buildings, steam plants, office space, maintenance facilities, and warehouses.

C.2.9 Unplanned Releases

Unplanned releases unintentional discharges of waste materials to the environment. These include both solid and liquid wastes. These locations exist all over the Hanford Site. Releases include both chemical and radiological contaminants.

C.3 CURRENT MONITORING ACTIVITIES

This section is a summary of activities from the Environmental Monitoring Plan (DOE/RL 1998b), which documents the effluent monitoring and environmental surveillance programs at the Hanford Site. DOE Order 5400.1 is an important requirements document for these activities.

C.3.1 Facility Effluent-Monitoring Plans

Section IIA of the Environmental Monitoring Plan discusses Facility-Effluent Monitoring Plans (FEMP). The effluent- and emission-monitoring activities for all media, with the exception of groundwater, are addressed by the FEMPs. The monitoring of liquid effluents for non-radioactive hazardous constituents, as defined by the Resource Conservation and Recovery Act of 1976 (RCRA), is covered in the site-specific sampling analysis plan. Two activities associated with the FEMPs are the determination of the need for a FEMP and the preparation of the FEMP. The FEMP determination consists of an initial evaluation of potential radioactive or hazardous material sources within a facility. If a significant quantity of radioactive or hazardous material is present, then a FEMP is prepared (DOE/RL 1998b).

Abstracts for each facility FEMP are available in Section IIA of the Environmental Monitoring Plan. These abstracts include a brief discussion of the facility, the effluents of interest, and a document number reference to the facility's FEMP.

C.3.2 Near-facility Monitoring

Near-facility monitoring is required by DOE Order 5400.1. The near-facility monitoring program includes pre-operational and routine near-facility monitoring. Pre-operation monitoring is conducted before operation of a facility or process that has the potential to significantly impact the environment. This pre-operational monitoring establishes a baseline for the routine near-facility monitoring activities. The study shall serve to:

- characterize existing physical, chemical, and biological conditions that could be affected
- establish background levels of radioactive and chemical components
- characterize pertinent environmental and ecological parameters
- identify potential pathways for human exposure and environmental impact as a basis for determining the nature and extent of the subsequent routine operational and emergency effluent monitoring and environmental surveillance programs (DOE/RL 1998b, section IIB).

Facility-specific environmental monitoring is provided for the protection of the environment adjacent to nuclear facilities and waste-treatment, -storage, and -disposal sites in compliance with applicable federal, state, and local environmental regulations and requirements (DOE/RL 1998b, section IIB). Table C-1 is a summary of the media to be monitored.

Table C-1.
Near-Field Sampling Media, Frequency, Analytes, and Parameters
Source: (DOE/RL 1998b, table II.B-2)

Sample Types	Collection or Measurement Frequency	Analytes/Parameters Monitored
Air	Biweekly	Total alpha and beta
	Semiannual	Strontium, plutonium, uranium, gamma
Soil	Annual	Strontium, plutonium, uranium, gamma
Vegetation	Annual	Strontium, plutonium, uranium, gamma
Animals	Annual	Strontium, plutonium, uranium, gamma
Thermoluminescent dosimeter	Quarterly	Radiation dose
Survey points	Annual	Radiation dose
Surface water	Weekly	PH
	Monthly	Total alpha, beta, strontium, gamma
River seepage	Annual	Strontium, gamma, tritium
Sediment	Annual	Strontium, plutonium, uranium, gamma
Aquatic vegetation	Annual	Strontium, plutonium, uranium, gamma

C.3.3 Surface Environmental Surveillance

The Surface Environmental Surveillance Project measures the concentration of radionuclides and chemicals in environmental media and assesses the integrated effects of these materials on the environment and the public. The project collects samples of air, surface water, sediments, soil and natural vegetation (approximately every 5 years), agricultural products, fish, and wildlife. Analytical capabilities include the measurement of radionuclides at very low environmental concentrations and non-radiological chemicals, including metals, anions, volatile organic compounds, semivolatile organic compounds, pesticides, and polychlorinated biphenyls. In addition, the project includes the capability to measure ambient external radiation (DOE/RL 1998b, section IIIA).

This project focuses on routine releases but is also responsive to unplanned releases and releases from non-DOE operations on and near the site (DOE/RL 1998b, Section IIIA).

C.3.4 Groundwater Monitoring

Groundwater monitoring at the Hanford Site includes near-field monitoring of specific facilities, site-wide monitoring of existing contaminant plumes, and monitoring to assess the effectiveness of groundwater-remediation activities. DOE has an integrated groundwater monitoring program called the "Hanford Groundwater/Vadose Zone Integration Project," currently led by the ERC. This project integrates the groundwater activities from CERCLA, RCRA, WAC, operational monitoring, and site-wide environmental surveillance (DOE Order 5400.1).

The Hanford Groundwater/Vadose Zone Integration Project uses a combination of older wells and newer wells built to WAC 173-160 standards. The majority of the older monitoring wells on the Hanford Site are 10, 15, or 20 cm in diameter and are constructed of carbon-steel casing. A number of newer wells are constructed of 10-cm stainless-steel casing. Most unconfined aquifer wells are completed with well screens or perforations in the upper 3 to 6 m of the aquifer (DOE/RL 1998b, section IIIB).

The project includes

- Hydrologic characterization: to gain understanding of hydrogeologic conditions and controls on groundwater and contaminant movement
- Water-level monitoring: to characterize the direction and velocity of groundwater flow, determine the impact of Hanford Site operations on the groundwater-flow system, and assess the adequacy of point-of-compliance wells to detect groundwater impacts from specific monitored facilities.
- Groundwater sampling and analysis: to meet programmatic data needs. Each well has a Statement of Work that specifies the well to be sampled, analytes, sampling frequencies, quality requirements, analytical and sampling procedures, and reporting requirements (DOE/RL 1998b, section IIIB).

C.3.5 Meteorological Monitoring

The Meteorological and Climatological Services Project provides meteorological and climatological support for emergency response, weather forecasting, climatological data, and related special requests through the operation of the Hanford Meteorology Station (HMS).

Thirty monitoring stations are located on-site and nearby off-site. The meteorological instrumentation provides data, including wind speed and direction, temperature, vertical temperature difference, dew-point temperature, and precipitation. Other data are collected via the surface observation program, including sky condition, cloud type and amount, ceiling height, mixing depth, atmospheric pressure, weather and obstructions to visibility, relative humidity, and solar radiation (DOE/RL 1998b, section IIIC).

C.4 SUMMARY OF DETAILED GROUNDWATER MONITORING ACTIVITY

By comparing the relative number of samples, a general understanding of the more important (either by the sampling frequency or the number of wells sampled) groundwater monitoring constituents can be obtained. The constituents are divided into different parameter groups (Table C-2) with the major constituents listed that are (only the most commonly monitored contaminants are listed in Table C-2) monitored for that group (PNNL 1998).

Table C-2.
Major Constituents Monitored in the Hanford Groundwater Monitoring Program

Parameter Group	Constituents		
Anions	alkalinity ammonia bromide	chloride cyanide fluoride	nitrate nitrite phosphate sulfate
Indicator Parameters	conductivity pH	total organic carbon total organic halides	
Metals	aluminum antimony arsenic barium beryllium cadmium calcium chromium cobalt	copper iron lead magnesium manganese mercury nickel potassium selenium	silicon silver sodium thallium tin titanium vanadium zinc
Miscellaneous:	temperature turbidity	total halogen diesel oil	
Pesticide:	Aroclor-1016, 1221, 1232, 1242, 1248, 1254, 1260		
Radiological	alpha beryllium-7 beta Carbon-14 Cobalt-58, -60	Cesium-134, -137 Europium-152, -155 Iron-59 Iodine-129 Potassium-40	Ruthenium-106 Antimony-125 Strontium -89 -90 Technetium-99 Tritium Uranium
Semi-Volatile Organic Compounds	1,4-Dichlorobenzene 2,4-Dichlorobenzene 2,6-Dichlorobenzene 2,4,5-trichlorophenol 2,4,6-trichlorophenol 2,4-dimethylphenol 2-methylphenol (cresol, o-) 2-nitrophenol 4,6-Dinitro-2methyl phenol	2-secButyl-4,6-dinitrophenol 4-chloro-3-methylphenol 2-chlorophenol chrysene Decane 2,4-dinitrophenol dodecane phenol 3,4 methyl phenol	Naphthalene 4-nitrophenol pentachloroethane pyrene tetradecane 1,2,4,5-tetrachlorophenol tributyl phosphate 1,2,4-trichlorobenzene tris-2-chloroethyl phosphate

Table C-2.
Major Constituents Monitored in the Hanford Groundwater Monitoring Program (continued)

Parameter Group	Constituents		
Volatile Organic Compound	1,1,1-trichloroethane	carbon disulfide	carbon xylene
	1,1,2-trichloroethane	tetrachloride	bromomethane
	1,1-dichloroethane	dibromochloromethane	chloromethane
	1,2-dichloroethane	chlorobenzene	2-butanone
	1,1,1,2-tetrachloroethane	chloroform	methylenechloride
	1,2-dichloroethene	cis-1,2-dichloroethylene	tetrachloroethene
	1-butanol	chloroethane	styrene
	2-hexanone	1,1-dichloroethene	toluene
	acetone	1,2-dichloropropane	trichloroethene
	bromodichloromethane	ethylbenzene	trans-1,3-
	benzene	ethyl cyanide	dichloropropene
	bromoform	4-methyl-2-pentaone	trichloroethene
			vinyl chloride

C.5 REFERENCES

- DOE/RL, 1997a, webpage document: *Closing the Circle from the War Years to the Future*, DOE/RL, Richland, Washington <http://www.hanford.gov/history/misc/circle.htm>
- DOE/RL, November 1998b, *Environmental Monitoring Plan*, DOE/RL-91-50, Rev. 2, DOE/RL Richland, Washington.
- PNNL, February 1998, *The Hanford Site Groundwater Monitoring for Fiscal Year 1997*, PNNL-11793, Pacific Northwest National Laboratory, Richland, Washington (<http://www.hanford.gov/doe/reading.htm>).
- WHC, October 1993, *Characterization of Wastes in and Around Early Reactors at the Hanford Site: The Use of Historical Research*, WHC-SA-2078, Westinghouse Hanford Company (WHC), Richland, Washington.