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WASTE DISPOSAL OPTIONS AND FERNALD LESSONS LEARNED TECHNICAL MEMORANDUM

FOR THE NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK

July 2011

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WASTE DISPOSAL OPTIONS AND FERNALD LESSONS LEARNED TECHNICAL MEMORANDUM
For The Niagara Falls Storage Site
Lewiston, NY

Prepared for:
U.S. Army Corps of Engineers
Buffalo District

Prepared by:
Energy*Solutions*, LLC
1009 Commerce Park Drive, Suite 100
Oak Ridge, Tennessee 37830

and

Science Applications International Corporation
4449 Easton Way, Suite 130
Columbus, Ohio 43219

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ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
°F	Degrees Fahrenheit
µCi/ml	Microcuries per milliliter
ACL	Administrative Control Level
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
AP-2	Alpha Analyzer
ARAR	Applicable or Relevant and Appropriate Requirement
AWR	Accelerated Waste Retrieval
BOP	Balance of Plant
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
cm	Centimeter
cm^2	Square Centimeter
D&D	Decontamination and Demolition
DAC	Derived Air Concentration
DOT	United States Department of Transportation
dpm	Disintegrations Per Minute
EPA	United States Environmental Protection Agency
ESD	Explanations of Significant Differences
FCAB	Fernald Citizens Advisory Board
FCHEC	Fernald Citizens for Health and Environment Committee
FCP	Fernald Closure Project
FEMP	Fernald Environmental Management Project
FRESH	Fernald Residents for Environmental Safety and Health
FS	Feasibility Study
ft	Feet
ft^3	Cubic Feet
FUSRAP	Formerly Utilized Sites Remedial Action Program
g	gram
gpm	Gallons Per Minute
ha	Hectare
hr	Hour
HRS	Hazard Ranking System
HVAC	Heating, Ventilation, and Air Conditioning
IP-2	Industrial Package Type 2
ISM	Integrated Safety Management
IWCS	Interim Waste Containment Structure
keV	Kilo electron Volt
kg	Kilogram
lbs	Pounds
LLMW	Low-Level Mixed Waste

ACRONYMS AND ABBREVIATIONS (continued)

LLRW	Low-Level Radioactive Waste
m	Meter
m^3	Cubic Meters
mph	Miles per Hour
mrem	Millirem
mrem/hr	Millirems per Hour
mrem/yr	Millirems per Year
NFSS	Niagara Falls Storage Site
NNSS	Nevada National Security Site
NORM	Naturally Occurring Radioactive Material
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
pCi/g	Picocuries Per Gram
pCi/L	Picocuries Per Liter
$pCi/m^2/s$	Picocuries Per Square Meter Per Second
pCi/m^3	Picocuries Per Cubic Meter
PE-g	Plutonium-239 equivalent grams
PPE	Personal Protective Equipment
Ra-226	Radium-226
RCRA	Resource Conservation and Recovery Act
RCS	Radon Control System
RI	Remedial Investigation
Rn-222	Radon-222
ROD	Record of Decision
RWP	Radiological Work Permit
SSAB	Site-Specific Advisory Board
SWRS	Silo Waste Retrieval System
TAC	Texas Administrative Code
TCLP	Toxicity Characteristic Leaching Procedure
TENORM	Technologically-Enhanced, Naturally-Occurring Radioactive Material
Th-230	Thorium-230
TM	Technical Memorandum
TTA	Tank Transfer Area
TWRS	Tank Waste Retrieval System
U.S.	United States
UCL	Upper Confidence Level
USACE	United States Army Corps of Engineers
USDOE	United States Department of Energy
VITPP	Vitrification Pilot Plant
VPP	Voluntary Protection Program
WAC	Waste Acceptance Criteria

ACRONYMS AND ABBREVIATIONS (continued)

WCS	Waste Control Specialists
WDI	Wayne Disposal, Incorporated
WIPP	Waste Isolation Pilot Plant
WL	Working-Level
wt%	Percent by weight
WT&P	Waste Treatment and Packaging
yd	Yard
yd^3	Cubic Yards
yr	Year

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GLOSSARY

ACTIVITY: A measure of the rate at which radioactive material is undergoing radioactive decay; usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time. The special unit of activity is the curie (Ci).

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENT (ARAR): ARARs consist of two sets of requirements, those that are applicable and those that are relevant and appropriate. *Applicable requirements* means those cleanup standards; standards of control; and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. *Relevant and appropriate requirements* means those cleanup standards; standards of control; and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not ”applicable“ to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

AQUIFER: A water-bearing layer of permeable rock or soil that will yield water in usable quantities to wells. Confined aquifers are bounded on top and bottom by less-permeable materials. Unconfined aquifers are bounded on top by a water table.

AS LOW AS REASONABLY ACHIEVABLE (ALARA): ALARA means making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical and consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to the state of technology, the economics of improvements in relation to the benefits to public health and safety, and other societal and socioeconomic considerations, and in relation to the utilization of nuclear energy and licensed materials in the public interest.

BACKGROUND (SOIL, GROUNDWATER, SURFACE WATER, OR SEDIMENT): A background concentration is a concentration that occurs in an area that is not impacted by site activities and contains characteristics similar to site conditions.

BACKGROUND (RADIATION): Background radiation includes both the natural and man-made (e.g., fallout) radiation in the human environment. It includes cosmic rays and radiation from the naturally radioactive elements that occur both outside and inside the bodies of humans and animals. For persons living in the United States, the average annual individual dose from background radiation is approximately 620 millirem per year (mrem/yr; 310 mrem/yr from natural sources and 310 mrem/yr from man-made sources) (National Council on Radiation Protection and Measurements Report No. 160).

BALANCE OF PLANT (BOP): An NFSS operable unit (OU) defined as all material not included in the IWCS OU, excluding groundwater. BOP material will include any remaining former building structures within the IWCS, remaining cap material and other soils within the IWCS, the IWCS dike, surface and subsurface soils across the rest of the site, surface water, sediment, railroad ballast, roads, Building 401, and pipelines, etc.

BYPRODUCT MATERIAL: As defined in the Atomic Energy Act of 1954 and revised by the Energy Policy Act of 2005, byproduct material includes any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material [11e.(1)], the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material [11e.(2)], certain discrete sources of radium-226 [11e.(3)(A)], other discrete sources of naturally occurring radioactive material [11e.(4)], and certain accelerator-produced radioactive material under NRC jurisdiction [11e.(3)(B)].

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA): This act was put into place in 1980 and is also known as Superfund. This act concerns releases of hazardous substances into the environment and the cleanup of these substances and hazardous waste sites. The U. S. Environmental Protection Agency website indicates that the act authorizes response actions and enabled the revision of the National Oil and Hazardous Substances Pollution Contingency Plan, more commonly referred to as the National Contingency Plan. The National Oil and Hazardous Substances Pollution Contingency Plan provided the guidelines and procedures needed to respond to releases and threatened releases of hazardous substances, pollutants, or contaminants. The National Oil and Hazardous Substances Pollution Contingency Plan also established the National Priorities List.

CONTAINMENT: Confining the radioactive wastes within prescribed boundaries (e.g., within a waste containment structure).

CONTAMINATED RUBBLE/WASTE: A waste stream that includes construction debris, concrete, rebar, etc. from the demolition of Buildings 410, 415, and 434. This material also includes K-65 slurry transfer piping, existing structures prior to the IWCS, the Thaw House Foundation and miscellaneous materials from Building 413 and 414.

CONTAMINATED SOIL: A waste stream that is comprised of materials from several on-site and off-site remedial actions over the years between 1982 and 1991. This material also consists of sand/clay separating layers in 411, dike material, cap material and the soil beneath the IWCS.

CURIE (Ci): A measure of the rate of radioactive decay. One curie is equal to 37 billion (3.7×10^{10}) disintegrations per second, which is approximately equal to the activity of 1 gram of radium-226.

DAUGHTER: The immediate product of the radioactive decay of an element or isotope.

DECAY PRODUCT: Also known as a "daughter product" that is left over after disintegration or transformation of a nuclide. During radioactive decay, a radionuclide emits energy, or transforms, to become another radionuclide, or decay product. The decay process eventually ends in a stable decay product.

DOSE: Total radiation delivered to a specific part of the body or to the body as a whole.

FEASIBILITY STUDY (FS): A study undertaken by the lead agency to develop and evaluate options for remedial action using data gathered during the remedial investigation (RI). The FS defines the objectives of the remedial actions for the site, performs an initial screening of remedial technologies and potential remedial action alternatives, and performs a detailed and comparative analysis of the alternatives. The FS evaluates the necessary information to select a preferred alternative for the remediation of a site. The term also refers to a report that describes the results of the study.

GROUNDWATER: Usually considered the water within the zone of saturation below the soil surface.

HALF-LIFE: The time required for half of the atoms of a specific radionuclide to undergo radioactive decay.

HEADSPACE: Gas space of a closed space (i.e. silo, tank, or drum) above a solid or liquid. Laboratory analysis of the headspace identifies components present in the gas.

INTERIM WASTE CONTAINMENT STRUCTURE (IWCS): The IWCS is an on-site waste storage facility that is the dominant site feature at the NFSS, occupying approximately 4.0 ha (10 acres) in the southwest portion of the site. During the 1980's, the USDOE consolidated radioactive wastes and contaminated materials at the NFSS into the IWCS, which was engineered to retard radon emissions, infiltration of water from precipitation, and migration of contamination to groundwater.

K-65 RESIDUES: The process wastes remaining after uranium was extracted from ore processed by Mallinckrodt Chemical Works located in St. Louis, MO. The ore originated from the Belgian Congo (Africa) region which contained uranium concentrations up to 65%. The process wastes, which still contained natural uranium decay products, were classified as K-65 residues.

LEACH: To remove or separate soluble components from a solid by contact with water or other liquids.

LOW-LEVEL RADIOACTIVE WASTE (LLRW): LLRW is radioactive material not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in 42 USC 2014(e)(2) and which the Nuclear Regulatory Commission classifies as low-level radioactive waste consistent with existing law (42 United States Code 108, 10101). LLRW has four subcategories: Class A is generally the least hazardous while greater than Class C is the most hazardous.

LOW-LEVEL MIXED WASTE (LLMW): LLRW that is mixed with hazardous wastes is classified as LLMW and must meet treatment, storage, and disposal regulations both as low-level waste and hazardous waste.

OPERABLE UNIT (OU): Site unit for which implementation of a focused CERCLA process will be conducted. Three separate NFSS OUs will be addressed by the CERCLA process: the IWCS, Balance of Plant and Groundwater. A separate Feasibility Study, Proposed Plan and Record of Decision will be developed for each NFSS OU.

OTHER IWCS RESIDUES/WASTES: Other wastes (other than K-65 residues) stored at the IWCS and designated as L-30, L-50, and F-32. These residues resulted from processing of ore with uranium concentrations ranging from 0.4% up to 10%, at the Linde Ceramics Plant, Tonawanda, NY (L-30 and L-50 residues) and residues from the Middlesex Metal Refinement Plan (F-32 residues) in Middlesex, NJ.

PNEUMATIC: Application or use of compressed air or gas to affect mechanical motion.

PROGENY: An isotope or group of isotopes derived from a parent isotope.

R-10 RESIDUES AND SOIL: A waste stream that consists of original R-10 residues that were stored north of Building 411 and contaminated soil that was placed on top of the R-10 pile. The contaminated soil was excavated during remedial actions conducted in 1972 prior to the IWCS construction (DOE 1982).The resulting R-10 residues and soil pile while under historic open ground storage at the NFSS, subsequently leached into the underlying soil, contaminating additional soil.

RADIATION: A very general term that covers many forms of particles and energy, from sunlight and radio waves to the energy that is released from inside an atom. Radiation can be in the form of electromagnetic waves (gamma rays and X-rays) or particles (alpha particles, beta particles, protons, and neutrons).

RADIOISOTOPE: An unstable isotope of an element that spontaneously loses particles and energy through radioactive decay.

RADIONUCLIDE: An unstable nuclide that undergoes radioactive decay.

RADIUM-226: A radioactive decay product in the uranium-238 decay series and the precursor of radon-222. Although radium-226 decays by alpha particle emissions with a half life of about 1,600 years, it has 10 successive daughter products ending in lead-206. As such, radium may be hazardous when it gets into the body. When taken into the body, radium accumulates in certain organs such as the bone.

RADON-222: A radioactive gas produced by the decay of radium-226. It is hazardous mainly because its solid decay products can be deposited in the lungs where they decay in a matter of minutes, emitting alpha particles that irradiate nearby tissue. Radon-222 has a half-life of 3.8 days.

REMEDIAL INVESTIGATION (RI): An RI is a site investigation consisting of a records search, environmental sampling, risk assessment, and groundwater flow modeling to define the identity, amount, and location of contaminants at a site.

RESOURCE CONSERVATION AND RECOVERY ACT (RCRA): RCRA is a law passed in 1976 that gave U.S. EPA the authority to control hazardous waste operations including waste generation, transportation, treatment, storage, and disposal.

SECULAR EQUILIBRIUM: In a radioactive decay series, the state that prevails when the ratios between the amounts of successive members of the series remain constant over time.

SOURCE TERM: The quantity of radioactive material (or other pollutant) released to the environment at its point of release (source).

TAILINGS: Byproduct materials or refuse remaining after ore has been processed.

THORIUM-230: An alpha particle emitting radioactive member of the naturally occurring uranium-238 decay chain. Thorium-230 is the daughter of uranium-234 and the parent of radium-226 and has a half-life of 77,000 years.

TOWER SOIL: The Tower soil waste stream represents material located outside of the silo (Building 434) which was historically used for storing the K-65 residues prior to construction of the IWCS. These soils were contaminated by K-65 residues during facility operations, transfer of the K-65 residues to the IWCS, and decommissioning of the silo. They were added to the north end of Bay D of Building 411 within the IWCS. The Tower soil is assumed to have approximately 2% of K-65 contaminant levels.

TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP): A laboratory method to determine the mobility of organic and inorganic analytes present in wastes. This method is usually used to determine if a waste is a characteristic hazardous waste as defined under RCRA. The TCLP analysis simulates leaching through a landfill and determines which contaminants identified by the U.S. EPA are present in the leachate.

TRANSURANIC RADIONUCLIDE: Radionuclides that have atomic numbers greater than that of uranium, which is 92. All transuranic isotopes are radioactive.

TRANSURANIC WASTE: Radioactive material with more than 100 nanocuries of alpha-emitting isotopes per gram and having an atomic number greater than 92, which is the atomic number for uranium. The half life of the radioactive material must also be more than 20 years.

TREATABILITY STUDY: A study in which a hazardous waste is subjected to a treatment process to determine: (1) whether the waste is amenable to the treatment process, (2) what pretreatment (if any) is required, (3) the optimal process conditions needed to achieve the desired treatment, (4) the efficiency of a treatment process for a specific waste or wastes, or (5) the characteristics and volumes of residuals from a particular treatment process. A treatability study may include liner compatibility, corrosion, and other material compatibility studies and toxicological and health effects studies.

URANIUM (NATURAL): A naturally occurring radioactive element that consists of 99.2830% by weight uranium-238, 0.7110% uranium-235, and 0.0054% uranium-234.

VICINITY PROPERTY: Vicinity properties are those properties that were designated by the U.S. Department of Energy (DOE) as eligible properties in the Formerly Utilized Sites Remedial Action Program (FUSRAP) and located within the boundaries of the former Lake Ontario Ordnance Works (LOOW) but outside the boundaries of what is now the Niagara Falls Storage Site (NFSS).

11e.(2) WASTE: Waste defined by the Atomic Energy Act as byproduct material in Section 11e.(2). Also see definition for "byproduct material."

WASTE ACCEPTANCE CRITERIA (WAC): Specific requirements that must be met for a waste to be disposed at a particular disposal facility. WAC control such things as the type of waste accepted, the type of waste container used, the amount of radioactive material in a container, the way a container is packaged and labeled, the contamination levels on the outside of a container, and the physical and chemical form of the waste.

WASTE STREAM: The flow of a specific waste material from generation to treatment and final disposition.

WORKING LEVEL (WL): One WL is defined as any combination of short-lived radon progeny in 1 L of air, under ambient temperature and pressure, that results in the ultimate emission of 1.3×10^5 million electron volts of alpha particle energy.

METRIC CONVERSION CHART

To Convert to Metric			To Convert from Metric		
If You Know	Multiply By	To Get	If You Know	Multiply By	To Get
Length					
inches	2.54	centimeters	centimeters	0.3937	inches
feet	30.48	centimeters	centimeters	0.0328	feet
feet	0.3048	meters	meters	3.281	feet
yards	0.9144	meters	meters	1.0936	yards
miles	1.60934	kilometers	kilometers	0.6214	miles
Area					
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.092903	square meters	square meters	10.7639	square feet
square yards	0.8361	square meters	square meters	1.196	square yards
acres	0.40469	hectares	hectares	2.471	acres
square miles	2.58999	square kilometers	square kilometers	0.3861	square miles
Volume					
fluid ounces	29.574	milliliters	milliliters	0.0338	fluid ounces
gallons	3.7854	liters	liters	0.26417	gallons
gallons	0.00378	cubic meters	cubic meters	264.55	gallons
cubic feet	0.028317	cubic meters	cubic meters	35.315	cubic feet
cubic yards	0.76455	cubic meters	cubic meters	1.308	cubic yards
Weight					
ounces	28.3495	grams	grams	0.03527	ounces
pounds	0.4536	kilograms	kilograms	2.2046	pounds
Temperature					
Fahrenheit	Subtract 32 then multiply by 5/9ths	Celsius	Celsius	Multiply by 9/5ths then add 32	Fahrenheit
Radiation					
picocurie	0.037	Becquerel	Becquerel	27.027027	Picocuries
curie	3.70E+10	Becquerel	Becquerel	2.703E-11	Curies
rem	0.01	sievert	sievert	100	rem
RAD	0.01	Gray	Gray	100	RADs

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EXECUTIVE SUMMARY

The United States Army Corps of Engineers (USACE) Buffalo District is conducting a Feasibility Study (FS) aimed at defining an approach for addressing the K-65 residues, other residues, debris, and contaminated soil associated with the Interim Waste Containment Structure (IWCS) at the Niagara Falls Storage Site (NFSS) in Lewiston, New York. This effort will involve collection and assessment of technical information covering various topics to define a remedy presenting a balanced perspective that is protective of human health and the environment.

USACE is committed to keeping the public well informed on the technical basis for evaluating the various components of the remedial alternatives under consideration for the IWCS and to providing a vehicle for their participation. The publication of a series of Technical Memoranda (TM) provides opportunities for active public involvement in the IWCS FS process.

USACE released the Waste Disposal Options and Fernald Lessons Learned Fact Sheet to inform the public of the scope and objectives for this TM. The public comments received were evaluated during development of this TM and will be further addressed during the development of the IWCS FS document. The fact sheet and the public comment/response summary have been included in Appendix A to this TM.

ES.1 Scope and Purpose

The scope and purpose of this TM is to present a summary of the Fernald Site K-65 Silos 1 and 2 Remediation Project with associated lessons learned and a waste disposal options study for the waste materials currently stored in the IWCS.

Emphasis is placed on identification and discussion of lessons learned at Fernald in the effort to process and dispose of the K-65 residues and other materials similar to those that will likely be found at the NFSS. The topics of the lessons learned include: radon abatement; material removal; material handling and transfer; packaging and transport; waste disposal; radiological personnel exposures and associated controls; programmatic actions including stakeholder and worker involvement, health and safety; procurement; and radiological exposures to the public and environment.

The objectives of this TM include:

- Identify similarities between the remediation of the Fernald K-65 residues and the future remediation of the IWCS K-65 residues and other associated waste;
- Identify lessons learned associated with the remediation of the Fernald K-65 residues that may apply to the future remediation of the IWCS K-65 residues and other associated waste;
- Identify current or foreseeable potential future disposal options for the IWCS waste streams anticipated to be generated during remediation; and

- Provide a preliminary estimate of waste volumes and disposal costs for the expected waste streams from removal of wastes from the IWCS.

This information will be used to support the development and evaluation of remedial alternatives in the IWCS FS. The presence of the K-65 residues at both Fernald and the IWCS provides an opportunity to identify numerous aspects of the Fernald Site remediation that may be applicable to future IWCS remedial activities including; the retrieval, treatment, shipping, and disposal of the K-65 residues and other wastes; radiological control program; and stakeholder and workforce involvement. Lessons learned associated with these activities will provide valuable insight into future remedial activities at the IWCS.

The identification and evaluation of current or foreseeable potential future waste disposal options for the IWCS remediation includes: the identification of viable waste disposal facilities; a summary of applicable waste forms, packaging, and transportation criteria; and the development of rough order of magnitude waste disposal volumes and associated costs. The identification of viable waste disposal facilities and the development of potential waste disposal volumes and costs is based on current facility licenses, permits, and regulations, and available IWCS waste information and current unit rate cost data.

ES.2 Fernald Closure Project

This TM provides background details and discusses remediation decisions and actions during the Fernald Closure Project (FCP) that have relevancy to the IWCS FS process. The primary focus is on the radium-bearing K-65 residues already addressed at the Fernald Site and to be addressed at NFSS. The history and types of radioactive wastes found at the Fernald Site are identified, the remediation decisions for the Fernald Site K-65 Silos 1 and 2 Remediation Project are discussed and the significant lessons learned from various remediation activities are presented.

A comparative review of the Fernald Site K-65 Silos 1 and 2 Remediation Project and known conditions at the IWCS FS indicates there are similarities with respect to the radiological and chemical characteristics of the K-65 residues. Significant differences exist, however, with respect to the way the K-65 residues were/are stored at each site.

Lessons learned from the Fernald Silos 1 and 2 Remediation Project are intended to provide value to NFSS; however, there may be some limitations with respect to the means and methods used to retrieve the waste material from interim storage. The Fernald Site K-65 Silos 1 and 2 Remediation Project, for example, developed and operated a slurry transfer system known as the Silo Waste Retrieval System (SWRS) which may or may not have application at the IWCS.

Although this TM does not identify or develop specific remedial alternatives for the IWCS, many of the key project components utilized at Fernald either will, or are likely to, have application during IWCS remediation. Specific remedial process technical components likely to be applied at the IWCS are:

- Radon control;
- Waste retrieval;

- Waste treatment; and
- Waste packaging, shipment, and disposal.

While the specific configuration and design details for these process components will be developed during the IWCS FS, lessons learned associated with these processes as they were employed at Fernald are applicable to their potential future use at the IWCS.

In addition to these key technical process components, the Fernald Site K-65 Silos 1 and 2 Remediation Project also provides an opportunity to consider lessons learned with other aspects of the project including stakeholder involvement, public participation, and workforce safety and health.

ES. 3 Interim Waste Containment Structure (IWCS) Waste Disposal Options

This TM also provides a waste disposal options study to evaluate the viability of various waste disposal facilities with respect to their ability to receive the K-65 residues and other waste streams associated with the IWCS. The waste materials stored within the IWCS materials are subdivided into five major subcategories:

- K-65 Residues;
- Other IWCS Residues/Wastes;
- Tower Soil;
- Contaminated Rubble/Waste;
- R-10 Residues and Soil; and
- Contaminated Soil.

Currently, only the residue waste materials placed into the IWCS are classified as byproduct material for the purpose of disposal per Section 11e.(2) of the Atomic Energy Act of 1954 as amended. This classification limits the number of potential disposal facilities that may accept this waste based on current facility licenses and permits. Additional disposal facilities licensed or permitted to accept other types of radioactive waste were considered in this study to address potential future changes to current regulations and disposal facility licenses and permits.

The consideration of the IWCS waste streams in these five categories supports the comparison of the known waste characteristics to the waste acceptance criteria (WAC) for each viable potential future waste disposal facility. The results of this comparison include the identification of the following viable waste disposal facilities:

- EnergySolutions (Utah);
- U.S. Ecology (Idaho);
- Waste Control Specialists (WCS) (Texas);
- Wayne Disposal, Inc. (WDI) (Michigan); and
- Nevada National Security Site (NNSS) (Nevada).

The WAC considered in this study included radionuclide-specific concentration limits, physical waste forms (i.e. solid, liquid, etc.), waste shipping container types, and transportation modes.

The summary of waste disposal options is presented in Appendix E.

In addition to the identification of viable potential future waste disposal facilities, this study also included the development of rough order of magnitude disposal waste volume and cost estimates. These estimates were developed to increase the current understanding of the volume of IWCS wastes to be removed, estimated waste volumes assuming mixing to meet disposal and shipping requirements, and current WAC requirements for the selected disposal facilities. Transport and packaging options were further assessed to determine a range of unit costs for differing modes of transport and the most suitable packaging types for transporting the wastes to the disposal facilities in question.

The estimated waste disposal volumes and costs should be considered preliminary due to uncertainties in the assumptions used to develop the estimates; it is likely that these assumptions will be modified during the development and evaluation of remedial alternatives in the IWCS FS.

ES.4 Conclusions

The information presented in this TM will be used to support the development and evaluation of remedial alternatives in the IWCS FS. The presence of the K-65 residues at both Fernald and the IWCS provides an opportunity to identify numerous aspects of the Fernald Site remediation that may be applicable to potential IWCS remedial activities including; the retrieval, treatment, shipping, and disposal of the K-65 residues and other wastes; radiological control program; and stakeholder and workforce involvement. Lessons learned associated with these activities will provide valuable insight into potential remedial activities at the IWCS.

Lessons learned from the Fernald Site K-65 Silos 1 and 2 Remediation Project are presented in tables at the end of Sections 2 through 6 and are compiled in Table 7-1 in this TM. The lessons learned include notes that describe the potential application to remediation of the IWCS.

1. INTRODUCTION

This Technical Memorandum (TM) presents a summary of the Fernald Site K-65 Silos 1 and 2 Remediation Project with associated lessons learned and a waste disposal options study for the waste materials currently stored in the Interim Waste Containment Structure (IWCS) at the Niagara Falls Storage Site (NFSS). The primary purpose of this TM is to aid in the development of remedial alternatives in the IWCS Feasibility Study (FS) that involve removal of all or a portion of the IWCS contents during remediation. The purpose of the FS is to develop and assess remedial alternatives to mitigate sources of potential risk to human health and the environment due to the presence of radioactive waste and contaminated materials contained within the IWCS. Providing information regarding potential disposal options for the IWCS residues and other wastes will allow consideration, early in the FS process, of the potential options for remedial actions and the potentially applicable lessons learned from the Fernald Project.

The NFSS located at 1397 Pletcher Road in Lewiston, New York, is a 77.3 hectare (ha) (191-acre) Federal property containing a 4.0 ha (10-acre) IWCS. The NFSS is part of the former Lake Ontario Ordnance Works that was used by the War Department beginning in 1942 for the production of trinitrotoluene. The Manhattan Engineer District and the Atomic Energy Commission (AEC) brought various radioactive wastes and uranium processing byproducts to the site for storage during the 1940s and 1950s. Today these residues, including the K-65 residues which contain high radium content, are stored in the IWCS.

The AEC initiated the Formerly Utilized Sites Remedial Action Program (FUSRAP) in 1974. Under the Department of Energy Organization Act of 1977, the United States Department of Energy (USDOE) was created; included was assuming responsibility for the NFSS (Clayton and Widdop 2006). The IWCS was engineered to inhibit radon emissions and reduce infiltration of precipitation leading to migration of contamination to groundwater. The most significant radioactive wastes stored within the IWCS are the K-65 residues containing high concentrations of radium-226 (Ra-226). These radioactive residues and other contaminated materials were placed into the IWCS in the reinforced concrete basement of Building 411, which was constructed in 1942 to securely store water as part of the freshwater treatment plant of the Lake Ontario Ordnance Works. In 1997, Congress transferred management of FUSRAP to the United States Army Corps of Engineers (USACE) and the USACE Buffalo District became responsible for the NFSS.

Waste of the same class of byproduct materials also was stored at the USDOE Fernald Site located northwest of Cincinnati, Ohio. This facility, which has already undergone cleanup and successful closure under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), contained two silos (Silos 1 and 2) used for the storage of K-65 residues and one silo (Silo 3) used to store uranium metal oxides. These wastes were produced during processing of the same Belgian Congo uranium ores from which the NFSS K-65 residues originated. The removal and disposal of the K-65 residues at the Fernald Site was completed in 2006.

1.1 Objectives

The objectives of this TM include:

- Identify similarities between the remediation of the Fernald K-65 residues and the future remediation of the IWCS K-65 residues and other associated waste;
- Identify lessons learned associated with the remediation of the Fernald K-65 residues that may apply to the future remediation of the IWCS K-65 residues and other associated waste;
- Identify current or foreseeable potential future disposal options for the IWCS waste streams anticipated to be generated during remediation; and
- Provide a preliminary estimate of waste volumes and disposal costs for the expected waste streams from removal of wastes from the IWCS.

The presence of the K-65 residues at both Fernald and the IWCS provides an opportunity to identify numerous aspects of the Fernald Site remediation that may be applicable to potential IWCS remedial activities. These topics include; the retrieval, treatment, shipping, and disposal of the K-65 residues and other wastes; the site radiological control program; and stakeholder and workforce involvement. Lessons learned associated with the Fernald Site activities as identified in this document should be applied to the potential remedial activities for the IWCS.

The identification and evaluation of current or foreseeable potential future waste disposal options for the IWCS remediation includes: the identification of viable waste disposal facilities; a summary of applicable waste forms, packaging, and transportation criteria; and the development of rough order of magnitude waste disposal volumes and associated costs. The identification of viable waste disposal facilities and the development of potential waste disposal volumes and costs is based on current facility licenses, permits, and regulations, and available IWCS waste information and current unit rate cost data.

During the IWCS FS, the USACE Buffalo District will be evaluating long-term remedies, to address potential long-term risks associated with the IWCS waste streams, ranging from complete or partial removal of IWCS contents, shipment to an approved off-site disposal facility or constructing a new on-site disposal cell, leave in place alternatives, and the no action alternative required under CERCLA.

USACE released the Waste Disposal Options and Fernald Lessons Learned Fact Sheet to inform the public of the scope and objectives for this technical memorandum. The public comments received were evaluated during development of this technical memorandum and will be further addressed during the development of the IWCS FS document. The fact sheet and the public comment/response summary have been included in Appendix A. USACE will determine whether public comments received on this TM will be addressed in a revision to this TM or included in the IWCS FS. This decision will be based on the extent and content of the public comments.

1.2 Scope and Organization

This TM is presented in seven sections. The order and content of these sections are discussed below.

Section 1. This section presents the introduction to the TM, the objectives and project scope, and TM organization.

Sections 2 through 5. These sections include a description of the Fernald Site K-65 Silos 1 and 2 Remediation Project, including major design elements; waste recovery; material handling, processing, packaging, and shipment; the radiological safety program; programmatic activities including stakeholder and worker involvement, and project procurement. These discussions provide the outline of the program and actual systems fielded successfully at Fernald. Each provides a starting point for development of potential remedial activities at IWCS, as well as lessons learned to improve the IWCS FS process. Although not all aspects of the Fernald Site Silos 1 and 2 Remediation Program apply directly to the IWCS, some of the information may provide insight into a technical or programmatic approach that would benefit the potential remedial activities at the IWCS. If additional details regarding the Fernald Site K-65 Silos 1 and 2 Remediation Project are needed to support specific technical tasks for the IWCS they will be obtained during the development of the IWCS FS.

At the end of Sections 2 through 5, a set of lessons learned for the Fernald Site Silos 1 and 2 are presented. These lessons learned were prepared for this TM and are intended to apply to the potential remediation actions of the NFSS IWCS. A note at the end of each lesson learned describes the potential application to the IWCS. The topics of the lessons learned include:

- Radon abatement;
- Material removal;
- Material handling and transfer;
- Packaging and transport;
- Waste disposal;
- Radiological personnel exposures and associated controls;
- Programmatic actions including stakeholder and worker involvement, health and safety, and procurement; and
- Radiological exposures to the public and environment.

Section 6. This section provides an analysis of the potential future disposal options for wastes that may be generated by remediation of the IWCS. The information presented is intended to provide the public an opportunity to become familiar with the various aspects of the IWCS waste streams and includes the following topics:

- An inventory, based on available documented information, of the various IWCS waste streams (e.g., K-65 residues, other residues, and other contaminated soil) by volume, activity, and generation.

- Identification, for each IWCS waste stream, of the potential waste disposal facilities, waste acceptance criteria (WAC) and licensing requirements, or other factors for each viable waste facility that, based on current information, may accept NFSS wastes.
- Identification of potential transportation modes and associated unit cost rates available for shipment of waste to the viable disposal facilities.
- An estimate of overall disposal costs associated with various waste types for each waste facility. This estimate is subject to considerable change as additional information is consolidated and analyzed in the IWCS FS. Cost information for waste packaging, transportation, and disposal are based on current 2011 pricing that will vary during the intervening years from preparation of this TM to actual project execution.

In addition, lessons learned from the waste disposal analysis are presented at the end of this section. These lessons learned were prepared for this TM and are intended to apply to the potential remediation actions of the NFSS IWCS. A note at the end of each lesson learned describes the potential application to the IWCS. The topics of the lessons learned include: packaging and transport; and waste disposal.

Section 7. This section provides a summary of the analyses conducted in the TM and a consolidated table of the lessons learned presented in the previous sections. Also, conclusions that can be drawn from the lessons learned in the TM are summarized to form the basis for identifying topics or issues needing further investigation or assessment in support of the IWCS FS.

Section 8. References for the TM are provided in this section.

2. FERNALD CLOSURE PROJECT

The purpose of this section is to provide background details and discuss remediation decisions and actions during the Fernald Closure Project (FCP) that have relevancy to the IWCS FS process. The primary focus of the information presented in this section is on the radium-bearing K-65 residues addressed at both Fernald and NFSS. This section presents the history and types of radioactive wastes found at the Fernald Site, the remediation decisions for the Fernald wastes and the significant lessons learned from various remediation activities such as material handling, radon control, and disposal.

2.1 Fernald Site Background and Operable Units

Table 2-1 presents an abbreviated timeline for the Fernald Site starting with construction in 1951 and concluding with the dedication of the Fernald Preserve Visitor Center in 2008.

For purposes of investigation and study, the Fernald Site was divided into five operable units (OUs). Four of the OUs (1 through 4) were considered "source" OUs as they represented the sources of contamination that affected the site's environmental media. The fifth OU (5) was considered the "environmental media" OU, as it represented the environmental media affected by past production operations and waste disposal practices, as well as the pathways of contaminant migration at the site. The OUs established at the Fernald Site include:

- **OU 1 Waste Pit Area:** Waste Pits 1 through 6, settling basin/clearwell, burn pit, berms, liners and soil within the OU boundary.
- **OU 2 Other Waste Units:** Fly ash piles, other south field disposal areas, lime sludge ponds, solid waste landfill, berms, liners, and soil within the OU boundary.
- **OU 3 Former Production Area:** Former production and production-associated facilities and equipment (including all above and below-grade improvements), including, but not limited to: all structures, equipment, utilities, drums, tanks, solid waste, waste, residual production materials, thorium, effluent lines, a portion of the K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and a coal pile. All affected soil beneath the facilities was excluded (the soil was included in OU 5).
- **OU 4 Silos 1 through 4:** Contents of Silos 1, 2 and 3, (Silo 4 remained empty) the silos structures, berms, decant sump tank system, and soil within the OU boundary.
- **OU 5 Environmental Media:** Groundwater, surface water, soil not included in the definitions of OUs 1 through 4, sediment, flora, and fauna. Included affected soil beneath the OU 3 facilities.

Table 2-1. Fernald Site History Timeline

Year	Activity
1951	Construction of the Feed Materials Production Center began.
1952	Uranium production started.
1986	United States Environmental Protection Agency (EPA) and USDOE signed the Federal Facilities Compliance Agreement, thus initiating the RI/FS process.
1989	Uranium production was suspended. The Fernald Site was placed on the NPL.
1990	As part of the Amended Consent Agreement, the site was divided into OUs for characterization and remedy determination.
1991	Uranium production formally ended. The site mission changed from uranium production to environmental remediation and site restoration.
1994	Decontamination and dismantling of the first building was completed under the OU 3 Interim ROD.
1996	The last OU ROD was signed, signifying the end of the 10-year RI/FS process. (The OU 4 ROD was later re-opened.) Construction began in support of the OU 1 selected remedy. Soil remedial excavation began as part of the OU 5 selected remedy.
1997	Construction of Cell 1 of the on-site disposal facility took place, and the first waste placement began in December. Environmental monitoring and reporting were consolidated under the Integrated Environmental Monitoring Plan to align with remediation efforts.
1998	OU 2 remedial excavation began.
1999	Excavation of the waste pits was initiated under the OU 1 ROD, and the first rail shipment of waste material was transported to Envirocare in Utah, Inc.
2000	The ROD Amendment for OU 4 Silos 1 and 2 Remedial Actions was signed by EPA, thus establishing a new selected remedy for OU 4.
2001	Cell 1 of the on-site disposal facility was capped. Remediation of the Southern Waste Units was completed.
2002	The Silos 1 and 2 Remediation Project Radon Control System began operation and successfully reduced radon levels within the silos. The off-site transfer of nuclear product material was completed. Wastes were placed into Cells 2-5 of the on-site disposal facility.
2003	All major OU 2 remedial actions were completed. In addition, approximately 315,015 m^3 (412,000 yd^3) of waste were placed in Cells 3-6 of the on-site disposal facility.
2004	Removal of Silos 1 and 2 wastes from the silos and transfer to the holding tank facility was initiated. Plans to reduce the size of the site's wastewater treatment infrastructure were approved and implemented. The last of Fernald's ten uranium production complexes, plus an additional 35 structures and 73 trailers, were demolished. Also, all eight cells of the on-site disposal facility were capped or received waste, and approximately 392,240 m^3 (513,000 yd^3) were placed in Cells 4 through 8.
2005	Removal of Silo 3 waste was initiated, and the first shipment of waste arrived at Envirocare in Utah. Remedial actions for OU 1 were completed in June. The first shipment of Silos 1 and 2 wastes arrived at Waste Control Specialists in Texas.
2006	The last waste placement into the on-site disposal facility occurred September 7, 2006, and the cap systems for cells 7 and 8 were completed in October 2006. Remediation of the Fernald Site was completed on October 29, 2006, and the site was officially transferred into USDOE's Office of Legacy Management on November 17, 2006.
2008	The old silos Warehouse was remodeled into the new Fernald Preserve Visitors Center and opened to the public in August 2008. In addition, the community was allowed unescorted access to the Fernald Preserve.

Source: Fernald Preserve 2006 and 2009 Site Environmental Reports (USDOE 2007 and USDOE 2010b)

2.1.1 Operational and Contractual History

The Fernald Site was a 425-ha (1,050-acre) government-owned, contractor-operated facility located in southwestern Ohio approximately 29 km (18 miles) northwest of downtown Cincinnati. In comparison to NFSS, Fernald is a much larger site; approximately five times larger than NFSS. The AEC, predecessor to the United States Energy Research and Development Administration and then the USDOE, established the Feed Materials Production Center in conformance with AEC orders in the early 1950s. From 1951 through 1985, the National Lead Company of Ohio, Inc. was the Management and Operations Contractor for the facility. Westinghouse Environmental Management Company of Ohio assumed the management and operations responsibilities for the site operations and facilities from January 1986 through December 1992. Uranium metal production operations at the facility were suspended in 1989, with the focus of the management and operations work shifting to the environmental remediation and restoration of the site. In 1991, USDOE renamed the site the Fernald Environmental Management Project (FEMP) to reflect the revised mission of the site. In December 1992, Fluor Fernald assumed responsibility for the site as the Environmental Restoration Management Contractor for USDOE and remained in this role through the completion of the site remediation and restoration efforts in late 2006. The FEMP was renamed the FCP in January 2003.

The primary mission of the Feed Materials Production Center during its 37 years of production operations was the processing of feed materials to produce high purity uranium metal. These high purity uranium metals were then shipped to other USDOE or Department of Defense facilities for use in the Nation’s weapons program. Manufacture of the uranium metal products generally occurred in seven of the more than 50 production, storage and support buildings that comprised what was known as the production area. Nearly 227 million kilograms (kg) (500 million pounds [lbs]) of uranium metal products were produced. The site also served as the Nation’s key Federal repository for thorium-related nuclear products and it also recycled uranium used in the reactors at the Hanford site in Washington State.

In accomplishing the site mission, liquid and solid radioactive wastes were generated by the various operations between 1952 and 1989. Before 1984, solid and slurried wastes from production processes were deposited in the on-property waste storage area. This area, located west of the former production area, included: six low-level radioactive waste (LLRW) storage pits; two earthen-bermed concrete silos (Silos 1 and 2) containing K-65 residues; one concrete silo containing uranium metal oxides (Silo 3); one unused concrete silo (Silo 4); two lime sludge ponds; a burn pit; a settling basin/clearwell; and a solid waste landfill. After 1984, wastes produced from operations were containerized for shipment to off-site disposal facilities. As a result of Feed Materials Production Center operations, contaminants from material processing and related activities were released into the environment through air emissions, wastewater discharges, storm water runoff, leaks, and spills.

2.1.2 Site Regulatory Designation

Congress passed CERCLA (Public Law 96-510) in 1980, commonly known as Superfund. The Superfund Amendments and Reauthorization Act (Public Law 99-499), which amended CERCLA in 1986, added certain specific provisions applicable to the cleanup of contaminated sites at Federal facilities. The primary goal of CERCLA is to encourage the identification and remediation of sites contaminated with hazardous substances. Even before the passage of the Superfund Amendments and Reauthorization Act, Federal agencies were required to identify sites where hazardous waste was treated, stored, or disposed of at any time. Section 120(c) of CERCLA requires the United States Environmental Protection Agency (EPA) to compile information about contaminated sites at Federal facilities and to enter the information into the Federal Agency Hazardous Waste Compliance Docket (the docket). The docket must also include information about Federal facilities where hazardous wastes are generated and managed under Sections 3005 and 3010 of the Resource Conservation and Recovery Act (RCRA), even if these facilities are not contaminated. The National Priorities List (NPL) is a list of top-priority hazardous waste sites that are eligible for extensive, long-term cleanup under CERCLA.

The following sections describe the regulatory designations for the Fernald Site and NFSS and note key differences for each site.

2.1.2.1 Fernald

As early as 1981, the State of Ohio found radioactive contamination in the Buried Valley Aquifer south of the Fernald Site. In December 1981, this contamination was identified as uranium by National Lead of Ohio (the operator of the plant) and confirmed by the United States Geological Survey in August 1982, eventually resulting in the closure of a private well down-gradient from the site. In 1985, elevated concentrations of uranium, technetium-99, and hexavalent chromium were detected in an effluent line discharging to the Great Miami River (ATSDR 2004). On July 18, 1986, a Federal Facility Compliance Agreement detailing actions to be taken by USDOE to assess environmental impacts associated with the FEMP was signed by USDOE and EPA. The Federal Facility Compliance Agreement was entered into pursuant to Executive Order 12088 (43 CFR 47707). The purpose of the Federal Facility Compliance Agreement was to ensure compliance with existing environmental statutes and implementing regulations. As required by the Federal Facility Compliance Agreement, a Remedial Investigation (RI)/FS was initiated in July 1986, pursuant to 42 U.S.C. 9601 et seq, CERCLA (USDOE 1994a). The RI identified widespread contamination of surface soil, sediment, and groundwater both on and adjacent to the facility as a legacy of the 38-year production mission. The RI identified over 90 contaminants of concern in the various environmental media and uranium as the predominant contaminant. In accordance with the requirements of CERCLA, the FEMP was placed on the NPL in November 1989 as a result of environmental impacts caused by facility operations (USDOE 1994a). The USDOE was the lead agency for remediation of the FEMP pursuant to the Consent Agreement as Amended under CERCLA Sections 120 and 106(a). Because Fernald was on the NPL, the EPA was the designated lead agency for deciding the appropriate remedial action, even though USDOE was responsible for the site. The Ohio Environmental Protection Agency (Ohio EPA) Office of Federal Facilities Oversight oversaw cleanup activities at the Fernald Site.

2.1.2.2 Niagara Falls Storage Site

Unlike Fernald, the NFSS is not listed on the NPL. Sites are eligible to be placed on the NPL if they receive a Hazard Ranking System (HRS) score of 28.5 or above. The decision to list may be affected by on-site conditions such as ongoing RCRA corrective actions. According to the NFSS Environmental Report for 1992 (BNI 1993), a site inspection report was submitted by USDOE to the EPA on July 1, 1992 which included the HRS scores for the NFSS. Two potential sources, the Waste Containment Structure (now the IWCS) and Building 401 were evaluated for the HRS scoring. The HRS score for the Waste Containment Structure was zero. The HRS score for the area near Building 401 was 0.533 based on the presence of low levels of volatile organic compounds. Additionally, a preliminary assessment of the NFSS conducted in 1990 and submitted to EPA concluded that: "*Given that extensive remedial action has been conducted at the site and access is controlled, the site poses little threat to the environment and the public*." (BNI 1990) By the time the NFSS site inspection and HRS evaluation of the site were concluded in 1992, the IWCS was already constructed and remedial cleanup at the site had been performed by USDOE (circa 1980s). In contrast, K-65 wastes were still stored in silos at the Fernald Site when Fernald was placed on the NPL.

The environmental investigation and potential remediation activities at NFSS are conducted under FUSRAP. The Energy and Water Development Appropriations Act for Fiscal Year 2000, Public Law 106-60, requires that USACE comply with CERCLA in conducting FUSRAP cleanup work. Because NFSS is part of FUSRAP, USACE is the lead agency for determining the long-term remedy for the site.

2.1.3 Applicable or Relevant and Appropriate Requirements

The CERCLA RI/FS process at the Fernald Site included the identification of potential Applicable or Relevant and Appropriate Requirements (ARAR) to be addressed during the evaluation of various remedial alternatives. Per CERCLA, the final ARARs are not established until the Record of Decision (ROD) is issued. The final Fernald ARARs that should be taken into consideration for the NFSS are those associated with the K-65 residues in Silos 1 and 2 of OU 4 and ARARs for the Balance of Plant (OU 5).

Just prior to the Fernald FS being completed, the EPA as the lead agency, identified 40 Code of Federal Regulations (CFR) Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes" as an ARAR that Fernald should address. The EPA and USDOE agreed that the K-65 residues did not meet the requirements of applicability of 40 CFR Part 191 since the K-65 residues are not spent nuclear fuel, high-level radioactive waste, or transuranic waste (USDOE 1990). EPA imposed 40 CFR Part 191 as an ARAR because they deemed it relevant and appropriate for the Fernald project as it was designed to regulate radioactive materials comparable to the K-65 residues in the degree of human hazard. This determination affected any remedial alternatives involving potential on-site disposal of the K-65 residues at Fernald. The USDOE conducted a detailed assessment of the impact of 40 CFR 191 on the remediation of the K-65 residues in the silos in OU 4. This assessment is included in Appendix B. The assessment also provides the rationale for dividing OU 4 into subunits in order to restrict application of the ARAR to K-65 residues only. A similar approach might be useful for dividing the NFSS IWCS waste streams, but the formal ARAR analysis has yet to be conducted and therefore no conclusion on the NFSS ARARs has been made.

Specific ARARs to support the development of soil remediation levels based on a specific historical site activity were not identified due to the variety of historical operations conducted at the Fernald Site. The operations included those involving the storage of the K-65 residues, uranium production operations, and other activities associated with uranium, radium, and thorium, which generally are not consistent with historical operations at NFSS.

The final remediation goals developed for soil in OU 5 also applied to soil within the OU 4 boundary (Section 2.1.5.3). The soil remediation goals developed for OU 5 (and OU 4 where applicable) were designed to attain the following post-remediation risk levels:

- Off-property farmer
  - Carcinogenic risk of 10^{-5}
  - Non-carcinogenic Hazard Index of 1
- Recreational user of FEMP property
  - Carcinogenic risk of 10^{-6}
  - Non-carcinogenic Hazard Index of 1
- Trespasser in the On-Site Disposal Facility (OSDF) area
  - Carcinogenic risk of 10^{-6}
  - Non-carcinogenic Hazard Index of 1

2.1.4 Fernald Site-Wide Operable Units, Cleanup Strategy, and End State

From 1994 to 1996, USDOE and EPA signed the final ROD for each OU, in cooperation with the Ohio EPA and the Fernald Citizen's Advisory Board, which set in motion the major cleanup requirements and approaches that collectively defined the FEMP/FCP cleanup. The RODs employed a combination of off-site and on-site disposal, under which approximately 77 percent of the remedial waste volume (the site's lower concentration, higher volume materials) was to be disposed in the OSDF while approximately 23 percent of the volume (the site's higher concentration, lower volume materials) was to be sent off-site for disposal, primarily at permitted facilities in Utah, Nevada, and Texas.

At the time the RI/FS activities were completed (from 1994 to 1996 for various OUs) and the RODs approved, 14 million kg (31 million lbs) of uranium products, 1.1 billion kg (2.5 billion lbs) of waste, 255 buildings and structures, and 2.1 million cubic meters (m^3) (2.75 million cubic yards [yd^3]) of contaminated soil and debris were identified as requiring action. In addition, a 90-ha (223-acre) portion of the Great Miami Aquifer was found to be contaminated at levels above radiological drinking water standards and also required remedial action. Unlike the low quality/yield water bearing zone at NFSS, the Great Miami Aquifer is the principal drinking water supply for the region (Yeracre, et. al. 1993). It is regulated as a sole source aquifer under the Safe Drinking Water Act and was to be restored to drinking water standards. Additionally, long-term stewardship actions and requisite institutional controls were established consistent with the target land use.

At completion, approximately 395 ha (975 acres) of the 425-ha (1,050-acre) property were restored for use as an undeveloped park (the target land use selected in the OU 5 ROD) including all of the land from the other four OUs. The remaining 30 ha (75 acres) were dedicated to the footprint of the OSDF, and placed in long-term stewardship by USDOE.

The following sections provide a detailed description of the remedial action history for OU 4. The presence of the K-65 residues in Silos 1 and 2 represent the most important similarity between Fernald and NFSS remedial projects. Remedial actions at the remaining Fernald OUs are included only when applicable to the OU 4 discussion.

2.1.5 Operable Unit 4 Remedial Action

The OU 4 remedial action (also referred to as the Fernald Site K-65 Silos 1 and 2 Remediation Project) addressed the remediation of the K-65 residues at the Fernald Site. The original ROD for OU 4 was published on December 7, 1994 (USDOE 1994a). Primary components of the original OU 4 ROD included on-site vitrification of the K-65 residues and the off-site disposal of the treated waste at the Nevada National Security Site (NNSS) (formerly known as Nevada Test Site). The preferred remedy prescribed in the original OU 4 ROD applied to the K-65 residues in Silos 1 and 2 and the cold metal oxides in Silo 3. In addition, criteria were established under the OU 5 ROD for the cleanup of all site soils including soils associated with the OU 4 (USDOE 1996a).

The K-65 residues in Silos 1 and 2 and the cold metal oxides in Silo 3 were classified as 11e.(2) byproduct material as defined under the Atomic Energy Act of 1954 and were excluded from regulation as solid or hazardous waste under the RCRA 40 CFR Part 261.4(a)(4) (USDOE 1994a).

2.1.5.1 Initial Selection of NNSS for Waste Disposal

The initial selection of the NNSS in Nye County, Nevada as the disposal facility during the OU 4 FS was based on two factors: USDOE Order 5820.2A and limitations associated with Envirocare of Utah WAC. Chapter III of USDOE Order 5820.2A provided that LLRW should go to a USDOE LLRW disposal site, such as the NNSS. This policy ensured that LLRW would be handled properly in accordance with applicable standards and USDOE guidelines. Approval from the appropriate USDOE field office was required to enable management of the 11e.(2) byproduct material for disposal at NNSS (USDOE 1994b).

Preliminary evaluation of the OU 4 wastes indicated they either met, or with treatment would meet, the NNSS WAC. However, because NNSS was a LLRW facility, and the silo residues were 11e.(2) byproduct material, additional approval by NNSS was required (USDOE 1994b). The NNSS established WAC considered disposal site characteristics consistent with an appropriate level of protectiveness to human health and the environment (USDOE 1994b). The evaluation determined the vitrified OU 4 waste would meet NNSS WAC and therefore would be managed within the bounds of the NNSS facility's protectiveness criteria (USDOE 1994b).

The OU 4 FS (USDOE 1994b) noted that licensing restrictions embodied in the WAC for Envirocare limited the ability of the facility to receive wastes above certain radionuclide specific activity concentrations. Specifically, the Envirocare WAC prohibited the receipt of waste exceeding 2,000 picocuries per gram (pCi/g) (Ra-226) and 15,000 pCi/g (thorium-230 [Th-230]). The mean activity concentration of Ra-226 and Th-230 in Silos 1 and 2 waste exceeded the WAC levels due to concentrations of 310,400 pCi/g (Ra-226) and 55,300 pCi/g (Th-230). Similarly, the mean activity concentration of Ra-226 and Th-230 in Silo 3 residues also exceeded the WAC levels at 2,900 pCi/g (Ra-226) and 51,200 pCi/g (Th-230). The process option of off-site disposal at Envirocare was therefore eliminated in the OU 4 FS.

2.1.5.2 Selection of Vitrification for Waste Treatment

As part of the OU 4 FS, a remedy selection treatability study was conducted with OU 4 materials to compare vitrification and cement stabilization (USDOE 1994b). The key criteria for the comparison of both technologies included: the leachability of the treated waste form; the waste volume reduction achieved; and the reduction in radon emanation. Cement stabilization reduced the mobility of contaminants by binding them into a cement mixture. As a result of the additives used in the process, the study revealed that radon emanation rates from the treated K-65 material exceeded 200 picocuries per square meter per second (pCi/m^2/s) and therefore did not pass the 20 pCi/m^2/s criteria established for USDOE in 40 CFR 61. Although the cementation process was effective in reducing radon emanation by an average of 78 to 87 percent, significant levels of radon continued to be emitted after treatment. The amount of volume increase caused by the addition of cement material averaged 169 percent. Results from Toxicity Characteristic Leaching Procedure (TCLP) testing of the treated material showed that cement stabilized material did not exceed RCRA regulatory levels for TCLP metals (USDOE 1994b).

The vitrification treatment process heats the waste materials to such temperatures that the materials fuse to a glass-like state, which in turn binds radioactive and non-radioactive metals within the vitrified waste in a low leachability condition. The TCLP testing results for the vitrified wastes demonstrated the effectiveness of glass as a durable leach-resistant waste form for OU 4 wastes. Studies completed on a bench scale as part of the RI/FS projected that the volume of material requiring disposal could be reduced by over 50 percent as a result of applying the vitrification process (USDOE 1994b). The radon emanation rate from the vitrified K-65 material ranged from 0.01 to 0.06 pCi/m^2/s, more than two orders of magnitude less than the 20 pCi/m^2/s limit.

As a result of the treatability studies comparing cement stabilization and vitrification, the vitrification process was selected to treat the K-65 residues using stabilization technologies to the extent necessary to meet NNSS WAC (USDOE 1994b).

2.1.5.3 Summary of Original Operable Unit 4 Record of Decision

At the time the original OU 4 ROD was approved in 1994, the NNSS was the only available disposal facility that could accept the vitrified K-65 waste materials for permanent disposal. The NNSS WAC required that all treated or untreated waste accepted for disposal at the facility meet TCLP limits for toxicity characteristic constituents otherwise regulated under RCRA (regardless of the RCRA statutory exempt or non-exempt status of the waste). Based on this disposal facility-specific requirement, the original OU 4 ROD adopted the TCLP limits as “relevant and appropriate” regulatory performance requirements for waste treatment (versus a broader adoption as “applicable requirements,” since the materials continued to retain their statutorily exempt legal status). The NNSS TCLP limits became the relevant and appropriate quantitative performance standard in the original OU 4 ROD for treating the waste from Silos 1, 2, and 3 to meet the existing NNSS WAC (USDOE 1994a and USDOE 2005b).

The selected remedy for OU 4 specified on-property disposal for OU 4 contaminated soil and debris associated with the removal of the silos and earthen berms; however, the soil and debris would be managed consistent with the disposal remedy put forth in the OU 3 and OU 5 RODs. The volume of soil, rubble, and debris to be generated under OU 4 were relatively small in comparison to the volume of similar materials to be generated by remedial activities at other Fernald OUs. All of the OU 4 alternatives evaluated through the FS detailed analysis considered integration of disposal activities with OU 3 and OU 5 in the final remedy chosen for OU 4 (USDOE 1994a).

The key components of the selected remedy as defined in the original OU 4 ROD included:

- Removal of the materials of Silos 1 and 2 (K-65 residues), Silo 3, (uranium metal oxides) and the decant sump tank sludge (material from the silos subsurface drain system);
- Treatment of the Silos 1, 2 and 3, and decant sump tank materials by encapsulation of waste by vitrification to meet disposal facility WAC;
- Off-site shipment of the vitrified wastes for disposal at the NNSS;
- Demolition of Silos 1, 2, 3, and 4 and decontamination, to the extent practicable, of the concrete rubble, piping and other generated construction debris;
- Removal of the earthen berms around the Silos 1 and 2 and excavation of the contaminated soil within the boundary of OU 4, to achieve remediation levels; placement of clean backfill to original grade following excavation;
- Demolition of all remediation and support facilities (e.g., waste processing facilities, old vitrification facility, radon control facility, etc.) within the OU 4 boundary after use; decontamination or recycling of debris prior to disposal;
- On-property interim storage of excavated contaminated soil and contaminated debris from within the OU 4 boundary, consistent with Removal Action No. 17 pending final disposal (Removal Action No. 17 was a site-wide removal action intended to mitigate adverse environmental impacts experienced from interim storage of contaminated soil and debris);
- Continuation of access controls and maintenance and monitoring of stored waste inventories;
- Implementation of institutional controls for the OU 4 area, including deed and land-use restrictions;
- Potential, additional treatment of stored OU 4 soil and debris using OU 5 and OU 3 waste treatment system;
- Pumping and treating, as required, of any contaminated perched groundwater encountered during remedial activities; and
- Disposal of the OU 4 contaminated debris and soil consistent with the RODs for OUs 3 and 5, respectively.

2.1.5.4 Operable Unit 4 Post-ROD Decision Changes

A total of five changes were made to the original OU 4 ROD during the remedial activities at the Fernald Site. These changes were made in accordance with CERCLA and included both Explanations of Significant Differences (ESD) and ROD Amendments. Pursuant to Section 117 of CERCLA and the National Oil and Hazardous Substance Pollution Contingency Plan [40 CFR 300.435(c)(2)(i)], an ESD document should be published when "*differences in the remedial or enforcement action, settlement, or consent decree significantly change but do not fundamentally alter the remedy selected in the ROD with respect to scope, performance, and cost.*" Pursuant to Section 117 of CERCLA and the National Oil and Hazardous Substance Pollution Contingency Plan [40 CFR Part 300.435(c)(2)(ii)], a ROD Amendment should be processed when "*differences in the remedial or enforcement action, settlement, or consent decree fundamentally alter the basic features of the selected remedy [in the original ROD] with respect to scope, performance, or cost*" (USDOE 2003b).

Following approval of the original OU 4 ROD in 1994, the remedial design for the selected remedy (retrieval, vitrification and off-site disposal of Silos 1, 2, 3, and decant sump materials) was initiated. As the initial step in the OU 4 remedial design process, a treatability study program was initiated in May 1996 to collect quantitative performance data to support full-scale application of the joule-heated vitrification technology used to treat the silos materials. During the treatability study program, many technical and operational difficulties were encountered. These technical and operational issues are discussed in detail in Section 1.1 of the Revised FS for the OU 4 (USDOE 2000b) and in the Vitrification Pilot Plant (VITPP) Melter Incident Final Report (FEMP 1997). These technical and operational difficulties are described in more detail below.

In December 1996, during the final stages of the last campaign to demonstrate lower temperature processing <1200 degrees Celsius (°C) (<2,200 degrees Fahrenheit [°F]) of the Silos 1 and 2 waste, non-radioactive surrogate material was used. The surrogate material contained lead and barium levels representative of the K-65 residues at the Fernald Site. During this testing, portions of the VITPP melter hardware failed - resulting in the suspension of further testing. The reason for the failure was attributed to the molybdenum disilicide bubbler tubes (used for agitation) located at the bottom of the melter chamber. The bubbler tubes quickly dissolved away once lead (via the surrogate material) was introduced into the molten glass by chemically reducing the molten glass to form metallic lead. A hole formed in the bottom of the melter refractory where the bubblers were located, which provided a pathway for the molten glass and precipitated lead to erode the understructure of the melter until containment was lost (USDOE 2000b). VITPP testing was suspended following the incident. Subsequent attempts to resolve these issues during VITPP operations resulted in documented schedule and cost increases (USDOE 2000a).

A Silos Remediation Project Independent Review Team was convened by USDOE to re-evaluate the selected remedy, with an internal evaluation of the December 1996 VITPP melter hardware failure performed in parallel. Based on the conclusions and recommendations from these two evaluations USDOE, EPA, and key stakeholders supported a decision that vitrification of the Silo 3 material (although possible) was not practical or necessary, due to the relatively low concentrations of hazardous and radiological constituents (as compared to the Silos 1 and 2 waste material) and the significant cost and schedule impacts (USDOE 2000b).

As a result, USDOE and EPA made the decision, with input from the public, that Silo 3 material would be treated separately from the Silos 1 and 2 materials. The conclusions and recommendations from the Silos Remediation Project Independent Review Team, with consensus from USDOE, EPA, and key stakeholders, also supported the decision that an alternate remedy, such as chemical stabilization, should be considered for treatment and disposal of the Silos 1 and 2 materials.

USDOE commissioned a "Proof of Principle" study to further evaluate alternate treatment options. Four vendors were contracted to perform testing on the materials, with two vendors conducting vitrification tests, and two vendors conducting chemical stabilization tests. Based on the results from this study, USDOE and EPA made the decision, with input from the public, that the remedy for the Silos 1 and 2 material should be changed from vitrification to chemical stabilization (USDOE 2000a). While vitrification was ultimately deemed to be not applicable at Fernald due to technical issues identified in the test program, advances in the technology have addressed those issues and vitrification may be appropriate for consideration at NFSS.

Per the decisions described above, remediation and disposal of the waste materials from Silos 1 and 2, and Silo 3 were conducted separately. The following sections summarize the post-ROD decision changes to the original OU 4 ROD.

2.1.5.4.1 Post-ROD Decision Changes – Silos 1 and 2

ROD Amendment for Operable Unit 4 Silos 1 and 2 Remedial Actions (June 2000). The ROD Amendment modified the treatment component of the Silos 1 and 2 remedy to on-site treatment by chemical stabilization. The modification of the treatment component was based on the conclusion that chemical stabilization satisfied threshold criteria specified by the National Oil and Hazardous Substance Pollution Contingency Plan and met the statutory requirements of CERCLA. In addition, chemical stabilization attained the Remedial Action Objectives identified in the OU 4 ROD and had an overall advantage over vitrification when evaluated against the five primary balancing criteria specified by the National Oil and Hazardous Substance Pollution Contingency Plan. Specifically, the advantages of chemical stabilization in implementability and short-term effectiveness (worker risk and time to achieve protection) were stronger than the advantages of the vitrification process' lower treated waste volume (USDOE 2000a).

For purposes of the selected remedy, chemical stabilization was defined as a non-thermal treatment process that mixed the Silos 1 and 2 materials (including the bentonite grout) with a variety of chemical additive formulations (e.g., lime, pozzolans, gypsum, portland cement, or silicates) to accomplish chemical and physical binding of the contaminants of concern. The chemical binding of the contaminants in the stabilized wasteform reduced their leaching rate sufficiently to meet the NNSS WAC. In addition, the stabilized wasteform, combined with sealed containerization, reduced radon emanation to meet regulatory standards. Particulates released as a result of the stabilization process were to be treated by an air emissions treatment system to satisfy all air-emission ARARs and To Be Considereds (USDOE 2000a).

Additionally, as part of the post-ROD decision, a plan was established to transfer the entire contents of Silos 1 and 2 and the Decant Sump Tank System to a newly constructed, environmentally controlled Transfer Tank Area (TTA). This allowed for storage of the material in a safer configuration than the Silos 1 and 2 structures while pending remediation by the selected treatment alternative. The plan included the construction of a radon control system (RCS) in conjunction with the TTA to control Radon-222 (Rn-222) emanation during the retrieval and storage of Silos 1 and 2 materials in the TTA. In addition, the RCS controlled Rn-222 emanation during retrieval, treatment, and storage of Silos 1 and 2 materials in the remediation facility (USDOE 2000a).

Explanations of Significant Differences for Operable Unit 4 Silos 1 and 2 Remedial Actions (October 2003). The ESD established the removal of the RCRA TCLP analyses and evaluation as a requirement for disposal at NNSS and other potential commercial facilities identified since the *Operable Unit 4 Silos 1 and 2 ROD Amendment* (USDOE 2000a). The NNSS WAC were updated in February 2002 to indicate materials that were not regulated under 40 CFR 261-268 or State of Nevada hazardous waste regulations [such as 11e.(2) byproduct materials] no longer needed to meet TCLP-based acceptance criteria, provided the waste was otherwise disposed in a manner protective of human health and the environment (USDOE 2003b).

The K-65 residues contained in Silos 1 and 2 were statutorily excluded from the definition of solid and hazardous waste under RCRA of 1976 per 40 CFR 261.4(a)(4) (USDOE 2003b) due to their status as 11e.(2) byproduct material. Although the Silos 1 and 2 wastes were excluded from TCLP under 40 CFR 261.4(a)(4), they did contain sufficient quantities of lead that could result in exceedances of regulatory TCLP limits. NNSS completed an eligibility review and determined the Silos 1 and 2 K-65 materials were exempt from Federal and State of Nevada hazardous waste regulations and therefore were acceptable for disposal at NNSS as 11e.(2) byproduct material (USDOE 2003b).

Also, when the *Operable Unit 4 Silos 1 and 2 ROD Amendment* (USDOE 2000a) was prepared, potential commercial disposal options were identified for the disposal of Silos 1 and 2 materials that also did not require application of the TCLP limits as quantitative performance standards - provided the material was deemed eligible for disposal by the regulatory agency, a waste-specific profile review was conducted, and all other applicable WAC were met.

After a review of the proposed changes to the remedy, USDOE and EPA determined that because the revised remedy would still include retrieval, chemical stabilization, and protective off-site disposal of Silos 1 and 2 material, the adjustments to the ROD provided in the ESD were significant but did not fundamentally alter the overall Silos 1 and 2 remedy with respect to scope, performance, or cost (USDOE 2003b). Additionally, it was noted that:

> "*...the only procedural modification arising from this ESD will be to eliminate sampling and TCLP testing of the treated waste since it is no longer necessary for WAC demonstration purposes. The removal of that sampling step will protect employees from having to work near the open containers to obtain samples and from being exposed to radiation from the waste material during the sampling and laboratory analysis activities. Over the life of Silos 1 and 2 treatment operations and the number of repetitive sampling activities that would have been necessary, this change should reduce potential worker exposure by more than 500 millirem (mrem) over the life of the project and is consistent with USDOE's As Low As Reasonably Achievable (ALARA) principles and practices. In addition, elimination of TCLP testing of the treated waste will result in a cost savings of approximately $400,000.*" (USDOE 2003b).

2.1.5.4.2 Post-ROD Decision Changes – Silo 3

Explanations of Significant Differences for Operable Unit 4 Silo 3 Remedial Action (January 1998). The ESD was the first Post-ROD Decision Change to the original OU 4 ROD and was signed by the EPA on March 27, 1998 (USDOE 1998a). The ESD modified the treatment component of the Silo 3 remedy to on-site or off-site treatment by chemical stabilization or polymer encapsulation and allowed the option for disposal at a permitted commercial disposal facility (in addition to the NNSS). The ESD was developed for Silo 3 to replace the vitrification technology with chemical stabilization/solidification or polymer encapsulation as the preferred treatment option for treating the Silo 3 wastes to achieve the TCLP-based waste acceptance limits in effect at the time for off-site disposal. This modification was adopted to address implementability concerns with vitrification that were revealed in the VITPP melter incident in 1996.

The Silo 3 ESD acknowledged that the adoption of a chemical stabilization/solidification or polymer encapsulation alternative for Silo 3 (as a replacement for vitrification):

> "*would not be a fundamental change to the original remedy identified in the 1994 ROD, provided that the alternate process continued to meet all remedial objectives and performance standards of the approved ROD for a cost roughly equivalent to the original remedy, and that the remedy includes disposal at a protective, appropriately permitted off-site disposal facility*" (USDOE 2003a).

ROD Amendment for Operable Unit 4 Silo 3 Remedial Actions (August 2003). The 2003 ROD Amendment modified the treatment component of the Silo 3 remedy to treatment (to the degree reasonably implementable) to address material dispersability and metals mobility (USDOE 2003a). Similar to Silos 1 and 2 materials, the Silo 3 materials were statutorily excluded from formal RCRA hazardous waste definitions and administrative requirements by their designation as 11e.(2) byproduct material. However, the Silo 3 residues did contain sufficient quantities of four RCRA regulated metals (arsenic, cadmium, chromium, and selenium) such that they could exceed RCRA TCLP limits.

As part of an eligibility evaluation necessitated by the NNSS WAC update in February 2002 (described previously for Silos 1 and 2 above), a draft waste profile was reviewed for the statutorily exempt 11e.(2) Silo 3 material, and deemed the material to be acceptable for disposal at the facility without the need for further treatment. The USDOE and EPA concluded the TCLP-based waste treatment performance standard, adopted in both the 1994 ROD and the 1998 Silo 3 ESD as a facility-specific criterion for treatment, was no longer necessary for the purposes of maintaining regulatory compliance with disposal facility WAC (USDOE 2003b). The USDOE and EPA removed the quantitative TCLP performance standard as a criterion for execution of the Silo 3 remedy.

During the development of the ROD Amendment the public expressed a concern regarding the removal of the primary requirement for treatment to satisfy WAC requirements. The public concern addressed the loss of associated secondary benefits of waste treatment – including the further incremental control of the dispersability of the Silo 3 material (in the unlikely event of a severe transportation accident).

For these reasons, USDOE and EPA selected a treatment alternative that included the addition of a chemical stabilization reagent and a reagent to reduce dispersability (to the extent practical). The revised plan included adding a lignosulfonate solution to the waste such that the moisture content of the waste was increased by up to 20 percent – thus reducing the dispersability of the material (USDOE 2003a). Under the revised remedy, if operational impediments resulted in the decision to discontinue all steps of the liquid treatment process, then a contingency backup action would be implemented. The contingency action included the use of a double packaging system as a backup to further reduce the potential dispersability of waste material released under a hypothetical severe accident involving material transit (USDOE 2003a).

Additionally, the revised remedy would remove waste from Silo 3 using both pneumatic and mechanical systems. As a result of the relatively high concentration of Th-230 (an alpha emitter) and the dry powdery consistency of the waste, special attention was necessary during design to ensure the construction of waste handling systems to minimize the release of particulates from the waste material to the work area or the environment.

2.1.5.5 Operable Unit 4 Final Remedy – Silos 1, 2, and 3

The Explanation of Significant Differences for Operable Unit 4 Remedial Actions (January 18, 2005). The 2005 ESD allowed the option for temporary off-site storage of treated Silos 1, 2, and 3 materials prior to permanent off-site disposal. The option for temporary off-site storage of treated waste was due to legal issues identified by the State of Nevada concerning the disposal of the treated Fernald silo materials at the NNSS. The EPA and USDOE maintained the OU 4 remedy (originally specified in 1994 with input from regulatory agencies and stakeholders in the states of Ohio and Nevada) was legal, compliant, and fully implementable. As a result of the State of Nevada response, the changes addressed in the ESD were required:

> "*…in order to maintain continuing progress towards completing treatment and off-site disposal of the Silo materials in the most cost-effective and expeditious manner; minimize risk to the public and the environment due to continued storage of silo materials in their in current configuration as soon as possible; maintain progress towards the scheduled 2006 closure of the FCP; and continue to honor its commitment to respond to stakeholder concerns.*" (USDOE 2005b)

Adding the option for temporary off-site storage prior to permanent disposal at the NNSS and/or an appropriately permitted commercial disposal facility represented a significant, but not fundamental, change to the OU 4 remedy (USDOE 2005b). The original OU 4 ROD had always provided for off-site management of the Fernald silo materials in the form of transportation to and disposal at a protective off-site facility (USDOE 2005b). As defined by this ESD, temporary off-site storage at a government-owned facility or a properly permitted commercial facility is a form of off-site management in accordance with the same criteria applied under the OU 4 ROD (as amended). At the time, the only option for temporary storage was at the Waste Control Specialists (WCS) facility in Texas as a result of the legal issues identified by the State of Nevada.

In addition, the revised remedy would: maintain the final remedy of protective, permanent off-site disposal of silo material; limit off-site storage to a finite period of time prior to permanent off-site disposal; maintain all current criteria for treatment, packaging, transportation and disposal; and preclude return of the material to Fernald.

Therefore, the selected remedy defined for OU 4 ROD and its subsequent modifications consist of:

- Removal of the K-65 residues from the Silos 1 and 2 and the Decant Sump Tank System sludge from the silos and transfer of these materials to the TTA for storage, pending subsequent transfer to the Silos 1 and 2 Remediation Project Waste Treatment and Packaging (WT&P) Facility.
- Complete removal of contents of Silos 1 and 2 and the Decant Sump Tank System sludge from the transfer tank area followed by treatment using chemical stabilization to attain the disposal facility WAC.
- Removal of material from Silo 3 by pneumatic and/or mechanical processes, followed by treatment to the extent practical by addition of a chemical stabilization reagent and a reagent to reduce dispersability.
- Off-site shipment and disposal of the treated silo materials at the NNSS and/or an appropriately permitted commercial disposal facility.
- Gross decontamination, demolition, size reduction and packaging of the Silos 1, 2 and 3 structures and remediation facilities in accordance with the Fernald OU 3 ROD.
- Shipment of the concrete from the Silos 1 and 2 structures for off-site disposal at the NNSS or an appropriately permitted commercial disposal facility.
- Disposal of contaminated soil and debris, excluding concrete from the Silos 1 and 2 structures, in accordance with the Fernald OSDF WAC or appropriate off-site disposal facility, such as the NNSS or a permitted commercial disposal facility.
- Removal of the earthen berms and excavation of the contaminated soil within the OU 4 boundary to achieve the remediation levels outlined in the OU 5 ROD.
- Appropriate treatment and disposal of all secondary wastes at either the NNSS or an appropriately permitted commercial disposal facility.
- Collection of perched water encountered during remedial activities for treatment at OU 5 water treatment facilities.
- Continued access controls and maintenance and monitoring of the stored waste inventories.
- Institutional controls of the OU 4 area, such as deed and land-use restrictions.

The change to the OU 4 remedy, as defined by the 2005 ESD, consists of the potential addition of an incremental step of the off-site management of the silo materials (temporary storage), prior to final disposal in accordance with the selected remedy (USDOE 2005b).

2.2 Silos 1 and 2 Remediation Project (K-65 Residues)

The following sections summarize the Fernald K-65 Silos 1 and 2 Remediation Project activities including the K-65 inventory and radiological characterization, and the specific remediation facilities designed and constructed for the project.

2.2.1 K-65 Residue Placement, Inventory and Radiological Characterization

The following sections discuss the Fernald Site K-65 Silos 1 and 2 Remediation Project residue placement, inventory and radiological characterization. This includes discussion regarding the project areas and facilities and the establishment of subprojects to facilitate timely site closure.

2.2.1.1 K-65 Residue Placement and Inventory

The Silos 1 and 2 Remediation Facility (Photographs 2-1 through 2-4) contained approximately 6,800 m^3 (240,000 cubic feet [ft^3]) of K-65 residues resulting from the processing of high-grade uranium ores, water, and bentonite grout. The objective for the bentonite was to reduce radon emissions from the silos to an ALARA level and is further discussed in Section 2.3.3. Fernald Silo 1 contained 3,282 m^3 (115,900 ft^3) of pitchblende ore byproduct material (K-65 residue) that was covered with 357 m^3 (12,600 ft^3) of bentonite. Silo 2 contained 2,843 m^3 (100,400 ft^3) of pitchblende ore byproduct material covered by 314 m^3 (11,100 ft^3) of bentonite. The K-65 residues contained elevated concentrations of radionuclides, including radium, thorium, and their associated decay products (radionuclide daughters).

The silos were cylindrical, domed, above-grade concrete tanks with steel reinforcement. Each silo was 24 meters (m) (80 feet [ft]) in diameter, 11 m (36 ft) high to the center of the dome, and surrounded by an earthen berm to provide structural support and shielding from radiation. The earthen berms were not contaminated with K-65 materials. This configuration is significantly different than the K-65 residues (and other wastes) stored within the IWCS at NFSS, as the K-65 materials stored within the IWCS are all below grade and covered by an earthen berm. The IWCS storage configuration has implications for access to and the geometry of the NFSS waste materials. Section 6.1.2 describes the historical relationship of the Fernald K-65 residues and the similar materials in storage at NFSS.

Photograph 2-1. K-65 Silos 1 and 2 Remediation Project

Photograph 2-2. General Overview of Fernald Silos 1 and 2 and Silo 3 Project Areas and Facilities

Photograph 2-3. Detail of Fernald Silos 1 and 2 with Surrounding Earthen Berms and TTA Structure with Four Temporary Storage Tanks

Photograph 2-4. Silo 3 – Same as Silos 1 and 2 Structurally but No Earthen Berm – Silos 1 and 2 in Background

2.2.1.2 K-65 Waste Radiological Characterization

The specific activities of the individual radionuclides found in the Fernald K-65 material are shown in Table 2-2. The radionuclide inventories were derived from the specific activity results obtained from sampling of Silos 1 and 2 Remediation Facility.

The data presented in Table 2-2 are based on the 95 percent upper confidence level (UCL) on the mean of sample data results. These radionuclide concentrations were derived from analysis of a relatively low number of samples of K-65 material. Obtaining and analyzing a greater number of samples to reduce the variance was not done due to the personnel exposure required and ALARA considerations. Therefore, the 95% UCL for the population of concentrations was used as the reference point for design. These values were used with a full understanding of potential uncertainties. Statistically, the 95% UCL provides the upper estimate of the true mean of the sample population involved and accounts for 95% of the unknown population mean.

The bolded values shown in Table 2-2 indicate that radium (Ra-226) and its shorter-lived decay products Rn-222, polonium (Po-210, Po-214, and Po-218), lead (Pb-210 and Pb-214), and bismuth (Bi-210 and Bi-214), account for approximately 90 percent of the total activity in the Fernald silos K-65 material.

Comparison of the Fernald K-65 radionuclide concentrations (Table 2-2) and the NFSS K-65 radionuclide concentrations (Table 6-2) while not exact, are very similar.

Table 2-2. Specific Activities of the Individual Radionuclides Found in K-65 Material at the Fernald Site

	Silo 1	***Silo 2***
Radionuclide	***95% UCL on Mean (pCi/g)***	***95% UCL on Mean (pCi/g)***
Actinium (Ac-227)	7,670	6,640
Actinium (Ac-228)	1,110	985
Bismuth (Bi-210)	**202,000**	**190,000**
Bismuth (Bi-211)	7,670	6,640
Bismuth (Bi-212)	2,280	7,360
Bismuth (Bi-214)	**477,000**	**263,000**
Francium (Fr-223)	106	92
Protactinium (Pa-231)	0	4,040
Protactinium (Pa-234)	1	2
Protactinium (Pa-234m)	693	1,120
Lead (Pb-210)	**202,000**	**190,000**
Lead (Pb-211)	7,670	6,640
Lead (Pb-212)	2,280	7,360
Lead (Pb-214)	**477,000**	**263,000**
Polonium (Po-210)	**281,000**	**231,000**
Polonium (Po-211)	21	18
Polonium (Po-212)	1,460	4,720
Polonium (Po-214)	**477,000**	**263,000**
Polonium (Po-215)	7,670	6,640
Polonium (Po-216)	2,280	7,360
Polonium (Po-218)	**477,000**	**263,000**

Table 2-2. Specific Activities of the Individual Radionuclides Found in K-65 Material at the Fernald Site (continued)

Radionuclide	Silo 1 95% UCL on Mean (pCi/g)	Silo 2 95% UCL on Mean (pCi/g)
Radium (Ra-223)	7,670	6,640
Radium (Ra-224)	2,280	7,360
Radium (Ra-226)	**477,000**	**263,000**
Radium (Ra-228)	1,110	985
Radon (Rn-219)	7,670	6,640
Radon (Rn-220)	2,280	7,360
Radon (Rn-222)	**477,000**	**263,000**
Thorium (Th-227)	7,560	6,550
Thorium (Th-228)	2,280	7,360
Thorium (Th-230)	68,900	76,200
Thorium (Th-231)	54	94
Thorium (Th-232)	1,110	985
Thorium (Th-234)	693	1,120
Thallium (Tl-207)	7,650	6,620
Thallium (Tl-208)	819	2,640
Uranium (U-234)	932	1,160
Uranium (U-235/U-236)	54	94
Uranium (U-238)	693	1,120

Source: USDOE 1993a

Bolded radionuclides represent 90% of the radiological activity associated with the residue constituents.

Note: Some of the radionuclide values represented were not derived from sample analysis, they are decay products assumed to be in secular equilibrium with their parent.

2.2.2 Establishment of Silos Sub-Projects

Early in the design process related to the Fernald Site K-65 Silos 1 and 2 Remediation Project, a decision was made to create several distinct projects; the RCS Project, the Accelerated Waste Retrieval (AWR) Project and the WT&P Project. When the OU 4 Remediation Project was separated into the Silos 1 and 2 Remediation Project and the Silo 3 Remediation Project it became apparent the Silos 1 and 2 Remediation Project represented the critical path for completion of the Closure Project for the overall Fernald Site. The Silos 1 and 2 Remediation Project infrastructure required a total area of 2.3 ha (5.8 acres) while the transportation staging area consisted of approximately 1.2 to 1.6 ha (3 to 4 acres). The critical requirement for project completion on schedule was the timely construction and startup of the key facilities needed to complete the project in the sequence that these facilities would need to be operational to transition from one phase of project execution to the next. Fernald management made the decision to establish subprojects to assure the appropriate focus could be placed on resolution of issues affecting the progress of work on each individual facility. A brief narrative description of these subprojects is provided below:

- The RCS Project provided control and treatment of radon emissions from the Silos 1 and 2 Remediation Facility headspaces, AWR, storage equipment, and the WT&P facility.

- The AWR Project provided facilities and equipment for transferring the K-65 residues from the silos to the temporary storage tanks, while awaiting construction and startup of the WT&P facility.
- The WT&P Project provided facilities and equipment for the transfer of K-65 residues from the temporary storage tanks to the remediation facility, where the residues were treated, mixed with cement and fly ash and transferred into the final disposal containers which were designed and tested to meet United States Department of Transportation (DOT) Industrial Package Type 2 (IP-2) requirements.

Each of the subprojects listed above is described in more detail in Sections 2.3 through 2.5.

2.3 Radon Control System Project

The following sections summarize the components and operation of the RCS Project during OU 4 remedial activities at the Fernald Site.

2.3.1 Radon Control System Project Description

The RCS Project was the first operational facility associated with the Fernald Site K-65 Silos 1 and 2 Remediation Project. The design, construction, start-up and operation of the RCS served to control and remove radon-laden air from all potential sources, which was then treated and discharged via a stack. The RCS, which took approximately two years to construct, was housed in a structure approximately 8.5 m by 40 m (28 ft by 130 ft) in size. There was also a 8.5 m by 13 m (28 ft by 42 ft) concrete exterior pad for support equipment such as the chiller units and exhaust stack (Flour Fernald 1994). The operation of the RCS project was conducted in three phases:

- **RCS Project Phase 1:** The RCS was connected to Silos 1 and 2 Remediation Facility with the internal headspace radon concentrations extracted which effectively negated any radon leakage to the environment.
- **RCS Project Phase 2:** The RCS continued to provide control of silos headspace concentrations. It was also connected to the temporary storage tanks contained within the TTA in order to remove headspace radon concentrations during transfer and storage of the K-65 materials. This effectively negated any radon leakage to the environment during the AWR Project.
- **RCS Project Phase 3:** The RCS continued to provide control of the silos and temporary storage tank headspace concentrations. During this phase, it was connected to the process tanks contained within the remediation facility through the Process Vessel Ventilation System and effectively negated any radon leakage to the environment during the WT&P Project.

A view of the operational RCS facility is shown is Photograph 2-5.

Photograph 2-5. View of the Operational RCS Facility

2.3.2 Radon Control System Design and Construction

Figures 2-1 and 2-2 show the basic components (e.g., the roughing filters, the desiccant dryers, the carbon beds, the high efficiency particulate air filters, the fans, and the monitored discharge stack). This design utilized redundant systems to ensure continued operations and maintainability. Centrifugal fans pulled radon-laden gas from the sources through the roughing filters for initial particulate daughter removal. The air stream was chilled and dried to enhance the dynamic adsorption capacity of the activated carbon. Condensed liquids from the gas stream were transferred to shielded holdup tanks until transfer and disposition in the Remediation Facility could be completed. There were four carbon beds, each containing 20,400 kg (45,000 lbs) of carbon. These beds were configured so that any two of the four beds were in use at any given time. This allowed for decay time of the alternate two beds, whereby no carbon changes were required over the life of the project. The RCS reduced radon concentration to less than 2% of the inlet concentration and the carbon bed outlet air was either recycled to the silos or exhausted through the 46-m (150-ft) tall stack. Approximately four inches of carbon steel shielding was designed and installed adjacent to the carbon beds to reduce general area dose rates.

During the design of the RCS, source terms for each of the three RCS operational phases were calculated utilizing anticipated radon concentrations produced at each location and the flow rates of air drawn from those locations (Section 2.3.1). These were dynamic conditions and were evaluated to ensure the flow rates from multiple sources, with varying assigned radon concentrations, did not compromise the overall carbon bed efficiencies which were designed to reduce the concentrations by 98% prior to discharge via the stack. The operational parameters assigned to each of the three RCS phases of the project are included in Table 2-3.

Table 2-3. Radon Control System Operating Parameters

Location	***Phase 1 (pCi/L)***	***Phase 2 (pCi/L)***	***Phase 3 (pCi/L)***
Silo 1	1.0 E+06	2.0 E+06	5.0 E+05
Silo 2	1.0 E+06	1.0 E+06	5.0 E+05
Storage Tank 1A	0	5.0 E+05	5.0 E+05
Storage Tank 1B	0	5.0 E+05	5.0 E+05
Storage Tank 2A	0	5.0 E+05	5.0 E+05
Storage Tank 2B	0	5.0 E+05	5.0 E+05
Remediation Facility	0	0	1.0 E+06
	Gas Flow Rate (ft^3/min)	***Gas Flow Rate (ft^3/min)***	***Gas Flow Rate (ft^3/min)***
Silo 1	325	500	350
Silo 2	325	500	350
Storage Tank 1A	0	125	125
Storage Tank 1B	0	125	125
Storage Tank 2A	0	125	125
Storage Tank 2B	0	125	125
Remediation Facility	0	0	300

Source: Fernald Closure Project 2006b

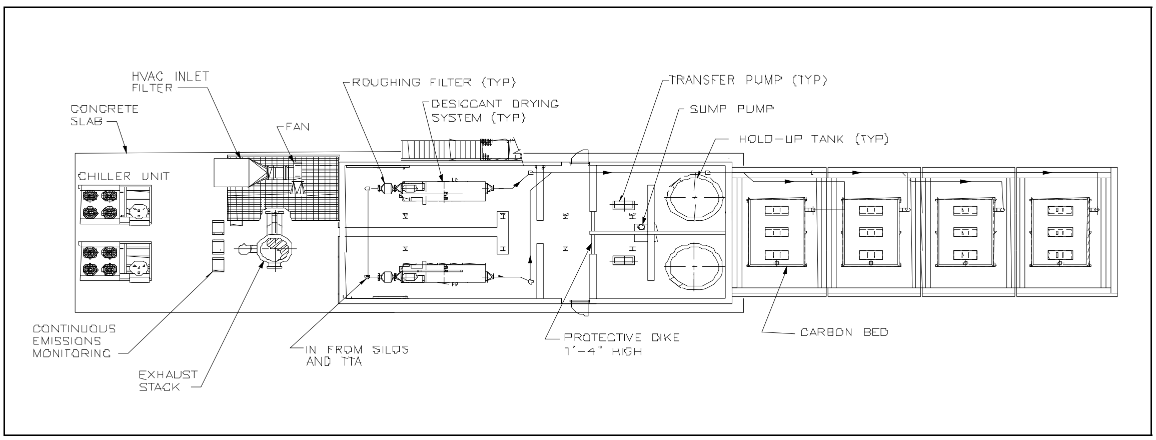

Figure 2-1. Radon Control System Air Flow Pattern – 1st Floor Plan

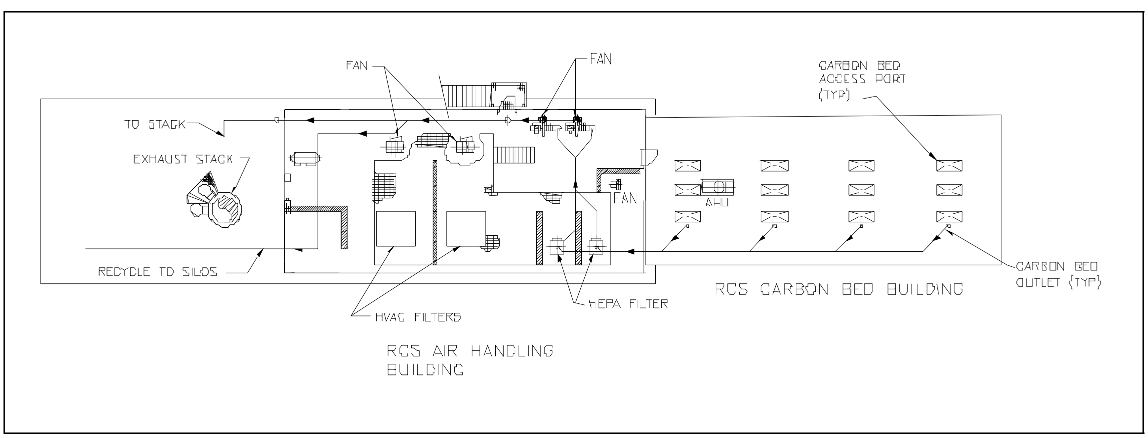

Figure 2-2. Radon Control System Air Flow Pattern – 2nd Floor Plan

2.3.3 Operations

The RCS initiated testing in January 2003 and Phase 1 operations began in May 2003. Figure 2-3 depicts historical silos headspace radon concentrations. A bentonite cover was placed over the K-65 material in November 1991, when headspace radon concentrations were also removed. The objective for the bentonite seals was to reduce radon emissions from the silos to an ALARA level. In 1998 radon concentrations around the silos started to trend upward at an unexpected rate. An investigation indicated the radon leakage was due to degradation of the existing polyurethane foam covering and several engineered penetrations on the silo domes. Inside the silos, radon within the headspace had increased due to the degradation of the bentonite seals. To address the radon leakage, the silo domes were treated in June 1999 by applying an epoxy sealer to all identified leak points. The epoxy was then covered with a polyurethane foam followed by a weather-proofing topcoat. From that time forward there was a steady rise in headspace radon concentrations as the effectiveness of the bentonite cover degraded due to drying and cracking. The subsequent decline in concentrations, during the period of January 2003 through the end of March 2004 represented in this graph, were due to the operations of the RCS.

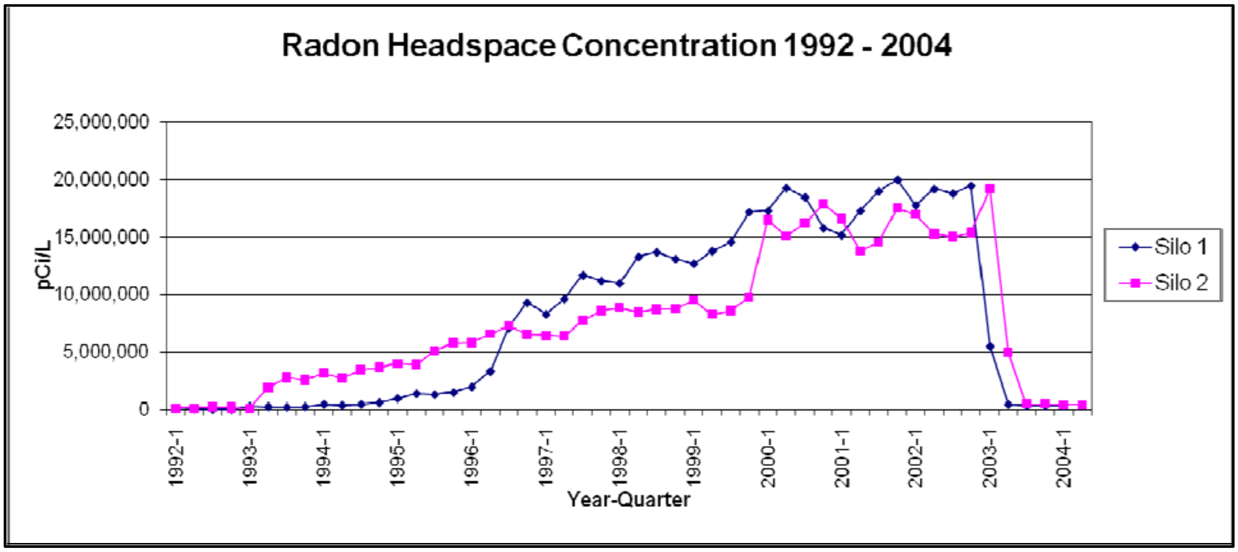

Figure 2-3. Silo Headspace Radon Concentrations

An additional advantage during RCS Phase 1 operation was the reduction of dose rates on both the Silos 1 and 2 domes and surrounding general areas. Historical radiological survey results are shown in Table 2-4. The highest recorded dose rates (>200 millirem per hour [mrem/hr]) were measured prior to the bentonite addition in 1992, whereupon the silos' dome dose rates were reduced to <10 mrem/hr after headspace concentration removal and application of the bentonite cover. Starting in 1992 and continuing through 2003, the headspace radon concentrations increased as the bentonite cover degraded. The silos' dome dose rates rose from <10 mrem/hr up to approximately 100 mrem/hr. Once the RCS operations began in 2003, the silos' dome dose rates were reduced to <5 mrem/hr.

Table 2-4. Historical Radiation Dose Rates at Silos 1 and 2

Historical Radiation Dose Rates	*Silo 1 Dose Rates (mrem/hr)*	*Silo 2 Dose Rates (mrem/hr)*
Pre-Bentonite		
Maximum on silo dome (11/30/87)	208	250
Maximum on silo dome (11/91)	175	215
Maximum on K-65 surface (8/78)	>600	>600
Maximum at exclusion fence line	0.239	0.326
Post-Bentonite		
Maximum on silo dome (3/92)	5.7	4.6
Maximum on silo dome (2/17/99)	90	80
Maximum at exclusion fence line (1992)	0.019	0.025
Maximum at exclusion fence line (8/25/99)	0.14	0.16
Post-RCS Phase 1 Operations		
Maximum on silo dome (09/05/03)	4.0	3.5
Maximum at bottom of the earthen berm (Controlled Area boundary) (09/05/03)	0.025	0.025

Source: Fluor Fernald 2004a

Notes: The exclusion fenceline physically surrounded the silos approximately 23 m (75 ft) outside the base of the earthen berms. The location identified as the maximum at the bottom of the earthen berm, was a ground level perimeter survey at the base of the earthen berm perimeter. This location was physically inside the previous exclusion area perimeter, which had been removed.

Early in the Fernald Site K-65 Silos 1 and 2 Remediation Project, it was verified that the flexibility in the RCS allowed discrete operational tasks to be conducted after system adjustments were made that implemented ALARA principles by causing a reduction in existing radiological conditions.

The principles involved in radon release to air (silos or tank headspace) are complex and vary based on radium concentrations, exposed material surface areas, material porosity, water saturation, differential pressures and other factors. However, headspace radon production (release) rates could be calculated once a static concentration was reached in a defined volume, with the RCS in a constant operational mode. This static concentration point is reached when the removal constant provided by the RCS (air extraction) is equal to the radon production rate, with make-up air drawn from clean external air space within a constant volume (headspace). Other related principles included the understanding that radon progeny (daughters) are the principle hazard with respect to both inhalation and the production of penetrating gamma dose rates.

Presence of radon progeny at equilibrium concentrations is not instantaneous; however, once a static radon concentration is reached in the headspace, the progeny equilibrium state will be attained. When radon and progeny are contained within a material matrix, photon emissions at surface areas are reduced due to the self shielding (attenuation) provided by the solids matrix, which is the same for the 186 kilo electron volt (keV) photons originating from the parent Ra-226. Unlike radon and its progeny, the radium solids stay in the matrix whereas the radon (gas) fractionally releases to air, which provides little self shielding and if contained within a defined volume can reach concentrations producing elevated dose rates at the structural or containment surfaces and adjacent areas.

With this knowledge, and an understanding of the RCS system capabilities, the Fernald Site K-65 Silos 1 and 2 Remediation Project was able to reduce radon and progeny concentrations in specific project areas such as an individual silo headspace and/or component enclosures, by increasing the RCS exhaust flow rates out of those areas. This resulted in a lowering of adjacent dose rates. The RCS system was balanced by reducing the exhaust flow rates out of other systems and/or components while still maintaining a negative pressure, whereby radon and progeny concentrations in those areas increased as did the adjacent dose rates. These conditions were anticipated, monitored and controlled and proved beneficial in reducing personnel radiological exposure.

RCS operations proved beneficial to the Fernald Site K-65 Silos 1 and 2 Remediation Project in many aspects. Continual removal of headspace radon concentrations effectively negated any further environmental leakage. Additionally, surrounding area radon concentrations and dose rates were reduced to environmental background levels. This allowed for construction of the TTA and the remediation facility to be accomplished without radiological controls, aside from verification monitoring. Prior to RCS operations, these areas were under radiological control due to the elevated dose rates and radon concentrations. Hence, removal of those controls and boundaries provided an increase in work production. The RCS continued to operate through each of the three RCS operational phases without upsets or discharge concentrations above the pre-determined set point. As each project facility reached the end of its individual operational phase, the RCS was isolated from that facility during the safe shutdown activities, prior to demolition of the facility.

Of the operational facilities associated with the Silos 1 and Remediation Project, the RCS was the first to start up and the last to enter safe shutdown and demolition.

2.4 Accelerated Waste Retrieval Project

The AWR Project provided facilities and equipment for transferring the K-65 residues from Silos 1 and 2 to temporary storage tanks while awaiting construction and startup of the remediation facility and then the transfer from the temporary storage tanks to the remediation facility when it was ready to receive the K-65 residues. Sluicing technology, also referred to as hydraulic mining, was utilized to achieve these material transfers.

2.4.1 Accelerated Waste Retrieval Project Description

The AWR Project was comprised of two system configurations identified as the Silo Waste Retrieval System (SWRS) and the Tank Waste Retrieval System (TWRS).

The SWRS consisted of water supply systems, two sluicing nozzles, and a slurry pump for each silo. This equipment and the associated support systems were housed in confinement structures residing on a steel bridge constructed over each silo. This system configuration was used to transfer K-65 residues from Silos 1 and 2 to temporary storage tanks.

The temporary storage tanks consisted of four approximately 2.8 m^3 (750,000-gallon) American Petroleum Institute 650 carbon steel storage tanks located in a shielded concrete vault identified as the TTA facility.

Photograph 2-6 shows the general configuration of the confinement structures residing on a concrete floor above one of the temporary storage tanks within the TTA facility. All of the equipment confinement structures were identical. The TWRS consisted of water supply systems, two sluicing nozzles, and a slurry pump for each of the four temporary storage tanks. This system configuration was used to transfer K-65 residues from the temporary storage tanks to the WT&P remediation facility.

Photograph 2-6. Confinement Structures in TTA above Storage Tank

2.4.2 Accelerated Waste Retrieval Operations

Transfer of the K-65 residues during SWRS and TWRS operations was implemented using a technique referred to as hydraulic mining. This operation was accomplished by directing sluice water nozzle stream(s) as close as possible to the center of the silo or tank under the slurry pump, which was located above the center of each silo or tank. This created a slurry pool under the pump which was then lowered into place. When sufficient pump submergence had been achieved, the material was transferred to either the temporary storage tanks or the remediation facility via the slurry pump and associated piping.

The SWRS and TWRS were designed to operate individually and at the same time with all of the piping and valve configurations designed to allow this flexibility, as well as the ability to transfer or move waste between storage tanks. A general depiction of the system configurations is depicted in Figure 2-4.

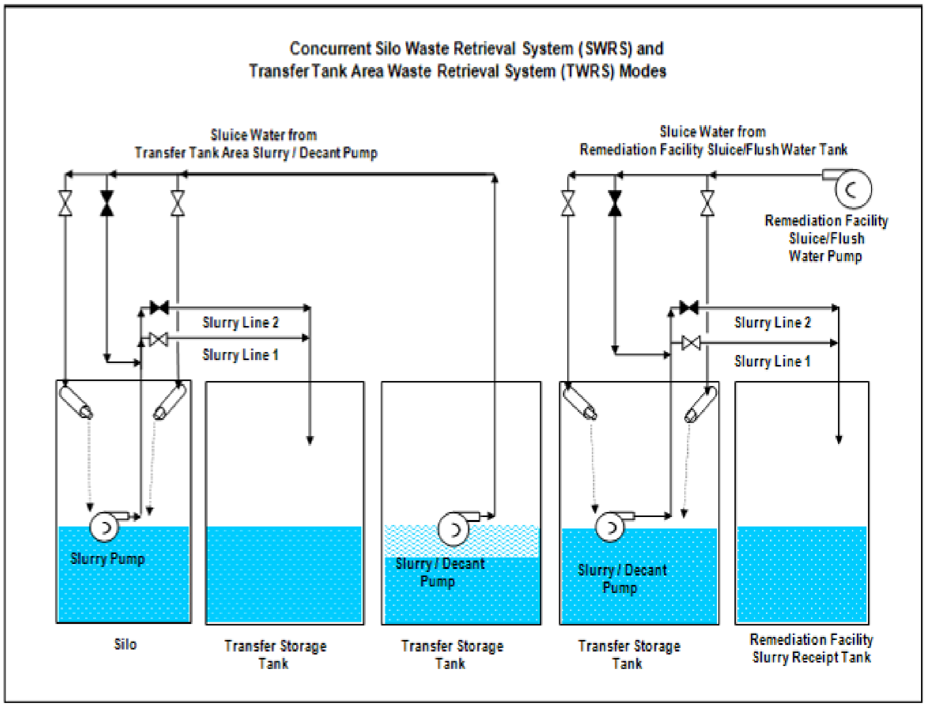

Figure 2-4. Operational Modes of the SWRS and TWRS

If the IWCS FS considers removal alternatives involving the sluicing of the K-65 and other residue material for removal, then the AWR design and operation features discussed above would be appropriate, particularly the TWRS portion. However, based on the significant differences between the K-65 residue storage configurations at the two sites, the SWRS portion of the AWR would have more limited applicability in terms of Fernald final design and operational details. The technology and application of the SWRS portion of the AWR should be considered for NFSS but would involve a much different design for it to be operable at NFSS

During the SWRS operations there was a condition encountered whereby material within Silo 2 had taken a physical form that was not transferable by the sluice/pump methods. This hardened material, which was approximately 0.6 m x 0.3 m 0.3 m (2 ft x 1 ft x 1 ft) in size, was located directly below the pump and could not be moved with the sluicing nozzles. The pump was removed from the enclosure and a mechanical retrieval device (clamshell) was lowered into the silo and the object was retrieved. Information related to this object, its formation and/or final disposition is not readily available, but the retrieval and resumption of operations was performed with no release of contamination or radon to the environment. When NFSS selects and/or designs the retrieval methods for the K-65 residues, alternative or recovery methods should be considered with respect to encountering anomalous conditions or materials.

One benefit realized by this waste transfer process was that K-65 residues were cycled or rotated through the four receiving temporary storage tanks. This allowed for an effective blending of the waste resulting in a consistent physical form and a balanced radionuclide specific activity, which minimized the process or operational adjustments needed in the remediation facility.

2.4.3 Design Alternatives

During the AWR design phase some additional retrieval methods were evaluated to address potential anomalous materials in the silos. A robotic arm, to be lowered through one of the silo roof openings, was evaluated for the removal of debris or other solid objects that might be present. A second robotic unit developed by USDOE called 'Houdini' was also evaluated for removal of potential heel material in the silos or TTA tanks. Houdini was a hydraulically powered, track driven, mobile work vehicle with a collapsible frame designed to enter underground or above ground waste tanks, where it would unfold and land on the waste surface or tank floor to become a remotely operated mini-bulldozer. A vehicle mounted plow blade and 6-degrees of freedom manipulator would be used to mobilize waste and carry other tooling such as sluicing pumps, excavation buckets, and hydraulic shears.

After extensive review of the project records regarding the materials that were placed in Silos 1 and 2, and the successful pilot tests of the hydraulic mining systems for mobilization of surrogate materials, it was determined that neither of these options would be required to complete the project. The cost and complexity of their implementation was determined to be prohibitive. As a back-up plan, a small clamshell device was specified for the removal of anomalous materials that might impede the hydraulic mining process. Once the bulk of the K-65 residues were removed from the silos, it was determined that the efficiency of the hydraulic mining process left little or no heel to be dealt with.

2.5 Waste Treatment and Packaging Project

The following sections describe the WT&P Project components including chemical stabilization treatability studies, design, construction, waste container handling, waste packaging, and waste disposal.

2.5.1 WT&P Project Description

The WT&P Project consisted of a remediation facility designed and constructed to accept the K-65 residues in slurry form as they were transferred from the temporary storage tanks via the TWRS. The waste was then treated and processed into final form and loaded into the final waste containers, which were placed on the transport trailers and readied for shipment to an off-site disposal facility.

2.5.2 Chemical Stabilization Treatability Studies/Design Development

The selected treatment remedy for Silos 1 and 2 wastes, chemical stabilization, was defined as a non-thermal process that mixed the Silos 1 and 2 material (the K-65 residues plus the bentonite grout) with a variety of chemical additive formulations (e.g., lime, pozzolans, gypsum, portland cement, or silicates) to accomplish chemical and physical binding of the contaminants of concern. The wastes removed from the TTA were to be transferred to the WT&P facility, which was constructed on-site. The chemical binding of the contaminants in the stabilized wasteform would reduce the leaching rate to meet the NNSS WAC. In addition, the placement of the stabilized waste form in sealed containers would reduce radon emanation to meet regulatory standards. Particulates and radon released as a result of the stabilization process would be captured by the RCS to satisfy all air-emission ARARs and To Be Considereds.

During the early stages of design for the WT&P facility (late 2000 to early 2001), the only well-defined aspects of the project were that the K-65 material would be delivered to the facility as a nominal 15 percent by weight (wt%) slurry from the TTA tanks, where it would be stabilized and turned into a packaged final waste form that would meet DOT requirements during transportation, and the WAC for disposal at the NNSS (per the OU 4 ROD). A number of key design criteria/assumptions and operational parameters were subsequently defined to guide the design process:

- Facilities and equipment would be sized to treat the K-65 waste in 250 working days in a one-year time period, resulting in a nominal on-line availability factor of 70%.
- All equipment and processes would be remotely operated to the maximum practical extent, to minimize worker exposure.
- The 95% UCL value for the Silo 1 material (Ra-226 = 477,000 pCi/g) would be used for the design of radiological controls.
- The final waste form was expected to contain 20 wt% (+/- 5%) of K-65 solids (based on the expected treatment process output and the design of the container to meet DOT requirements).
- Processing operations would be conducted 24/7, with shipping operations limited to day shift (due to safety concerns).
- Design production capacity (maximum) would be 30 product containers per day.
- Total number of estimated single-use product containers was 7,000 (based on the expected waste loading, container capacity, and estimated quantity of K-65 residues).
- Product containers would be 1.3-centimeters (cm) (½-inch) thick steel cylinders, with nominal dimensions of 190-cm (75-inch) diameter by 201-cm (79-inch) height, with a maximum gross weight of approximately 11 tons.
- Transportation quantity would be 3,500 truck trips (two containers per truck).
- Disposal volume would be approximately 40,000 m^3 (1.4 million ft^3) (which is approximately 5.7 m^3 [~200 ft^3] per container).

Throughout the design process, and continuing into the construction phase of the project, a number of studies, tests, and other measures were implemented to try to mitigate the risks associated with designing, building, and operating this first-of-a-kind facility. Brief summaries of these risk mitigation measures are provided below.

2.5.2.1 Treatability Testing

It was known that the K-65 slurry received into the facility (at a nominal 15 wt% solids) would need to be dewatered in order to maximize the waste loading in the final waste, and a formulation would need to be developed to stabilize the material to meet TCLP limits for leachability (primarily for lead). A series of treatability tests were conducted during the conceptual design phase on archived K-65 materials from previous sampling events to address these issues, and allow the finalization of the treatment processes:

- The dewatering portion of the studies resulted in the selection of a single polymer that would allow the 15 wt% slurry to be concentrated in a clarifier/thickener system to a nominal 30 to 40 wt% slurry.
- The stabilization portion of the studies showed that a final waste form that contained 8 to 12 wt% Portland cement and a total solids content (K-65 plus cement and fly ash) of 65 to 70 wt% would meet the TCLP limits, be self-leveling when poured into a product container, set up as a solid within 24 hours, and have no free liquids (even after shaking and freezing/thawing cycles).
- The results from the two studies indicated that a compliant final waste form could be produced. The stabilized waste was expected to contain 15 to 25 wt% K-65 solids, 10 wt% cement, 35 to 45 wt% fly ash, and 30 to 35 wt% water that was bound up in the grout matrix. The stabilized waste was also expected to contain less than 100,000 pCi/g of Ra-226, in order stay within the DOT dose rate limits for the selected 1.3- cm (½-inch) thick steel disposal containers.

2.5.2.2 Early Vendor Selection for Key Process Equipment

Early in the design process, it was decided that vendor input/expertise, including prototype testing, would be essential to complete the design of the processes within the facility, many of which represented a first-of-a-kind application for the various components. A number of "best value" procurements were implemented near the end of the preliminary design phase to bring the key vendors on board in time to get their inputs into the final design of the facility and processes. These early procurements included: tank agitators (and final design of tank internals), product mixers, clarifier/thickener, fill room equipment (gantry manipulators, transfer cars, and fill chutes), cement/fly ash systems, bridge crane, conveyors, and in-line instrumentation (densitometers and Ra-226 analyzers). In many cases, cooperative efforts among the vendors and the design group were required to ensure that the various systems and components interfaced properly.

2.5.2.3 Cold/Hot Loop Tests

A series of tests were conducted to evaluate potential pumps, piping, and instrumentation with respect to K-65 slurry processing, with a primary focus on functionality and durability/reliability. Tank, pump, and piping loops were constructed and operated at Oak Ridge National Lab and the Diagnostic Instrumentation and Analysis Laboratory facility at Mississippi State University, using both surrogate and K-65 slurries. The results of these tests were used to select the most appropriate equipment for the facility.

2.5.2.4 Integrated Test Program

A full-scale mock-up of a treatment facility fill room, including prototypes of the gantry manipulator, fill chute, transfer car, and waste container, was constructed and operated to finalize the design of each of these components, verify remote equipment operations/system controls, and evaluate the reliability and maintainability of these components. The mock-up was also used for operations and maintenance procedure development and operator training.

2.5.2.5 Container and Transport System Design and Prototype Testing

The container and transport system designs were conducted in parallel with the WT&P facility design, especially the fill room and material handling systems, to ensure seamless integration. Prototype waste containers, transport trailers, and grapples (for container handling) were built to verify compliance with DOT regulations and disposal site WAC, and allow testing of facility material handling systems. The DOT testing included the completion of container drop tests at the National Transportation Resource Center in Knoxville, TN, to verify compliance with IP-2 package (DOT) requirements. Additional details on the design and testing of the K-65 waste containers are provided in Section 2.5.5.

Alternate transportation modes, including shipment of the waste containers in gondola or flat railcars, were also evaluated extensively. A prototype insert for a gondola railcar, to allow the shipment of seven containers per car, was designed, constructed, and successfully tested. During subsequent analysis, it was determined the costs associated with this approach may be higher than the (baseline) truck approach, especially if NNSS was the disposal facility (off-loading from the railcars to trucks would be required for the final leg of the trip). It was also determined that flatcars may not be economically feasible, due to the significant supplemental shielding required to meet DOT requirements for a reasonable payload (5-7 containers per railcar).

2.5.2.6 Remediation Facility Startup Testing

Extensive integrated system operability tests were conducted on all portions of the remediation facility using surrogate slurry to verify operations and identify and resolve any material handling and control system issues. These tests were also used to develop and validate operations procedures and train operations and maintenance personnel.

2.5.3 Design and Construction

The remediation facility contained the control room, process and support systems for slurry receipt, feed preparation, chemical stabilization/product forming, containerization and loading of the treated K-65 materials for shipment to an off-site disposal facility.

There were five primary systems designed and constructed for the chemical and physical stabilization processing of K-65 residues within the remediation facility. The overall process flow diagram (Figure 2-5) shows the basic flow of materials through the remediation facility.

There were five additional systems designed and constructed within the remediation facility to provide control of contamination and mitigate the release of radioactive emissions. The five additional systems were the heating, ventilation and air conditioning system, supernatant water system, sluice/flush water system, process vessel ventilation system and the sampling system.

2.5.3.1 Slurry Receipt System

K-65 residues were transferred from the TTA to the remediation facility by the TWRS at approximately 350 gallons per minute (gpm) and at 15 wt% solids. Material were transferred via one of two elevated double-walled transfer lines and was received in one of three carbon steel slurry receipt tanks, each having a maximum capacity of approximately 317 m^3 (83,800 gallons).

During normal operations, one tank would be receiving material from the TTA, one would be in standby mode, and the third would be feeding material forward to the Feed Preparation System (clarifier).

Each tank was fitted with a mechanical agitator that was designed to keep the tank contents relatively homogeneous. Each tank had its own variable speed centrifugal pump, with associated piping and valves, that would allow the slurry to be fed forward to the clarifier, recirculated back into the tank, or transferred to one of the other tanks. A densitometer and sampling system were installed on each recirculation loop to measure and verify the density/wt% solids of the slurry. Magnetic flow meters were installed on the feed forward piping from each pump to monitor and control the flow of slurry to the clarifier, and quantify the amount transferred.

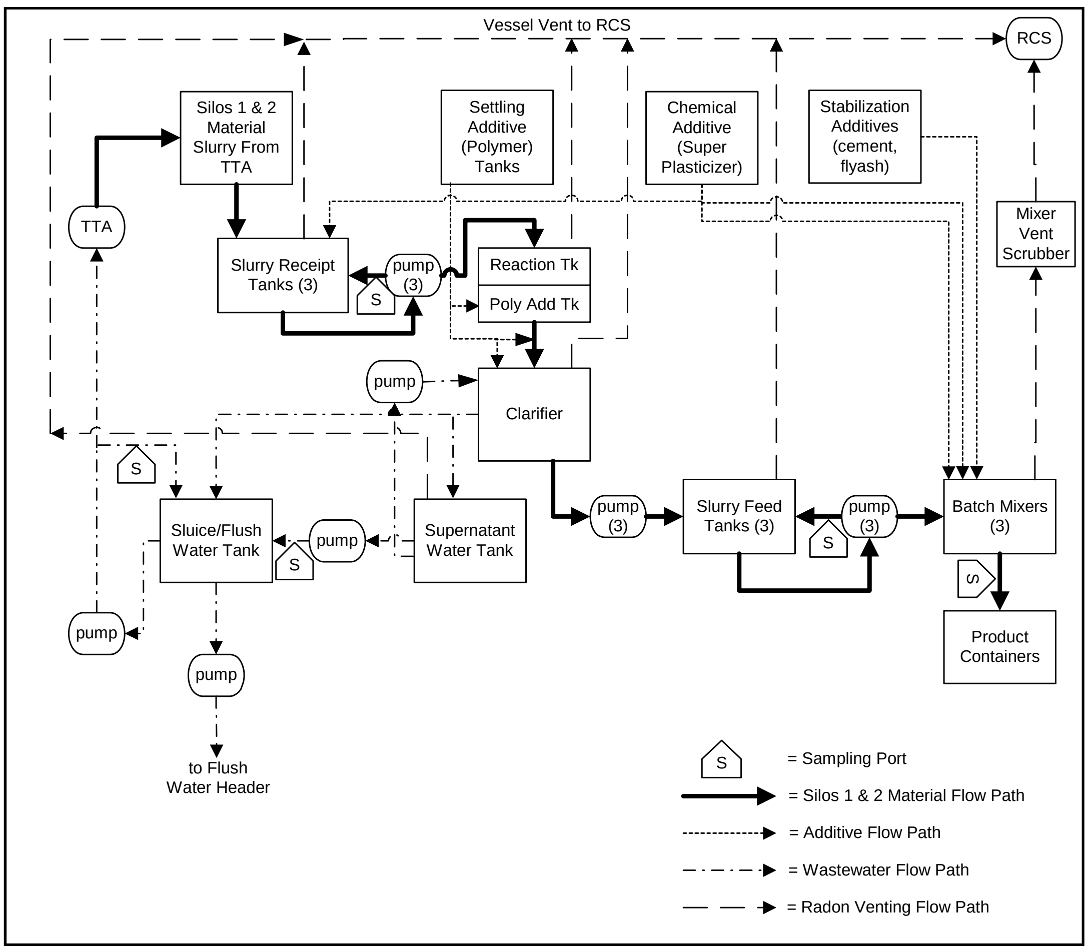

Figure 2-5. WT&P Process Flow

2.5.3.2 Feed Preparation System

From the slurry receipt tanks, the material was transferred to the reaction tank and polymer addition tank in the feed preparation system where it was mixed with a polymer additive to aid in flocculation and settling of the K-65 solids. The reaction and polymer addition tanks directed overflow to a clarifier which allowed settling and thickening of the slurry to 30-40 wt% solids in preparation for product mixing. Typical flow rate of the slurry through the system was 20-30 gpm.

Three variable speed centrifugal pumps were installed to transfer the thickened slurry from the bottom of the clarifier to one of the three slurry feed tanks in the Processor Feed System, with typical flow rates of 10-20 gpm. A densitometer and magnetic flow meter were installed on transfer line to measure the density/wt% solids of the thickened slurry, and monitor, control, and quantify the flow of slurry from the clarifier to the feed tanks. The supernatant (clarified liquid) from the overflow weir at the top of the clarifier flowed by gravity to the Supernatant Water System.

2.5.3.3 Processor Feed System

The clarifier continuously fed thickened slurry (nominally 30-40 wt % solids) to one of the three carbon steel slurry feed tanks in the processor feed system. The thickened slurry was then transferred by batches to the product mixers. During normal operations, one tank would be receiving material from the clarifier, while the other two were feeding material forward to the processor system (product mixers).

Each slurry feed tank had a maximum capacity of approximately 91 m^3 (24,100 gallons), and was fitted with a mechanical agitator that was designed to keep the tank contents relatively homogeneous. Each tank had its own variable speed centrifugal pump, with associated piping and valves that would allow the slurry to be fed forward to the processor system (product mixers), recirculated back into the tank, or transferred to one of the other tanks. A densitometer and sampling system were installed on each recirculation loop to measure and verify the density/wt% solids of the feed slurry. An in-line analyzer was also installed on each recirculation loop to measure the Ra-226 concentration in the feed slurry, so that the quantity of Ra-226 in each batch of product could be determined. Magnetic flow meters were installed on the feed forward piping from each pump to monitor, control, and quantify the flow of slurry to the product mixers.

2.5.3.4 Product Additive System

In the product additive system, cement and fly ash were unloaded, stored and transferred to the product mixers where they were added to the thickened slurry. The cement and fly ash were pneumatically transferred from delivery trucks into large storage bins outside the WT&P facility. Each bin was designed to hold approximately 7-10 days worth of material, based on the maximum production rate of 30 product containers per day. The cement and fly ash were pneumatically transferred from the outside storage bins to smaller receiving bins and weigh hoppers that were situated on a floor above the product mixers. The receiving bins and hoppers were designed to hold 4-6 product batches worth of material. Each product mixer had its own set of receiving bins and hoppers for the two additives, with weigh cells on the hoppers used to verify the quantity of material added to each product batch. Rotary airlock valves under the hoppers were used to discharge the materials by gravity into the product mixers.

2.5.3.5 Processor System

In the processor system, three product mixers were used to mix the thickened slurry with the cement and fly ash on a batch basis. The mixers were carbon steel double ribbon blenders with variable speed drives, each having a working capacity of approximately 5.66 m^3 (200 ft^3) (nominal 16,000 pounds of product), such that each batch of product prepared was designed to fill one waste container. Weigh cells on the mixers were used to verify the quantities of each component added to the batch (K-65 feed slurry, cement, and fly ash). After the mixing was completed (nominal 15-20 minute mixing time), the product was discharged via gravity to a waste container in one of the container fill rooms on a lower floor.

2.5.3.6 Heating, Ventilation and Air Conditioning System

The Remediation Facility Building heating, ventilation, and air conditioning (HVAC) system maintained temperatures, air flow patterns and provided sufficient air change rates in the recommended ranges. These temperatures were maintained for the comfort and safety of workers in normally occupied areas and for contamination control. The system maintained all spaces with the potential for contamination under varying levels of negative pressure, with respect to both the outside environment and adjacent spaces, to ensure that all air leakage was inbound. Exhaust air was filtered before it is released to the environment via a stack.

2.5.3.7 Supernatant Water System

The supernatant water system incorporated an approximately 390 m^3 (100,000-gallon) carbon steel tank to collect a variety of wastewater streams including: clarifier supernatant (overflow), spills, and wash water from the product mixer room sumps, and other treatment facility sumps. Settled solids from the bottom of the supernatant tank were pumped back to the clarifier for processing. Water from the center and bottom of the supernatant tank was pumped to the sluice/flush water tank for reuse.

2.5.3.8 Sluice/Flush Water System

The sluice/flush water system incorporated a large tank. This tank collected supernatant water from the supernatant tank or directly from the clarifier and provided it as sluice water to the TTA and as flush water for line and equipment flushing throughout the remediation facility.

2.5.3.9 Process Vessel Vent System

To control radon emissions from process tanks and equipment, the vessel vent system collected and transferred vent gases from each of the process vessels, including the product mixers, to the RCS. In the RCS the air was treated before release via the RCS stack. Fresh make-up air was introduced to the process vessels through pressure relief valves. When vacuum set points were reached for a given vessel, fresh make-up air was allowed to enter the process vessel.

2.5.3.10 Sampling System

Sampling stations for processed waste material were incorporated into the WT&P design. At the sampling ports shown in Figure 2-5, slurry samples were drawn for analysis at the facility's on-site laboratory. The sampling was intended to ensure that the treatment process was working as designed and was producing stabilized product that met the disposal facility WAC. A small laboratory in the Silos 1 and 2 Remediation facility provided in-house, short turnaround (one- to two-day results) analysis of Ra-226 and percent solids concentrations in the K-65 slurry streams (pre- and post-clarifier) to validate the readings of the in-line Ra-226 analyzers and densitometers (i.e., calibration checks).

2.5.4 Operations – Waste Treatment and Packaging

Elevated radiation levels produced by the K-65 residues residing in processing equipment such as large tanks or vessels were addressed in the design by placing the components within concrete shielded vaults. Associated equipment (i.e., pumps, motors, valves) which had a potential for needing maintenance were placed outside the vaults in adjacent accessible areas. These areas were connected by piping that could be isolated and flushed. Thus, the presence of the K-65 residues in the components and the area dose rate was reduced. Examples of the placement of serviceable equipment are provided in Photographs 2-7 and 2-8.

A primary feature of the design was the use of parallel or redundant operational systems. This design allowed for continued operations in cases where equipment and/or components needed maintenance or repair, minimizing production downtime. This design capability proved valuable on numerous occasions during the operational period. There were incidents related to equipment and system impacts such as leaking valves, plugged lines and occasional repairs on the batch mixer internal mechanical components.

Initially a conservative design assumption was that the remediation facility would produce an estimated 7,000 final containers. The initial estimate of containers was due primarily to the use of conservative values related to the K-65 radionuclide concentrations, waste volumes, and dry material densities, as discussed in Section 2.5.2. However, the final number of containers produced over the approximate 14 months of operations was 3,776.

Photograph 2-7. Placement of Motors on Shielded Floors above the Receipt Tanks

Photograph 2-8. Placement of Fly Ash and Cement Feeders Above the Batch Mixers

2.5.5 Waste Container Handling, Staging and Transport

As part of the remediation facility design, development included the mechanical equipment and processes that were used to receive, move, stage, and prepare product containers for filling with stabilized Silos 1 and 2 material. Much of the equipment was designed to operate automatically and remotely to minimize personnel involvement and exposures in radiological areas. The waste container handling system was designed to produce filled containers that were secure and safe for transportation and final disposal directly into the off-site disposal cell.

Movement of the product containers was automatically controlled by an integrated control system, with manual overrides available for each step of the operation which allowed for operator control. In addition, programmed hold points were designed into the handling system for operator verification. Inputs to the control system were from devices such as limit switches, positional detectors, and motor device feedbacks.

Empty product containers were delivered to the remediation facility by truck trailers carrying five containers per trailer. Monorail hoists, which were manually controlled by an operator pendant, were used to unload the containers from the truck and to place the containers on conveyors. These conveyors were used to transport the containers into the building.

Empty containers brought into the remediation facility were allowed to approach ambient conditions to reduce sweating; visually inspected for moisture, dirt, or debris and manually cleaned if needed; and labeled before their use.

Following receipt, the product containers were transferred onto one of three conveyors that automatically advanced empty containers for preparation. This preparation involved removing temporary fasteners used to secure the lid to the container during transport and lifting the container lid for inspection. The container lid was inspected to ensure that the gasket was securely affixed to and properly positioned on the lid and the lifting bracket also was not damaged. Markings on the lid and top of containers were inspected to ensure they were clean and in good condition. Touch-up paint was used when feasible to correct minor defects. If the lid was damaged or missing, the lid was replaced using a spare lid. The approximate defect rate for the lids was less than one percent.

After inspection, the lid and container were weighed while on the conveyor and the weight was recorded prior to the container entering into the filling operation. The container was then advanced to another conveyor. Then a 16-ton monorail hoist equipped with a container grapple was positioned over the container. The monorail hoist was operated remotely from the facility control room. The container was raised, moved to a position over one of three container transfer cars and then lowered onto the transfer car. The grapple was then disengaged and raised.

Transfer cars were driven by a servomotor connected to a gearbox, which rotated the rear wheels and provided movement along two parallel rails. The wheels of the container transfer cars were connected to the gearbox by axles with independent safety couplings. During container filling, the transfer cars positioned containers in the product fill station by redundant positioning controls.

After the container transfer car was positioned within the product fill room, a gantry manipulator in front of an operator-viewing window, equipped with a gripping tool, raised the lid above the container (Photograph 2-9).

The container transfer car was then moved to the filling station, located beneath a product fill chute. The chute was attached to a 46-cm (18-in) diameter discharge valve from one of the batch mixers located above each product fill room. The fill chute had a bellows portion, which was extended so that the fill chute was coupled to the container opening. The mixer discharge valve was opened and product material was allowed to flow by gravity from the mixer towards the container.

After the container was filled with product material, the container transfer car was moved to an inspection/lid fastening station next to the gantry manipulator in front of the operator-viewing window. An operator inspected the container using a remotely-operated camera to determine whether any product had dripped or splashed onto the container surface.

Photograph 2-9. K-65 Waste Container Ready for Lid Removal by Gentry Manipulator in WT&P Fill Room

After container inspection was complete, the operator engaged the gantry manipulator to replace the container lid by using alignment pins and cameras in order to fasten the lid with rivets. A vision system and programmable logic controller identified the locations of the rivet holes to allow the gantry manipulator to accurately insert the rivets automatically. After the container lid was fastened, the transfer car was moved out of the product fill room. Next, the container transfer car was moved into the container railcar loading area and a 15-ton bridge crane and trolley equipped with a container grapple was moved over the container to be shipped. The container grapple was lowered and engaged, as verified by indicator lights. The container was then raised off of the container transfer car, moved by the bridge crane, weighed and lowered onto a shipping trailer. The container was then moved to the transportation staging area (Photograph 2-10).

Photograph 2-10. Silos 1 and 2 Remediation Project Transport Trailers and Containers Staged in WT&P Loaded-out Bay During Startup Phase

2.5.6 K-65 Waste Disposal

The packaging requirement for the Silos 1 and 2 K-65 residue materials was an IP-2 container. Specific regulatory requirements are contained in Sections 6.4.1 and 6.4.2. The containers were tested per DOT methods (drop, vibration and stacking tests) to verify compliance for an IP-2 package. The containers were secured to a flat bed truck, each truck capable of handling two containers, in accordance with DOT requirements. Quality Control personnel inspected the loaded trailers prior to leaving Fernald. The shipping followed a pre-determined route approved in the Silos 1 and 2 Transportation and Disposal Plan.

The performance standards to be met for the treated Silos 1 and 2 materials involved complying with the waste profile (WCS 2005) established for temporary storage at WCS. WCS was selected as the off-site repository (for temporary storage) of the treated K-65 residues, due to the issues that had arisen regarding their disposal at NNSS (Section 2.1.5.5). The material also complied with the NNSS WAC as a potential final disposal facility. Feed batch data, recipe formulation data, and process control data for each container produced was collected to demonstrate compliance with the waste profile.

Treatment and packaging of the Fernald Site K-65 Silos 1 and 2 Remediation Project residue materials in the remediation facility was initiated May 19, 2005. The first shipment to WCS left Fernald on June 6, 2005. Bulk processing of waste materials in the remediation facility was completed March 19, 2006. A total of 3,776 containers of treated K-65 residues (including 80 containers produced through direct load out in support of safe shutdown of the facility) were packaged and shipped to WCS for temporary storage, pending permanent disposal. Shipping containers were designed to comply with DOT shipping requirements (storage or WAC requirements were not drivers for container design). Each shipment was manifested to ensure that all of the Silos 1 and 2 Remediation Project residues were properly shipped and received by the facility. The logistics of waste transport, receipt and placement at the WCS facility were highly effective in that nearly 2000 shipments were made to the facility without adverse events or issues impacting the campaign. This was largely due to development of a careful and methodical approach on the part of the Fernald Project to assure the accuracy of shipping papers before submission to the disposal facility. This also provided the documents for review and approval as far ahead of the planned shipping date as possible so potential discrepancies could be identified and resolved at the earliest possible time.

At the end of the shipping campaign (June 2006), the license application for permanent disposal of the Silos 1 and 2 K-65 residues at WCS was in the final review and approval process, with disposal originally targeted to begin in early 2007. WCS was eventually issued a license for the disposal of 11.e(2) byproduct material on May 29, 2008, thus allowing permanent disposal of the Fernald K-65 waste containers in their byproduct cell.

2.6 Material Handling and Disposal of Impacted Waste

The Silos 1 and 2 Remediation Project consisted of K-65 waste storage, retrieval, processing, and packaging operations which required construction of support facilities, structures and processing systems. The principal wastes at the Fernald Site were known and volumetrically defined, however, it was important to evaluate and recognize that construction of processing facilities/systems for the Fernald waste also resulted in volumetric wastes requiring disposal. These same considerations regarding additional waste disposal volumes will be necessary for any potential NFSS remedial actions involving the removal of the K-65 residues.

This section includes a brief summary of the means and methods for disposal of Silos 1 and 2 Remediation Project waste streams other than the bulk K-65 waste.

2.6.1 Surrounding Soil (Earthen Berms)

Prior to the start of the K-65 silos material extraction, the earthen berms which had been historically placed around the concrete structures were sampled and it was agreed that the low-level contaminants qualified the waste for disposal in the Fernald OSDF. The sampling analysis results for Ra-226 did not indicate that there had been any transfer of K-65 waste to the earthen berms.

As the K-65 bulk material transfer from the silos to the temporary storage tanks neared completion, heavy equipment was brought into the project area and the earthen berms encompassing the concrete silos were removed via loading into dump trucks for transport across the site and placement in the OSDF.

2.6.2 Concrete Silos Debris and Underlying Soil

After the entirety of the K-65 bulk materials had been removed from the silos and verified through multiple internal flushing operations, it was anticipated that a residual surface contamination was present on the inner wall surfaces of the silos. This surface contamination caused concern with respect to the dispersal of loose contaminants and residual radon emissions during the demolition and exposure of the concrete structures. The residual Ra-226 concentration, either fixed in the concrete or partially loose was determined to be approximately 3 curie (Ci) in each silo (Fernald Closure Project, 2005c). As a result, grout was applied to the inner surfaces, stabilizing potentially loose contaminants and providing suppression of radon emissions.

As the RCS was isolated from the individual silos, monitoring was performed to ascertain the change in headspace radon concentrations. This information allowed for the use of calculations to determine the residual Ra-226 remaining in each silo. With this information, it was determined that each concrete silo structure could be demolished without significant impact or release to the environment. The silos were then demolished one at a time through use of heavy equipment, down-sized in place, loaded into dump trucks and moved to a staging location on-site where the materials were loaded into railcars and transported to Envirocare, Utah (currently known as the Energy*Solutions* disposal site).

After both concrete structures were demolished and removed, several feet of underlying soil were excavated and also relocated to the staging area for load-out and disposal with the concrete rubble. This was principally due to contact with K-65 materials during demolition, handling and removal of the silos structures.

2.6.3 Constructed Support Facilities/Structures

Prior to constructing the new processing and support facilities for the Silos 1 and 2 Remediation Project, it was decided that all underlying soil would be certified as “clean”. Sampling and analysis was done in accordance with criteria established under the OU 5 ROD for the cleanup of all site soils (USDOE 1996a). Volume estimates were not performed as they were determined to be ancillary. If contamination was detected above the final remediation levels as defined in Table 9-3 of the OU 5 ROD, the soil was excavated to meet the remediation levels and stockpiled until placement in the OSDF. After soil removal, a mud mat was placed in support of the construction of the facility foundations. Facility designs included measures to ensure that these underlying concrete structures and soil were not impacted by potential spills or waste handling operations. Prior to site closure, these foundations and underlying soil were sampled and found to have contaminant characteristics below agreed upon free release limits and were, in part, left in place.

During the safe shutdown phase of each sub-project facility (Silos 1 and 2, TTA, Remediation Facility, RCS), waste processing equipment (piping and tanks) were flushed with water, which was forwarded to the remediation facility and processed into containers. As the WT&P facility entered safe shutdown, a final flush of those systems allowed for containment and dewatering. The residual sludge flushed from the operating systems was then transferred by temporary pumping operations into containers where cement and fly ash were added and manually mixed and lidded.

All Silos 1 and 2 process equipment and facilities, including the RCS, TTA, and WT&P facilities, were dismantled prior to disposal. The steel support bridges; TTA; and the facility's concrete, structural steel, piping systems, and vessel steels were surveyed and determined to be free of K-65 waste, with the exception of surface contamination, which allowed for disposal of this waste in the OSDF and disposal via railcar to the Envirocare facility in Utah.

2.6.4 Residual Wastewater

The Silos 1 and 2 Remediation Project required the use and management of water in its processes. There was an excess of process water at the completion of the project, which required treatment to meet the site's National Pollutant Discharge Elimination System permit requirements and USDOE Orders for Environmental Protection.

Storage and treatment of the excess water for removal of gross radium, lead, uranium, and total suspended solids was conducted in the Remediation Facility through use of water storage tanks, a clarifier system, and an installed bag and cartridge filter system. Once those filtering operations were completed, the water was transferred and transported via truck to the Silos Wastewater Treatment facility. The Silos Wastewater Treatment was a new facility housed in an existing South Plume Interim facility. The Silos Wastewater Treatment consisted of a 662 m^3 (17,500 gallons) Influent Feed Tank with two feed pumps and a three-stage treatment process. The first stage was bag and cartridge filtration for removal of solids, the second consisted of granular activated carbon for removal of lead, and an ion exchange resin for radium removal as needed. After final filtering and treatment, the water was processed through an existing South Plume Interim facility ion-exchange discharge pipeline, and then to the combined site effluent discharge pipeline leading to the Great Miami River. If a similar WT&P system is used at NFSS, then there will likely be excess process water needing treatment for total solids, lead, and radium at the end of the project.

2.7 Operable Unit 4 Remediation Cost Summary

The USDOE published the *Operable Unit 4 Final Remedial Action Report* in September 2006 (USDOE 2006b). This report provided a comprehensive review of the project including a summary of the overall costs associated with the Silos 1 and 2 Remediation Project and the remediation of the Silo 3 materials. The discussion presented here focuses primarily on aspects of the report which deal with the Silos 1 and 2 Remediation Project.

The total cost of the OU 4 remedy was $588.3 million in 2006 dollars. The overall Silos 1 and 2 Remediation Project comprised $488.6 million of this total, with the balance of $99.7 million attributed to the Silo 3 Project. This includes direct, indirect, and operation and maintenance costs associated with the retrieval, processing, packaging, and shipping of the waste material located in Silos 1 and 2, as well as Silo 3. This cost does not include Decontamination and Demolition (D&D) of the silos or the remediation facilities, nor does it include the costs of remediation of the underlying soils within the OU 4 boundary.

The estimated cost of the OU 4 remedy, as detailed in the original OU 4 ROD (USDOE 1994a), was $96.7 million dollars. This cost estimate was based on removal, vitrification, and off-site disposal at NNSS for the material in all three silos (that is, Silos 1, 2, and 3). The difference between the estimated cost and actual cost was attributed to the following:

- Unsuccessful efforts to design and operate a vitrification process. This resulted in a remedy change from vitrification to a chemical stabilization process (for Silos 1 and 2) and a conditioning process (Silo 3).
- The use of separate treatment processes for Silos 1 and 2 versus Silo 3. This required construction and use of separate remediation processing infrastructure. The original cost estimate assumed common costs for processing facilities and packaging and transportation facilities supporting all three silos.
- The decision to add interim storage of retrieved material from Silos 1 and 2 via the AWR Project.
- Unsuccessful attempts at fixed price/performance-based contracts for both the AWR and Silo 3 Projects.

A high level breakout of the $488.6 million cost for the Silos 1 and 2 Remediation Project, based on the information provided in the *Operable Unit 4 Final Remedial Action Report* (USDOE 2006b), is shown in Table 2-5. Additional detail on subproject costs of the Silos 1 and 2 Remediation Project is being developed to support the IWCS FS.

Table 2-5. Silos 1 and 2 Remediation Project Cost Breakout

Cost Component	*Total Remedy (millions)*	*Other Subprojects[a] (millions)*	*WT&P Subproject (millions)*	*Unit Cost $/yd^3 [b]*
Direct and Capital Cost	$193.5	$115.5	$78.0	$8,774
Indirect Costs	$161.4	$106.2	$55.2	$6,209
Operations and Maintenance	$71.3	$22.3	$49.0	$5,512
Transportation and Disposal	$62.4	$0.0	$62.4	$7,019
Total Cost	**$488.6**	**$244.0**	**$244.6**	**$27,514**

[a] Other subprojects includes AWR, RCS, Vitrification, Revised FS, Proof-of-Principle Tests, and other pre-2000 activities.

[b] Based on an estimated 8,007 cubic yards of in situ K-65 material.

Generally, direct and capital costs include design construction and startup of the facility while indirect costs entail support and management activities, project management and support, health and safety, environmental monitoring and other similar functions. Operations and maintenance routinely includes the cost associated with actual operation of the facility and maintaining the operational status of the remediation and other facilities required to produce a transport-ready shipment. This includes labor costs, materials, and supplies.

Cost growth in direct capital construction and indirect costs was experienced in the selected remedy for Silos 1 and 2. The capital cost growth was attributed to:

- The need to increase the waste treatment capacity of the facility to accommodate a compressed operational schedule;
- The need to install redundant transportation infrastructures supporting both rail and truck transport modes;

- The need for facility modifications to accommodate more remote operations in response to ALARA based worker dose analyses; and
- The need for capital improvements following startup to address identified safety and operational deficiencies.

The actual capital improvements included addition of shielding to protect workers from levels of radiation from the contents of Silos 1 and 2, addition of interim storage of retrieved material, unsuccessful attempts to design and operate the vitirification system that resulted in additional construction to implement chemical stabilization, and the separation of silos into separate treatment systems instead of a combined waste stream.

The growth in indirect costs was attributed to the need for increased quality and safety oversight during startup and operation of the facility. Increased oversight was deemed necessary to maintain disposal documentation and a heightened level of waste container quality control to ensure its acceptability for final disposal at a number of commercial and Federal disposal facilities. Increased safety oversight was deemed appropriate based on the identified facility hazards following detailed safety and nuclear systems analysis.

Table 2-6. Lessons Learned Summary

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
2.1.3	Final ARARs in approved FS.	• 40 CFR 191 Subpart B *Environmental Standards for Disposal* identified as a "relevant and appropriate" ARAR by EPA during the OU 4 FS • Impacted plans for on-site disposal at Fernald • Introduced new waste containment requirements and quantitative release limits • Impacted already-completed FS activities based on previously identified ARARs	• USDOE conducted detailed assessment of the impact of this ARAR on the OU 4 silos remediation	• Reconfiguration of OU 4 into sub-OUs • Re-evaluation of new technologies/process options • Investigation of disposal site availability for K-65 residues • Identified off-site temporary storage pending final disposal options • Development of new/revised alternatives • Significant project cost and schedule impacts
Lesson Learned: *The ARAR was identified by EPA after the OU 4 FS was already in development. The resulting requirements significantly impacted the technical requirements, remedial alternatives, and planned on-site disposal options for the K-65 residues. Significant project cost and schedule impacts resulted from the late identification of this ARAR during the remedial process. Although the ARARs at NFSS are determined by the USACE, efforts at the beginning of the FS process need to focus on gaining agreement on the complete set of ARARs to be addressed. Also, the NFSS should consider application of subunits, or a similar approach, should there be K-65 specific ARARs identified for IWCS OU FS that should not be applied to the remainder of materials within the IWCS.*				
2.1.5.3	Interim storage and management of debris and contaminated soils for on-site disposal	• Under Removal Action No. 17, contaminated debris was generated that was suitable for on-site disposal when placed with fill material (soil). Sufficient contaminated soil was excavated under a separate action, but was not available until after the debris was generated.	• An on-site interim storage facility (Engineered Central Storage Facility) was established to store the debris pending excavation and availability of on-site soils from a separate remedial action.	• Waste materials from separate actions stored until sufficient volumes were available to meet on-site disposal requirements. • Wastes managed and disposed on-site, avoiding off-site disposal.
Lesson Learned: *On-site interim management of waste materials can be used to avoid dispositioning wastes off-site when on-site options are available but will require a delay prior to disposal. This allows integration of individual subproject schedules, resulting in cost savings and optimizing disposal methods. During remediation of the IWCS, wastes with varying characteristics will be generated and a similar interim storage strategy may prove cost-effective.*				

Table 2-6. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
2.1.5.4	Selection of innovative treatment technologies	• Numerous technical and operational problems were encountered in the OU 4 vitrification treatability study process.	• A proven technology, chemical stabilization, was selected as the alternate treatment technology.	• Waste treatment achieved waste certification, licensing, transport, health and safety, and disposal requirements • Technology was proven reliable and fully implementable.
Lessons Learned: *Consideration of innovative treatment technologies should include an understanding of the potential increased level of complexity and potential negative impacts to implementability, cost, and schedule. IWCS FS should balance potential positive and negative impacts when considering innovative treatment technologies.*				
2.2.1.2	Pre-design waste characterization	• Limited waste characterization data for K-65 residues available during pre-design remedial activities • Elevated radiological activities and concerns for worker safety limited the amount of sampling conducted • Limited data set represented an uncertainty in anticipated waste properties	• Fernald utilized a 95% UCL statistical approach to quantify waste characteristics	• Uncertainties remained with respect to K-65 residue characterization throughout the Fernald pre-design • Significant differences between the statistical results and actual results could have represented significant impacts to Fernald Project technical design, schedule, and cost
Lesson Learned: *Pre-design waste characterization data collection should be conducted, to the extent possible, to maximize available data for the K-65 residues and other IWCS waste materials at NFSS. Any reduction in the level of uncertainty associated with waste characterization prior to the start of waste removal/treatment/disposal will mitigate potential negative impacts to project technical, cost, and schedule plans.*				

Table 2-6. Lessons Learned Summary (continued)

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
2.2.2	Incorporation of subprojects into remedial approach	• Potentially complex, long-term, and high cost remedial implementation	• Consider dividing the remedial project into more manageable subprojects based on significant technical tasks or schedule-based work phases	• More effective management of project implementation • More flexibility to apply varying contract mechanisms based on the scope of activities
Lesson Learned: *Although the incorporation of subprojects for the OU 4 remediation was necessitated by the late identification of an ARAR by EPA (see above), dividing a large and complex project such as the potential NFSS IWCS remediation may provide management and contracting option benefits – even if this approach is not required for other reasons.*				
2.3.3	RCS operation/system design	• K-65 residue radon leakage to surrounding area • The need to adjust system applications as project continued	• Continuous removal of headspace radon • Incorporation of flexible system design	• Effectively negated further leakage • Surrounding area radon concentrations/dose rates reduced to background • Allowed TTA construction without radiological controls • Increased work production in surrounding area • Flexible system design reduced system downtime and maximized incorporation of ALARA
Lesson Learned: *Although the presence of significantly elevated radon levels is anticipated during the potential NFSS IWCS remediation, the waste storage configuration at the IWCS is very different from that used at Fernald. As a result, the configuration of a RCS at the IWCS also is likely to differ from the Fernald design. Even though the system designs are likely to differ, the design of an effective RCS at the IWCS should consider the benefits from generally lower radon concentrations/dose rates in the immediate and surrounding work areas, the elimination of significant off-site radon exposures, reduced radiological controls, and overall increased work productivity during project completion.*				

Table 2-6. Lessons Learned Summary (continued)

<table>
<tr><th>Section</th><th>Topic</th><th>Adverse Condition</th><th>Attempted Correction</th><th>Result</th></tr>
<tr><td>2.4.2</td><td>AWR operation/system design</td><td>• Hardened material encountered during waste retrieval operation
• Inconsistent waste form/imbalanced radiological activity</td><td>• Utilized center confinement structure for mechanical retrieval device access
• Circulation through receiving temporary storage tanks</td><td>• Allowed hardened material removal without contamination spread or release of headspace radon to environment
• Effectively blended waste material – increasing consistency in resulting waste form and activity
• Flexible system design and planning for potential waste form variations minimized project schedule and cost impacts</td></tr>
<tr><td colspan="5">Lesson Learned: The waste storage configuration at the IWCS will require an AWR system design that addresses the removal of K-65 residues from an open bay configuration (versus the relatively confined environment within the silos at Fernald). The potential for beneficial waste blending and the resulting consistent waste form and radiological activity should be considered during IWCS system design – as these benefits may represent significant positive impacts to waste packaging, transport, and disposal.</td></tr>
<tr><td>2.5.2.2</td><td>Inclusion of technology vendors in WT&P process design development</td><td>• Potential negative impacts due to improper component compatibility or interfacing
• Need to identify specifications from numerous component vendors
• Challenges related to development of "first-of-kind" systems</td><td>• Process system component vendors included in design
• Best value procurement approach utilized
• Cooperative efforts among vendors</td><td>• Minimized potential complications associated with complex system designs
• Best value contracting approach considered technical expertise (not low-cost only).</td></tr>
<tr><td colspan="5">Lesson Learned: Including vendors for various complex system and process design activities helped to minimize component interface issues and associated negative impacts to project cost and schedule. The efficient design of complex systems and processes requires close coordination with component vendors to ensure compatibility and effective implementation.</td></tr>
</table>

Table 2-6. Lessons Learned Summary (continued)

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
2.5.4	Incorporation of redundant systems in remedial processes	• Potential negative impacts to worker safety, project schedule and cost due to excessive delays for equipment maintenance/repair	• Inclusion of redundant capabilities for key system components	• Minimization of overall process downtime due to scheduled/unscheduled equipment maintenance or repairs • Minimization of potential personnel exposures related to maintenance or repairs
Lesson Learned: *The utilization of redundant system components for key applications will minimize overall process schedule delays and potential worker exposures due to required equipment maintenance activities. The presence of redundant system components allows the process to continue operation while the affected components were repaired. Excessive downtime in a single process may result in delays to numerous other processes or operations.*				
2.5.6	Transportation to, and Interim Storage at Off-site Disposal Facility	• Legal issues identified by the State of Nevada concerning the off-site disposal of the treated Fernald silo materials at the ROD designated off-site disposal facility (NNSS) required diversion of waste to alternate interim storage location (WCS).	• Feed batch data, recipe formulation data, and process control data for each container produced was collected to demonstrate compliance with the waste profile. • Each shipment was manifested to ensure that all of the Silos 1 and 2 Remediation Project residues were properly shipped and received by the facility. • Careful, methodical review approach for assuring accuracy of shipping papers to prevent rejection of shipments at the disposal facility. • Earliest possible submittal of shipping papers to disposal facility to facilitate early discovery of discrepancies and sufficient scheduling of shipments.	• Maintained the final remedy of protective, permanent off-site disposal of silo material. • No delay or rejected shipments at the disposal facility. • Approximately 2000 shipments to disposal facility without adverse occurrence or event impacting shipping campaign.
Lesson Learned: *Process control data for each container produced was collected to demonstrate compliance with the waste profile. Careful, methodical*				

Table 2-6. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
review to ensure accuracy of shipping papers and early submittal of papers to disposal facility facilitated early discovery of discrepancies and sufficient scheduling of shipments.				
2.6	Consideration of system components/materials in waste disposal volumes at project completion	• Potential negative impacts to project waste volume estimates if all waste streams are not considered	• Ensure consideration of project shutdown waste volumes associated with system demolition, waste line cleanout, infrastructure removal, etc.	• More accurate estimates of final waste volume and associated disposal cost planning • Minimize negative schedule impacts due to insufficient funding
Lesson Learned: *The inclusion of remedial system component shutdown, demolition, or removal waste materials in the overall project waste disposal volumes is essential for accurate waste disposal cost estimates and scheduling. Negative impacts to project schedule and costs may result if additional unplanned waste materials are not identified until project completion. Potential waste types may include: equipment containment, work pads/surfaces, contaminated system components, excess wastewater from process operation or system decontamination, treatment process residues/tailings, etc.*				

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3. RADIOLOGICAL CONTROL LESSONS LEARNED

Throughout the design, construction, startup and operational phases, the Silos 1 and 2 Remediation Project was supported by a Radiological Control Group, comprised of a Certified Health Physicist (Manager), Radiological Engineers and Radiological Control Technicians. This section includes lessons learned related to engineering designs and operational controls that were incorporated into the project for protection of the workforce, the environment and the public.

The Silos 1 and 2 Remediation Project was required by the Department of Energy to implement requirements for the design of new facilities in accordance with 10 CFR 835, Occupational Radiation Protection. Two key components of these requirements included:

- 10 CFR 835.1002(b), Facility Design and Modifications, states that the design objective for controlling personnel exposure from external sources of radiation in areas of continuous occupancy (2,000 hours per year) shall be to maintain dose rates below an average of 0.5 mrem/hour and as far below this limit as is reasonably achievable. Therefore, the continuous occupancy design objective for the gamma radiation exposure rate is established at 0.5 mrem/hour.
- 10 CFR 835.1002(c), Facility Design and Modifications states that the design objective of confinement and ventilation for the control of airborne radioactive material shall be, under normal conditions, to avoid releases to the workplace atmosphere and in any situation, to control the inhalation of such material by workers to levels that are ALARA. Confinement and ventilation shall normally be used.

3.1 Design Engineering

The Radiological Control Group reviewed and ensured that radiological control requirements were incorporated during the design of new Silos 1 and 2 Remediation Project facilities. ALARA considerations were an integral part of the design process. Qualitative and quantitative analyses were performed on proposed design features to choose an engineered and/or administrative control that would provide a radiological work environment that was ALARA. To capture the ALARA analyses that were performed as part of the design process, a checklist was used for each phase of the Silos 1 and 2 Remediation Project. Table 3-1 is an example of the checklist and associated rationale used during the design of the Remediation Facility Building.

The waste processing systems comprising the Silos 1 and 2 Remediation Project incorporated several principal engineering elements: containment, shielding and ventilation, which were combined to provide for control of the associated radiological hazards in the work areas and/or the environment.

The slurry process used for transfer, treatment, and packaging of K-65 materials was contained through use of piping, pumps, and associated storage and/or treatment tanks. This approach to the handling of contaminated waste minimized releases to immediate work areas and provided a reduced potential for personnel contamination incidents. Additional benefits included no transfer of contamination outside defined areas and the reduction of suspended particulate contamination in air.

As the various project facility designs progressed, each component and/or system was reviewed for potential failure, the impact of a potential material release, and the radiological and chemical hazards associated with the dispersal of the K-65 materials contained within the piping and/or components. These analyses were performed to establish hazard categorizations in accordance with Department of Energy standards and requirements. The general methodology was comprised of comparing inventories of potentially releasable materials to prescribed radiological and chemical threshold values and then performing accident analyses to quantify dose consequences for workers, co-located workers and off-site populations.

With respect to the RCS Operation, the analyses consisted of failure of the RCS during retrieval operations, carbon bed failure (elusion of adsorbed radon), and failure of silo containment due to over-pressurization or under-pressurization of a silo with the RCS in operation. With respect to the AWR Operations, the analysis consisted of tank failure in the TTA and transfer line failure. With respect to the WT&P Operation, the analyses consisted of overfill of a product container, transfer line failure, clarifier failure, and RCS exhaust ducting breach.

Conclusions drawn from the hazard analyses yielded no consequences that required additional changes to structures, systems, components or controls (Fluor Fernald 2006).

Table 3-1. Silos 1 and 2 Remediation Facility Building ALARA Features

Item	***Location or Item***	***Feature***
1	Remediation Facility Building	Protects workers from weather and provides partial secondary containment of radiological materials.
2	Interior building concrete tank vaults, walls and local shielding	Reduces dose rates in work areas near tanks or equipment containing large volumes of Silos 1 and 2 materials
3	Concrete exterior walls in container loading area	Reduces dose rate in areas outside building
4	Secondary containment dikes and tank vaults	Provides secondary containment of leaks and spills from tanks, piping and equipment
5	Concrete surface coatings in selected areas and on secondary containment dikes walls and floors	Reduces exposures to workers during decontamination and dismantlement of facility at the end of the project. Coatings prevent absorption of contamination by concrete.
6	Control Room Ventilation System	Maintains control room at a slightly positive pressure to prevent inflow of contamination from other areas of the Remediation Facility Building or from the outside.

Table 3-1. Silos 1 and 2 Remediation Facility Building ALARA Features (continued)

Item	***Location or Item***	***Feature***
7	Remediation Facility Building Ventilation System	Directs ventilation air flow from cleaner areas to more contaminated areas, provides high efficiency particulate air filtration and controlled exhaust via stack. Supply air was provided to non-contaminated areas such as hallways, general areas and operator stations which was then extracted by ventilation exhaust fans through areas of higher contamination. The exhaust air was filtered prior to discharge via an exhaust stack. This design reduces the potential for contaminated air to migrate into non-contaminated areas and maintains the facility with negative pressure to the environment.
8	Three 50% capacity air conditioning units in HVAC supply system	Provides backup
9	Three 50% capacity exhaust filter trains	Provides backup
10	Redundant exhaust fans	Provides backup
11	HVAC System and Vessel Vent System vacuum relief lines	Ensures that airflows are maintained throughout Remediation Facility Building
12	Interior building doors, walls and vestibules	Provides physical separation of clean and potentially contaminated areas, work in conjunction with the HVAC system, monitoring systems, PPE and administrative controls to control spread of contamination
13	HVAC exhaust stack	Provides dispersal of trace radon and particulates not collected elsewhere
14	Stack monitor	Provides real time assessment of release rates
15	Breathing air	Protects workers from inhalation of radon gas and particulate radionuclides
16	Back-up breathing air	Provides redundancy in event that primary source of breathing air is not available
17	Remote operation of wet processing operations	Minimizes personnel exposure to penetrating radiation emanating from Silos 1 and 2 material in process tanks, pipes and equipment. Contamination control minimizes internal exposure from inhalation of airborne contamination and radon. Minimizes heat stress related to working in PPE
18	Building sumps, sluice/flush water and supernatant water systems	Collects and confines contaminated water until it is pumped to the supernatant and sluice/flushwater tanks for reuse as sluice/flush water
19	Glove boxes	Reduces worker exposure during sampling of Silos 1 and 2 material from process tanks

Table 3-1. Silos 1 and 2 Remediation Facility Building ALARA Features (continued)

Item	***Location or Item***	***Feature***
20	Locating tank piping flanges outside shield enclosures	Reduces worker exposure during maintenance
21	Pump galleries	Reduces worker exposure by putting pumps and associated equipment in limited access areas separated and shielded from large tanks containing Silos 1 and 2 material
22	Remote-viewing cameras and viewing windows	Reduces worker exposures; facilitate remote operations by providing visual observation/assessment of conditions without entering high contamination areas
23	Remote operation of container filling, weighing, inspection, lid fastening and loading	Reduces worker exposure to penetrating radiation emanating from stabilized product inside container. Facilitates control of contamination
24	Fill loading spout drip pan	Minimizes potential for fill spout to drip and contaminate container surface or surrounding area
25	Vessel vent system	Reduces worker exposure to radon by collecting vent gases from process tanks and equipment and directing them to the RCS for treatment
26	Flush lines for tanks, pumps and valves	Reduces worker exposure; provides means to reduce/remove contamination prior to performing maintenance
27	Mixers/agitators	Keeps solids from accumulating in tank bottoms; keeps materials throughout process mixed so that hot spots are minimized
28	Radiation survey equipment at access control points	Detects contamination, thereby preventing inadvertent tracking of contamination from contaminated areas to clean areas
29	PPE and respiratory protection	Protects workers from exposure to contamination and radon
30	Area radiation monitors and continuous air monitors	Reduces worker exposure to direct radiation and airborne and surface contamination.
31	Gondola railcar supplemental steel shielding (if shipped by rail)	Reduces dose rates adjacent to train during staging and transport
32	Selection of reliable process and mechanical equipment	Minimizes worker exposure to direct radiation, airborne and surface contamination by minimizing the need for non-routine maintenance, repairs and clean-up associated with failed equipment. Facilitates contamination control.
33	Container preparation – Inspection/cleaning and bar coding of incoming empty containers	Reduces worker exposure to direct radiation by eliminating need for workers to be in proximity to filled containers. Minimizes risk of filling a defective container and resultant exposures related to repackaging/repairs.

Table 3-1. Silos 1 and 2 Remediation Facility Building ALARA Features (continued)

Item	***Location or Item***	***Feature***
34	Double-walled pipe for contaminated materials outside the facility boundary	Minimizes the potential for release of material to the environment.

3.2 Personnel Exposures and Administrative Controls

Administrative control levels (ACLs) were used by the Silos Remediation Project to maintain ALARA personnel exposures. The FCP Radiological Control Requirements manual established an annual ACL of 1,000 mrem total effective dose equivalent to an individual in a year. The Silos Remediation Project was initially deemed likely to approach and/or exceed this ACL, but individual exposures were not expected to exceed the USDOE ACL for individuals of 2,000 mrem/yr total effective dose equivalent.

Workers were to be restricted from working in radiologically controlled areas if their individual exposures in any one calendar year neared 1,000 mrem total effective dose equivalent without prior approval. During the Silos 1 and 2 Remediation Project this restriction was never implemented as no single individual was found to approach this ACL.

An extensive ALARA Analysis was performed for the Silos 1 and 2 Remediation Project, with the projected collective external dose estimate from all activities to include operations and maintenance conservatively assigned at 76.218 person-rem. (For expressing the collective dose to a population, the person-Sv and person-rem are the units used. These units represent the product of the average dose per person times the number of people exposed (e.g., 1 Sv to each of 100 persons = 100 person-Sv = 10,000 person-rem]).

A breakdown of the personnel exposure estimates is provided as follows:

- The collective dose projected for the approximate three-year operations and maintenance period of the RCS was conservatively estimated to be 4.178 person-rem (5.5 percent of the project).
- The collective dose projected for the approximate 16-month SWRS operations and maintenance period was conservatively estimated to be 6.726 person-rem (8.8 percent of the project). This includes the exposures from all AWR operations above the silos.
- The collective dose projected for the approximate 16-month operations and maintenance of the TTA was conservatively estimated to be 8.575 person-rem (11.3 percent of the project).
- The collective dose for radiological support activities for the entire 3-year project was conservatively estimated to be 22.408 person-rem (29.4 percent of the project).
- The collective operations and maintenance dose for the 12-month WT&P phase (treatment, packaging and staging) was conservatively estimated to be 33.083 person-rem (43.4 percent of the project).

- The collective dose projected for the approximate 6-month safe shutdown of the TTA, RCS and WT&P facilities was conservatively estimated to be 1.248 person-rem (1.6 percent of the project).

Radiological work and personnel exposures were managed under the Site Radiation Protection Program with project tasks evaluated in accordance with the Radiological Work Permit (RWP) program. RWPs were used for all activities that involved the potential for personnel exposure to ionizing radiation or radioactive material.

The RWP program designated the specific radiological controls, precautions and/or instructions to personnel such as the assigned anti-contamination clothing, respiratory protection requirements, training requirements, and dosimetry (i.e., the absorbed dose in matter and tissue resulting from the exposure to indirectly and directly ionizing radiation) requirements. Additional instructions, based on the activity or task included steps to minimize the spread of contamination, steps to limit radiation exposure to adjacent personnel and provisions for augmented monitoring and surveillance.

Personnel entering areas controlled by RWP's were required to read, understand, sign, and abide by the requirements prescribed on the applicable RWP.

RWPs authorizing individuals to enter areas with elevated dose rates required use of self-reading pocket dosimeters. These devices were read upon exit and allowed for assignment of estimated exposure on daily entry/exit logs which was tracked and monitored on a daily basis. Results were compiled and compared against quarterly readings of personnel thermoluminescent dosimeters to ensure individual and cumulative exposures were understood. During the Silos 1 and 2 Remediation Project there were no anomalous thermoluminescent dosimeters readings and no individual exceeded the project ALARA exposure goals.

3.3 Air Monitoring

The Silos Radiological Control organization produced an air sampling plan which was approved and issued prior to initiation of each phase of the Silos 1 and 2 Remediation Project. The air sampling plan was based on radon and particulate air emission modeling performed for postulated accident scenarios, stack discharges; and operations that involved exposed K-65 materials.

A site-specific predictive calculation methodology, Fernald Radon Model, was used to estimate radon air concentrations at different site locations for various accident release scenarios and the RCS stack discharge and is further discussed in Appendix C. For particulate air emissions, the site utilized the Clean Air Act Assessment Package – 1988 (herein referred to as CAP-88), which is a computer model comprised of a set of computer programs, databases, and associated utility programs for estimation of dose and risk from radionuclide emissions to air. The model, which reasonably fit existing site monitoring data, is described in the Radon Modeling Report for the OU 4 Safety Analysis Plan. The model predicts a radon concentration downwind from a release and allows inclusion of a "lag" term. The "lag" model is more complex and provided a more accurate depiction of radon transport when compared to existing monitoring data. This was because the model accounted for the persistence of radon in the vicinity closest to the release point. The non-lag model was used for accident analyses. The CAP-88 model was based on "F

Class" meteorological stability. A wind speed of 1.8 m/second (4 miles per hour [mph]) was used at 30 m (98 ft) and 330 m (1,083 ft) as a basic assumption for the model. Additionally, a wind speed of 4.5 m/second (10 mph) was used at 100 m (330 ft) which was consistent with USDOE guidance documents. Once radon air concentrations were determined at different receptor locations, the dose consequence was determined.

Short-term air modeling scenarios were also evaluated. For example, prior to demolition of each of the concrete silos, individual headspace radon concentration measurements were taken to derive the radon production rates originating from residual contamination in the inner concrete surfaces. With this data, release rates were calculated and used as input for localized air modeling which was performed using BEE-line ISCST3 "BEEST" Version 8.60 software. Two models were run using 1991 site meteorological data for release heights of 10 m (33 ft) and 40 m (131 ft) to simulate the initial condition of the silo dome being exposed (40 m [131 ft]) and a subsequent lower release point as the silo itself is brought down, sized and packaged for disposition (10 m [33 ft]). Modeling results provided the highest 1 hour Rn-222 concentrations for several hundred meters in all directions surrounding the silos.

Using the results of this modeling, the Silos Radiological Control group was able to develop an air sampling plan, establish radiological boundaries around Silos 1 and 2 Remediation Project areas, and initiate real time radon air sampling to verify the conditions. Radiological monitoring was performed to assess changes in radiological conditions, assess release levels of radon and particulates, prevent the spread of radioactive contamination and limit personnel exposure. This plan included individual sections providing details and/or descriptions for each of the following:

- System or operational activity;
- Expected behavior of the radionuclide(s) (particulate, radon gas or progeny);
- Potential sources of release (valves, pumps, etc);
- Engineering controls (process ventilation system, HVAC, pump seals, flushing, containment, etc.);
- Administrative controls (postings, RWPs, etc.);
- Air sampling equipment and sample analysis;
- Locations for sampling (immediate and adjacent areas); and
- Response and notifications if pre-determined suspect or confirmed elevated concentrations were detected (non-radon daughter particulates, radon gas or progeny) (Figure 3-1).

Response to Suspect Airborne Radioactivity Concentrations per the Air Sampling Plan

A single air sample result is greater than or equal to 1 DAC in a non-posted area or if radon WLs exceed 0.3 WL for a daily average:

- Non-critical work activities will be stopped.
- Notify the AWR Project Manager, Operations Manager, and Site Radiological Control Manager
- Radiological boundaries will be established for the effected area and posted as an Airborne Radioactivity Area.
- Evaluations of adjacent and/or adjoining areas will be initiated.

A single air sample result > 30% DAC but less than the assigned effective DAC or if radon WLs exceed 0.09 WL for a daily average in an un-posted area:

- Promptly take action to limit or mitigate personnel exposures (e.g., prevent or limit occupancy, prescribe respiratory protection, etc.) in the area;
- Evaluate air monitor placement;
- Notify the Operations Manager, AEDO and Site Radiological Control Manager;
- Evaluate prior sampling data for the potential to exceed 12 DAC-hrs in one week (this will require an evaluation of radon concentrations and long lived particulate concentrations combined).

If weekly particulate air sampling results average greater than 2% of the effective DAC in a non-posted area or if radon WLs exceed 0.03 WL on a weekly average;

- Notify the Site Radiological Control Manager.
- Notify Internal Dosimetry for bioassay determinations.

NOTES:

1. The above actions are not intended to establish sequential criteria and may not be all-inclusive. Responsible project personnel such as the Radiological Engineering/Control Manager or Radiological Engineer are most likely to be the first persons to recognize the above conditions (from air sampling data) and should initiate the process prioritizing the actions dictated by the severity of potential worker exposure.
2. All work performed in Airborne Radioactivity Area posted areas was conducted under RWPs and assigned respiratory protection with a Protection Factor of 1,000 with respect to particulate isotopes and radon progeny.

   For example: If air monitoring data indicates concentrations posing a significant potential for worker exposure and one, or all, of the persons to be notified are not available, non critical work should still be stopped and/or exposure mitigation techniques (respiratory protection) implemented.
3. Very few AWR Project operations were conducted in ARAs where the radon concentrations would exceed 10% of the DAC without the use of respiratory protection. In these cases, the selection and use of respiratory protection equipment was designed to prevent internal exposure to radon and its decay products. In cases where the radon concentration was greater than 10% of the DAC and respiratory protection was not required, the concentrations of radon was monitored, stay-times were established, and estimates of worker internal exposure was made where applicable.
4. In all cases, when workers were to breach systems and there was a potential to be exposed to contamination from K-65 materials, they were required (by RWP) to wear full anti-contamination clothing and respiratory protection. Thus, the probability of AWR Project workers being internally contaminated was very low. Nevertheless, AWR Project radiological workers participated in the FCP bioassay program as required. Adequate precautions were taken to maintain internal exposure to workers ALARA. Air monitoring was performed for system breaches and as dictated per the RWP.

Figure 3-1. Response to Suspect Airborne Radioactivity Concentrations per the Air Sampling Plan

With respect to particulate air monitoring, the Silos 1 and 2 Remediation Project deployed pressure-flow regulated air sampling pumps at designated areas within, and adjacent to, project areas and facilities. These air sampling pumps collected particulates on filters from ambient air for specific periods and were then retrieved. The filters were held for approximately three days to allow for radon progeny decay and then counted for gross alpha activity and compared to a project-specific derived air concentration (DAC).

Airborne Radioactivity Areas were posted around locations that exceeded, or were likely to exceed, the DAC values for the applicable radioisotope(s) assigned for the Silos Remediation Project. The DAC levels that applied to the Silo 1 and 2 Remediation Project are presented in Table 3-2.

Table 3-2. Silos 1 and 2 Remediation Project DAC Levels

Applicable Radioisotope	Derived Air Concentration (DAC)
Effective DAC for K-65 Material[1]	2 E-11 microcuries per milliliter (µCi/mL)
DAC for Th-230	3.0E-12 µCi/mL
DAC for Ra-226	3.0E-10 µCi/mL
DAC for Uranium	2.0E-11 µCi/mL
DAC for Radon Progeny (Working-Level [WL] Monitoring)	0.33 WL

[1] The effective DAC for Silos 1 and 2 materials is conservatively based on the assigned isotopic mixture.

Monitoring results during the silos demolition and removal of the contaminated debris did not exceed predicted values of the modeling and did not exceed the radon and/or particulate concentration trigger levels established in the Silos Air Sampling Plan (Figure 3-1). There were no significant concentrations measured or reported within posted airborne radioactivity areas or outside the controlled area.

Throughout the project, skyshine was not a significant issue in worker dose or cumulative worker exposure; the exposure was to direct line of sight source term configurations.

With respect to radon monitoring, the Silos 1 and 2 Remediation Project utilized continuous radon monitors within the project areas and at the perimeters of the project boundaries. These monitors filter out the particulate progeny prior to counting radon gas activity and calculating the concentrations. This information served as a baseline whereupon increases in concentrations could be evaluated against project activities to determine if a release had been initiated or was ongoing. These monitors were valuable in that they recorded radon concentrations on a continuous basis and demonstrated that at no time did the Silos 1 and 2 Remediation Project have any significant radon releases. These instruments can present one minor drawback, in that natural fluctuations of ambient radon concentrations need to be well understood prior to initiation of operational activities, so that significant daily fluctuations and/or gradual cycling (increases and decreases) caused by local temperature inversions or seasonal changes are not attributed to operational activities.

The Silos 1 and 2 Remediation Project also used working-level (WL) monitors, an instrument that draws air through a filter (radon gas passes through) and counts the progeny activity on the filter. This activity is then converted through an internal algorithm to a WL value. These instruments were deployed in areas where personnel were making entry to ensure the concentrations were below the airborne radioactivity concentrations with respect to the inhalation hazard or that the prescribed respiratory protection was appropriate.

Lastly, the Silos 1 and 2 Remediation Project used a portable radon gas monitoring instrument which was easily and rapidly deployable to investigate radon gas concentrations. There were occasions where the placement of the fixed radon or the WL monitors did not provide means to assess concerns relative to specific or differing locations. These portable instruments provided a means to evaluate localized areas and take corrective actions as necessary.

As a result of the Fernald activities, it was learned that movement of the fixed radon monitors can require considerable effort and the availability and use of a portable radon gas instrument is recommended to provide a means to quickly evaluate localized areas and take corrective actions as necessary.

3.4 Personnel Contamination Monitoring Alpha Analyzer

On a daily basis, Silos 1 and 2 Remediation Project personnel were working in areas where low-level radon concentrations and surface contamination required the use of Personal Protective Equipment (PPE), including respiratory protection and anti-contamination clothing. One of the complications associated with these activities was the monitoring of personnel exiting radiologically controlled areas against established thresholds, for the long-lived particulate isotopes of concern (i.e., Ra-226 and Th-230), which are both principally alpha emitters. Selected personnel contamination monitors were calibrated and sensitive to both beta-gamma and alpha contamination but were unable to discriminate short-lived radon progeny activity which has a propensity to collect on clothing or personal articles such as hard hats. The Silos 1 and 2 Remediation Project addressed this issue through use of an Alpha Analyzer (AP-2) instrument.

The AP-2's primary application was to provide radiological control personnel the ability to quickly discriminate Rn-222 short-lived progeny contamination from other isotopes in a field environment. The AP-2 (Photograph 3-1) is a multi-channel analyzer capable of alpha spectrometry measurements. The AP-2 was set up to provide count rate data in several regions of interest for isotope identification and was also capable of displaying the alpha energy spectrum. The AP-2 was well suited for instantaneous analysis of clothing and personnel.

Regions of interest were established for specified alpha energy ranges during calibration by resetting energy discrimination bands. This provided a mechanism for the counting of alpha radiation from radon (Rn-222) short-lived progeny in a different region of interest than that for other alpha radiation emitting radionuclides with differing alpha energies (i.e., Ra-226 and Th-230).

Photograph 3-1. Alpha Analyzer Model AP-2

3.5 Radiological Support of Waste Characterization

The Silos 1 and 2 Remediation Project contracted for development and deployment of in-line Ra-226 Analyzer Systems. There were three identical, but separate, calibrated systems installed in the WT&P facility. Each system consisted of a low-energy Germanium detector, a shielding/collimator assembly, a transmission source and source holder, as well as the necessary hardware and software to operate the system. These systems were used to measure and quantify Ra-226 concentrations and slurry densities, within monitored piping.

The detection system(s) were installed on a diverter loop (piping) for each of the three slurry feed tanks. The shield/collimator/detector assemblies were installed in a controlled area where piping was exposed. Each of the detector assemblies weighed approximately 218 kg (480 lbs) and required structural mounting to support the weight, allowing for the monitored piping to pass through the assembly without being structurally attached. The weight of these assemblies was mostly comprised of the shielding components as they were installed in areas with elevated radiation levels resulting from adjacent and/or associated piping and components. These systems utilized a proprietary refrigerant under approximately 16.9 kg/m^2 (240 $lbs/inch^2$) pressure contained within steel braided hoses connecting the compressor to the cold head located at the detector. The refrigerant compressor and operator hardware/software were maintained at work stations outside the mixer unit rooms, in low-dose rate areas allowing continuous access (Photograph 3-2).

Each detector system contained a cobalt (Co-57) radioactive source emitting gammas at 122 keV, which were used in conjunction with the Ra-226 (187 keV) gamma signature to produce both a slurry density and a Ra-226 concentration value through algorithms embedded in the software. Data obtained by this system was continuously transmitted to the control room for input and/or use during final grout formulations. This system was highly reliable, accurate, and provided real time information, greatly reducing the time constraints associated with sampling and laboratory analysis which would otherwise be required prior to the slurry being diverted to the mixing tanks. Subsequent sampling and analysis was performed by the laboratory, for comparative calibration analysis and/or verification of the final waste concentrations and never identified this system as being outside the accepted quality ranges.

Photograph 3-2. Computer Software and Calibration Work Station

3.6 Radiological Release and Staging of Containers

During the Silos 1 and 2 Remediation Project, several activities related to the radiological release and staging of the containers on trailers awaiting transport from the site, accounted for a major portion of the overall accumulated personnel exposure for the project.

The removal of the K-65 waste from the silos, storage in the temporary tank area, transfer to the waste treatment facility, final waste preparation, and container filling operations were all conducted through use of slurry pipe and vessel confinement, under positive ventilation controls and extensive shielding of areas where significant quantities of the waste produced elevated dose rates. These engineering and design controls were very effective and maintained personnel isolation from areas of elevated dose rates up until the time that filled containers were produced and required more contact or exposure time by project personnel.

Remote operations related to the placement and securing of the containers on transport trailers through use of overhead cranes and forklifts did provide a means to reduce personnel exposure; however, there were several aspects of these operations that could not be effectively performed remotely.

Final waste containers were required to meet a surface contamination release criteria of 20 disintegrations per minute per 100 square centimeters alpha (20 dpm/100 cm^2), based on the Ra-226 and Th-230 radionuclides. This surface contamination release criteria is well below DOT criteria, but was driven by the fact that the containers and transports were retained on site in a staging area prior to final release. In order to meet the criteria, waste operations personnel were required to perform a surface wipe down (decontamination) of all containers after lidding and removal from the filling rooms. After the container wipe down, radiological control technicians performed surface swipes on the container and either directed an additional wipe down or authorized the release of the container from the staging areas, to the trailer loading area. These operations were evaluated and optimized by use of long-handled tools but in all cases did require some close contact with the containers. This inevitably led to personnel exposure, as the filled containers ranged up to 80 mrem/hr contact and there were approximately 3,800 containers produced by the project.

Another contributor to personnel exposure was related to the staging, handling and final DOT surveys performed prior to leaving the site. This operational aspect was a result of the final product process which involved the mixing of stabilization components (K-65, fly ash and cement) which resulted in an increased radon emanation from the product. The radon was removed by the vessel ventilation system. Hence depending on factors such as the Rn-222 equilibrium state to the Ra-226 entering the mixer and the mixing time removing off-gassed radon, the final product was effectively not at its natural radionuclide state. It was anticipated that the container dose rates would increase from the time of production up until the time the radon ingrowth approached equilibrium. This condition was recognized early in the project design phase and was verified once operations began. In order to address the radon ingrowth and to ensure transportation surveys verified that the final trailer dose rates were in compliance with DOT requirements, the filled containers were staged in a radiologically controlled transportation yard for up to approximately five days prior to performing the final dose rate surveys and release from the site.

In addition to the elevated dose rates in the immediate controlled areas of the transportation staging yard, the array of trailers and containers resulted in elevated dose rates above natural background at significant distances from the yard. This required that the work area boundaries where non-radiological workers or members of the public could access (on the Fernald Site properties) be expanded. General area dose rates in the trailer staging area ranged between 5-10 mrem/hr with contact dose rates on individual containers at approximately 80 mrem/hr. Boundaries for exclusion of the public and non-radiological workers were established at approximately 137-183 m (150-200 yard [yd]) from the staging area. One additional action that resulted from this situation involved the construction of an earthen berm approximately 91 m (100 yd) long, at a specified distance from the staging yard to ensure ground level dose rates were shielded to background levels.

3.7 Radiological Support of Waste Container Design and Transport

In the early stage of the Silos 1 and 2 Remediation Project, the Ra-226 final waste concentrations were evaluated and identified. This provided a means by which radiological engineering could assist in the container and transport design, ensuring DOT requirements were met. These reviews ultimately resulted in a final waste container design of specific dimensions compatible with the WT&P facility container handling and filling components. The final Ra-226 concentrations in the waste containers were targeted at 80,000 pCi/g. During operations, the wastes in Silos 1 and 2 were homogenized as they were transferred to the Temporary Storage Tanks, and the waste was mixed with flyash or cement to reach the targeted concentration for the waste containers. During process design, the Ra-226 95% UCL as noted in Table 2-2, was used to estimate the necessary mix and to establish radiological controls. The Radium Analyzer discussed in Section 3.5 provided real-time radium concentrations and material density during operations; these measurements were within design parameters and no adjustment to the process was required. Final container design/configuration was developed to meet achievable waste loading and comply with DOT shipping requirements, while being compatible with WAC.

There were multiple issues that required evaluation - one of which included a concern related to whether transporting two containers weighing approximately 10,000 kg (22,000 lbs) each could be accomplished without exceeding the 36,287 kg (80,000 lbs) gross vehicular weight limit for a legal weight shipment. A prototype trailer was fabricated, using as much aluminum as possible in the design, which weighed approximately 5,000 kg (11,000 lbs) (Photograph 3-3). Including 20,000 kg (44,000 lbs) for the weight of the two containers plus 900-1,360 kg (2,000-3,000 lbs) for tiedowns and the weight of the tractor, it was found that the gross vehicular weight would be maintained below the maximum allowed.

Photograph 3-3. Prototype of the Containers, Trailer, and Tiedown System

The container tiedowns were designed to safely secure the containers during transport, but were designed also to be quickly installed and removed. A tiedown assembly consisted of a "cap" with four cables attached and ratchet binders on the ends of the cables. With the containers in place inside chocks on the trailer bed, the cap was placed on the container using a crane or forklift, the loose ends of the cables secured to lugs on the trailer and the cables tightened with the ratchet binders.

Another issue was related to the DOT dose rate limitations of 2 mrem/hr in the transport cab and 10 mrem/hr at 2 m (6.6 ft) from the vertical plane of the transport. Once the Ra-226 waste loading and container dimensions were identified, this issue was resolved by calculational methods determining the spacing requirements between the two containers. This method of analysis ensured the forward container did not result in >2 mrem/hr in the cab, the aft container did not exceed 10 mrem/hr at 2 m (6.6 ft) behind the vertical plane and that dose rates 2 m (6.6 ft) of the vertical planes of the trailer sides did not exceed 10 mrem/hr from the combined effect of the two containers.

All of the transport trailers prepared and shipped from Fernald were verified by the Silos Radiological Control group and the State of Ohio and were found to meet DOT requirements before leaving the site. The first shipment to leave the Fernald Site is presented in Photograph 3-4.

Photograph 3-4. Transport Shipment Leaving Fernald

3.8 Radiological Impact to Public and Environment

Throughout the entirety of the project, the USDOE maintained and monitored the site boundary for airborne and particulate concentrations and issued annual reports with respect to environmental limits and requirements. A summary of the site-wide environmental monitoring program including media sampled, frequency, and analytical parameters is provided below. During the operations, there were no reported concentrations in excess of applicable limits. The Fernald Site Environmental Group Annual Site Environmental Reports are available for all relevant years at the website: http://www.lm.doe.gov/Fernald/reports

Three types of air monitoring were conducted under Fernald's Integrated Environmental Monitoring Program to address elevated direct penetrating radiation in the vicinity of the K-65 Silos and the emission of radon to the atmosphere. They include: radiological air particulate monitoring, radon monitoring, and direct radiation monitoring. Based on the large volume of K-65 material present at the NFSS, these three types of air monitoring may be appropriate at the NFSS. During potential remediation of the IWCS they would support assessment of the effectiveness of emission control practices during remediation and would help to ensure particulate emissions and radon levels remain below health protective standards. In addition, the data could be evaluated to identify any increasing trends that may be related to remediation activities. Some of the relevant features of the air monitoring program associated with the K-65 Silos at the Fernald Site are noted below.

The radiological air particulate monitoring conducted in support of restoration projects at the Fernald Site (including the Silos 1 and 2 Remediation Project) involved establishment of a network of high-volume air particulate monitoring stations located along the fenceline to allow measurement of the collective contributions from all fugitive and point source particulate emissions from the Fernald Site (USDOE 2005a). The air particulate analyses include biweekly total uranium and total particulates, and composites (eight times per year) for isotopic thorium, in addition to a quarterly composite sample analyzed for the expected major contributors (i.e., uranium, thorium, and radium) to the radiological air inhalation dose at the site's boundary. The quarterly results verified compliance with the National Emission Standards for Hazardous Air Pollutants 10-mrem dose limit. In addition, one fenceline thorium monitor was used to provide biweekly particulate and monthly isotopic thorium analyses. Total particulate, total uranium, and Th-230 data were collectively evaluated to identify any increasing trends that could be related to remediation activities. During remediation activities at the K-65 silos, there were no reported concentrations in excess of the applicable limits (the USDOE derived concentration guide value of 0.1 picocuries per cubic meter [pCi/m^3]) for radiological dose at the Fernald boundary (USDOE 2006a).

Continuous (real-time) radon monitoring was conducted at locations near the K-65 silos and along the property fenceline. The continuous radon monitors use scintillation cells to continuously monitor environmental radon concentrations based on an hourly average. A RCS was constructed to minimize radon concentrations in the headspaces of Silos 1 and 2, thereby minimizing radon emissions and worker exposure during construction of the remaining AWR facilities. Radon concentrations within the headspace of K-65 Silos 1 and 2 were continuously monitored to assess the effectiveness of the control measures in reducing radon emissions (USDOE 2006a). Long-term comparisons were performed on average radon concentrations recorded at the K-65 silos exclusion fence locations. Historical alpha track-etch and continuous alpha scintillation detector data were used for this comparison. There were no exceedances of the radon limits defined under USDOE Order 5400.5 (3 picocuries per liter [pCi/L] annual average above background at the site fenceline and off-property locations) (USDOE 1993b). A continuous radon monitoring network provides frequent feedback to remediation project workers, regulatory agencies, and stakeholders on trends in ambient radon concentrations, and also provides sufficient radon monitoring data to ensure compliance with applicable requirements. Therefore, a similar radon monitoring program (with the exception of the headspace monitoring), may be appropriate for the NFSS. However, the use of the continuous monitors is restricted by certain conditions. For example, potential monitoring sites are limited by the availability of electricity (USDOE 2005a).

Direct radiation (e.g., x-rays, gamma rays, energetic beta particles, and neutrons) originated from the material stored in K-65 Silos 1 and 2. Gamma rays and x-rays were the dominant types of radiation emitted from the silos. To monitor this exposure route, direct radiation levels were continuously measured with thermoluminescent dosimeters at the site fenceline and the K-65 silos boundary (37 locations on and off the Fernald property). The monitoring results were compared to historical results to identify trends.

In addition to the air monitoring described above, monitoring of surface water and sediment was conducted at the Fernald Site to fulfill both surveillance and compliance monitoring functions. Surface water samples were collected at several locations in drainages within the Fernald Site and at two background locations. Surface water was sampled semi-annually and analyzed for various radiological and non-radiological constituents. Sediment was sampled annually for radiological constituents in the major site drainages and in the Great Miami River. The surface water monitoring results were used to assess the collective effectiveness of site storm water controls and wastewater treatment processes in preventing unacceptable impacts from remediation activities to the surface water and groundwater pathways. Compliance monitoring included sampling at storm water and treated effluent discharge points into the surface water, and results were compared to the provisions of the National Pollutant Discharge Elimination System Permit. The data were also evaluated to identify any unacceptable trends.

Table 3-3. Lessons Learned Summary

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
3.3	Air monitoring for radon	• Movement of fixed radon monitors requires considerable effort.	• Monitoring program supplemented with portable radon gas monitors	• Rapid evaluation of localized areas made easier, supporting development of corrective actions
Lessons Learned: *Portable gas monitors should be considered for use in the air monitoring system during remediation effort at IWCS remediation. Provides flexible system design and enhances ability to adapt to changing conditions during remedial activities.*				
3.5	Integrated radiological monitoring system	• Waste treatment and packaging required measurement and quantification of Ra-226 concentrations and slurry densities. Collection of samples for laboratory analysis would interrupt operations and increase potential personnel exposures	• In-line Ra-226 Analyzer Systems were developed and installed on a diverter loop (piping) for each of the three slurry feed tanks	• Continuous measurements were available with minimal exposure to workers and without process interruption for laboratory analysis.
Lessons Learned: *The integration of radiological monitoring systems with process operations may minimize down time and worker exposures during IWCS remedial activities. Integrated monitoring systems may apply to numerous process components during the life of the project.*				

4. LESSONS LEARNED FROM OTHER FERNALD REMEDIAL ACTIONS

While a primary objective of this report was to provide lessons learned from the successful disposition of Fernald K-65 residues and potential applicability to NFSS, there were several other successful projects completed at the Fernald Site which were evaluated for lessons learned and potential applicability at NFSS. The following sections provide a brief narrative description of those projects and their potential applicability.

4.1 Feasibility of Radium Recovery

Radiotherapy research (beginning in 1995) included efforts to test a new methodology that links a radium-based isotope, bismuth-213, to attempts to cure cancer with a radium-based monoclonal antibody (Environmental Health Perspectives 1995). This discussion provides information on the status of the evaluation of use of the K-65 residues at the Fernald Site for resource recovery which will also provide information for use during the IWCS FS evaluation for K-65 residues at NFSS.

Fernald did not evaluate the potential recovery of Ra-226 from the K-65 residues during the FS for OU 4 (USDOE 1994b) or the Revised FS (USDOE 2000b) activities. There is indication that radium recovery was addressed in a Value Engineering Study as noted "*Future recovery of radium as medical resource from a grout matrix would be much more readily accomplished than from a fused matrix*" (USDOE 1996a).

The Fernald Revised FS for the OU 4 Silos 1 and 2 Remedial Action was released for public comment in April 2000. Formal comments submitted during the public comment period included a comment stating USDOE should consider potential medical benefits of utilizing the radium-bearing K-65 material stored within Silos 1 and 2 (USDOE 2000a). As stated in the Fernald Summary of Responses to Public Comments in the June 2000 ROD, the USDOE made a decision to move forward with the implementation of chemical stabilization technology for the remediation of Silos 1 and 2 K-65 material (USDOE 2000a). The USDOE cited several significant issues related to the feasibility for recovery of the Ra-226; determining if Ra-226 can be separated from the K-65 material in a medically usable form; identifying the risk to workers, public, and environment posed by the recovery of Ra-226; and quantifying the costs for the recovery of Ra-226 as well as the uncertainty associated with the actual future need for Ra-226 (USDOE 2000a). Radium extraction at the Fernald Site was estimated at a cost of $5 million to $6 million, not including additional costs to refine and purify the radium to be used as a medical therapy (Environmental Health Perspectives 1995).

In the 1994 ROD for OU 4, it was stated that the "*the reprocessing of silo wastes to recover radiological or inorganic constituents was determined not to be feasible due to poor treatability test results involving chemical separation techniques*" (USDOE 1994a).

An alternative approach for recovery is to select the disposal technology so that the material may be recovered in the future. This mitigates technological limitations on segregation of the material and long-term market fluctuations. However, this option was not exercised at the Fernald Site because of the cost impact of selecting a retrievable site disposal and because a retrievable form of Ra-226 would present elevated risk of release.

The feasibility of recovering radium for medical purposes or as precious metals for cost recovery will be evaluated in the IWCS FS based on economic conditions at the time.

4.2 Silo 3 Project

The Silo 3 Project involved the retrieval of radioactive cold metal oxides (i.e., residues consist of the metallic and non-metallic impurities that remained following the extraction of uranium from ore and ore concentrates) stored in a free-standing, post-tensioned, concrete-domed silo approximately 24 m (80 ft) in diameter and 100 m (33 ft) in height prior to treatment and disposal in accordance with the OU 4 ROD and subsequent ROD amendments.

Silo 3 was constructed in 1952 for the transfer and storage of uranium processing byproduct material. The materials contained in Silo 3 consist of relatively dry, powder-like residues that were placed in the silo over the time period 1954 to 1957. The residues consist of the metallic and non-metallic impurities that remained following the extraction of uranium from ore and ore concentrates in Fernald's refinery operations during the mid-1950s. Following solvent extraction processing for uranium, the residues were prepared for storage following a volume reduction and concentration step known as calcining. These concentrates underwent high temperature processing at a temperature of 650°C (1200°F) to 820°C (1500°F) or a spray calciner operated at a temperature of 510°C (950°F) to further remove liquids. After calcining, the finely-powdered, dried metal oxides were pneumatically conveyed by pipeline to Silo 3 for longer term interim storage as part of USDOE's ongoing custodial responsibility for the materials (USDOE 2003a). Transfers began in 1952 and ceased in 1957.

Although both the Silos 1 and 2 and the Silo 3 materials share similar uranium processing origins and the same regulatory status, the Silo 3 residues have different engineering properties and are radiologically different from the Silos 1 and 2 K-65 residues. As "cold" residues (a term of engineering convenience used to reflect the residual radium-bearing content of the residues), the Silo 3 materials have a much lower radium content than the K-65 materials, and therefore Silo 3 exhibits a much lower direct radiation field and has a substantially lower Rn-222 emanation rate compared to Silos 1 and 2. The K-65 materials in Silos 1 and 2 were moisture rich, silty, and clay-like materials, whereas the Silo 3 materials were dry and powdery. Ambient moisture contents for the materials in Silo 3 ranged from 3 to 10 wt%, which reflect their dry condition (USDOE 2003a).

The difference in engineering properties for Silo 3 affected the success of material recovery methods, as described below.

4.2.1 Pneumatic Retrieval System

Due to the powder-like character of Silo 3 cold metal oxide residues, the selected remedy for the Silo 3 remediation utilized a pneumatic removal process to transport Silo 3 contents to the material processing facility. The pneumatic removal system consisted of a compressed air driven pump that displaces and removes the dry wastes. Air entrained in the cold metal oxides, suctioned from Silo 3, was separated using filter/receiver systems allowing the cold metal oxides to be pneumatically "pushed" to the vitrification facility (USDOE 1994a).

The system was able to handle material of varying consistency including clumping and small chunks of agglomerated residue. The pneumatic retrieval system utilized wands inserted from the top of the silo at various locations. The entrained material was transported to a pneumatic retrieval collector, where screw conveyors and rotary feeders transferred the waste to one of two packaging stations. The waste was then dropped into a lined, soft-sided container. The 2.7-m^3 (96-ft^3) bag was a sturdy, soft-sided container, which met the transportation requirements for an IP-2 package.

The primary advantage of this operation is the fact that it did not require construction of a superstructure over Silo 3 or dome segment removal. This avoided lifts of heavy equipment over the dome and eliminated the need for personnel to spend significant amounts of time over the dome performing operations and maintenance in an area with significant external dose.

Additionally, the pneumatic system could access the material through the silo wall without penetrating the radon-containing dome headspace (USDOE 1996b). This advantage is not pertinent to the NFSS because there is no headspace at the IWCS.

4.2.2 Mechanical Retrieval System

When sufficient material was removed from the silo to expose the inside of the silo wall, an opening was cut into the exposed wall of the silo enabling insertion and use of a mechanical excavator. The remotely-operated excavator entered the silo and dug into the waste pile. The auger utilized a specially constructed 15-cm (6-inch) diameter screw conveyor. The screw conveyor was cantilevered 1.2 m (4 ft) into the silo with more than half of its section exposed to the material. The cantilevered section of the auger had teeth to help erode any residue which might have become compacted or hardened. According to the 1996 Conceptual Design Plan for the silo residues, it was anticipated that localized areas of agglomerized residue may exist within Silo 3 at the residue surface or along the silo walls due to the infiltration of moisture (USDOE 1996b).

Removed material was placed into a below-grade bin and moved from there to the packaging stations by four conveyors. The last of the screw-type conveyors was common to the pneumatic retrieval system and also transferred the material to soft-sided containers. Final cleanup of the Silo 3 interior was conducted by manned entry using the pneumatic retrieval process equipment as available.

The primary limitations on the effectiveness of removal systems are the limited production rates for the pneumatic retrieval when pumping materials with high moisture contents. This process option is more amenable to dry material (USDOE 1994b). Use of the pneumatic removal system for the retrieval of Fernald Silos 1 and 2 materials was not implemented due to the reduced effectiveness on materials with a high moisture content (USDOE 1994b). The remotely operated excavator should be considered as a potentially viable option for removal technologies for NFSS.

4.3 Waste Pits Remedial Action Project

OU 1 Waste Pits Remedial Action Project was a 115-ha (37-acre) area encompassing several waste pits located in the northwest portion of the Fernald Site. Beginning in 1952, the waste pits were constructed to store slurried or dry residues resulting from various stages of uranium processing. Over a 37-year period, these wastes were stored or disposed of in six waste pits, the burn pit, and the clearwell. Waste pits varied in size, ranging from 0.2 to 2 ha (0.5 to 5 acres) and varied in depth from approximately 3.7 to 13 m (12 to 42 ft). The waste pits were estimated to contain approximately 450,000 m^3 (600,000 yd^3) of waste material.

The Waste Pits Remedial Action Project involved the removal, thermal treatment (drying) and off-site disposal of the contaminated waste pit materials and soil. This project entailed the construction of structures, including the material handling building, the railcar loadout facility, the railcar preparation and liner storage area, a maintenance area, warehouse buildings, as well as the dryers and their associated gas cleaning and wastewater treatment systems.

Radioactive waste, caps and liners which had been placed over the waste and the excavated surrounding contaminated soil were prepared for shipment through sorting, crushing, shredding and thermal drying to ensure the waste met the moisture content WAC for the off-site disposal facility. Once sampling and analysis of the material confirmed it was WAC compliant, the waste was loaded into rail cars and shipped off-site.

The thermal treatment system included the following features:

- Two indirect natural gas-fired rotary kiln dryers, with a total evaporative capacity of 8 tons of water/hr, firing up to 50 million British Thermal Unit (i.e., BTU) per hour, and a nominal combined sludge/waste feed rate of 20 tons/hr. Each dryer had its own automated infeed and outfeed systems.
- A single gas cleaning system to treat the combined off-gas stream from both dryers. It included wet scrubbing of the particulates in the off-gas, subcooling of the condensate, electrostatic precipitation of the fine particulate, high efficiency particulate air filtration of the exhaust gas stream, and final thermal oxidation polishing of the discharge stream. Real-time isokinetic sampling of the exhaust stack discharge stream included measurements for Rn-222 and radionuclides, as well as process monitoring parameters (oxygen, carbon monoxide, and hydrocarbon emissions), to verify compliance with project requirements.
- A water treatment system to treat the blowdown from the wet scrubber and condenser, with a nominal capacity of 200 gpm. Treatment included metals precipitation, suspended solids removal, and uranium absorption with resin beds. The treated water was sent to the site wastewater treatment facility for final polishing and discharge.

The thermal drying process associated with the waste pits at the Fernald Site has limited applicability to the IWCS due to the probable difference in moisture content in the non-residue wastes. The waste pits at the Fernald Site were open to the environment for some time without a cover, thus a significant amount of water was present in the pits. The NFSS waste consists of soils and other debris brought to the IWCS; the wastes were capped shortly after placement. If pockets of waste within the IWCS exhibit elevated moisture content, then the moisture content could be reduced by adding an absorbent or other low moisture level waste. This method should be sufficient to meet WAC requirements.

The use of thermal drying might be more appropriate for evaluation as part of the NFSS BOP FS because the BOP OU soils are more likely to require conditioning.

4.4 Soil Remediation Project

OU 2 consisted of multiple waste units: the active and inactive fly ash piles, the south field disposal area, north and south lime sludge ponds, the solid waste landfill berms, liners, and affected soil.

While the majority of these areas were not anticipated or characterized as having any significant radiological contamination, the south field (which was reportedly used as a burial site for non-process wastes such as fly ash) was discovered during remediation to contain uranium product, old drums, and contaminated transite. These discoveries were not fully anticipated and required implementation of radiological controls and requisite PPE needs, excavation approaches, and waste handling/disposal practices.

Remediation of these areas involved large scale excavations, with environmental controls implemented during each phase of the project. Storm water collection basins were constructed and fugitive dust controls were implemented during excavation and loading of material into dump trucks. During the actual transfer to the OSDF, haul trucks were covered by dust screens, speed restrictions were placed on the trucks and a wheel-wash facility was constructed. A dedicated haul road was constructed and placed under routine monitoring and cleaning.

Construction of dedicated haul roads, haul truck wheel washing, and segregated storage areas for the haul trucks should be considered at NFSS for excavation, handling and transfer of low-level contaminated soil.

4.5 On-Site Disposal Facility Project

The OSDF is an engineered above-grade waste disposal facility that was constructed for permanent disposal of LLRW and treated mixed LLRW generated from soil remediation and D&D activities at OU 2, OU 3, and OU 5 on the site. It is located in the northeastern corner of the Fernald Site and occupies approximately 28 ha (70 acres). It was designed to store 2.24 million m^3 (2.93 million yd^3) of waste in eight cells and was intended to isolate the material from the environment for 1,000 years. Construction of the OSDF began in 1997 and placement of materials was completed in April 2006.

Approval of the special waiver that allowed the OSDF to be sited at the Fernald Site was a result of a combined effort by a range of stakeholders including, USDOE, prime subcontractor employees, local citizen groups, and regulatory agencies. This effort is described at a programmatic level in Section 5.1.3.

4.5.1 On-Site Disposal Facility Design Features

The disposal facility had several key design features provided to be protective of human health and the environment and to assure that long-term performance would meet regulatory requirements. Each of the eight individual disposal cells shared the following design features.

- A height of 20 m (65 ft) and lateral dimensions of 122 m (400 ft) length by 213 m (700 ft) width;
- An individual leachate collection and leak detection system;
- A multi-layered liner system integrated with leachate collection and leak detection systems; and
- A multi-layered cap containing environmental protection, erosion control and intrusion prevention components.

Each cell in the OSDF was lined with a 1.5-m (5-ft) thick multi-layer double liner system consisting of clay liner, primary and secondary composite geosynthetic liners, leak detection system, and leachate collection system. Leachate is collected at valve houses and conveyed to the on-site wastewater treatment facility for processing. After each cell was filled to capacity, it was covered with a 2.7-m (8.75-ft) thick final cover system that consisted of a clay liner, geosynthetic liner, drainage layer, biointrusion layer, vegetative layer, topsoil, erosion mat and vegetation.

4.5.2 On-Site Disposal Facility ARARs and Permitting

The OU 2, OU 3, and OU 5 RODs established on-site disposal as the selected remedy and established the ARARs for the remediation. A permitting plan was developed to account for all waste that was to be disposed in the OSDF from these three OUs. ARARs for these three OUs are consistent with each other; the only variations are based on different waste types that were to be generated during the remediation. The remedial actions performed at the Fernald Site were regulated under CERLA, as amended. Section 121(e)(1) of CERCLA states that no Federal, state, or local permit shall be required for the portion of any removal or remedial action conducted entirely on site, where such remedial action is selected and carried out in compliance with Section 121. While an on-site action is exempted from complying with the administrative requirements associated with a permit, it is not exempt from complying with the promulgated substantive requirements that would have been imposed by the permit.

Four permitting activities applied to the OSDF: National Pollutant Discharge Elimination System Permit, Wetlands Nationwide Permit, RCRA Permit, and Ohio Solid Waste Permit to Install. A permitting plan was developed to identify the administrative and substantive requirements for these four permits. In addition, two waivers were granted to allow the facility to be cited at the Fernald Site.

The State of Ohio granted a special waiver from State Solid Waste Disposal Regulations to allow the OSDF to be sited on the Fernald Site; however, Ohio EPA in return required certain restrictions on disposal of RCRA characteristic waste in the OSDF. These restrictions were related primarily to constraints on disposal of such wastes with concentrations beyond the numerical WAC limits established for the facility and included in the final RODs for OUs 2, 3, and 5. These RODs acknowledged that EPA’s corrective action management unit rule was an ARAR for the Fernald on-site disposal remedy that provided the regulatory framework for determining the treatment and on-site disposal requirements for RCRA-regulated constituents in the materials destined for on-site disposal. The corrective action management rule provided needed relief for on-site disposal from strict RCRA Subtitle C disposal requirements, including land disposal restrictions and minimum technology requirements.

A CERCLA ARAR waiver from an Ohio solid waste disposal facility siting criteria was granted in the OU 2, OU 3, and OU 5 RODs. This waiver allowed construction of the OSDF over a high-yield, sole-source aquifer although it is prohibited in the Ohio Solid Waste Disposal Regulations. This waiver was based on the condition that the OSDF be located in the area of the FEMP which exhibits the best hydrogeologic conditions to ensure protection of human health and the environment (USDOE 1997a).

4.5.3 Modeling Studies

Modeling studies were utilized as one of the steps in the process to establish OSDF WAC. A first step in the process considered all 93 of the soil and groundwater constituents at the Fernald Site and determined, based on their expected fate following placement in the OSDF, which constituents required a numerical WAC limit. The modeling conducted to make this determination was a conservative approach that considered the following:

- An OSDF performance period of 1,000 years;
- The hydraulic and geochemical barrier properties of the OSDF engineered earthen liners and caps;
- The persistence and mobility characteristics of the constituents placed in the facility;
- The hydraulic and geochemical properties of the grey clay layer present within the glacial overburden beneath the OSDF; and
- The potential for cumulative impacts to the Great Miami Aquifer across the width of the OSDF extending to its down-gradient edge.

The results of the modeling demonstrated that numerical limits were required for 12 of the 93 constituents of concern due to their potential to impact groundwater. RCRA compliance requirements were addressed by performing fate and transport modeling for 27 additional RCRA-regulated constituents known to have been managed in the Fernald hazardous waste management units. The results of the modeling indicated that numerical WAC limits were necessary for 6 of the 27 RCRA constituents of concern, bringing the total number of constituents requiring a numerical WAC limit for soil to 18.

The approach for determining WAC for debris and ancillary wastes was based on the OU 5 soil WAC development modeling adjusted for application to debris-specific materials. The debris WAC determined from this modeling was established in the issue of the OU 3 ROD. WAC modeling was not conducted for the ancillary remediation waste streams as these wastes were determined for the most part to be either soil-like or debris-like in nature. The WAC development for this waste type instead relied on the extensive modeling conducted for the soil to support the OU 5 ROD or for the debris to support the OU 3 ROD.

4.5.4 On-Site Disposal Facility Construction

The OSDF Project Phase 1 construction activities involved several different areas of the Fernald Site. The construction scope included the Impacted Material Haul Road, installation of over two miles of leachate piping, relocating approximately a mile of the Site North Entrance Road, installing erosion and sediment controls, and constructing Cell 1 for the OSDF.

Several of the construction activities were executed in parallel to maintain schedule based on completion during the most favorable timeframe for construction. Clearing and grubbing activity for the Cell 1 footprint began in June 1997 and excavation on the cell began in July. Work on the former North Entrance Road started in July 1997. Excavated soil was inspected and segregated during excavation based on determinations of its usefulness for construction of the cell berms or the clay liner. This material was taken directly from the excavation to the areas of the berms undergoing construction or to stockpile areas for further testing of physical properties to confirm suitability for use as the compacted clay liner.

Initially clay liner placement progressed more slowly than anticipated due to the overabundance of rock found in the clay liner soil material which was being removed by hand. Additionally, field construction quality control testing of the clay liner material indicated that significant numbers of field tests were producing unsatisfactory results due primarily to moisture content and compaction requirements needed to reach the Acceptable Permeability Zone as determined from the test pad results. These issues were addressed by bringing three screening plants on site to screen the clay soil. It was found that the soil screening not only removed the rock and other unwanted materials from the clay but also made the clay more workable during construction.

Once clay liner construction was completed, installation of the secondary geosynthetic layers was initiated in October 1997. This was late in the construction season and impacts to construction progress were experienced, primarily due to problems with fusion welding of the membrane materials and a delayed start of liner installation which had to await conformance test results. Completion of the top protective soil layer was delayed until the spring of 1998 due to the late completion of the liner sub-layer components.

These construction planning issues apply to effective use of the available construction season. They might be used to improve planning for on-site construction of the long-term remedy at NFSS.

Two significant issues arose with the regulatory bodies during the Cell 1 construction phase of the project. They were related to the need to provide the regulators with updated project schedules that identified all required project/construction activities with times required to implement the activities and defining the process for addressing design change notices. Once these items were addressed and corrective actions taken interactions on later phases of the project were much improved. These types of interfaces and requirements for information transfer between the NFSS Project Team and the regulators should also be made a part of the planning process for on-site disposal cell design and construction.

A more complete and detailed listing of lessons learned during the Fernald OSDF Phase 1 construction has been compiled by USDOE in the document "*Lessons Learned Associated with Phase 1 Construction of Cell 1 at the On-Site Disposal Facility*" (USDOE 1998b). This listing of lessons learned will be beneficial to the NFSS Project Team as well during the further development of the IWCS FS and BOP FS and during the planning phase of the on-site disposal cell should it be a part of the selected remedy for NFSS.

4.5.5 On-Site Disposal Facility Waste Acceptance Criteria

Waste materials that were approved for on-site disposal in the OSDF were divided into three categories:

- Soil and soil-like material;
- Facility D&D debris; and
- Ancillary remediation waste.

Soil and soil-like material made up the majority (by volume) of the waste disposed of in the OSDF. Facility D&D debris consisted of both above-grade and at- and below- grade debris. Ancillary remediation waste consisted of waste streams that did not lend themselves to general WAC attainment and required evaluation on a case-by-case basis.

4.5.5.1 Excluded Materials

The RODs for all five OUs identified materials and waste streams excluded from disposal in the OSDF due to levels of contamination or agreements with EPA and the Ohio EPA. Other materials were excluded from disposal based on engineering design standards, facility integrity considerations or Ohio EPA regulations. Those materials excluded from on-site disposal by the RODs included:

- The contents of Silos 1, 2**,** and 3 from OU 4.
- Concrete from OU 4 Silos 1 and 2 that exhibits highly-elevated direct radiation fields. (Note: A definitive threshold criterion for identifying the affected concrete was established as part of Remedial Design for OU 4.)
- Waste pit contents from OU 1, including any debris found within the waste pits.
- Waste pit covers and liners from OU 1.
- Off-site waste that was not generated as a direct result of Fernald remediation (i.e., Fernald analytical residual waste from off-site laboratories was permitted).
- Lead bullets from the South Field Firing Range and the associated soil identified as RCRA characteristic.
- Process-related metals (i.e., piping and equipment that did not pass visual inspection) as defined in the OU 3 ROD.
- Product, residues, and other special materials (e.g., uranium and thorium inventories) as defined in the OU 3 ROD.
- Acid brick generated from OU 3 facility D&D activities.
- Material exceeding any of the radiological/chemical WAC.
- Materials containing free liquids.
- Used oils.

- Whole or shredded scrap tires (those specific types of tires defined by Ohio EPA).

Additional materials were restricted from OSDF disposal if they could not meet the restricting requirements permitting disposal. Restricted items included:

- RCRA toxicity characteristic soil from the six geographic areas designated in the
- OU 5 ROD, unless it has been treated.
- Lead sheeting from facility D&D activities within the boundaries of OU 3 unless it has been treated.
- Pressurizable gas cylinders (i.e., gas cylinders that are still mechanically able to be pressurized).
- Intact drums (i.e., they must be empty and crushed).
- Transformers that have not been crushed nor had their void spaces filled with grout, or another acceptable material. Used oil must be drained from all transformers.

The following four requirements were applicable to all waste streams destined for disposal in the OSDF**.**

- Materials above the chemical WAC were treated to meet the WAC or sent off site for disposal.
- Material not meeting the physical WAC must be size reduced or repackaged to meet the WAC or sent for off-site disposal.
- Planned blending (i.e., dilution) is not to be used to satisfy the WAC.
- The radiological/chemical WAC represent maximum values, rather than average values. Where measurement data are obtained to characterize eligible waste streams for WAC attainment, the planned averaging of known above-WAC measurements with known below-WAC measurements is not acceptable for attainment demonstration.

4.5.5.2 Soil and Debris Waste Acceptance Criteria

The radiological criteria for soil and debris differed, while debris did not have any chemical WAC associated with it. Similarly, soil did not have any physical WAC.

4.5.5.2.1 Radiological/Chemical Waste Acceptance Criteria for Soil.

The radiological and chemical WAC for soil are presented in Table 4-1.

Table 4-1. Soil Radiological/Chemical WAC for OSDF

WAC Constituent[a]	***Maximum Concentration***
Neptunium-237	3.12×10^{9} pCi/g
Strontium-90	5.67×10^{10} pCi/g
Technetium-99	29.1 pCi/g
Total Uranium	1,030 mg/kg
Carbazole	7.27×10^{4} mg/kg
Bis(2-chloroisopropyl)ether[b]	2.44×10^{-2} mg/kg
Alpha-chlordane	2.89 mg/kg
Bromodichloromethane	9.03×10^{-1} mg/kg
Chloroethane	3.92×10^{5} mg/kg
1,1-Dichloroethene[c]	11.4 mg/kg
1,2-Dichloroethene	11.4 mg/kg
4-Nitroaniline[b]	4.42×10^{-2} mg/kg
Tetrachloroethene[c]	128 mg/kg
Toxaphene[c]	1.06×10^{5} mg/kg
Trichloroethene[c]	128 mg/kg
Vinyl chloride[c]	1.51 mg/kg
Boron	1.04×10^{3} mg/kg
Mercury[c]	5.66×10^{4} mg/kg

Source: USDOE 1998c

[a] In addition to these numerical limits, the Operable Unit 5 ROD states that a best management approach is to be applied during excavation activities to identify, segregate, and treat as necessary, soil containing concentrations of organic compounds at levels that could potentially jeopardize the integrity of the earthen liners of the OSDF.

[b] The WAC for bis(2-chloroisopropyl)ether and 4-nitroaniline may be below the laboratory practical quantitation limits for these compounds in soil. Analytical limitations for these compounds will be addressed in the individual project-specific plans for the supplemental characterization activities in areas that involve these compounds. See Section 4 of the Waste Acceptance Criteria Attainment Plan (USDOE 1998c) for descriptions of the supplemental characterization activities planned during soil remediation.

[c] RCRA COCs which had WAC limits established for disposal in the OSDF.

4.5.5.2.2 Radiological Waste Acceptance Criteria for Debris

The radiological WAC for debris was for Technetium-99 which was limited to a total of 105 grams (3.7 ounces) from debris waste streams in the OSDF. This limit was to be controlled through the ROD-based categorical exclusions. USDOE also committed to EPA and Ohio EPA to complete the following actions as a means of assuring that the radiological limits for debris removed from the OU 3 footprint and destined for disposal in the OSDF would not exceed the radiological WAC for debris:

- The top inch of concrete was to be scabbled and sent off-site for disposal from the three most contaminated concrete areas identified in the OU 3 ROD; and
- The top 1.3-cm (½-inch) of concrete in the southern extraction area of the Pilot Plant would be scabbled and sent off site for disposal.

The mass of total uranium placed in the OSDF was controlled by visually inspecting debris generated from within the boundaries of OU 3 to ensure that it did not contain discernable process materials.

4.5.5.2.3 Physical Waste Acceptance Criteria for Debris

The following physical limitations were applicable to all waste streams destined for disposal in the OSDF**.**

- The maximum length of irregularly shaped metals or other components of a building superstructure or finish components shall be 3 m (10 ft).
- The maximum thickness of irregularly shaped metals or other components of a building superstructure or finish components shall be 46 cm (18 inches).
- The maximum thickness of an individual concrete member or other component of a building slab or substructure shall be 1.2 m (4 ft), when the item is handled individually and is a regular shape having no concrete protrusions greater than 46 cm (18 inches).
- Concrete reinforcement bars shall be cut within a nominal 10 cm (12 inches) of the concrete mass. The additional length added by these bars is not considered in determining the total length of the concrete mass.
- The maximum thickness of uniform pallets of building cladding (e.g., transite panels), properly banded into rectangular shapes, shall be 1.2 m (4 ft).
- Regulated asbestos-containing material shall be double-bagged.
- Asbestos-containing material brick and commingled debris shall be double contained.
- Piping having insulation of asbestos-containing material shall be segregated.
- Equipment shall be drained of all oils and liquids.
- Piping with a nominal diameter of 10 cm (12 inches) or greater shall be split in half.
- Items having voids greater than 0.03 m^3 (1 ft^3) shall be filled with a quick set grout, or flowable cohesionless material approved by the OSDF Construction Manager. If a grout is used in this manner, it shall be allowed to set for a minimum of four hours prior to the commencement of placement of that item.

4.5.5.3 Waste Acceptance Criteria for Allowable Ancillary Wastes

The WAC requirements for ancillary remediation waste were determined on a case-by-case basis as ancillary waste streams were identified. Because all ancillary waste was either inherently soil-like or debris-like, the process of determining WAC requirements for this waste stream included applying the soil or debris WAC, as appropriate.

Three known ancillary waste streams were designated for placement in the OSDF: wastes associated with the Advanced Wastewater Treatment Facility; residues from Fernald Site samples returned from off-site laboratories following analysis; and PPE. These waste streams were not directly generated as a result of the soil excavation or D&D activities, and therefore were classified as ancillary waste.

There were a number of related soil-like waste streams associated with the Advanced Wastewater Treatment Facility operations. These included sludge from the Slurry Dewatering Facility which included dewatered sediment from storm water retention basins; spent resins; and spent carbon. The OU 5 ROD states that sediment from retention basins and Advanced Wastewater Treatment Facility residues will meet the OU 5 WAC or be disposed of off-site. In accordance with the OU 5 ROD, the OU 5 radiological/chemical WAC and physical WAC, therefore, was applied to the sediment and treatment residues from the Advanced Wastewater Treatment Facility.

PPE from all Fernald Projects was managed as debris. The debris physical WAC were applied to the PPE ancillary waste stream.

4.5.6 Material Placement

In late 1998, a waste placement optimization plan was prepared to support the construction schedule for the placement of D&D debris in 1999 with minimum soil-debris ratio to minimize space requirements. The waste placement optimization plan along with waste placement tracking helped meet the soil demands needed for protective and intervening layers, optimized the D&D debris volume and avoided the leftover soil without debris placement. A computer model was developed to track daily by location the waste category, source and layer thickness in which it was placed. This plan was subsequently prepared every year ahead of the start of waste placement and to optimize space requirements in the cells.

4.5.7 Environmental Monitoring and Management

The overall management of the Fernald Preserve under the Legacy Management Program is outlined in the *Comprehensive Legacy Management and Institutional Controls Plan Volumes I and II* (LMS/FER/S03496) (USDOE 2010a). This plan is updated annually and the most current version is Revision 4, issued in April 2010. Volume I is the Legacy Management Plan, and is a high level overview of the long-term overall management of the site. Volume II is the Institutional Control Plan which addresses the following:

- Control to Eliminate Disturbance and Unauthorized Use of the Fernald Preserve, including the OSDF;
- Controls to Minimize Human and Environmental Exposure to Residual Contaminants;
- Contingency Planning; and
- Information Management and Public Involvement.

This document is further supplemented with attachments which provide detailed requirements for the following:

- Operations and Maintenance Master Plan for Aquifer Restoration and Wastewater Treatment;
- Post-Closure Care and Inspection Plan;
- Groundwater/Leak Detection and Leachate Monitoring Plan;

- Integrated Environmental Monitoring Plan; and
- Community Involvement Plan.

The Legacy Management and Institutional Controls Plan, inclusive of the OSDF monitoring, was developed by reviewing the pertinent regulatory requirements for detection, monitoring and translating those requirements into site-specific monitoring elements. Available site-specific information generated from more than 15 years of detailed site characterization efforts, including geology and hydrogeology, results of detailed contaminant fate and transport modeling, OSDF construction activities, monitoring results from the OSDF program during site closure activities, and an Integrated Environmental Monitoring Plan were used to develop the monitoring strategy. This strategy includes sampling frequency and required analytical parameters as well as determination of monitoring locations.

Specific media monitored include the groundwater, surface water, treated effluent, sediment, and air. Other assessments include radiation dose surveys and ecological monitoring. Ecological monitoring encompasses general health of the preserve including the presence of nuisance and burrowing species, population health of native or endangered species, and erosion.

The result of Legacy Management and Institutional Controls Plan implementation is an ongoing comprehensive management and monitoring program at the Fernald Preserve. The output of this monitoring is the *Fernald Annual Site Environmental Report*. This report details and presents the information obtained through the ongoing monitoring. In addition to discussions and interpretations of the information, actual monitoring data is provided for review by the public.

The environmental monitoring programs conducted during the Fernald Site remediation activities and during the Legacy Management Program phase have direct applicability to the NFSS regardless of the decision to include an on-site disposal cell in the preferred remedy. The radiological and environmental parameters to be monitored will be similar in many cases to those that were and continue to be monitored and tracked after Fernald Site closure.

Table 4-2. Lessons Learned Summary

<table>
<tr><th>Section</th><th>Topic</th><th>Adverse Condition</th><th>Attempted Correction</th><th>Result</th></tr>
<tr><td>4.1</td><td>Feasibility of Radium Recovery</td><td>• In-process recovery would increase processing cost and increase potential worker exposure; post-disposal recovery could limit waste disposal options, increase disposal cost and/or decrease stability of the disposed waste form.</td><td>• Qualitative evaluation of impact of in-process or post-disposal recovery versus benefits of reuse.</td><td>• Ra-226 recovery was not used to affect waste processing or the disposal form or disposal method.
•
•</td></tr>
<tr><td colspan="5">Lessons Learned: The feasibility of radium recovery for medical purposes or as precious metals for cost recovery will be evaluated in the IWCS FS based on economic conditions at the time.</td></tr>
<tr><td>4.2</td><td>Waste retrieval systems</td><td>• Waste materials varied physical form (grain size, moisture content, and compacted masses).</td><td>• Developed waste retrieval tools that addressed the range of waste forms identified.</td><td>• Waste retrieval system successfully removed all waste forms encountered.</td></tr>
<tr><td colspan="5">Lessons Learned: Potential variations in the physical state of the wastes to be removed from the IWCS may necessitate the incorporation of multiple retrieval components.</td></tr>
<tr><td>4.5.1</td><td>OSDF Design</td><td>• Strict/defined engineering requirements resulted in difficulty in meeting design specifications during construction due to varying field conditions.
• Impacts to schedule and cost to expend additional effort or redo work to meet specified criteria</td><td>• Proposed additions and revisions to the approved plans and specifications that enhanced constructability of the facility with no impact to worker safety or performance of the OSDF.</td><td>• Proposed changes created negative perception by the public and regulators.
• Design with specifications with flexibility to increase ease of construction.</td></tr>
<tr><td colspan="5">Lessons Learned: Provide flexibility in the engineering requirements indicated on design drawings, detailed in technical specifications and described in the work plan. Perform detailed constructability review by experienced construction professionals to identify elements that may impact construction costs and schedule. This approach will minimize change orders and non-compliance reports (NCRs) and avoid negative perception by the regulators and stakeholders.</td></tr>
</table>

Table 4-2. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
4.5.4	OSDF Cell Construction	• Clay borrow material contained an unexpected overabundance of rock • Clay material did not meet moisture content and compaction requirements need to reach the Acceptable Permeability Zone Curve for material acceptability	• Material was screened to remove rocks • Material excavated and stockpiled into smaller piles and tested two to three months ahead of placement	• Mechanical removal of rocks from material was much more effective than manual removal • Screening of material enhanced its workability during compaction • Testing material early enhanced likelihood of material meeting performance standard after placement, by avoiding sub-par materials.
Lessons Learned: *Verify variability of clay material, particularly in glacial till environments, and accordingly develop material preparation, handling, sorting and testing plans to enhance compaction and quality control performance.*				
4.5.5 and 4.5.6	OSDF WAC and Waste Placement	• Regulatory and Public Concerns over waste placement in OSDF meeting regulatory requirements • Inefficient waste placement could result in requiring significantly more soil than planned for layers and covers resulting in increased costs and reduction in cell capacity.	• Development of a Waste Acceptance Organization (WAO) to track excavation, transport and placement of all material in the OSDF • Development of a waste placement optimization plan to plan and track soil needs for the protective, select and intervening layers, placement of D&D and other materials.	• WAO for monitoring and tracking waste at source as an independent oversight organization added value and stakeholder trust. • Waste placement optimization plan and daily placement tracking optimized the OSDF placement capacity.
Lessons Learned: *Planning and tracking of waste from point of generation to point of final disposal provides credibility to the stakeholders and provides ability to address questions or issues after project has been completed. In addition, developing a methodical plan and procedure for waste handling and disposal, whether on-site or off-site, will reduce costs impacts and schedule delays during remedial implementation.*				

5. PROGRAMMATIC LESSONS LEARNED FROM FERNALD

The purpose of this section is to provide an overview of the strategies implemented at the Fernald Site regarding the programmatic development of their community relations, health and safety, and procurement efforts. The actions taken at the Fernald Site demonstrated an effective means to provide information to stakeholders, develop a consensus among involved parties, created an effective and safe work environment, and furthered the goal toward site remediation and closeout. Lessons learned from these efforts provide techniques for programmatic enhancements that may also benefit the NFSS CERCLA activities.

5.1 Stakeholder Involvement

Public participation is required for the completion of any Federal environmental effort. More complex sites sometimes must go far beyond the minimum public participation requirements under CERCLA to be effective. The Fernald Site accomplished effective public participation through a multi-dimensional, intense, highly interactive and enduring effort.

The Fernald Site conducted and supported stakeholder involvement/engagement activities from 1984 continuously through the Silos 1 and 2 Remediation Project and to site closure in 2006.

5.1.1 Development of the Fernald Stakeholder Involvement Program

This period included placement of the site on the NPL (in 1989), the shift in mission to environmental remediation (in 1991), ROD approval (in 1995), and transition to the USDOE Office of Legacy Management of the closed site (in 2006). The initial goal of the stakeholder involvement program was to inform the public of the extent and possible health risk from uranium dust releases and surface water contamination, Fernald's role in national defense as a refiner of uranium; facts about ionizing radiation; the types and potential hazards of chemicals used; site protective controls and emergency planning; and remediation in place and underway.

Prior to placement on the NPL, Fernald developed the stakeholder outreach program to be compliant with CERCLA requirements as a best management practice and to minimize delays to the program as it progressed through the site closure process by establishing an active process for communication to the public.

Up until the mid-1980s, the site had been shrouded in secrecy because of its national security mission and the necessity of information security. The public knew little about what went on at the site and nothing of any environmental damage. In the early years of the Fernald environmental cleanup, USDOE followed the minimum regulatory requirements for communication with the public; this did not satisfy the public, but instead resulted in distrust and frustration.

As the communication with stakeholders increased, USDOE was better able to understand the primary concerns of the stakeholders and educate them about how those concerns were being addressed. This interaction with stakeholders helped USDOE recognize that public participation in decision-making was beneficial for improving the effectiveness of the environmental cleanup program.

In the early 1990s, the USDOE and the Fernald Site expanded the scope of public participation. The program developed more comprehensive methods to gather stakeholder concerns, including both meetings in public places and making survey materials available in public places such as supermarkets. The input received from these efforts provided a better understanding of the public's primary concerns about the site. This information in turn was used to refine outreach materials, public meeting agendas, and discussion of remedial actions at the site. There was an expansion of public meetings and, most importantly, the introduction of smaller workshops and roundtables with 3-6 people. In these smaller venues, members of the general public asked more questions and offered opinions. These smaller discussions involved many of the senior managers and technical staff from both USDOE and the prime contractor. The community came to see them as caring people engaging in personal conversations with them. One result of this process was improved trust of USDOE by public stakeholders and support of USDOE initiatives.

The Fernald experience demonstrated that simply following the CERCLA process does not necessarily deliver citizen input during the site study and remediation selection phases. CERCLA does not require that state acceptance and community acceptance be considered until after an agency has identified a preferred remedy, a point at which either the stakeholder has no input or any changes to the plan require significant expenditure and have the potential for schedule delays. Substantive efforts were made by USDOE at the Fernald Site to facilitate the flow of information, with frequency and consistency and engaging many different people from the community. The information was provided in a language that the public was able to understand and in forums that permitted questions and comfortable dialogue, including small workshops, roundtables, or one-on-ones. The community achieved a basic understanding of the issues and problems faced by Fernald, and most importantly, a basic understanding of the actual risks posed by the site. The discussion of views among members of the community enhanced their understanding of the site issues, and helped them to develop a stronger, more unified voice on the issues. All parties had a greater appreciation of the trade-offs that are inherent in many complex cleanup decisions. Also of major significance was the fact that the community is able to be an effective, fully-informed, articulate participant in agency decision-making. The agency officials had a better understanding of the perceptions, values and attitudes of the community, thereby making their participation effective, reasonable, and valuable in shaping the cleanup program.

The stakeholder involvement process implemented at the Fernald Site included:

- Development and distribution of media outreach materials.
- Training for USDOE and site technical staff in effective media and public communications.
- Formation of a speakers' bureau consisting of site staff and area scientists who were technical experts. These speakers first addressed active Fernald and Cincinnati community groups; their contribution expanded to include community organizations and area schools.
- Public meetings and outreach programs.

- Development and staffing of a Fernald Joint Public Information Center in conjunction with the Emergency Operations Center. The information center offered press support for emergency preparedness and exercises, full audio-visual support, and outreach materials.
- Development and conduct of the first public tours of the site, including providing tour guides and presentations.
- Integration with local emergency response organizations for coordinated response.
- Development of three public reading rooms at the FMPC site and two local public libraries.

Through this period, the local USDOE office at the Fernald Site maintained a public affairs staff of four full-time prime contractor employees supported by four subcontractor community relations specialists to develop and support the program. Fernald also established the "envoy program." An employee (envoy) would serve as a conduit of information between the agency and civic groups within the community, channeling community concerns to management while reporting cleanup progress or management responses to the citizens.

5.1.2 Community Organizations

A significant reason for success of the stakeholder involvement program at the Fernald Site was the use of a broad-based, comprehensive identification of community organizations as stakeholders and their inclusion early in the process. This was exemplified by the committed, informed, and USDOE funded site-specific citizens advisory board and inclusion of the other primary stakeholder groups on the board. In addition, lack of emphasis on local government representation limited the influence of political orientation on the board, as well as the loss of institutional knowledge and technical expertise that can result from turnover driven by government term limits.

Three community organizations were key to stakeholder engagement and involvement:

- The Fernald Citizens Advisory Board (FCAB);
- The Fernald Residents for Environmental Safety and Health (FRESH); and
- The Fernald Citizens for Health and Environment Committee (FCHEC).

Fernald Citizens Advisory Board. In 1993, the EPA sponsored a blueprint for involving stakeholders at the Fernald Site, leading to the creation of the Fernald Citizens Task Force. The Task Force was renamed the FCAB in 1997; it was disbanded after site closure in 2006.

The 1993 blueprint was in response to the increasing need for public participation in USDOE decisions. It was a result of USDOE participation in a national policy dialogue on federal facility environmental restoration decision-making and priority-setting issues. Through the Federal Advisory Committee Act of 1972 (Public Law 92-463), the U.S. Office of Management and Budget and General Services Administration approved the charter that established the USDOE Environmental Management Site-Specific Advisory Board (SSAB) in 1994 (USDOE 2008). The board met the CERCLA guidelines as a Citizens Advisory Board and the USDOE Office of Environmental Management designated the FCAB as an official SSAB.

The USDOE Office of Environmental Management established the SSAB to provide a means to involve stakeholders more directly in agency cleanup decisions and to provide USDOE's Assistant Secretary for Environmental Management and the appropriate USDOE Environmental Management field managers with advice and recommendations concerning environmental restoration. Additionally, the purpose of the SSAB was to develop partnerships among citizens, the site, and regulators, including the EPA and State environmental agencies. The structure of the USDOE Environmental Management SSAB is a single Federal Advisory Committee Act-chartered advisory board consisting of multiple local site-specific boards or committees. Regardless of their location, USDOE SSAB local boards operate under one charter. Per USDOE policy, decisions to create local boards are made when the USDOE's Assistant Secretary, Site Managers and other USDOE officials determine that there is local citizen interest in site planning but no existing mechanism for it; and that the formation of a board under the USDOE Environmental Management SSAB charter can be expected to provide the information, advice and recommendations that management seeks (USDOE 2010).

An independent convener was employed by USDOE to select the initial members of the Fernald Citizens Task Force (later the FCAB). The FCAB included fourteen board members, representing a broad spectrum of interests and backgrounds. The members served two-year terms, however, there was no limit on the number of consecutive terms and five members served the entire 13 years of the board’s existence. The members selected new members to fill vacancies, but all members were subject to final approval by USDOE. In addition to the 14 members, four ex-officio members served on the board. They included the local USDOE office, EPA, the Ohio EPA, and the Agency for Toxic Substances and Diseases Registry. The ex-officio members participated fully in discussions but not final recommendations to the agencies.

The FCAB met nearly every month between August 1993 and September 2006 to learn about issues related to the remediation of the Fernald Site, discuss their viewpoints and interests, seek consensus positions, and craft recommendations. Meetings were held on or near the Fernald Site and lasted 2 ½ to 3 ½ hours. Most meetings were held on Saturdays and included updates on Fernald Site planning and cleanup, ex-officio comments, presentations of information, group dialogue, and developing consensus recommendations. Occasionally, meetings included tours of the Fernald Site. All of the FCAB meetings were open to the public and included the opportunity for public comment. For some issues, the FCAB actively sought participation of the wider FEMP community and held open community workshops. The major issues addressed by the FCAB were: future use of Fernald after site cleanup, establishing cleanup target levels, disposition of waste and establishing the OSDF, selection of cleanup remedies, recommendations for waste transport, recommendations on site budget and cleanup schedule, long-term stewardship of the Fernald Site, community stewardship of the site after cleanup was complete, and historic preservation of Fernald history.

The FCAB created ad-hoc committees as needed for issues of particular import. These committees performed in-depth analyses of specific issues. Two of the prominent committees included the Remediation Committee (covering transportation, silos, waste pits, OSDF, D&D, and nuclear materials disposition), and the Stewardship Committee (Fernald Living History Project, Native American issues, historic preservation, archiving of site records, support of museum/cultural center, advising on ecological restoration issues, stewardship planning and funding, and the Natural Resources Working Group). Because long-term stewardship was a major concern to the community, the Stewardship Committee met monthly for 13 years. Board members served as chairs for these committees, but membership was open to all interested community members.

Several times a year, the FCAB submitted formal recommendations to local and national representatives of USDOE. The Board also provided specific comments on key decision documents. In addition, as an official SSAB for the USDOE Office of Environmental Management, members of the FCAB participated in national workshops and meetings with other site boards and was a signatory to several joint recommendations crafted during national SSAB meetings. Through these documents, the FCAB sought to explain community interests and steer USDOE towards safe, effective, and economically sensible cleanup decisions.

As a board chartered under the Federal Advisory Committee Act and sponsored by USDOE, the FCAB was entitled to adequate resources from USDOE to conduct its work. The primary resources provided included an ongoing contract to provide board facilitation, administrative and technical support. Annual appropriations from USDOE Environmental Management were the sole source of funding for regular FCAB activities. USDOE did provide one-time grants to fund occasional special projects, such as official SSAB events and independent review of certain technical issues. In addition, the primary cleanup contractor provided staff support for many of the planning and administrative tasks associated with the FCAB. USDOE funding of local boards generally reflected the size of the site, the nature and quantity of the issues involved (political and technical), and the number of workers at the site. For the smaller sites (e.g., Mound Site, OH), the annual funding was anticipated in the range of $50,000 to $100,000. Medium-sized sites such as Fernald or Los Alamos, New Mexico were anticipated to be in the $100,000 to $250,000 range. Finally, larger sites such as Rocky Flats, Colorado and the Savannah River Site, Georgia were anticipated to be in the $200,000 to $350,000 range (USEPA 2010b). The current annual budget for the SSAB at the Savannah River Site is $412,000 (Flemming 2011). In this context, NFSS would likely be considered a medium-sized site, as was Fernald. Although it is similar to Fernald in that it involves K-65 wastes, NFSS does not have the same extent of groundwater contamination, ancillary waste pits, and number of buildings requiring decontamination and decommissioning as Fernald did.

Throughout its life, the FCAB had a great deal of high-quality support. An independent consulting firm provided facilitation and technical support for the FCAB. The consulting firm planned decision processes, developed meeting agendas, summarized technical documents, coordinated communications, facilitated meetings, drafted recommendations and other documents for FCAB review, and served as a liaison between USDOE and FCAB members. Although paid through the USDOE budget, the consultants served the needs and requests of the FCAB. USDOE and Fluor Fernald supported the FCAB by providing additional technical information and logistical support on site, and provided outside technical experts that provided independent advice during the Silos 1 and 2 Remediation Project.

Many of the recommendations put forward by the FCAB regarding the residual risk and remediation levels, waste disposal, priorities among remedial actions and the future use of site were accepted by USDOE, EPA and Ohio EPA, making it one of the most successful SSABs in the USDOE complex.

Fernald Residents for Environmental Safety and Health. FRESH was established in 1984 and disbanded in 2006 after site closure. It was an independent community action group comprised of local residents that acted as a grass-roots organization that advocated cleanup of the Fernald facility, worked to educate the surrounding communities, and promoted responsible environmental restoration and public health and safety. Funding was provided by a private foundation, public contributions, and membership dues. FRESH held monthly open meetings to provide residents with an update on Fernald-related issues and published a newsletter five to six times per year. A representative from FRESH served on the FCHEC and representatives served as FCAB board members at various times.

Fernald Health Effects Subcommittee / Fernald Citizens for Health and Environment Committee. This organization began as the Fernald Health Effects Subcommittee in 1996 and became FCHEC in 2002; its activities continued through 2004. The initial organization, Fernald Health Effects Subcommittee, was sponsored by the Centers for Disease Control, Agency for Toxic Substances and Diseases Registry, and National Institute for Occupational Safety and Health. Its mission was to provide community-based advice and recommendations to Centers for Disease Control and Agency for Toxic Substances and Diseases Registry concerning the agencies' public health activities at the site. This included such activities as conducting workshops for public health workers in the Fernald and Cincinnati areas. It was composed of members from the Fernald community, labor representatives, and technical experts. Officials from Ohio EPA, the Ohio Department of Health, and the Hamilton County General Health District served as *ex officio* members. In 2002, after the Fernald Health Effects Subcommittee was disbanded, the FCHEC was formed as a non-profit community organization to address concerns regarding adverse health effects on the local community potentially caused by the Fernald Site. Both organizations met several times per year, and meetings were open to the public.

Other stakeholder engagement activities of note:

- Fernald Community Reuse Organization was formed in 1996 of 19 USDOE appointees. These personnel were selected to serve as focal points for local communities regarding socioeconomic issues resulting from the downsizing and eventual closure of the Fernald Site once cleanup was complete.
- FCAB subcommittee workshop participants were able to attend meetings on-line starting in 2000, and a website was established in 2001.

In 2006 after site closure, many Fernald community groups disbanded as their missions were complete. In its final years, the FCAB in particular, focused much of its attention on how to make sure that its vision of the site and the long-term stewardship requirements would be implemented. Through its insistence and specific recommendations, the FCAB was ultimately successful in getting community involvement included in the legally binding institutional controls plan for the site. The FCAB worked with other local groups to initiate the Fernald Community Alliance, a new non-profit organization whose goal would be to ensure public support and attention remained on activities at the Fernald Site well into the future and filled gaps in what USDOE would do for public outreach and education.

5.1.3 Stakeholder Involvement in the On-Site Disposal Facility

As noted in Section 4.5, siting of the OSDF at the Fernald Site was a result of an effective stakeholder involvement program with committed participants in USDOE, the prime contractor, citizen groups, and regulatory agencies. At first, the predominant feeling in the surrounding community was that every atom of contamination should be removed from Fernald, and the site restored to pristine (pre-operational) conditions. In this environment, USDOE initiated intense efforts to educate and engage the public, using the methods and actions described above. During this period, USDOE, members of the community organizations (FCAB, FRESH, and FCHEC) and members of the general public spent many days every month discussing the nature of the site's issues at public meetings, in educational workshops, reviewing informational publications, and in small discussion groups. This campaign served to educate the public about the cost and schedule implications of various remedial alternatives that could be implemented at the Fernald Site. USDOE engaged the stakeholders actively in the planning process, and in particular looked at what could be done with various funding levels and what future uses could be made of the site. The public began to realize that, given the projected funding levels for the site, removal of all contaminated material would cost significantly more and would take decades longer to accomplish than engineered management of some material on-site. They realized that if the materials with the highest radioactive concentrations were to be shipped off site and the remaining material disposed on site, then cleanup could be completed significantly earlier and would place the waste into a safe, long-term condition. At the same time, USDOE went to great lengths to educate the public on the safety features provided by a well-engineered disposal cell.

As part of the educational process, local Fernald community organization leaders engaged in a number of national meetings with other environmental activists, including those from Nevada and Utah. The result was recognition that the Fernald Site was one part of a truly national issue, and that many communities and states needed to share the burden of resolving it. In other words, sending everything to Nevada or Utah was not particularly acceptable to the stakeholders in those states.

At the Fernald Site, the waste pits and the silos (which together constituted 20% of the waste by volume) represented the areas of highest radioactivity. An analysis demonstrated that by shipping those materials off-site and disposing of the remaining contamination on-site, 80% of the radioactivity would be removed from the site. Likewise, on-site disposal of the D&D waste and soils (which constituted 80% of the waste by volume) meant only about 20% of the radioactivity would remain on site. The public realized that this combination sent most of the radioactivity off-site, while resulting in cost projections that ensured earlier cleanup.

USDOE also stressed that it would be providing long-term stewardship of any on-site waste. Extensive communications were conducted to educate the public on the level of protection that could be provided in an on-site disposal cell, and engaged them in developing certain design criteria of the solid disposal facility. These discussions, USDOE transparency, and a commitment to ongoing public involvement led to success in gaining approval of the special waiver from the State of Ohio for placement of the OSDF at the Fernald Site.

5.2 Workforce Involvement

Fernald incorporated an Integrated Safety Management (ISM) system to ensure the integration of safety into all facets of the Silos 1 and 2 Remediation Project work planning and execution. The goal was to systematically integrate safety into management and work practices at all levels so that remediation was accomplished while protecting the public, the workers, and the environment. The responsibilities for implementation of ISM were assigned to both USDOE and Fluor-Fernald line management. The ISM was incorporated into the Silos 1 and 2 Remediation Project and was also incorporated into the contracts awarded to support the work scope, thus assuring that the precepts of ISM flow down to all subcontractors (Fluor-Fernald 2004a).

The safety program derived for the Silos 1 and 2 Remediation Project resulted from a site-wide hazard survey and assessment based on the defined scope of work. Based upon the types of hazards identified, applicable standards and requirements were used to develop health and safety plans that defined work controls to prevent or mitigate hazard. ALARA concepts were incorporated into work activities to reduce the overall radiological exposures to workers. Work requirements were communicated to the workforce through training, daily work briefings, and emergency plans. A core component of the health and safety program at the Fernald Site was the focus on feedback and continuous improvement through an “open door policy” and management response to employee’s safety concerns. The high degree of commitment to health and safety by both management, employees, and subcontractors resulted in a cohesive workforce that was demonstrated by Fernald’s approval into the Occupational Safety and Health Administration’s (OSHA) Voluntary Protection Program (VPP) as recognition of a commendable occupational safety and health program.

5.2.1 Hazard Assessment

The Silos 1 and 2 Remediation Project dealt with hazardous materials that contain both radiological and chemical hazards. At Fernald, a site-wide hazard survey and assessment was conducted for OU 4; it provided the mechanism for the development of project-specific Health and Safety plans. The quantitative analysis of the hazards associated with the construction, operations, and maintenance tasks for each project component was performed using guidance that was taken from 10 CFR 830.204 *Nuclear Safety Management*, *Documented Safety Analysis*, USDOE Order 5480.23 Nuclear Safety Analysis Reports, USDOE-STD- 1 027, and OSHA regulations; 29 CFR 1910.119 and 29 CFR 1910.120 (Fluor Fernald, Inc., 2004a).

In accordance with DOE-STD-3009-94, *Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Documented Safety Analyses* (USDOE 2006), a range of unique and representative accident scenarios were analyzed. Unique accidents are those with sufficiently high-risk estimates that individual examination is needed (e.g., a single fire whose specific parameters result in approaching a specific evaluation guideline [e.g., 25 rem total effective dose equivalent]). Representative accidents bound a number of similar accidents of lesser risk (e.g., the worst fire for a number of similar fires, the worst spill, etc). All types of hazards were considered and documented, including standard industrial hazards, human capability limitations, health hazards, electrical hazards, energy-release hazards, radiological hazards, biological hazards, toxic and hazardous materials, and natural phenomena. All of the activities were analyzed against a master list of hazards to decide which were potentially applicable.

The most severe radiological and chemical hazards were carried forward to the accident analysis so that a complete set of conditions were addressed to define the range of accident conditions that might occur during the operation. The most significant potential release identified was the result of a silo dome failure before waste retrieval activities started. The radiological analysis of a release considered three parameters; total activity of the various radionuclides, total activity that could be reasonably released, and dose to on-site and off-site personnel. The chemical analysis considered two parameters; the quantities of the various hazardous chemicals present, and the concentrations that would be generated during the modeled accident.

Twenty-nine potential worst-case accidents were quantitatively analyzed for dose consequences, controls, and mitigators, using a graded approach. Of those 29 accidents, the only accidents that showed significant localized consequences were tied to the uncertainties in silo structural life expectancy (i.e., probability of failure) and the vast amount of radiological materials presently stored. The initiating events for a collapse of a silo dome include (1) loss of containment due to natural phenomena and structural failure due to degradation, (2) a person on top of a silo penetrates the dome and falls into a silo, (3) over- or under-pressurization of a silo, and (4) a load drop or crane failure. Numerous precautions were taken during the Fernald AWR Project to avoid the possibility of breaching the silo domes in a way that would release significant quantities of radon gas to the workplace and the environment.

A few potential hazards such as electrical energy, confined-space, or elevation hazards, were assessed to have an unlikely frequency and moderately severe consequences and these hazards warranted some additional analysis. Most of the hazards were associated with minor accidents (i.e., chemical spills) that were expected to occur during the life of the project. A strong, comprehensive health and safety program has been established on the AWR Project to minimize the actual frequency of such accidents. The identified hazards were documented along with the possible causes, potential consequences, and estimated frequency and severity based on experience and judgment. Controls and mitigators for all hazards were identified.

This information was then used to identify safety hazards that require special attention and/or additional analysis. 10 CFR 830.204, *Nuclear Safety Management Documented Safety Analysis* and USDOE Order 5480.23 *Nuclear Safety Analysis Reports*, states that consequences of unmitigated releases of radioactive and/or hazardous materials from a USDOE nuclear facility shall be evaluated and classified into either a:

- Category 1 Hazard - shows the potential for significant off-site consequences;
- Category 2 Hazard - shows the potential for significant on-site consequences; and
- Category 3 Hazard - shows the potential for only significant localized consequences.

The final hazard category was determined by comparing the radiological and toxicological consequences of the unmitigated hazards for hazard categorization.

Silos 1, 2, and 3 at the Fernald Site qualified as USDOE nuclear facility Hazard Category 3 based on inventory, the radon reduction, waste retrieval, and interim storage qualified as Radiological based on analytical consequences (Fluor Fernald 2004). For the three silos at the Fernald Site, Nuclear Health and Safety Plans were created to allow remediation facilities to be built and operated as radiological facilities within the geographical boundaries of a Hazard Category 3 facility area (Fisk et. al., 2003). The AWR Project was classified as a USDOE Radiological facility with low chemical hazards because the largest potentially releasable inventory does not result in significant localized consequences and therefore a Health and Safety Plan was developed. The results of the each sub-project hazard assessment are provided in the respective Health and Safety Plan or Nuclear Health and Safety Plan prepared for the Fernald Silos 1 and 2 Remediation Project.

5.2.2 Health and Safety Plans

In accordance with 1910.120(b)(1)(i) employers shall develop and implement a written safety and health program for their employees involved in hazardous waste operations. The program shall be designed to identify, evaluate, and control safety and health hazards, and provide for emergency response for hazardous waste operations. The minimum elements for this plan are contained in 29 CFR 1910.120(b)(4)(ii). For those USDOE operations or facilities at the Fernald Site that were defined as a Category 1, 2, or 3 nuclear facility, Nuclear Health and Safety Plans are developed.

The Health and Safety Plans and Nuclear Health and Safety Plans were developed to ensure that hazards were identified and analyzed prior to work began and that controls or mitigators were be in place to support the safe operation. The objectives of the health and safety plan are to:

- Identify and evaluate hazards contained in the facility/process to establish a sound technical basis for their control.
- Establish worker safety controls to reduce and mitigate hazards.
- Establish Process Requirements to ensure that the activities remain safe in accordance with good management practices, routine conditions, and anticipated operating modes.
- Establish Safety Basis Requirements, which limit the activities based on a direct association with its analyzed safety envelope and current Hazard Categorization or classification.

The Silos 1 and 2 Remediation Project closure activities were: silo waste retrieval, treatment, shipping and facility D&D, loading and transporting silo materials by truck and rail for off-site disposal, waste management, and removal of uranium contamination from site run-off and processes water. Additionally, closure activities at the OU 4 area were associated with the removal of building foundations and associated impacted soils as well as filling and closing of the OSDF. The Health and Safety Plan for each of the major closure activities relevant to the Silos 1 and 2 Remediation Project were:

- RCS Nuclear Health and Safety Plan;
- AWR Nuclear Health and Safety Plan;
- Silos 1 and 2 Retrieval and Disposition Nuclear Health and Safety Plan;
- Silo 3 Retrieval and Disposition Nuclear Health and Safety Plan;
- Facilities D&D Projects Integrated Health And Safety Plan;

- Soil and Disposal Facility Project Integrated Health and Safety Plan; and
- Wastewater Treatment Operations Integrated Health and Safety Plan.

The Nuclear Health and Safety Plan combines the project safety basis, occupational safety, industrial hygiene, fire safety, radiological, and other safety-related requirements, along with project-specific controls and implementation methods. This consolidation of requirements via the Nuclear Health and Safety Plan has several benefits, including:

- Increased emphasis on project-specific hazards;
- Improved worker access to project-specific safety-related requirements;
- Reduced costs associated with document upkeep and revision;
- Enhanced consistency between project and safety documentation; and
- A simplified comprehensive document for workers briefings.

5.2.3 ALARA Analysis and Review Processes

The ALARA philosophy adopted by the FCP requires that any exposure to ionizing radiation to general employees, the public, or the environment shall be minimized to the extent that social, technical, economic, practical, and public policy considerations allow. ALARA analyses were conducted at the Fernald Site to present estimates of the radiation dose rates, the concentrations of radon in the air, and the duration of exposures. Each subproject task was reviewed relative to individual as well as collective doses. Shielding requirements were considered for all the higher dose rate tasks, and ventilation requirements were considered for all tasks where radon concentrations greater than 0.01 WL are expected in the air in occupied spaces, such as the TTA and RCS buildings. Other factors were considered in the ALARA analyses to determine the duration of exposures, such as the frequency of maintenance tasks, access to equipment that requires maintenance, the path taken to reach the equipment, the complexity and duration of maintenance tasks, local ventilation, and PPE requirements. The tasks with the highest collective dose estimates and tasks in the highest dose rate areas were given the most rigorous technical reviews to ensure proper safety protocols were established (Fluor-Fernald 2004a). All remediation work personnel were medically-qualified for respiratory protection usage and working in heat stress conditions with PPE. Bioassays (whole body counting, fecal analysis and urinalysis) were required if a worker’s personnel internal dose potential exceeded 100 mrem/yr (excluding radon and progeny). FCP relied mainly on Personal Air Sampling as it was more representative of low level exposures.

5.2.4 Work Controls

Hazards and their control mechanisms were communicated to the workforce through standard policies, plans, and procedures. The Health and Safety Plan defined and communicated silos project hazards and the controls required to mitigate those hazards. At the task level, job planners were required to consider the level of competency required for each job. This includes consideration for training, experience, use of walkdowns, and pre-job briefings. Proper work planning ensured that the workers have all the materials, training, equipment, supervision, and technical support necessary to perform the assigned task successfully, safely, and efficiently.

Individual tasks also relied on job briefings, radiological and industrial work permits, and other hazard-specific mechanisms used to protect the worker. Employees were responsible for understanding the scope of the work, including hazards and controls, prior to initiating a task. Job planners were required to consult safety and health personnel in the areas of industrial, radiological, and chemical hazards to ensure that the strategy for mitigation of one hazard does not increase the risk or change the mitigation strategy for another. All employees, including subcontractors, were involved in providing feedback through the safety work groups and/or safety representatives. This approach ensured that employees with the greatest knowledge of the work evaluated the work planning and execution processes. Safety First work groups identified and resolved issues pertaining to work process safety.

PPE was used to protect workers from the various hazards present in the work place. Levels of protection were based on air monitoring data, radiological data, and other types of work-area monitoring data. Task-specific information on PPE was defined though work plans, work permits, procedures, and by radiological control activities. All personnel were evaluated by use of personnel contamination monitors prior to exiting radiological areas to ensure the absence of contamination. Provisions such as clean water and towels were staged and available for personnel/clothing decontamination it the need were to arise. All Fernald workers were medically evaluated prior to anti-contamination and respiratory protection usage (heat stress/strain) and some biokinetic monitoring was performed at the work location (pulse, temperature and pressure) when heat stress evolutions were in effect.

5.2.5 Training

The Silos 1 and 2 Remediation Project established training and qualification requirements for silos personnel. The program ensures that workers meet the minimum requirements of 29 CFR 1910.120, USDOE Order 5480, 40 CFR 264.16 and other relevant regulations, as applicable.

The program's objectives were to ensure that workers understood the potential hazards they may encounter, to ensure that workers possessed the knowledge and skills necessary to perform their work with minimal risk to their health and safety, to ensure that workers were aware of the safety requirements, including the purpose and limitations of safety equipment, and to ensure that workers could safely avoid or escape from emergencies.

Workers received the appropriate training based on their scope of work. Workers performing

activities which fall under 29 CFR 1910.120 received a required number of hours of initial and annual-refresher health and safety training for hazardous waste site operations. In addition to the initial health and safety training, workers received one to three days of directly supervised field experience. All personnel performing work under 29 CFR 1910.120 were required to be trained in one of the following categories: Occasional Site Worker or General Site Worker.

Workers whose work scope did not require hazardous waste site operations training would receive a level of training that is specific to the type of activities to be performed and the hazards to be encountered. Personnel could not participate in field activities until they had been appropriately trained.

Workers whose work scope does not require hazardous waste site operations training received a level of training that is specific to the type of activities to be performed and the hazards to be encountered. Personnel were not eligible to participate in field activities until they were appropriately trained.

Hazard communication training was provided per the OSHA 29 CFR 1910.120 requirements. The training provided workers with information on chemicals used on the Silos Project and their potential hazards. The training incorporated formal instruction and/or pre-job briefings. Material Safety Data Sheets, labeling, and other forms of warnings were used in conjunction with the training to foster worker awareness.

5.2.6 Job and Safety Briefings

Before commencement of field activities, all personnel performing fieldwork would participate in a briefing that will specifically address the activities, procedures, monitoring, and equipment used in the work. The briefing included a description of the work to be accomplished, known hazards (all types), administrative controls, and PPE requirements. This briefing also allowed field workers to receive clarification of anything they did not understand and confirmed their responsibilities regarding safety and operations for their particular activity.

Briefings were conducted at the start of each day and at the start of a new task in order to ensure that site personnel were conducting their work safely. The briefings included information on new operations to be conducted, changes in work practices, changes in the project's environmental conditions, and periodic reinforcement of previously-discussed topics. The briefings also provided a forum to facilitate conformance with safety requirements and to identify safety-related performance deficiencies observed during daily activities or as a result of safety inspections. The meetings were also an opportunity for safety personnel to periodically update the workers on monitoring results. Before starting any new activity, an analysis of hazards was performed and used to inform workers of the potential hazards, with an emphasis on the particular hazards involved with each job. Written documentation of the briefings and attendance sheets was maintained as part of the project safety files.

5.2.7 Emergency Response Plan

Emergency plans were developed to cover extraordinary conditions that might occur at the Fernald Silos 1 and 2 Remediation Project that were used in conjunction with Site Emergency Action Plan. Project personnel were responsible to be aware of the actions required of them under all site emergency procedures. Two types of plans were developed for the project; a standard emergencies plan (e.g., Fire, Severe Weather, Bomb Threat) and a plan for actions to be taken in the event of a potential significant release of radon from Silo 1 or Silo 2.

Under 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response,* an emergency exists when a site experiences an occurrence that results in, or is likely- to result in, an uncontrolled hazardous waste or hazardous substance release, causing a potential health or safety hazard that cannot be mitigated by personnel in the immediate work area where the release occurs. In the case of an emergency, trained responders from the FEMP Emergency Response Organization was relied upon for response. Under 29 CFR 1910.120, responses to incidental releases of hazardous substances where the substance can be absorbed, neutralized, or otherwise controlled at the time of release by employees in the immediate release area, or by maintenance personnel, are not considered to be emergency responses within the scope of Hazardous Waste Operations and Emergency Response. Responses to releases of hazardous substances where a potential health or safety hazard (i.e., fire, explosion, or chemical exposure) does not exist are considered to be non-emergency responses. Only qualified personnel, trained in incidental release clean-up under the Hazard Communication Standard, will respond to incidental releases. These personnel are not considered emergency responders.

5.2.8 Voluntary Protection Program

In 1982 the OSHA started a new program called the VPP. The VPP recognizes employers and workers in the private industry and Federal agencies who have implemented effective safety and health management systems and maintain injury and illness rates below national Bureau of Labor Statistics averages for their respective industries. Under this program, if corporate or Federal agencies meet certain health and safety guidelines and have employee involvement programs, they could be exempted from random OSHA inspections. To qualify for the VPP applicants must have in place an effective safety and health management system that meets rigorous performance-based criteria. In addition, all relevant OSHA standards must be met. OSHA verifies qualification through a comprehensive on-site review process. OSHA approves successful applicants as Star, Merit, or Demonstration participants with exemptions from programmed or scheduled inspections. Participation in the VPP does not diminish the rights and responsibilities of employers or employees under OSHA.

To qualify for participation in the VPP program, the employer must develop a plan, based upon three full years of records that would reduce their accident, injury, or illness rate to below the industry average within two years. If there is a Union at the workplace, the Union must play an active role in the VPP and must sign a formal statement indicating support of the VPP Program.

The FEMP obtained a Star status as a VPP site. The USDOE-VPP on-site review of Fernald Federal, Inc. for recertification was conducted from June 28 through July 1, 2004, at the FCP and Fernald Federal, Inc. each year, as required, submitted an annual status report for the USDOE-VPP, verifying the continuance of the quality of their program. Using a series of self-assessments and routine self-examinations, Fernald Federal, Inc. maintained its STAR program. These assessments have found a pattern where workers and their supervisors and/or managers have sustained a high quality of effort to control and to mitigate safety and health hazards. Employees remain well trained in hazard recognition, and actively utilize those skills to identify hazards and potential hazards. FFI has consistently reported major adjustments and refinements to their initial VPP baseline that have added significant value to their safety program.

5.2.9 OSHA Safety Reports

The FEMP is properly classified under the Standard Industrial Classification Code 4953 for Refuse Systems. Statistics available for Standard Industrial Classification 495 from the United States Department of Labor’s Bureau of Labor Statistics were used for comparative purposes.

As reported in the June 2000 VPP Report, the lost workday incidence and recordable injury incidence rates (Fluor Fernald 2000) were calculated based on a review of the OSHA 200 logs covering the current year-to-date and the previous three years. The three-year injury incidence rate and lost or restricted workday rate for the period (1997-1999) were 1.74 and 0.99 respectively. Thus, the site's injury incidence rate is 84 percent below comparable 1997 and 1998 industry averages for Standard Industrial Classification 495 (1999 data were unavailable at the time of the visit) and the injury incidence rate is similarly 83 percent below its comparable benchmark (Fluor Fernald 2000).

As reported in the July 2004 VPP Report (Fluor Fernald 2004b), a review of the OSHA 200 logs was made covering the current year-to-date and the previous three years. The three-year injury incidence rate and lost or restricted workday rate for the period (2001-2003) were 0.47 and 1.43 respectively. Thus, the site's injury incidence rate was 93 percent below comparable industry averages for Standard Industrial Classification 495 and the injury incidence rate was 53 percent below its comparable benchmark (Fluor Fernald 2004b).

Additionally, the following site-specific safety statistics were noted for the FEMP:

- First-aid incidents dropped from 300 in 1992 to 50 in 2005 and 19 in 2006.
- Fernald's OSHA-measured lost day work rate was .18 lost work days per 100 full-time workers in 2003 and .47 days in 2004. By comparison, the average OSHA lost day work rate during that period was 4.1 days.
- In 2006, a safety record was set of 107 days without a first-aid injury (Fluor-B&W 2011).
- Maintained an OSHA-recordable injury rate at the Fernald Site that is eight times better than the average for the U.S. construction industry.
- Reduction of the OSHA Total Recordable Case rate for Fluor's workforce at the Fernald Site from 3.83 in 1992 to 0.8 in 2005 - 7 times better than the 5.9 U.S. construction industry average - during a period of heavy field work and construction.
- A Lost Work Day Case Rate of 0.05, 52 times better than the U.S. construction industry average.
- Recordable Case Incidence Rate of 0.45 was 16 times better than the construction industry national average of 7.3, per the U.S. Department of Labor, Bureau of Labor Statistics.
- 10 million safe work hours and 11 years were recorded without a single lost-time accident.
- Obtained the USDOE ISM System validation of Fernald in 1999, nine months ahead of schedule.
- Designated a VPP Star Site in January 2001 and recertified its Star status in November 2004, making Fernald the first USDOE closure site to be re-certified (Fluor Fernald 2007).

5.2.10 Lessons Learned

Some of the significant safety challenges at FEMP that resulted in the Safety First initiative were that remediation fieldwork required heavy equipment movement and multiple demolition and construction project activities occurring within an aging infrastructure and a shrinking site footprint and the influx of nearly 800 construction personnel and heavy equipment operators in 2002 and 2003 created a challenge to train the new workers to embrace the site's safety culture before they were allowed to work. The key features of the safety program at the Fernald Site that helped to counterbalance the challenges included:

- Streamlining the site's safety committee structure;
- Continuing emphasis on worker involvement and enhanced work planning;
- Assigning each employee to a Safety Work Group and empowering the work groups and their safety advocates to take charge of safety;
- Communicating safety expectations and emphasizing a site-wide focus on 24-hour safety—not just safety during business hours;
- Treating first aid cases as importantly as recordable incidents as the first line of defense;
- Granting employees the authority to stop work if necessary to address safety concerns;
- Educating workers on the guiding principles and core functions of ISM and implementation of the ISM System;
- Sharing management's responsibility for safety with individual employees and work teams; and
- Communicating accidents and their causes throughout the site, the corporation and the USDOE complex to mitigate repeat incidents.

5.3 Contracting

A variety of contracting vehicles were employed at the Fernald Site to achieve site closure. Some were more effective than others for meeting the objectives established for the various activities related to remediation of OU 4 and the broader Fernald Site.

The USDOE prime contract with the site remediation contractor was initially a cost plus award fee management and operation contract, similar to the ones used at the time to manage most of the sites in the USDOE complex. In July 1994 a major modification was made in the prime contract to transition to a performance-based contract that contained fee incentives. The fee incentives were tied to performance areas and quality factors that the contractor and USDOE used to collectively identify objectives to be met in a given evaluation period, normally a period of six months. A key feature of this contracting approach was that it required the prime contractor to accept financial responsibility for its actions at the Fernald Site, including any fines or penalties arising from the contractor's negligence. The contractor in turn was granted greater latitude to make aggressive decisions about remediation methods. Contract fee awards were based on evaluation of contractor performance quality in the three elements of the mission statement, to include safe cleanup, least cost earliest and final cleanup, and addressing stakeholder concerns. The contractor was incentivized through this type of contract to execute the project with a focus on safe and cost effective completion of projects that would provide final remedies at the earliest possible time. This approach was successful and no change was made to the contract type for the prime contractor.

The prime contractor faced a number of challenges with regard to determination of the most appropriate contracting vehicles to use in procurement of support services, specialized equipment and systems and facilities design and construction services. A number of contracting mechanisms were employed to include fixed price, cost plus incentive fee, and time and materials. Some difficulties were encountered early in the efforts to complete the design and construction of the facilities needed for OU 4 remediation activities. Much of the waste processing, handling and support infrastructure for remediation of the Fernald Silos 1 and 2 K-65 residues involved first-of-a-kind facilities and technology. As a result the requirements for design and system performance were not well defined at the onset of project activities. Fixed price subcontracts were initially put in place for some of these innovative activities which were necessary to meet schedule deadlines; however, details of the performance requirements for affected systems continued to evolve and resulted in scope changes that necessitated change orders. The cost and schedule impact of the integrated change order process was mitigated by moving to time and materials contracting for the innovative activities. This allowed the prime contractor to act as the lead of an integrated project team, with subcontractor support providing adequate resources and specialized skill sets and resources required executing the work scope and responding to unanticipated issues as they arose with minimal impact to cost and schedule. Some resources and services were well defined or routine; these were procured using cost plus incentive fee, other incentive contract types, or fixed price contracts. The incentives were tied to the prime contractor's performance goals under its contract with USDOE; for example, fee incentives were offered for early milestone completion, a reflection of the early completion incentive in the prime contract.

Many of these approaches to contracting are appropriate for consideration at NFSS. The challenges encountered at the Fernald Site with respect to remediating and disposing of the K-65 residues will be encountered in USACE efforts to address the NFSS K-65 residues and other waste streams in the IWCS. The performance-based contracting approach should be considered for the prime contractor because this approach was a success at the Fernald Site; however, lessons learned about performance-based contracting from other USDOE and Federal projects should also be evaluated. The use of a combined set of contract types to build the project team, to include time and materials for innovative or poorly-defined scopes and incentive or fixed price contracts for better-defined scopes, should be considered. If NFSS can implement proven systems with minimal risk of scope change for resources and services, then time and materials contracts may not need to be used. However, it appears likely that, similar to the experience at the Fernald Site, some elements of the NFSS systems will require innovation and time and materials contracts may be the appropriate mechanism to contract that support.

Table 5-1. Lessons Learned Summary

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
5.1	Public Involvement Strategy	• Limited public-facing communication and limited public participation in the decision-making process led to an adversarial relationship between the facility and the public.	• Fernald expanded public communication beyond the CERCLA requirements to develop a participatory relationship with citizen groups. • Expanded feedback pathways (online surveys, surveys in public places) to collect input from a larger cross-section of the public.	• Public participated as a fully engaged member of the Fernald planning and development team, advocated for site future use, and contributed to solution of major issues in Fernald site cleanup. • DOE communications, facility open house tours, public meetings, regular media contact, immediate press releases when events occurred, and public outreach materials (flyers, educational seminars) addressed public concerns, raising public trust in USDOE and site activities.
Lessons Learned: *NFSS could design and implement a public involvement program with elements similar to that developed for Fernald Citizens Advisory Board. The USACE-FUSRAP program does not have the authority to establish a Citizens Advisory Board, but the principles and structure of the FCAB should be considered given financial limitations.*				
Lessons Learned:				
5.2	Voluntary Protection Program	• 300 first aid incidents reported in 1992 • Influx of large workforce inexperienced in a radiological work environment.	• Implementation of the VPP • Continuing emphasis on worker involvement and enhanced work planning	• First aid incidents dropped to 50 in 2005 and 19 in 2006. • Ten million safe work hours and 11 years were recorded without a single lost-time accident.
Lessons Learned: *Implementation of a VPP, with management team commitment and a robust health and safety culture, can mitigate potential hazards and incidents that may occur during IWCS remediation.*				

Table 5-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
5.3	Contracting Strategy	• Subtier FFP/PBC contracts for innovative or specialty services/resources during the design phase resulted in multiple change orders, impacting cost and schedule.	• Contracts were re-evaluated to determine how well the scope of services was defined; services and resources that could not be adequately defined (e.g. innovative or evolving technologies and designs) were procured using time and materials contracts.	• Significant reduction in contract change orders and the cost and schedule for integrated change management, as well as renewed focus on project execution.
Lessons Learned: *In developing the procurement strategy, time and materials or cost-reimbursable contract types could be considered for work packages requiring innovative or specialty services and resources with incentives tied to performance goals for the contract.*				

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6. WASTE DISPOSAL OPTIONS

This section presents the results of the waste disposal options study. This study focused on what are currently believed to be the most viable waste disposal facilities for the waste material associated with the NFSS IWCS. Consideration was given to all applicable disposal facilities and potential waste classifications for the IWCS material. The viability of each potential facility is discussed and a determination made based on available data and current facility license requirements/limitations. Facilities not determined to be currently viable may be re-considered during the IWCS FS to evaluate future license or permit modifications that mitigate existing constraints.

6.1 IWCS Waste Streams – Inventories, Characterization and Classification

Radioactive wastes and contaminated materials at NFSS were placed into the IWCS. For the purposes of this study, waste streams associated with the IWCS at NFSS have been broken out into five separate categories:

- K-65 Residues;
- Other IWCS Residues/Wastes;
- Tower Soil;
- Contaminated Rubble/Waste;
- R-10 Residues and Soil; and
- Contaminated Soil.

Table 6-1 presents the volumes and densities of the materials in the NFSS IWCS. Additionally, Table 6-2 provides the calculated average source term for the residues, soil and wastes associated with the IWCS. The Fernald K-65 waste characterization data had a calculated 95% UCL, whereas a mean concentration is calculated for the NFSS K-65 residues. The calculated 95% UCL is a higher concentration than the mean; it is expected that most actual waste concentrations would be lower than the 95% UCL. The mean concentration is generally a lower value and a significant fraction of the observed values may exceed the mean.

Table 6-1. Volumes and Densities of Materials in the NFSS IWCS

NFSS IWCS Waste Stream	Density		Volume					
			11e.(2)		LLRW		LLMW	
	(kg/m^3)	(lb/yd^3)	(m^3)[1]	(yd^3)[1]	(m3)	(yd^3)	(m3)	(yd^3)
K-65 Residues	1,800	3,000	3,080	4,030	0	0	0	0
Other IWCS Residues/Wastes	1,800	3,000	8,070	10,550	0	0	0	0
Tower Soil	1,800	3,000	3,150	4,115	0	0	0	0
Contaminated Rubble/Waste	1,898	3,200	35,650	46,610	0	0	0	0
R-10 Residues and Soil	1,800	3,000	45,500	59,500	0	0	0	0
Contaminated Soil	1,800	3,000	15,860	20,746	156,450	204,630	17,370	22,724

[1] The volume in the table represents the in-situ volumes and does not take into account down-blending or processing of the material.

Note: The results presented in this table were derived from the tables contained in Appendix D.

Table 6-2. Calculated Source Term for IWCS Waste Streams and Fernald Silos 1 and 2 K-65 Residues

	NFSS IWCS [1]						*Fernald* [2]			
	K-65 Residues	***Other IWCS Residues/Wastes***	***Tower Soil***	***Contaminated Rubble/Waste*** [3]	***R-10 Residues and Soil***	***Contaminated Soil***	***Silo 1 Residues***		***Silo 2 Residues***	
	Broad Radium-226 Concentration Category(pCi/g)						***Arithmetic Mean***	***95%UCL***	***Arithmetic Mean***	***95%UCL***
Radionuclide	***~520,000***	***<100,000***	***<15,000***	***<10,000***	***<100***	***<100***				
Actinium (Ac-227)	10,000	147	200	69	0.1	0.4	5,960	7,670	5,100	6,640
Actinium (Ac-228)	1,210	24	24.2	13	0.2	0.03				
Bismuth (Bi-210)	155,000	18,000	3,100	6,977	143	24				
Bismuth (Bi-211)	10,000	1,534	200	370	1.5	4.2				
Bismuth (Bi-212)	1,210	24	24.2	13	0.2	0.03				
Bismuth (Bi-214)	520,000	14,000	10,400	6,891	95	16				
Francium (Fr-223)	138	2	2.8	1	0.0	0.0				
Lead (Pb-210)	155,000	18,000	3,100	6,977	143	24	165,000	202,000	145,000	190,000
Lead (Pb-211)	10,000	1,534	200	370	1.5	4.2				
Lead (Pb-212)	1,210	24	24.2	13	0.2	0.03				
Lead (Pb-214)	520,000	15,000	10,400	7,246	95	16				
Polonium (Po-210)	155,000	18,000	3,100	6,977	143	24	242,000	281,000	139,000	231,000
Polonium (Po-211)	27	4	0.5	1	0.004	0.01				
Polonium (Po-212)	775	15	15.5	8	0.1	0.02				
Polonium (Po-214)	519,896	13,997	10,398	6,890	95	16				
Polonium (Po-215)	10,000	1,534	200	370	1.5	4.2				
Polonium (Po-216)	1,210	24	24.2	13	0.2	0.03				
Polonium (Po-218)	520,000	12,000	10,400	6,181	95	16				
Protactinium (Pa-231)	5,000	147	100	50	0.1	0.4			2,350	4,040
Protactinium (Pa-234)	1	2.3	0.02	1	0.002	0.006				
Protactinium (Pa-234m)	650	1,750	13	393	1.7	4.8				
Radium (Ra-223)	10,000	1,534	200	370	1.5	4.2				
Radium (Ra-224)	1,210	24	24.2	13	0.2	0.03				
Radium (Ra-226)	520,000	12,000	10,400	6,181	95	16	391,000	477,000	195,000	263,000
Radium (Ra-228)	1,210	24	24.2	13	0.2	0.03				
Radon (Rn-219)	10,000	1,443	200	350	1.4	4.0				

Table 6-2. Calculated Source Term for IWCS Waste Streams and Fernald Silos 1 and 2 K-65 Residues (continued)

Radionuclide	*NFSS IWCS* [1]						*Fernald* [2]			
	K-65 Residues	*Other IWCS Residues/Wastes*	*Tower Soil*	*Contaminated Rubble/Waste* [3]	*R-10 Residues and Soil*	*Contaminated Soil*	*Silo 1 Residues*		*Silo 2 Residues*	
	Broad Radium-226 Concentration Category(pCi/g)						*Arithmetic Mean*	*95%UCL*	*Arithmetic Mean*	*95%UCL*
	~520,000	*<100,000*	*<15,000*	*<10,000*	*<100*	*<100*				
Radon (Rn-220)	1,210	24	24.2	13	0.2	0.03				
Radon (Rn-222)	520,000	12,000	10,400	6,181	95	16				
Thallium (Tl-207)	9,973	1,529	199	369	1.5	4.2				
Thallium (Tl-208)	435	9	8.7	5	0.07	0.01				
Thallium (Tl-210)	104	2.8	2.1	1	0.02	0.003				
Thorium (Th-227)	10,000	144	200	68	0.1	0.4				
Thorium (Th-228)	1,210	24	24.2	13	0.2	0.03	422	2,280	645	7,360
Thorium (Th-230)	54,000	12,000	1,080	4,470	50	16	60,000	68,900	48,400	76,200
Thorium (Th-231)	33	126	0.7	28	0.1	0.3				
Thorium (Th-232)	1,210	24	24.2	13	0.2	0.03	424	1110	402	985
Thorium (Th-234)	650	1,750	13	393	1.7	4.8				
Uranium (U-234)	650	1,750	13	382	1.7	4.8	800	932	961	1,160
Uranium (U-235)	33	126	0.7	28	0.1	0.3	38*	54*	73*	94*
Uranium (U-238)	650	1,750	13	382	1.7	4.8	642	693	912	1,120

[1] The results presented in this table were derived from the tables contained in Appendix D.

[2] Values from Fernald OU 4 FS Report, Table 1-2 (USDOE 1994b).

[3] Weighted average of the volume and source term concentrations for each of the wastes in Building 411 (L-30, F-32, Tower Soils and Contaminated Soils excluding the K-65 residues) as a conservative estimate.

* Values represent U-235/U-236 results.

The assumed waste volume used to conduct this waste disposal options study and to obtain information from disposal facilities is based on the current in-situ waste inventory in the IWCS. The final volume of material to be disposed may vary significantly depending on the specific methods of processing and/or treatment evaluated in the IWCS FS remedy evaluations. However, such variations in waste volume will not impact the identification of viable disposal facilities because the overall currently available disposal capacity is more than adequate to accommodate the processed waste volumes that can be reasonably expected (these volumes include the in situ waste plus the volume added by processing). A comprehensive breakdown of waste inventory, characterization and classification of each separate waste stream is presented in the following sections. An estimate of the waste volumes potentially subject to disposal (based on the in-situ volumes and the addition of other materials to achieve required Ra-226 concentrations) is presented in Section 6.3.2.

6.1.1 IWCS Waste Classification

Categorization of waste into classes is performed in order to simplify waste management actions, rules, and regulations while protecting human health. Radioactive wastes are generally classified according to radioactivity and include high-level radioactive waste, LLRW, low-level mixed waste (LLMW), nuclear fuel and byproduct waste.

Analysis and evaluation of the constituents in a waste (characterization) is the means by which a waste is categorized. The waste category ultimately determines the requirements for treatment, storage and disposal according to regulatory criteria established by the Federal or state governments. The category of a particular waste can limit the options for selection of facilities that can receive the waste for treatment and/or disposal as well as impose constraints on the type(s) of packaging that may be used to transport and dispose of the wastes in question. Depending on the proximity of disposal facilities licensed or permitted to receive a given waste from the generator, and the modes of transport the facilities can accommodate to receive the waste, costs can vary widely for treatment, storage or disposal of the waste. The categorization of the waste type becomes a primary consideration in evaluation of options for treatment, storage and disposal as they are related to cost.

The following sections describe the primary waste classifications known to be applicable or potentially applicable to the IWCS waste streams.

6.1.1.1 11e.(2) Byproduct Material

The following text was presented in Section 312 of the Energy and Water Development Appropriations Act for the Fiscal Year ending September 30, 2004:

> *"SEC.312. Notwithstanding any other provision of law, the material in the concrete silos at the Fernald uranium processing facility currently managed by the United States Department of Energy and the ore processing residual materials in the Niagara Falls Storage Site subsurface waste containment structure managed by the United States Army Corps of Engineers under the Formerly Utilized Sites Remedial Action Program will be considered "byproduct material" as defined by section 11e.(2) of the Atomic Energy Act of 1954, as amended [42 U.S.C. 2014(e)(2)]. The Nuclear Regulatory Commission*

or an Agreement State, as appropriate, will regulate the material as "11e.(2) byproduct material" for the purpose of disposition of the material in an NRC-regulated or Agreement State-regulated facility."

In Section 11e.(2) of the Atomic Energy Act of 1954, ''byproduct material'' is defined as "the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content." Congress, in House Report 108-554 (under Accelerated Completions, 2006) as part of the Energy and Water Development and Appropriations Bill, 2005, clarified that " The language included in the Energy and Water Development Appropriations Act, 2004, was intended to allow the Department to consider commercial NRC-regulated disposal options as well as use of government-owned disposal sites." In other words, the Nuclear Regulatory Commission (NRC) or agreement state will regulate the NFSS residues as 11e.(2) byproduct material for the purpose of disposal in the event that USACE seeks to dispose of those materials at a regulated facility. An "agreement state" is a state that signed an agreement with the NRC authorizing the state to regulate certain uses of radioactive materials within the state. Since the definition of LLRW is a radioactive waste that is not classified as Special Nuclear Material, high level, or byproduct material, the NFSS IWCS contents are not LLRW, but byproduct material according to the legislation mentioned above. However, materials in the NFSS IWCS that are not residues (to include soils not mixed with residues) may be considered LLRW.

According to 40 CFR 261.4(a)(4), byproduct material is excluded from the RCRA definition of solid waste and is, therefore, not subject to these regulations in regards to transportation, treatment, or disposal of waste. However, should other hazardous waste materials be combined with the 11e.(2) material designated for disposal that is not associated with ore processing, then the waste could potentially be regulated as a hazardous waste under RCRA and not be permitted to be placed in an 11e.(2) disposal cell. This is a potential concern for the residues located within the IWCS. Unlike Fernald Silos 1 and 2, where only K-65 residues were placed within the silos, other waste materials associated with remedial actions across the site and with vicinity properties were placed in the IWCS as well as the residues. This presents the potential for other hazardous waste or radiological materials not associated with ore processing to be present within the IWCS. Any removal actions associated with the residues within the IWCS would need to be conducted in a manner that minimizes the potential for other non-11e.(2) material to be commingled with the residues.

6.1.1.2 Low-Level Radioactive Waste

LLRW is radioactive material not classified as high level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material (as defined in 42 U.S.C. 2014), and which the NRC classifies as LLRW consistent with existing law. LLRW has four subcategories: Class A, Class B, Class C and greater than Class C. On average, Class A is the least hazardous and greater than Class C is the most hazardous. Because 11e.(2) byproduct material is specifically excluded from the definition of LLRW, it does not require an LLRW subcategory classification in accordance with the requirements of 10 CFR 61.55.

If the IWCS residue were classified as Low Level Waste for disposal (instead of 11e.(2) byproduct material), the waste would require an LLRW subcategory classification. The overwhelming majority of activity in the IWCS waste originates from Ra-226 and its associated daughters. While Ra-226 is not specified in 10 CFR 61.55 Table 1 long-lived nuclides limits, Utah and Texas state regulations specify Ra-226 concentration limits for determination of low level classification. Both states have specified a limit of 100 nCi/g Ra-226 which, if exceeded, would render the waste greater than Class C. If the waste ranges between 10 nCi/g and 100 nCi/g, the waste is considered Class C; below 10 nCi/g the waste is considered Class A provided all other nuclide limits are not exceeded. Using this definition, the Fernald K-65 waste would have been at least Class C waste due to the Ra-226 concentration, as defined by the eligible state licensing statutes. Consideration of the daughter activities could elevate the waste to greater than Class C. Based on the limited data and information associated with the materials placed into the IWCS, it is expected that some of the waste will be classified as LLRW.

If LLRW is mixed with hazardous wastes, then it has a special status as LLMW and must meet treatment, storage, and disposal regulations both as LLRW and hazardous waste. Given the materials placed in the NFSS IWCS and the presence of potentially hazardous materials at the NFSS, it is reasonable to expect that some fraction of the LLRW at NFSS may be characterized as LLMW. Based on the limited data and information associated with the materials placed into the IWCS, there is potential for LLMW to be present in the IWCS but the volume is considered to be minimal.

6.1.1.3 Naturally Occurring Radioactive Material

Naturally Occurring Radioactive Material (NORM) is defined as material that contains radionuclides commonly found in nature including uranium, thorium and potassium and any of their decay products, such as radium and radon. There are two types of NORM waste: discrete and diffuse. Discrete NORM has a relatively high radioactivity concentration in a very small volume (e.g. a medical radium source). The relatively high concentration of radioactivity in discrete NORM results in a direct radiation exposure hazard. Diffuse NORM has a much lower concentration of radioactivity in a relatively large volume of waste.

Discrete NORM is subject to regulatory control under the Atomic Energy Act of 1954, or the Low-Level Radioactive Waste Policy Act. Because of these regulatory exclusions, NORM is subject primarily only to individual state radiation control regulations. NORM waste is commonly associated with the oil and gas industry due to the presence of naturally occurring radium isotopes in drilling and production wastes (water, scale and sludge). By definition, NORM radionuclides do not include those produced artificially by humans. No NORM waste is known or expected to be present in the IWCS.

6.1.1.4 Special Nuclear Material

Special nuclear material is defined by Title I of the Atomic Energy Act of 1954 as plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. The definition includes any other material that the NRC determines to be special nuclear material, but does not include source material. The NRC has not declared any other material as Special Nuclear Material. No special nuclear material waste is known or expected to be present in the IWCS.

6.1.1.5 Technologically Enhanced Naturally Occurring Radioactive Materials

The definition of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) was developed by the National Academy of Sciences as: *" …any naturally occurring radioactive materials not subject to regulation under the Atomic Energy Act whose radionuclide concentrations or potential for human exposure have been increased above levels encountered in the natural state by human activities."* Similar to NORM, TENORM contains radionuclides commonly found in nature including uranium, thorium and potassium and any of their decay products, such as radium and radon. Examples of TENORM include wastes generated by mining and wastewater treatment. The most common radionuclide of concern in TENORM waste is Ra-226. The terms NORM and TENORM are often used interchangeably. No TENORM waste is known or expected to be present in the IWCS.

6.1.1.6 Transuranic Waste

Transuranic waste is defined as:

> "*waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, per gram of waste, with half-lives greater than 20 years, except for (A) high-level radioactive waste; (B) waste that the Secretary [of Energy] has determined, with concurrence of the Administrator [of the Environmental Protection Agency], does not need the degree of isolation required by the disposal regulations; or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of Title 10, CFR*" (Waste Isolation Pilot Plant [WIPP] Land Withdrawal Act, Public Law 102-579).

All transuranic elements are heavier than uranium, have several isotopes, and are typically man-made. Key radionuclides found in transuranic waste include americium-241 and several isotopes of plutonium. The United States currently permanently disposes of all transuranic generated waste from defense nuclear activities at the WIPP in Carlsbad, New Mexico. No transuranic waste is known or expected to be present in the IWCS.

6.1.1.7 Waste Classification Uncertainties

The classification of the various NFSS waste streams has major implications for waste management and available disposal options. The 11e.(2) licenses reviewed under this TM require the generator to state or certify that no additional radioactive or hazardous material has been introduced to the 11e.(2) waste accepted for disposal. Thus, if transuranics or other radionuclides not associated with 11e.(2) waste originating from the Knolls Atomic Power Laboratory waste or the University of Rochester burial ground have infiltrated the NFSS residues and associated waste streams (i.e., materials contaminated only by the ore processing residues designated as 11e.(2) for disposal purposes), there is a potential that any impacted residue waste would require segregation and alternate disposal. Sampling and analysis can be utilized to segregate the impacted waste, thus minimizing or eliminating the amount of waste requiring alternate disposal due to the presence of non-11e.(2) nuclides. In addition, the volume of waste from Knolls Atomic Power Laboratory waste or the University of Rochester burial ground is expected to be minor in comparison with the NFSS K-65 residues. In 1972 a total of 392 m^3 (512 yd^3) of waste was excavated from Vicinity Property "G", where the University of Rochester wastes were located (USACE 2004). Assuming that all of this waste was University of Rochester waste and that all of it was placed in the IWCS, this represents less than four percent of the of the total volume of material expected in the IWCS (Table E-1). The volume of KAPL waste in the IWCS is likely even less; KAPL waste was shipped to the site in containers, the containers stored at NFSS, and then shipped off-site for disposal. The residual waste that would have been placed in the IWCS would have been incidental contamination related to storage, burning of low-level combustibles on-site, and management of the containers, which is anticipated to be a small volume. If it is determined that wastes other than 11e.(2) wastes (for purpose of disposal) are present, the waste may require reclassification and subsequent management as LLRW or as LLMW. Based on the review of the information from the NFSS RI Report on additional radionuclides (e.g. plutonium, strontium or cesium), the concentrations are well below the LLRW and LLMW WAC limits for the facilities under review. Regardless, if the residues are classified as 11e.(2) or LLRW, the limiting radionuclide will be Ra-226.

NRC has provided provisions for disposal of non-11.e(2) material in an 11e.(2) facility. However, the provisions indicate that the disposal facility would need to demonstrate a compelling need to dispose of special nuclear material and Section 11e.(2) material in this way (NUREG-1620, Appendix I, Attachment 1) [NRC 2003] making this disposal path applicable only to very specific waste materials and requiring extraordinary effort to obtain approval.

6.1.2 K-65 Residues

The Manhattan Engineering District/AEC work conducted by Mallinckrodt Chemical Works located in St. Louis, MO, included the development of uranium-processing techniques and the production of uranium metal. The main uranium ore processed by Mallinckrodt originated from the Belgian Congo (Africa) region which contained uranium concentrations up to 65%. After uranium extraction was completed, the remaining process wastes were classified as K-65 residues and still contained the natural uranium decay products: Actinium (Ac-227), Bismuth (Bi-210 and Bi-214), Protactinium (Pa-231), Lead (Pb-210 and Pb-214), Polonium (Po-210), Radium (Ra-226), Thorium (Th-228, Th-230, and Th-232), and Uranium (U-235/U-236 and U-238). Table 6-2 provides the calculated average source term for the residues, soil and wastes associated with the IWCS.

The Fernald K-65 waste characterization data had a calculated 95% UCL. This contrasts with the average concentration for the NFSS K-65 residues (Table 6-2). The calculated 95% UCL is a higher concentration than the average; it is expected that most actual waste concentrations would be lower than the 95% UCL. A significant fraction of the observed values may exceed the average. This means that there is a higher likelihood that the actual concentrations encountered with the NFSS K-65 residues, should they be removed, would be higher than the concentration presented in Table 6-2.

In or around 1949, these K-65 residues were transported to the Lake Ontario Ordnance Works facility, located in Lewiston Township, New York, where they were stored in an above-ground silo in the northeast portion of the site. In the 1940s approximately 607 ha (1,500 acres) in the southern portion of the Lake Ontario Ordnance Works production area were transferred to the Manhattan Engineering District, which later became the AEC and then the USDOE. In February 1944, the USACE's Manhattan Engineering District was granted use of a portion of the

Lake Ontario Ordnance Works for the storage of radioactive residues generated through the processing of uranium ore. With this action, the NFSS was created (USACE 2007). From the 1950s to the 1980s this area was used for various activities including the production of high energy fuel (USACE 2011a) and storage of radioactive materials during the development of the atomic bomb. Of the original 607 ha (1,500 acres), 77.3 ha (191 acres) is still owned by the USDOE and is known as the NFSS, while the remainder are owned by other entities and known as current or former vicinity properties of the NFSS.

Once the Lake Ontario Ordnance Works storage silo had reached capacity, the K-65 residues were transported to the Feed Materials Production Center which is currently known as the Fernald Site. The Feed Materials Production Center performed further uranium extraction processes on some of the K-65 residues which differed in process from that used by the Mallinckrodt Chemical Works. However, all of the K-65 residues stored at the two sites had basically the same chemical and radiological characteristics. It should be noted that residual Th-230 was generally transported to the St. Louis Airport Site to account for the reduced concentration present in Mallinckrodt process residues.

The estimated volume of K-65 material at the NFSS is shown in Table 6-1. The broad Ra-226 characterization categorizes this material as approximately 520,000 pCi/g in its current state (Table 6-2). This waste stream has been deemed 11e.(2) material for purposes of disposal.

Data results for soil and building materials at NFSS showed that there were detects of other radionuclides, particularly plutonium, found at low levels (USACE 2007 and USACE 2011b). The concentrations are not typically associated with residues classified as 11e.(2) material and would not exceed the acceptance criteria for LLRW for the facilities under review.

Given that the K-65 residues at NFSS and in Fernald Silo 1 are residues resulting from the same processing source (Mallinckrodt processing of African ore) it is expected they are both chemically and radiologically similar, as discussed in Section 6.1.2. On this basis, it is not expected that there would be any other radiological or chemical constituents in the K-65 residues that would have an impact on their disposal options. However, there will have to be some consideration in the detailed analysis of alternatives in the IWCS FS for the alternatives that would involve the removal of the K-65 and other residues and the possibility of using some of the contaminated soils within the IWCS to attenuate the activity in the residues. Care must be taken to preclude these residues from becoming commingled with other radiological or hazardous constituents not typically associated with 11e.(2) residues because the disposal facilities require the generator or owner to certify in writing that the waste is 11.e(2) byproduct material as defined by the Atomic Energy Act, as amended. If commingling of wastes were to occur, the material would not be acceptable for placement into the 11e.(2) disposal cells and the waste would have to be reclassified as LLRW or LLMW to allow for disposal.

6.1.3 Other IWCS Residues/Wastes

Other wastes stored at the IWCS were designated as L-30, L-50, and F-32 residues. These were residues resulting from processing of ore with uranium concentrations ranging from 0.4% up to 10%, at the Linde Ceramics Plant, Tonawanda, NY (L-30 and L-50 residues) and residues from the Middlesex Metal Refinement Plan (F-32 residues) in Middlesex, NJ. These materials are referred to as other IWCS residues/wastes; their total estimated volume is shown in Table 6-1, and the individual volumes are presented in Appendix D, Table D-1. The broad Ra-226 characterization categorizes this material as <100,000 pCi/g. Due to the potential contact with K-65 materials that may have occurred during placement and subsequent to storage in the IWCS, this waste stream can be deemed 11e.(2) material for purposes of disposal. However, as discussed in Section 6.1.1.1, all residues within the IWCS have been designated by Congress as 11e.(2) byproduct material for purposes of disposal.

See Section 6.1.1 regarding the potential impacts and design considerations associated with the introduction of other radiological and hazardous constituents to these residues.

6.1.4 Tower Soil

Tower soil consists of soils that were originally located outside the K-65 storage silo (Building 434) at the NFSS. These soils were contaminated during facility operations, transfer of the K-65 residues to what is now the IWCS, and decommissioning of the silo. The broad Ra-226 characterization categorizes this material as <15,000 pCi/g. Because the soil was contaminated with K-65 materials, it is classified as 11e.(2) material for purposes of disposal.

6.1.5 Contaminated Rubble/Waste

The contaminated rubble waste includes construction debris, concrete, rebar, etc. from the demolition of Buildings 410, 415, and 434. This material also includes K-65 slurry transfer piping, existing structures prior to the IWCS, the Thaw House Foundation and miscellaneous materials from Building 413 and 414. The estimated volume of the contaminated rubble and waste is 35,650 m^3 (46,610 yd^3). Due to potential extended contact with K-65 materials this waste stream can currently be deemed as 11e.(2) material for purposes of disposal.

6.1.6 R-10 Residues and Soil

The R-10 soil includes R-10 residues from the processing of ore containing approximately 3.5% U_3O_8 at the Linde Ceramics Plant in Tonawanda, New York. These residues were shipped to the site sometime between 1944 and 1949 and were stored in a pile on open ground north of Building 411 (USACE 2007). Information from previous reports (BNI 1986 and USDOE 1986) indicates that the R-10 soil pile consists of approximately 7,000 m^3 (9,500 yd^3) of original residues and approximately 11,500 m^3 (15,000 yd^3) of contaminated soil from remedial actions conducted in 1972 (pre-IWCS construction). The 1972 remedial action soils were placed on top of the original R-10 pile (DOE 1982). The resulting R-10 soil pile while under historic open ground storage at the NFSS, subsequently leached into the underlying soil, contaminating approximately an additional 26,500 m^3 (35,000 yd^3) of below grade soil for a total of approximately 45,500 m^3 (59,500 yd^3) (Appendix D, Table D-1). The reported concentrations are results from sampling of the soil pile and subsurface.

The broad Ra-226 characterization categorizes this material as <100 pCi/g. Due to the contact with R-10 residues, this waste stream can be classified as 11e.(2) material for purposes of disposal.

6.1.7 Contaminated Soil

The contaminated soil material is comprised of materials placed into the IWCS from several on-site and off-site remedial actions over the years between 1982 and 1991 as well as sand/clay separating layers in Building 411. This material also includes other materials contaminated by proximity to the IWCS wastes. The estimated volume of the contaminated soil is shown in Table 6-1 and detailed in Appendix D, Table D-1. Materials contaminated by contact or leaching are expected to include a fraction of the dike material, cap material, and the soil beneath the IWCS. Uncontaminated portions of the dike material, cap material, and soils beneath the IWCS are not included in the IWCS OU; they are included with the BOP OU.

The volumes (Table 6-1) used in this waste disposal options analysis and for the purposes of the cost estimate presented later in this section assume that 0.6 meters (2 feet) of the dike material and cap material in contact with IWCS wastes are contaminated, and the depth of contamination by leaching beneath the R-10 residues and beneath the IWCS is 3 m (10 ft). It is likely that the actual depth of contamination beneath the R-10 residues and the IWCS is closer to one meter (three feet), but that has not yet been evaluated by sampling.

The soils from the 1972 Remedial Action (including R-10 residues), the sand/clay separating layers in Building 411, and the higher activity tower soils in Building 411 are currently considered 11e.(2) material for purposes of disposal due to their contact with K-65 residue materials and no other waste materials. Any contaminated soils beneath the structures containing the 11e.(2) residues (Buildings 411, 413, and 414) would also be considered 11e.(2) material for purposes of disposal since there would not have been any other radiological contamination present under these structures which were built before the residues and other waste materials were brought to the site. Therefore, any contamination found would be associated with the residues stored within that structure. The other contaminated soils are considered LLRW because of limited contact with K-65 residue materials. Given the presence of potentially hazardous materials at NFSS, it is reasonable to expect that some of these soils will be characterized as LLMW. For cost estimating purposes, USACE has assumed that 10% of the non-11e.(2) waste volume should be considered LLMW.

If all of the waste materials in the IWCS are removed, then the remaining IWCS structure (e.g., remaining cap material, cut-off walls, residual soils that had waste placed on them, structures or foundations not removed as part of residue removal, etc.) would be addressed within the scope of the BOP OU (USACE 2009). The broad Ra-226 characterization categorizes this material as < 100 pCi/g.

6.2 Potential Waste Disposal Facilities

The potential waste disposal facilities identified in this section include some facilities considered by USDOE during its search for a disposal site for the Fernald K-65 residues. Additional facilities also have been included to provide greater flexibility for potential accommodation of waste streams at NFSS that were not present in the wastes associated with Fernald OU 4.

For the purposes of this report, the following licensed or permitted disposal sites were considered for the NFSS waste streams:

- Commercial Facilities
    - Barnwell Waste Management Facility
    - Energy*Solutions*
    - U.S. Ecology, Grand View, Idaho
    - U.S. Ecology, Robstown, Texas
    - U.S. Ecology, Richland, Washington
    - WCS, Texas
    - Wayne Disposal, Incorporated (WDI), Belleville, Michigan
- USDOE Owned Facilities
    - Hanford Reservation (two facilities), Richland, Washington
    - NNSS
    - WIPP
- Canadian Facilities
    - Chalk River, Deep River, Ontario

A number of the facilities listed above are located in states which are members of a waste compact. Congress passed the Low-Level Radioactive Waste Policy Act in 1980 (amended in 1985) to promote regional LLRW disposal facilities. Under the Act states may join together to build regional facilities by forming organizations called compacts. The Act defines a compact as a legal agreement between two or more states to share in the disposal of LLRW. For a state to become a member of a compact, its state legislature must enact the compact agreement as a statute. After the legislatures of all states in a compact enact the agreement, Congress must also consent to it. Each compact is responsible for the development of disposal capacity for commercial LLRW generated within the compact and can deny any wastes from outside the compact.

The compact disposal facility is generally located in one of the compact states and the compact defines the requirements for the types of wastes to be disposed of by compact members. In some instances the compact may also establish constraints on waste disposal by other states or organizations that are not part of the compact membership. Exceptions, when granted, may also carry provisions on type or amount of waste from non-compact member states that can be disposed of at the waste facility.

Currently there are ten compacts, with the newest being the compact developed between Texas, Maine and Vermont (Maine has since withdrawn). New York does not belong to a compact thus the NFSS waste would not be eligible for disposal sites limited by compact.

The following section addresses each of the disposal facilities listed above, including those located in states which are members of a compact. Restrictions associated with compact requirements are noted, where applicable.

6.2.1 Determination of Viable Disposal Facilities for the IWCS

The following disposal facilities identified in Section 6.2 have been determined to be viable waste disposal options for the IWCS:

- Energy*Solutions* (Utah);
- U.S. Ecology (Idaho);
- WCS (Texas);
- WDI (Michigan); and
- NNSS (Nevada).

The rationale associated with the determination of viability or non-viability for each facility is included in the following sections.

6.2.1.1 Viable Disposal Facilities - Rationale

The Energy*Solutions* facility in Clive, Utah, was considered for this study as it operates both a Class A LLRW disposal cell and an 11e.(2) disposal cell. For the purposes of this study, Energy*Solutions* is considered to be a viable disposal option within the confines of their specific WAC. Although the State of Utah is a member of the Northwest compact, the Clive disposal facility in Utah is not included in the Northwest compact. The Clive disposal facility may accept LLRW without exemptions or approvals with the exception of the following. Specific compact export approval must be given to generators within the Northwest, Southwest, Rocky Mountain, Texas and Central compacts when shipping waste to Clive. All other compacts have given blanket authorization for generators to ship waste to Clive. USDOE sites do not require any compact export approval.

U.S. Ecology was considered for this study as all three of their facilities accept LLRW. The Richland facility is a member of the Northwest Compact. The Northwest Compact consists of member states Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, and Wyoming. While the facility can receive wastes from the Rocky Mountain Compact states (Colorado, Nevada, and New Mexico) by current arrangement, the NFSS waste would not be considered compact waste. The facility in Grand View, Idaho, accepts NORM and NRC exempt material and as a RCRA Part B facility is limited to wastes that are not subject to the Atomic Energy Act of 1954 as amended for the purposes of disposal. The Idaho site has accepted FUSRAP waste for disposal in the past and is recognized as a potentially viable facility for NFSS waste that meets the facility's WAC.

WCS was considered for this study as it currently operates a Byproduct 11e.(2) Landfill. The WCS license was initially approved to accept the Fernald Silos 1 and 2 waste. In late 2011, the facility will open a Texas Compact Waste Disposal Facility. This Compact consists of Texas and Vermont. It will allow for Class A/B/C waste disposal. Rules are in place to authorize the Compact Commission to allow out-of-Texas Compact generators to dispose of waste at WCS. Additionally, the Federal Waste Disposal Facility will be operational during the second quarter of 2012. Both the 11e.(2) cell and the new federal LLRW disposal cell will be subject to long-term management oversight by USDOE and, as such, will not be subject to Texas Compact

Authority. This facility will allow for Class A/B/C mixed waste disposal from USDOE sites. For the purposes of this study, WCS is currently a viable disposal option within the confines of their specific WAC.

The Wayne Disposal Site #2 Landfill operated by WDI was considered for this study due to its ability to accept FUSRAP waste. Specifically, the facility is permitted to accept NORM, TENORM, and exempted radioactive materials including: specific State of Michigan regulated materials; FUSRAP materials; and specific NRC regulated materials. The facility is not authorized to dispose of waste that was generated at a facility that has, or formerly held, a NRC or Agreement State license. The facility also is not authorized to accept 11e.(2) byproduct material (i.e., K-65 residues or associated waste). This facility is considered a viable option for some of the potential NFSS waste streams.

The NNSS (formerly known as the Nevada Test Site) was considered for this study as it operates a LLRW facility with ten cells in use and one cell in use for mixed LLRW. Although the facility operates (is geographically located) in the Rocky Mountain Compact, the USDOE disposal facility is not subject to Compact authority. Although NNSS has not accepted waste from other FUSRAP projects to date, it is still considered a viable disposal option for NFSS waste based on their WAC.

6.2.1.2 Non-Viable Disposal Facilities - Rationale

The Barnwell Waste Management Facility was considered for this study as it operates a Class A/B/C trench packaged radioactive waste. The site operates as the Atlantic Compact Regional Disposal Facility. Information provided by facility personnel indicates that the site currently accepts Atlantic Compact waste only. The Atlantic Compact consists of Connecticut, New Jersey, and South Carolina. For this reason, Barnwell is not currently a viable disposal option for the NFSS waste streams.

To address legacy issues as well as to manage newly generated wastes, the USDOE has developed several facilities or cells for disposal of radioactive wastes. Two of these sites are located on the Hanford reservation in Richland, Washington: The Environmental Restoration Disposal Facility for LLRW and the Integrated Disposal Facility with cells for LLMW. These facilities are currently limited to accepting only waste arising from the Hanford reservation. This limitation is found at other USDOE on-site disposal facilities as was the case of the On-site Waste Disposal Facility at the Fernald Site. For the purposes of this evaluation, site-specific USDOE facilities (including Hanford and Fernald) are not considered viable options for disposal of waste from NFSS.

WIPP was considered for this study but is currently not a viable disposal option for the NFSS waste streams, due to the fact that the facility currently accepts only transuranic waste. Transuranic waste is any material contaminated with elements that have an atomic number greater than 92, including plutonium, neptunium, americium and curium, and that are in concentrations greater than 10 nanocuries per gram, or in such concentrations as the NRC may prescribe to protect human health and safety (42 USC Section 2014, chapter 23). For WIPP, the transuranic concentration is 100 nanocuries per gram, as discussed in Section 6.1.1.6. The reader is referred to the discussion on transuranic waste in Section 6.1.1.6. The K-65 residues and the other residues in the IWCS do not qualify as transuranics on the basis that they do not contain radioisotopes with an atomic number greater than 92.

Due to the proximity of NFSS to Canada, the availability of Canadian disposal facilities for IWCS wastes was investigated. Currently, Canada does not have a long-term disposal facility for low- and intermediate-level radioactive waste. Low- and intermediate-level waste in Canada is currently held on-site in storage (Canadian Nuclear Safety Commission 2009 and Chambers 2011a). The only repository that is licensed or permitted to receive commercial radioactive waste in Canada is the Chalk River facility near Deep River, Ontario which is owned by Atomic Energy of Canada, Limited (2011a). In the past, the Atomic Energy of Canada, Limited Chalk River disposal facility has routinely declined to take commercial waste from organizations in the United States (Chambers 2011a). The Canada Nuclear Safety Commission also stated that other potential options would be limited to transfer to licensees such as Cameco Corporation or Areva Resources, Inc., which have their own mill tailings piles in northern Saskatchewan (Chambers 2011a).

6.2.2 Waste Acceptance Criteria and Licensing

Table 6-3 summarizes the applicable waste streams and WAC limits for Ra-226 at each viable disposal facility identified in Section 6.2.1. The information in the table is focused on Ra-226 (as the primary IWCS contaminant) and excludes other radionuclides, chemicals, and other potential acceptance criteria.

Table 6-3. Disposal Facility Licensing for Ra-226

Disposal Facility	***Radioactive Waste Streams***	***Licensing Limits***
Energy*Solutions*	11e.(2) LLRW, LLMW	4,000 pCi/g 10,000 pCi/g
U.S. Ecology (Idaho)	NORM, TENORM Exempt and Source materials	500 pCi/g
WCS	Class A/B/C (Federal and Commercial) 11e.(2)	N/A[1] 100,000 pCi/g[2]
Wayne Disposal Landfill	NORM, TENORM Exempt and Source materials	Ra-226: 50 pCi/g
NNSS	LLRW, LLMW	Package: 300 PE-g Shipment: 2,000 PE-g Ra-226: 412 pCi/g (calculated)[3]

[1] No specified limits for radionuclides (total curies and volume specifications only). LLRW and LLMW must meet definitions in 30 Texas Administrative Code (TAC) 336.2(76) and 30 TAC 336.2(80). As of June 2011, commercial cell is described in the facility Waste Acceptance Plan. WAC to be updated after approval of plan.

[2] Licensing limit based on Fernald K-65 waste received at WCS for disposal in 11e.(2) byproduct material disposal cell.

[3] See Section 6.2.2.5 for calculation details. NNSS specifies Radionuclide Action Limits for waste characterization and reporting, additionally NNSS requires the normalization of all nuclides to Plutonium Equivalent Grams for each package and shipment. Both criteria must be addressed for wastes submitted to NNSS.

Note: the license limits noted in this table apply to Ra-226 and are provided for comparative purposes only. Individual facilities may have additional requirements for chemicals, other radionuclides, total activity, or sum-of-fraction calculations that may be applicable to specific NFSS waste streams.

Based on experience at the Fernald Site with the K-65 residues, it is likely that some IWCS waste streams may require mixing to reduce Ra-226 concentrations in order to meet disposal facility WAC and/or DOT transportation requirements. Rough order of magnitude estimates for post-treatment waste volumes subject to disposal are presented in Section 6.3.

6.2.2.1 Energy*Solutions* Waste Acceptance Criteria

Energy*Solutions* is licensed by the Utah Division of Radiological Controls to receive and dispose of 11e.(2) byproduct material defined by the Atomic Energy Act as amended. Shipments of 11e.(2) waste will be managed and disposed of in a separate disposal embankment specifically licensed and designed for the material.

The Energy*Solutions* 11e.(2) byproduct license states natural uranium, Ra-226 series nuclides, Th-230 and any nuclides in the thorium decay series are acceptable for disposal as byproduct. The generator or owner of the waste is required to certify in writing that the waste is 11e.(2) byproduct material as defined by the Atomic Energy Act as amended. Specifically, the owner must certify that the waste materials are tailings or waste produced by extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. The generator or owner must also certify that the waste material does not contain any other radioactive or hazardous waste.

If it is determined that there are any other nuclides present in the NFSS waste, namely from the University of Rochester burial area or the Knolls Atomic Power Laboratory waste, the waste would not be permitted in the 11e.(2) cell.

Per the WAC, the facility may accept 11e.(2) byproduct material with an average concentration in any transport vehicle (truck or railcar) not to exceed 4,000 pCi/g for natural uranium or for any radionuclide in the Ra-226 series, 60,000 pCi/g for Th-230, or 6,000 pCi/g for any radionuclide in the thorium decay series. Energy*Solutions* does not require a sum of the fractions rule for 11e.(2) material. The concentration limits are based on average concentrations within a given transport vehicle upon receipt and not each individual container on the transport. The current average Ra-226 in the K-65 residues at 520,000 pCi/g far exceeds the 4,000 pCi/g limit at the 11e.(2) disposal embankment. The limit could be met by downblending with contaminated soil, but the volume of soil required likely renders this option not feasible. The intentional mixing or downblending of soil (and soil-like materials) to achieve disposal facility WAC limits is consistent with NRC policy discussed in NRC Policy Issue SECY-04-0035 (March 1, 2004). Mixing waste materials to lower the radionuclide concentration does not alter the isotopes present in the waste or the regulatory classification of the waste. This approach differs from the unacceptable practice of "diluting" RCRA waste to change the hazardous characteristics (and, therefore, the regulatory classification) of the waste.

In addition to 11e.(2) byproduct, Energy*Solutions* can receive both LLRW and LLMW. Due to more stringent engineering controls, the limits for Ra-226 in the LLRW and LLMW cells are currently10,000 pCi/g, still significantly below the 520,000 pCi/g K-65 concentration. The limit could be met by downblending with contaminated soil, but the volume of soil required may render this option not feasible.

Utah is in the Northwest compact, however, the Clive disposal facility is not in the Northwest compact. The Clive disposal facility may accept LLRW without exemptions or approvals with the exception of the following. Specific compact export approval must be given to generators within the Northwest, Southwest, Rocky Mountain, Texas and Central compacts when shipping waste to Clive. All other compacts have given blanket authorization for generators to ship waste to Clive. USDOE sites do not require any compact export approval.

6.2.2.2 U.S. Ecology Waste Acceptance Criteria

The U.S. Ecology facility in Grand View, Idaho, is regulated by the Idaho Department of Environmental Quality. The site accepts radioactive materials in accordance with their WAC, specifically:

- Unimportant Quantities of Source Material Uniformly Dispersed in Soil or other Media;
- NORM other than Uranium and Thorium Uniformly Dispersed in Soil or Other Media;
- Non-Production Particle Accelerator Produced Radioactive Material;
- NRC Exempted Products, Devices, or Items; and
- Materials Specifically Exempted by the NRC or NRC Agreement State.

Numeric criteria are specified for the "unimportant quantities" and the NORM wastes. There is no discussion within U.S. Ecology WAC regarding the acceptance of 11e.(2) byproduct material – therefore this facility is not considered to be an option for K-65 residue (or any other byproduct materials) from NFSS. While not specifically discussed in their WAC, there is a reference to FUSRAP waste acceptance. As a result, the Grand View, Idaho is considered to be viable disposal option for non-11e.(2) byproduct material waste streams generated at NFSS.

6.2.2.3 Waste Control Specialists Waste Acceptance Criteria

WCS is licensed by the Texas Commission on Environmental Quality to receive and dispose of 11e.(2) byproduct material defined by the Atomic Energy Act as amended. A dedicated 11e.(2) disposal cell has been constructed for receipt and disposal of these wastes generated by USDOE and other Federal facilities. Unlike the Energy*Solutions* license, the byproduct 11e.(2) Landfill License Application specifies a total curie and volume limit. The current license allows for 895,000 m^3 (1.17 million yd^3) and 24,530 Ci. WCS initially requested License capacity for only the Fernald Silo 1 and 2 waste which expended 23,000 m^3 (30,000 yd^3) and 13,400 Ci. Thus, 872,000 m^3 (1.14 million yd^3) and 11,130 Ci capacity remains.

WCS can submit a request to the Texas Commission on Environmental Quality to utilize the remaining capacity as established in the License Application. Relative to the byproduct Landfill, as customer needs materialize, WCS would address the need to amend the Byproduct 11e.(2) License to allow for use of the entire disposal capacity defined in the License Application. While the WCS Byproduct License Application substantiates acceptability of the NFSS waste, the initial License granted for byproduct disposal only addressed the USDOE Fernald Silo 1 and 2 waste. WCS has indicated they would entertain submission of a license amendment to add the NFSS waste to their current byproduct disposal license.

For high radium 11e.(2) waste, containerization and waste form consistent with the waste received from the Fernald Silos 1 and 2 Remediation Project would likely be acceptable. Other waste forms and packaging requirements will be dictated by the characteristics of the waste to be disposed. For waste being disposed in the byproduct 11e.(2) landfill, no generator certification is required. However, the generator must comply with the requirement that no other radioactive or hazardous waste is present.

For LLRW, separate disposal units for Commercial and Federal waste are available. The Commercial Waste Facility accepts containerized Class A/B/C LLRW waste based on the activity and half-lives of various radioisotopes. The Federal Waste Facility accepts Class A/B/C LLRW and LLMW. For the purposes of the WCS WAC, LLRW is defined under 30 TAC 336.2(76) and LLRW is defined under 30 TAC 336.2(80).

There are certain generator certification requirements which are under development. The license that allows acceptance of LLRW and LLMW also is a total curie/volume license. Concentration limits, therefore, would likely be dictated by DOT limitations on package dose as was the case for the Fernald Silo Project.

WCS is affiliated with the Texas Compact (Texas and Vermont). The WCS Compact Waste Facility allows for disposal of Class A/B/C waste from any commercial generator in Texas or Vermont. Waste going into the Compact Facility must be from Texas or Vermont; waste from any other states must have importation approval from the Texas Compact Low-Level Radioactive Waste Commission. Waste going into the RCRA landfill, byproduct landfill, or the Federal Waste Disposal Facility is not subject to Compact jurisdiction limitations.

6.2.2.4 Wayne Disposal, Incorporated Waste Acceptance Criteria

The Wayne Disposal Landfill is permitted by the State of Michigan to receive and dispose of various types of radioactive waste including NORM, TENORM, FUSRAP, and exempted radioactive materials. Specific WAC limits for FUSRAP waste are provided in Table 6-4. Waste disposed at the facility will not contain any high-level or LLRW or any radioactive material generally licensed under 10 CFR 31.7, 31.10, 31.12, or 40.22 or any material that would require the facility to have a specific or a general radioactive material license from the NRC.

Table 6-4. WDI Radiological WAC Limits

Nuclide	***Concentration (pCi/g)***	***Nuclide***	***Concentration (pCi/g)***
U-238	75	U-235	4
U-234	75	Pa-231	4
Th-230	75	Ac-227	4
Ra-226	50	Th-232	13
Pb-210	50	Ra-228	13
Po-210	50	Th-228	13

The WAC limits provided in the table above represent the average radioactivity concentration in a shipment. A waste generator who wishes to send FUSRAP material to the facility must provide representative documentation of its chemical/physical/radiological properties and its regulatory status. For FUSRAP waste only, if the activity of any isotope listed in the table above exceeds the noted concentrations, the material will require specific approval by the State of Michigan.

An acceptable waste stream is approved to come into the facility for a one-year period. After one year, the waste stream must be re-evaluated. The waste generator must certify the waste stream has not changed or must document any changes. New radiological analysis may be required. The generator's certification and the results of the radiological analysis will be evaluated. If the waste is consistent with the previous characterization, the waste will be re-approved for another year.

6.2.2.5 Nevada National Security Site Waste Acceptance Criteria

The NNSS is currently authorized to receive LLRW and Mixed Waste. By definition in the current WAC, USDOE/NV-325-Rev.8-01, January 2011, LLRW is defined as radioactive waste that is not high level radioactive waste, spent fuel, transuranic waste, byproduct material (as defined in Section 11e.(2) of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material. Small quantities of 11e.(2) byproduct material and naturally occurring radioactive material may be managed as LLRW provided they can be managed to meet the requirements for LLRW disposal [DOE-M-435.1-1, Section IV.B.(4)]. At this time, there is no definitive definition of the term "small quantities" and interpretation must be sought from USDOE Office of Environmental Management prior to disposal. Prior precedent regarding the Fernald silo waste ultimately dictated an alternate disposal location (WCS).

Prior to shipment of any LLRW or LLMW to the NNSS, a generator waste certification program must be in place and approved by the NNSS/Nevada Site Office Radioactive Waste Acceptance Program. Waste streams are evaluated for compliance with the most current WAC requirements which include a number of physical and chemical standards. Radionuclide activity is evaluated based on designated radionuclide action levels as specified in the WAC and the calculation of Plutonium-239 equivalent grams (PE-g). There are limits on both package and shipment PE-g. The package criteria limits are:

- Per the WAC, package activity limits at NNSS are based on PE-g. The total PE-g for either a waste package or a shipment will be calculated by multiplying the activity of each radionuclide by the PE-g conversion factor and adding each radionuclide PE-g to get the total PE-g. (NNSS WAC Appendix B, Plutonium-239 Equivalent Gram (PE-g) Radionuclide Conversion Factors)
- The PE-g limit for all waste packages is 300 PE-g total activity. The PE-g limit for a shipment is 2000 PE-g total activity. Any shipment that has a package that exceeds the package limit will be refused for disposal. Any shipment that exceeds the shipment limit will be refused for disposal.

The concentration limit for Ra-226, based on a theoretical waste density of 1.0 g/cm^3, can be determined from the NNSS WAC as follows:

$$(2.7\text{x}10^{7}\ \text{Bq/m}^{3}) * (1.0\ \text{pCi}/0.037\ \text{Bq}) * (1.0\ \text{m}^{3}/1.0\text{x}10^{6}\ \text{cm}^{3}) * (1.0\ \text{cm}^{3}/\text{g}) = 730\ \text{pCi/g}$$

Considering a site-specific assumed representative density of (1.77 g/cm^3) 3,000 lb/yd^3 per Table 6-1 for IWCS waste streams, the concentration limit for Ra-226 can be further refined as follows:

$$(2.7x10^7 \ Bq/m^3) * (1.0 \ pCi/0.037 \ Bq) * (1.0 \ m^3/1.77x10^6 \ cm^3) * (0.565 \ cm^3/g) = 412 \ pCi/g$$

It is important to note that Section 6.2.2.5 of the NNSS WAC specifies that if the waste is above the radionuclide action levels it still may be acceptable if it does not exceed the PE-g limits per package. Also, the actual PE-g per package would be directly proportional to the final package size. As a Federal facility, there are no waste compact considerations. NNSS is only authorized to receive Federal waste.

6.2.3 Waste Form Container Requirements

6.2.3.1 EnergySolutions Waste Forms

Final waste forms will comply with several aspects in the WAC. Importance is stressed on items listed below:

- Does not accept solid waste containing unauthorized free liquids.
- Solid waste containing liquid will contain as little free-standing and non-corrosive liquid as is reasonably achievable, but in no case will the liquid exceed 1% of the volume.
- Waste packages must be loaded to ensure that the interior volume is as efficiently and compactly loaded as practical to minimize void space.
- Waste packaging that is received must be marked and labeled as specified in the WAC and also comply with DOT requirements in 49 CFR.

6.2.3.2 U.S. Ecology Waste Forms

In accordance with U.S. Ecology protocols, the waste generator must provide a complete description of all components of the waste forms present ensuring that 100% of the waste types are specified. The generator is also required to give an indication as to whether incidental free liquids may be present that will require management upon receipt of waste at the facility.

Bulk material for trans-loading at the U.S. Ecology rail transfer facility should be less than 0.7 m^3 (1 yd^3). Over-sized debris may be received (i.e. structural steel or building debris) with prior notification. U.S. Ecology is equipped with containment buildings permitted to perform material sizing. Materials may be downsized prior to treatment such as stabilization or for debris encapsulation. The facility’s EPA permit does not include size restrictions for direct landfill wastes.

6.2.3.3 Waste Control Specialists Waste Forms

Final waste forms will comply with several aspects in the WAC. Importance is stressed on items listed below:

- Solid waste containing liquid will contain as little free-standing and non-corrosive liquid as is reasonably achievable, but in no case will the liquid exceed 1% of the volume.
- All waste packages will be loaded as efficiently and compactly as practical to maximize utilization of interior volume.

- All waste received for processing, storage, or disposal must be classified in accordance with the requirements in Texas Regulation for Control of Radiation Part 21 Appendix E.

6.2.3.4 Wayne Disposal, Incorporated Waste Forms

The WDI facility only accepts solid FUSRAP waste. All DOT-compliant packing is accepted for receipt, although coordination with the facility is required for specialized applications to ensure the availability of the appropriate off-loading equipment upon waste receipt. Free liquids are not permitted in solid FUSRAP waste disposal at WDI.

6.2.3.5 Nevada National Security Site Waste Forms

Final waste forms will comply with several aspects in the WAC. Importance is stressed on the following items listed:

- In addition to the weight limits for specific packaging designs, packages will not exceed 4,080 kg (9,000 lbs) per box and 540 kg (1,200 lbs) per drum. This weight limit does not apply to bulk waste.
- Solid waste containing liquid will contain as little free-standing and non-corrosive liquid as is reasonably achievable, but in no case will the liquid exceed 1% of the volume.
- Waste packages must be loaded to ensure that the interior volume is as efficiently and compactly loaded as practical to minimize void space.
- Each waste package must be marked and labeled as specified in the WAC which includes a barcode, a package certification label, as well as meeting all DOT requirements in 49 CFR.

6.2.4 Other Factors Affecting Disposal

Lessons learned from the Fernald Site indicate that in-situ K-65 waste may require a reduction in the radioactive constituent concentrations and additional processing of the material to produce a final waste form that meets transportation and disposal requirements. Three primary concerns are related to:

- Ensuring the final waste form radionuclide and chemical concentrations meet the disposal facility WAC limits;
- Ensuring the final waste form physical characteristics meet the requirements related to disposal facility WAC (i.e. moisture content, free standing liquids, etc.); and
- Ensuring the final waste form radionuclide concentrations and containers meet DOT shipping requirements.

At Fernald, the primary method of verifying WAC compliance was through process instrumentation, which measured the quantities and key characteristics of the materials that went into each batch of treated waste. As discussed in Sections 2.5.3 and 3.5, this included the following methods:

- Densitometers and sampling systems installed on the recirculation loops of each slurry feed tank were used to measure and verify the density/wt% solids of the feed slurry (i.e., the K-65 solids).
- An in-line Ra-226 analyzer was also installed on each slurry feed tank recirculation loop, so that the quantity of Ra-226 in each batch of product could be determined.
- Magnetic flow meters were installed on the feed forward piping from the slurry feed pump to quantify the flow of slurry to the product mixers.
- Weigh cells on the cement and fly ash feed hoppers were used to measure the quantity of these materials added to each product batch.
- Weigh cells on the product mixers were used to verify the quantities of each component (K-65 slurry, cement, and fly ash) added to each product batch.
- A weigh cell on the bridge crane in the container loadout bay was used to determine the gross weight of each filled container. Tare weights of each container, obtained from a scale in the container receiving bay, allowed the net weight of treated waste in each batch to be calculated.

The data from the above instruments was captured by the facility control system for each batch of treated waste and forwarded in real-time to the quality assurance personnel that were assigned to each operating shift so they could verify that the composition and characteristics of the batch met the specified acceptance criteria. In addition, after each container was filled with product material, it was moved to an inspection/lid fastening station in the fill room, where a remotely-operated camera was used by the quality assurance personnel to perform a visual inspection of the treated waste. If the surface of the waste looked too ‘soupy,’ which could lead to free liquids in excess of WAC limits after the curing of the grout, the container was moved to another station for the addition of absorbent material prior to affixing the container lid.

Calibration checks were performed regularly on all of the above instruments to ensure that the data being used to verify WAC compliance was valid. In addition, at the beginning of waste treatment operations, the first 5-7 containers produced from each of the three process lines were set aside for approximately 5 days for evaluation prior to affixing the container lid. Samples of the feed slurry and treated product were taken for each, and analyzed for wt% solids, Ra-226, and TCLP metals. Although the October 2003 ESD for the OU 4 ROD removed the TCLP requirement, as discussed in Section 2.1.5.4.1, the sampling and analysis for TCLP metals was conducted on the first few batches/containers produced from each process line to ensure that the stabilization method worked as designed. The treated product was also allowed to cure, to ensure that no free liquids would be present. Contact dose readings on the outside of the containers were also taken to validate the predicted values from previous modeling. These actions provided the initial calibration of the in-line instrumentation and the validation of the chemical stabilization recipe, to ensure that the treated product would be WAC compliant.

Compliance with disposal facility WAC requirements will be the focus of remedial waste characterization, pre-disposal treatment (if required), and final physical waste form. Compliance with disposal facility WAC alone will not guarantee the suitability of waste for transport.

Requirements for radioactive waste shipping per DOT are provided in 49 CFR 173.441 – *Radiation Level Limitations and Exclusive Use Provisions*. The DOT requirements define limits based on dose rates for several types of shipments and packages including:

- Excepted package shipment (empty, limited quantity, instruments and articles);
- Non-exclusive use shipment (transported via common carriers); and
- Exclusive use shipment (transported in open or closed vehicles).

Surface activity limits based on beta, gamma, and alpha emitters are defined for the following:

- External package surfaces (beta/gamma/low toxicity alpha emitters);
- External package surfaces (all other alpha emitters);
- External package surfaces/transport vehicle (beta/gamma/low toxicity alpha emitters) – exclusive use shipment; and
- External package surfaces/transport vehicle (all other alpha emitters) – exclusive use shipment.

For the purposes of this evaluation, the waste transport approach anticipated for NFSS is assumed to involve exclusive use shipping. Exclusive use shipping is defined as “loaded by and for the exclusive use of the consignor and unloaded by the consignee”. Per DOT, the specific limits associated with exclusive use shipping are summarized as follows:

- Dose-based limits (external package surface)
    - Open vehicle (all package surfaces) – 200 mrem/hr
    - Closed vehicle (all package surfaces) – 1,000 mrem/hr
- Dose-based limits (transport vehicle)
    - Open vehicle (outer vehicle surface) – 200 mrem/hr
    - Open vehicle (2 m from vehicle surface) – 10 mrem/hr
    - Closed vehicle (outer vehicle surface) – 200 mrem/hr
    - Closed vehicle (outer vehicle surface) – 200 mrem/hr
    - Vehicle cab (normally occupied space) – 2 mrem/hr
- Surface activity limits (external package surfaces)
    - Beta/gamma/low toxicity alpha emitters – 220,000 dpm/100 cm^2
    - All other alpha emitters – 22,000 dpm/100 cm^2
- Surface activity limits (transport vehicle surfaces)
    - Beta/gamma/low toxicity alpha emitters – 22,000 dpm/100 cm^2
- All other alpha emitters – 2,200 dpm/100 cm^2

The following conditions for exclusive use/closed vehicle transport also must be met for the package for dose-based limits:

- Shipment is in a closed transport vehicle;
- Package is secured within the vehicle so that it's position remains fixed during transportation; and
- There are no loading or unloading operations between the beginning and end of transportation.

Additional DOT criteria, such as weight limits, over-sized load restrictions, etc. also must be considered during the development of specific waste shipping configurations during the development of remedial alternatives in the IWCS FS.

Compliance with DOT and all other applicable waste transport requirements is not directly associated with the acceptability of the waste material per disposal facility WAC. It is possible that transported waste material concentrations compliant with DOT requirements may still be above disposal facility WAC limits for radionuclides. In this case, the disposal facility WAC limits will represent the limiting criteria for successful waste shipment and disposal. Conversely, DOT compliant transported material concentrations may be well below disposal facility WAC limits for radionuclides. In this case, the DOT limits will represent the limiting criteria for successful waste shipment and disposal.

Regardless of the relationship between DOT and other applicable shipping requirements and disposal facility WAC, both sources of potential limiting criteria must be considered during the development of waste treatment, packaging, transport, and disposal approaches during the IWCS FS.

6.2.5 Niagara Falls Storage Site IWCS Waste Streams, Viable Disposal Facilities and Transportation Modes Summary Tables

The applicable NFSS IWCS waste streams, viable disposal facilities, and modes of transportation considered previously in this section are summarized in Appendix E.

6.3 Estimated Disposal Costs by Waste Type and Facility

This section presents disposal cost information for each anticipated waste stream associated with the potential remediation of the NFSS IWCS identified in Section 6.1. The objective of this section is to provide a rough order of magnitude estimate for waste disposal costs resulting from potential remedial actions.

The waste volume and cost estimates developed in this section are provided for comparative purposes only and are not supported by a detailed engineering assessment of the anticipated volumes associated with the IWCS waste streams or waste treatment technologies that will result from the potential remedial activities. Detailed quantitative engineering assessments and evaluations will be conducted during the IWCS FS detailed analysis of remedial alternatives.

6.3.1 Disposal Facility Unit Rate Costs

All cost information is based on current (April 2011) unit rates provided by the potential disposal facilities for solid waste streams. The detailed analysis of alternatives to be completed as part of the IWCS FS will provide a more detailed evaluation of disposal costs to allow comparisons between remedial alternatives. The detailed cost evaluations developed during the IWCS FS will be based on specific conceptual design concepts for potential remedial options that may be applied to the IWCS in the future.

Table 6-5 summarizes the range of waste disposal unit costs for each solid waste stream identified in Section 6.1.

Table 6-5. Estimated Disposal Facility Unit Rate Costs

NFSS IWCS Waste Stream Designation for Disposal	*Average Disposal Cost ($/yd^3)*
K-65 Residues: 11e.(2)	$1,025
K-65 Residues: LLRW	$266
K-65 Residues: LLMW	$1,341
Other IWCS Residues/Wastes: 11e.(2)	$1,025
Other IWCS Residues/Wastes: LLRW	$266
Other IWCS Residues/Wastes: LLMW	$1,341
Tower Soil: 11e.(2)	$1,025
Tower Soil: LLRW	$273
Tower Soil: LLMW	$577
Contaminated Rubble/Waste: 11e.(2)	$1,025
Contaminated Rubble/Waste: LLRW	$338
Contaminated Rubble/Waste: LLMW	$482
R-10 Residues and Soil: 11e.(2)	$1,025
R-10 Residues and Soil: LLRW	$273
R-10 Residues and Soil: LLMW	$577
Contaminated Soil: 11e.(2)	$1,025
Contaminated Soil: LLRW	$267
Contaminated Soil: LLMW	$364

Unit rate costs are based on waste disposal only and do not include potential treatment activities if required.

Although liquid wastes are likely to be generated in the form of wastewater during the performance of potential remedial activities at the IWCS, disposal cost estimates for this waste stream are not included in this evaluation. Specific details regarding liquid waste stream classification and volume will depend upon the type of contaminated solid materials associated with liquid waste generation. The types and estimated volumes of liquid wastes generated during potential IWCS remediation will be developed as part of the detailed analysis of remedial alternatives during the IWCS FS.

6.3.2 Waste Volume Estimates

In order to generate overall rough order of magnitude waste disposal cost estimates, volumes must be assumed for each waste stream identified in Section 6.1 and Table 6-1. While the in-situ waste volumes presented in Table 6-1 could be used for this estimate, the actual volume of waste subject to disposal during potential remediation may increase due to removal or pre-shipping waste treatment activities. As a result, the use of in-situ waste volumes would likely generate volume estimates lower than realistically expected.

Based on the significantly elevated Ra-226 concentrations associated with several of the IWCS waste streams in Table 6-1, it is assumed additional materials will be added to the in-situ volumes to reduce the Ra-226 concentrations to meet disposal facility WAC and/or DOT shipping requirements. The intentional mixing of soil (and soil-like materials) to achieve disposal facility WAC limits is consistent with NRC policy discussed in NRC Policy Issue SECY-04-0035 (March 1, 2004). Mixing waste materials to lower the radionuclide concentration does not alter the isotopes present in the waste or the regulatory classification of the waste. This approach differs from the unacceptable practice of "diluting" RCRA waste to change the hazardous characteristics (and, therefore, the regulatory classification) of the waste.

The use of impacted contaminated soil as a waste additive is considered potentially applicable due to the availability of this waste stream at the NFSS and the resulting benefit of both waste streams (contaminated soil and K-65 residues) being disposed together. The use of impacted soil would require sampling and analysis to preclude the possibility of residues becoming commingled with other radiological or chemical constituents not typically associated with 11e.(2) residues (see Section 6.1.2). The addition of a chemical stabilization agent also is considered potentially applicable due to its previous use at the Fernald Site to treat the K-65 residues prior to shipment and disposal. For the purposes of this evaluation the volumes of material added to the in-situ WCS waste streams for contaminated soil and chemical stabilization agent are assumed to be equal. Table 6-7 summarizes the estimated post-treatment waste volumes subject to disposal. These volumes are based on the waste volume multipliers shown in Table 6-6 and the assumed in-situ waste volumes shown in Table 6-1.

Table 6-6. Waste Volume Multipliers

NFSS IWCS Waste Stream	***In-Situ Waste Ra-226 Concentration (pCi/g)***	**EnergySolutions: 11e.(2)**	**EnergySolutions: LLRW/LLMW**	**US Ecology: FUSRAP**	**WCS: 11e.(2)**	**WDI: LLRW**	**NNSS: LLW/LLMW**	**DOT Compliant (Fernald Configuration)**
		Ra-226 Limit (pCi/g)						
		4,000	***10,000***	***500***	***100,000***	***50***	***412***	***80,000***
K-65 Residues	520,000	130.0	52.0	1,040.0	5.2	10,400.0	1,262.2	6.5
Other IWCS Residues/Wastes	12,000	3.0	1.2	24.0	1.0	240.0	29.2	1.0
Tower Soil	10,400	2.6	1.1	20.8	1.0	208.0	25.3	1.0
Contaminated Rubble/Waste	6,181	1.6	1.0	12.4	1.0	123.7	15.1	1.0
R-10 Residues and Soil	95	1.0	1.0	1.0	1.0	1.9	1.0	1.0
Contaminated Soil	16	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Waste Classification is defined for purposes of Disposal

Volume Multiplier = (In-Situ Ra-226 Concentration) / (Ra-226 Disposal Limit)

Table 6-7. Estimated Waste Disposal Volumes

NFSS IWCS Waste Stream	*In-Situ Waste Volume (yd^3)*	EnergySolutions: 11e.(2)	EnergySolutions: LLW/LLMW	US Ecology: FUSRAP	WCS: 11e.(2)	WDI: FUSRAP	NNSS: LLW/LLMW	DOT Compliant (Fernald Configuration)
		Estimated Disposal Volume (yd^3)						
K-65 Residues: 11e.(2)	4,030	523,900	209,560	4,191,200	20,956	41,912,000	5,086,666	26,195
K-65 Residues: LLRW	0	0	0	0	0	0	0	0
K-65 Residues: LLMW	0	0	0	0	0	0	0	0
Other IWCS Residues/Wastes: 11e.(2)	10,550	31,650	12,660	253,200	10,550	2,532,000	308,060	10,550
Other IWCS Residues/Wastes: LLRW	0	0	0	0	0	0	0	0
Other IWCS Residues/Wastes: LLMW	0	0	0	0	0	0	0	0
Tower Soil: 11e.(2)	4,115	10,699	4,527	85,592	4,115	855,920	104,110	4,115
Tower Soil: LLRW	0	0	0	0	0	0	0	0
Tower Soil: LLMW	0	0	0	0	0	0	0	0
Contaminated Rubble/Waste: 11e.(2)	46,610	74,576	46,610	577,964	46,610	5,765,657	703,811	46,610
Contaminated Rubble/Waste: LLRW	0	0	0	0	0	0	0	0
Contaminated Rubble/Waste: LLMW	0	0	0	0	0	0	0	0
R-10 Residues and Soil: 11e.(2)	59,500	59,500	59,500	59,500	59,500	113,050	59,500	59,500
R-10 Residues and Soil: LLRW	0	0	0	0	0	0	0	0
R-10 Residues and Soil: LLMW	0	0	0	0	0	0	0	0
Contaminated Soil: 11e.(2)	20,746	20,746	20,746	20,746	20,746	20,746	20,746	20,746
Contaminated Soil: LLRW	204,630	204,630	204,630	204,630	204,630	204,630	204,630	204,630
Contaminated Soil: LLMW	22,724	22,724	22,724	22,724	22,724	22,724	22,724	22,724
TOTALS: 11e.(2)	**145,551**	**721,071**	**353,603**	**5,188,202**	**162,477**	**51,199,373**	**6,282,893**	**167,716**
TOTALS: LLRW	**204,630**	**204,630**	**204,630**	**204,630**	**204,630**	**204,630**	**204,630**	**204,630**
TOTALS: LLMW	**22,724**	**22,724**	**22,724**	**22,724**	**22,724**	**22,724**	**22,724**	**22,724**

Waste Classification is defined for purposes of Disposal

Estimated Disposal Volume = (In-Situ Waste Volume) * (Volume Multiplier)

Table 6-6 presents the calculated waste volume multipliers for the IWCS waste streams. These multipliers represent the amount of volume growth and are based on the assumed average Ra-226 concentration for each waste stream and the WAC limits for Ra-226 for each potential disposal facility (Table 6-6).

For informational purposes, the average Ra-226 concentration that allowed for the DOT-compliant shipping of the K-65 residues at the Fernald Site also is included. The DOT-compliant Ra-226 concentration (80,000 pCi/g) is independent of any specific disposal facility and assumes the use of the same shipping configuration as Fernald (IP-2 containers). Waste streams with in-situ Ra-226 concentrations less than their respective limits do not require treatment and therefore are assigned a volume multiplier of 1 (i.e., no change).

The estimated waste volumes shown in Table 6-7 may also be used to evaluate whether sufficient volumes of contaminated soil are present at the IWCS to be a source for material to be mixed with the K-65 residues in order to achieve the required Ra-226 concentrations associated with the various disposal options. This approximation can be performed by comparing the volume of contaminated soil needed for downblending to the volume of contaminated soil available. For example, the volume of in-situ K-65 residue (4,030 yd^3) needs to be blended with 519,870 yd^3 of contaminated IWCS soil to meet the Ra-226 limit concentration of 4,000 pCi/g for Energy*Solutions* 11e.(2) disposal. The soil volume needed is approximated by subtracting the in-situ volume (4,030 yd^3) from the disposal volume (523,900 yd^3) on Table 6-7. However, only 204,630 yd^3 of contaminated soil is available at the IWCS (Contaminated Soil: LLRW on Table 6-7). This indicates that mixing of IWCS contaminated soil to downblend the K-65 residues for disposal at Energy*Solutions* 11e.(2) would not work because not enough soil is available. A viable option is to use some other material, which could include contaminated soil from the BOP OU or a mixing material such as grout, to supplement the IWCS soil, subject to restrictions on mixing waste streams. Nonetheless, the large volume of material required to downblend the in-situ K-65 wastes for disposal at Energy*Solutions* 11e.(2) cell is likely not feasible. In contrast, for disposal at WCS 11e.(2) cell, the volume of contaminated soil needed to blend with the in-situ K-65 residue is 16,926 yd^3 making it a viable option because the required volume for downblending is less than the contaminated soil available (Table 6-7).

This type of analysis can be conducted for any of the waste streams in Table 6-7. It is important to note, however, that this is just an approximation that should be used for screening only, pending better definition of waste volumes, waste characteristics, and technology selections in the FS. The use of contaminated soil already present at the IWCS to mix with higher activity waste streams, as presented here, would be beneficial as there would be no associated purchase cost (contaminated soil is already present on-site) and the contaminated soil would require disposal as a separate medium if it is not used for mixing.

In addition to the above, the following assumptions were made for the purposes of this cost estimate:

- Three meters (10 ft) of soil are contaminated by leaching beneath the R-10 residues and beneath the IWCS. This is likely an overestimate, but that has not yet been proven conclusively through sampling.
- Contaminated soils beneath the NFSS structures where K-65 wastes were placed are considered 11e.(2) material for purposes of disposal. This is because the buildings were constructed prior to the wastes being placed, so the contamination is due to releases from the K-65 wastes.
- Approximately 10% of the LLW is mixed with hazardous constituents, requiring that it be disposed as LLMW. The remainder can be disposed as LLRW.

Table 6-7 summarizes the estimated post-treatment waste volumes subject to disposal. These volumes are based on the waste volume multipliers shown in Table 6-6 and the assumed in-situ waste volumes shown in Table 6-1.

The intent of developing these waste disposal volume estimates is to demonstrate the wide variation in volumes that may apply during potential IWCS remedial activities depending on the specific facilities selected for disposal of the various waste streams. These estimates are provided for comparative purposes only and are not intended to represent a detailed engineering assessment of the anticipated volumes associated with the IWCS waste streams that will result from potential remedial activities. These volumes are further used in the development of the rough order of magnitude waste disposal cost estimates developed in the following section.

The waste volumes estimated for NFSS IWCS and for Fernald are compared in Table 6-8. The data include the in-situ waste volume for the K-65 residues in the Fernald Silos 1 and 2, and the actual volume of treated K-65 residues transported to the WCS 11e.(2) disposal cell. The values entered in the WCS 11e.(2) column and the DOT Compliant column are the same because the radiological activity present in the containers shipped to WCS was based on the DOT driven criteria. These values have been adjusted to remove the volume of bentonite that was removed from the silos and processed with the residues. The bentonite was placed over the residues in the silos to help reduce the Radon emissions from the silos. As shown in Table 6-8, the NFSS IWCS K-65 wastes are expected to have a significantly higher concentration of Ra-226 than was observed in the Fernald Silos 1 and 2 K-65 waste. As a result, a significantly greater amount of material is needed to downblend the NFSS IWCS waste to meet packaging and DOT requirements. This is the primary reason that a lower volume of in situ K-65 waste at the NFSS IWCS is estimated to produce a similar volume of waste for transport and disposal as was generated by Fernald. This result is based on the assumption that the NFSS IWCS waste is treated and packaged using the same process as was used at Fernald.

Table 6-8. Comparison of K-65 Waste Disposal Volumes, NFSS and Fernald

Waste Stream	***Ra-226 Concentration pCi/g****	***In Situ Volume***		***DOT Compliant Volume***	
		(m^3)	**(yd^3)**	**(m^3)**	**(yd^3)**
NFSS K-65 Residues	520,000	3,080	4,030	20,030	26,195
Fernald Silo 1	391,000	6,120	8,007	19,320	25,270
Fernald Silo 2	195,000				

* From Table 6-2

6.3.3 Calculation of Estimated Project Waste Disposal Costs

The disposal facility unit rate costs presented in Section 6.3.1 and the estimated waste volumes subject to disposal developed in Section 6.3.2 are used to determine the estimated overall project cost for the disposal of solid waste material at the IWCS shown in Table 6-9.

The subtotal by waste type and IWCS project estimated total disposal costs are shown in Table 6-9. Because disposal unit rate costs for individual disposal facilities are not presented in this document, the cost estimate above is based on the volume estimates associated with the DOT-compliant shipping option in Table 6-7.

It is important to note this rough order of magnitude cost estimate is based on numerous assumptions and available information. The cost estimate is provided for comparative purposes only and is not supported by a detailed engineering assessment of the potential volumes associated with the IWCS waste streams and potential specific treatment processes associated with potential remedial activities. This estimate is based on waste disposal only and does not include treatment, packaging, or disposal transportation costs. The detailed analysis of remedial alternatives conducted during the IWCS OU FS will develop specific detailed assumptions regarding various waste treatment options and associated costs. Additional detailed cost estimates regarding IWCS waste disposal activities would also be developed for any potential remedial design for the IWCS. These detailed estimates would incorporate costs associated with numerous additional remedial components including, but would not be limited to: IWCS waste removal/packaging/transportation; radon control/monitoring; site restoration; and the treatment and disposal of other waste streams (i.e.,wastewater).

Table 6-9. Estimated Project Waste Disposal Cost

NFSS IWCS Waste Stream	Estimated Waste Disposal Volume (yd^3)[1]	Average Disposal Unit Rate Cost	Total Disposal Cost
K-65 Residues: 11e.(2)	26,195	$1,025	26,849,875
K-65 Residues: LLRW	0	$266	0
K-65 Residues: LLMW	0	$1,341	0
Other IWCS Residues/Wastes: 11e.(2)	10,550	$1,025	10,813,750
Other IWCS Residues/Wastes: LLRW	0	$266	0
Other IWCS Residues/Wastes: LLMW	0	$1,341	0
Tower Soil: 11e.(2)	4,115	$1,025	4,217,875
Tower Soil: LLRW	0	$273	0
Tower Soil: LLMW	0	$577	0
Contaminated Rubble/Waste: 11e.(2)	46,610	$1,025	47,775,250
Contaminated Rubble/Waste: LLRW	0	$338	0
Contaminated Rubble/Waste: LLMW	0	$482	0
R-10 Residues and Soil: 11e.(2)	59,500	$1,025	60,987,500
R-10 Residues and Soil: LLRW	0	$273	0
R-10 Residues and Soil: LLMW	0	$577	0
Contaminated Soil: 11e.(2)	20,746	$1,025	21,264,650
Contaminated Soil: LLRW	204,630	$267	54,636,210
Contaminated Soil: LLMW	22,724	$364	8,271,536
		Subtotal Totals: 11e.(2)	**$171,908,900**
		Subtotal Totals: LLRW	**$54,636,210**
		Subtotal Totals: LLMW	**$8,271,536**
		TOTAL ESTIMATED COST	**$234,816,646**

Waste Classification is defined for purposes of Disposal

Total Disposal Cost = (Estimated Waste Disposal Volume) * (Average Disposal Unit Rate Cost)

[1] Estimated waste disposal volumes based on DOT Compliant (Fernald Configuration) values in Table 6-7

The detailed analysis of remedial alternatives conducted during the IWCS FS will develop specific detailed assumptions regarding various waste treatment options and associated costs. Additional detailed cost estimates regarding IWCS waste disposal activities would also be developed for any potential remedial design for the IWCS. These detailed estimates would incorporate costs associated with numerous additional remedial components including, but would not be limited to: IWCS waste removal/packaging/transportation; radon control/monitoring; site restoration; and the treatment and disposal of other waste streams (i.e., wastewater).

6.4 Transportation Modes and Estimated Unit Rate Costs

Transport of radioactive material is strictly regulated by the DOT. The DOT regulates packaging, handling, marking, labeling, placarding and paperwork. The DOT also establishes standards for personnel, conveyance performance and maintenance. Additionally, the NRC and DOT set radioactive packaging standards. Shipping container specifications are typically defined to meet DOT shipping requirements. Facility-specific WACs are usually written to be consistent with approved DOT containers; however, the choice of shipping container may be influenced by WAC acceptance criteria.

There are a wide variety of packaging and transportation modes that exist for transporting the material associated with NFSS. Based on the information in Appendix D, the most efficient and probable modes of transportation are by truck, by rail, or by a combination of both. The following list summarizes the transportation modes available for each potential disposal facility:

- **Energy*Solutions***: Receives inbound waste by both truck and direct rail. Packaging allowed for inbound shipments includes drums, boxes, soft-sided bags, rail cars and custom cask liners. All intermodals, Sealands and cargo containers must have International Standards Organization connectors on the top corners unless otherwise approved by the facility.
- **U.S. Ecology**: Receives inbound waste shipments by both truck and direct rail. Their rail transfer facility accepts hoppers, gondolas and intermodal containers via rail for trans-loading to over-the-road vehicles. Acceptable packaging via trucks would require compliance with DOT requirements and include bulk liquid tankers, vacuum sludge boxes, end-dumps, trucks and pups, and side dumps (special projects). They also accept non-bulk containers in the form of bags, boxes, drums, totes, pails and other DOT containers.
- **WCS**: WCS receives inbound material by both truck and direct rail although direct rail waste shipments are limited to non-radioactive waste. WCS is involved in various requests to their regulator for modification and amendments to their current authorizations. One of those would include allowance for receipt of radioactive waste via rail. Also, for any waste being classified as LLRW [e.g. not 11e.(2)], WCS is pursuing an amendment to allow for disposal of Class A waste in bulk form (e.g., un-containerized).
- **WDI**: receives inbound material via truck, rail, and rail-to-truck/truck-to-rail transfers. During the winter season, transportation containers must be properly lined to ease offloading of frozen loads. Failure to provide proper lining may cause frozen loads to hang up in the containers and assistance of a backhoe may be required (for a fee).
- **NNSS**: Supports inbound transport by both truck and rail-to-truck transfer of materials since no rail spur is available on site. Allowable packaging for inbound shipments includes drums, wooden or steel boxes, cargo containers, soft-sided bags, intermodals with liners, bulk (large solid items) and custom cask liners.

6.4.1 Transportation Modes

The trailer used for transporting the Fernald IP-2 waste containers was specifically designed to convey as much waste as possible per shipment, to allow for the quick and safe removal of the containers, and to ensure the packages remained secure during shipment.

One issue that was evaluated and overcome by design efforts was the presence of two packages (weighing 10,000 kg [22,000 lbs] each) being conveyed during each shipment that could create a gross weight exceeding the 36,287 kg (80,000 lbs) gross vehicular weight limit for a legal shipment. The solution to this issue involved the incorporation of as much aluminum as possible in the design of a prototype trailer - which weighed approximately 5,000 kg (11,000 lbs). Including 20,000 kg (44,000 lbs) for the weight of the containers, plus 900-1,360 kg (2,000 - 3,000 lbs) for tie-downs and the weight of the tractor, it was found that the gross vehicular weight was approximated to be 34,020 – 34,470 kg (75,000 – 76,000 lbs).

During the shipping campaign, all transports were weighed and verified to be in compliance prior to leaving the Fernald Site.

The USDOE decided early on that the trailers would be not purchased since no follow-up use was envisioned within the USDOE program, the capital costs were significant ($3 to 5 million), and because a property disposition process would be required at the end of the campaign. The transportation subcontract was structured such that the contractor would provide not only the tractors and qualified drivers, but they would also provide the trailers and tie-down systems, which were to be fabricated in accordance with specifications and drawings provided by the Fernald Silos 1 and 2 Remediation Project. The subcontract allowed for the contractor to buy or lease the trailers, but the trailer costs to USDOE would be a unit rate per shipment along with some initial start-up costs to pay for the capital costs associated with the tie-down systems and trailer modifications. At the end of the shipping campaign at Fernald, the subcontractor owned the trailers and tie-down hardware.

The number of trailers required to meet the requirements of the Fernald K-65 shipping campaign was 177 (Diggs 2011). USDOE initially leased 45 of the trailers at the end of the shipping campaign for use at the WCS for local container movement during the transfer from storage to disposal, but then purchased these trailers in the event the license modification for disposal was not approved. Once the WCS license was approved for disposal, and the placement of the containers in the byproduct cell was completed, USDOE retrieved the trailers from WCS and distributed them to other facilities for de-modification or further disposition as appropriate. The subcontractor demodified the remaining 132 trailers and sold them (Diggs 2011).

6.4.1.1 Estimated Transportation Costs

According to the conclusions provided in Appendix D, bi-modal transportation is the most favorable mode of transporting the NFSS waste to an off-site disposal facility. Although direct rail shipments using gondolas is the least costly mode of transportation to the selected disposal facilities, there is currently not an operating rail spur at the NFSS. Tables 6-10 and 6-11 present a summary of unit costs for transport to the facilities currently considered viable candidates for waste disposal.

Bi-modal mode of transportation involves the loading of material onto a truck, transferring it to a rail car and then shipping the material to a disposal facility. Additionally, in the case that the disposal facility does not have a rail spur on site, material would have to be unloaded from the rail car, loaded onto a truck and then unloaded again once it arrives at the disposal facility.

The experiences with the packaging and transport of the K-65 residues at the Fernald Site suggest that transport of the NFSS K-65 and other residues will likely derive greater net benefit from the employment of direct truck transport due to the requirements for design and construction of rail cars to meet DOT certification criteria for transporting these residues.

Table 6-10. Direct Rail Transportation Estimated Costs Per Railcar*

Mode of Transport	**Energy*Solutions***	***Nevada National Security Site***	***Waste Control Specialists***
Direct Rail using High Sided Gondolas[a]	$24,997.00[b]	$22,433.00[b]	$20,691.00[b]
Fuel Surcharges[c]	$1,221.00[d]	$1,088.00[d]	$1,048.00[d]

[a] This cost is estimated on a per railcar basis (66 yd^3).

[b] The above rate includes the following: 1) Rail Transportation – Project site to disposal or transfer facility site, 2) Mobilization/Demobilization of railcars project transfer facility site, 3) Railcar utilization.

[c] This cost is estimated on a per railcar shipped basis.

[d] The estimated fuel surcharge is based on the published rates in effect June 1 through July 31, 2011.

[*] Ancillary Charges to consider:

- Damage to rail equipment = Cost Plus 15% per Event
- Fuel surcharges are variable and will be passed through at Cost per Event
- Over-weight railcars = Cost Plus 15% per Event
- Railcars ordered but not used by customer = $13,000.00 per Event plus Fuel Surcharges
- Railcar demurrage = $80.00 per Day per Railcar

Table 6-11. Truck Transportation Estimated Costs Per Truck*

Mode of Transport	**Energy*Solutions***	**Nevada National Security Site**	**Waste Control Specialists**
Flatbed	$8,424.00	$9,868.00	$7,488.00

* - Ancillary Charges to consider:

- Detention = $65.00/hr After three (3) hours free time at the initial origin and three (3) hours free time at destination; free time will not be afforded to stops in between the original point of origin and final destination. All detention over three (3) hours will be charged at $73.50 per hour with maximum of twelve (12) hours per day for the first day then sixteen (16) hours per day for each day thereafter. For teams, detention over three (3) hours will be charged at $65.00 per hour, maximum of twenty (20) hours per day
- Driver Layover = When It becomes necessary, through no fault of the carrier, for a driver to remain at an origin or destination fifty (50) miles or more from terminal overnight in order to complete loading or unloading, there will be an additional charge of $99.00. This will be in addition to all other lawfully applicable rates and charges. When transporting over dimensional or overweight shipments and a motel charge is incurred, an additional $99 per night will apply.
- Fuel Surcharge = Emergency fuel surcharges will apply when the price of diesel fuel exceed $1.10 as per the USDOE Fuel Price Index.

6.4.2 Container Options

For waste transportation purposes, stabilized Fernald Silos 1 and 2 material was classified as low specific activity LSA-II waste as defined in 49 CFR 173.403 (1) and the packages themselves were designed to meet transport regulations in 49 CFR 173.411 for IP-2 packages. Each package was a right circular cylinder approximately 1.8 m (6 ft) tall and 1.8 m (6 ft) in diameter and was calculated to weigh slightly less than 10,000 kg (22,000 lbs) when filled with stabilized waste.

The waste shipping containers used at the Fernald Site for the K-65 residues were designed to meet DOT shipping regulations for an IP-2 package and the WAC for the disposal facility. The containers were initially intended to be shipped by either flatbed railcar or truck trailer to the disposal site. The final mode of transportation was a specially designed truck trailer that carried two containers per trip to WCS, where both were unloaded from the conveyance, stored for an interim period and then disposed in the same container used for transport. Although the wastes were disposed within the same containers used for shipping, the key container design criteria were based on compliance with DOT shipping regulations.

Container design considerations included an evaluation to ensure that shipping and disposal facility handling/disposal requirements did not conflict and the resulting waste container design satisfied both sets of criteria without incurring additional, and potentially prohibitive, costs. Examples of disposal facility requirements associated with specific container design criteria may include:

- Ability of the container to support a load or specific weight, whereas transportation regulations specify different criteria. Until the limiting criteria are known, the container design schedule and the transportation requirements for a stacking test may be impacted.
- Container lifting attachment specifications and minimum safety factors for handling at disposal facilities may differ from transportation regulations.
- Surface radioactive contamination limits prescribed by a disposal facility may be more restrictive than those associated with transportation regulations.

The prototype containers for the Fernald K-65 Silos 1 and 2 Remediation Project were fabricated for testing per the transport conditions specified in 49 CFR 173.465, which include IP-2 packages. Tests conducted included drop tests and stacking tests.

The drop tests consisted of dropping a container filled with concrete to a weight that exceeded the design weight from a height of 1 m (3 ft) onto an unyielding surface. Three sets of drop tests were actually conducted, the first two being preliminary assessments prior to the record tests. The preliminary tests were conducted from a height of 1.2 m (4 ft) to compensate for the target pad used, which was less than “unyielding.” However, conducting these tests proved valuable because it was found that during the top end drop, the container’s formed head deflected enough that the blind bolt heads impacted the target pad, which pushed the head of the blind bolts into the their holes and consequently loosened the lid. To correct this condition, a spacer ring was added to the top of the grapple ring, which recessed the lid further inside the grapple ring.

Official drop tests of the prototype containers were conducted by the National Transportation Research Center located near Oak Ridge, Tennessee. Three drop orientations were tested from a height of 1 m (3 ft) (top end, side, and center of gravity over corner). The container met the requirements in all three tests.

A stacking test was also conducted on one of the prototype containers. Per the requirements of 49 CFR 173.465, the stacking test consisted of placing a compressive load of 49,782 kg (109,750 lbs) on the container for 24 hours. The load of 49,782 kg (109,750 lbs) was based on five times the weight of the container; the container met the test specification.

The custom IP-2 container and conveyance combination designed and employed for transport and disposal of the Fernald K-65 residues proved to be highly successful in meeting its intended objectives. A total of 3,770 containers utilizing a new design were transported in 1,885 shipments with a conveyance specially designed for this purpose to meet DOT criteria. These shipments were completed without a single environmental release, in-transit incident, or rejection at the disposal site for failure to meet physical WAC. This success record is indicative of the benefit of an efficient design approach and a well planned and executed test and certification program for the container and conveyance combination The implication for NFSS is that this container and conveyance combination are likely directly transferrable in its current configuration with a performance record that will facilitate acceptance by state and federal agencies as well as the public.

6.4.2.1 Estimated Container Costs

Proper packaging is a key factor in safety while transporting radioactive material. Both bulk and containerized shipment of materials are presented in Appendix D for the NFSS. Containerizing and temporarily storing waste on site provides some flexibility in the terms of shipment schedules.

Based on the conclusions provided in Appendix D, packaging is based on the radiological concentrations associated with each waste stream. Using the worst-case scenario, it was determined that the K-65 residues could be shipped as low specific activity material. The activities in the residues meet the low specific activity definition in 49 CFR 173.403 and the transportation requirements in 49 CFR 173.427.

Waste packaging must meet applicable Title 10 CFR Energy, Title 40 CFR Protection of Environment and Title 49 CFR DOT requirements such as design, nuclear safety, radiation levels, activity limits and multiple hazards. Applicable USDOE Orders would apply to those facilities which USDOE owns and operates under its jurisdiction. Waste packages must be capable of withstanding the stresses associated with the loading, handling, stacking and shipping of the package.

Available container options evaluated in Appendix E include:

- Custom IP-2 containers;
- Intermodal; and
- Gondola and soft-sided bags.

Table 6-12 presents a summary of unit costs associated with the various package types.

Table 6-12. Type of Packaging Estimated Cost[a]

Type of Packaging	*Estimated Cost*
Soft-Sided Bags (9 yd^3)	\$335.00[b]
B-25 (5.3 yd^3)	\$3,300.00[c]
Custom IP-2 (6.3 yd^3)	\$5,339
Intermodal (25 yd^3)	\$13,000.00[d]
Gondola (66 yd^3)	See Table 6-10

[a] Freight costs for delivery will be incurred.

[b] Ancillary Costs:
Loading Frame - \$525.00 per frame per month rental
Lifting Frame - \$525.00 per frame per month rental

[c] Based on historical costs for containers purchased at the Fernald Site

[d] This is the cost to purchase the container. Rentals are estimated at \$13.00 a day.

6.5 K-65 Residue Disposal - Fernald Lessons Learned

Lessons learned from Fernald waste management and disposal are applicable to the K-65 residues at NFSS due to assumed similarities between the K-65 residues addressed at the Fernald Site and those currently stored within the IWCS.

Table 6-13. Lessons Learned Summary

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
6.1.2	Potential for cross-contamination of 11e.(2) byproduct material during remediation	• Introduction of non-11e.(2) contaminants into byproduct waste streams may alter waste classification • Cross-contamination due to mixing waste with other on-site waste streams • Cross-contamination due to incidental contact with other site media during waste removal	• Thorough pre-remediation characterization of all site media that may contact waste material during removal or treatment • Confirmation testing of materials on a relatively small batch basis to identify impacts early and minimize the overall volume affected	• Minimize, to the extent possible, the potential for cross-contamination of 11e.(2) byproduct waste streams during remediation • Identify impacts related to waste process options early to ensure the final design accounts for all possible variations in waste composition
Lessons Learned: *The option of using NFSS on-site soil to mix with higher activity IWCS waste streams presents the risk of cross-contamination with constituents that may significantly impact the treatment, classification, and disposal of project waste. Proactive and thorough characterization of site media that may be used as a waste treatment component – or that may incidentally contact waste material during removal – will help to minimize potentially significant changes to waste disposal options, project schedule, and overall cost.*				
6.2.4	Relationship between disposal facility WAC and USDOT waste shipping requirements	• Inaccurate identification of the key criteria for waste shipping and disposal acceptance • Inaccurate design of waste treatment processes • Incorrect assumption that meeting one set of criteria guarantees compliance with the other	• Thorough study and consideration of all applicable requirements that may impact waste treatment, packaging, transport, and disposal facility acceptance	• Post-treatment waste materials that meet packaging, transport, and disposal acceptance • Eliminate unanticipated changes in waste packaging and transport configurations • Accurately target design of customized packages or containers
Lessons Learned: *An accurate understanding of the relationship between disposal facility WAC and USDOT (and any other) shipping requirements is essential for determining waste treatment objectives, shipping configuration design, and accurate waste profiles. Either the disposal facility WAC or the USDOT shipping requirements may prove to be a limiting factor with regard to waste material activities and associated dose rates. Both sets of criteria also may prove to be equally restrictive. Limiting criteria may include those associated with: waste concentrations, transport package dose rates, transport package weight. All potentially limiting criteria should be considered during the FS and potential remedial design.*				

Table 6-13. Lessons Learned Summary (continued)

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
6.4.2	Waste Container Design and Testing	• Potential excessive weight of containers designed to meet USDOT requirements and disposal facility WAC • Potential container certification test failure due to design deficiency	• Prototype of truck trailer incorporating aluminum to minimize trailer weight • Performance of preliminary testing prior to certification testing	• Transport vehicle configuration was confirmed prior to full scale operations. • Transport container and vehicle shipping was compliant with USDOT and disposal facility WAC • Container design defect identified and corrected prior to certification testing
Lessons Learned: *Preliminary testing and development of container prototypes should be considered as a key component of a potential IWCS remedial design. Incorporation of preliminary and prototype testing will allow for the identification and correction of process system flaws.*				

7. CONCLUSIONS

This TM focused on a review of the USDOE Fernald Site Silos 1 and 2 Remediation Project, and an evaluation of the potential waste disposal options for wastes generated by remediation of the IWCS at NFSS.

Review of the Fernald Silos 1 and 2 Remediation Project confirmed there is valuable technical information that can be used to evaluate potential remedial alternatives for removal of K-65 residue in the IWCS FS. This review presents a discussion of many features of the Fernald Silos 1 and 2 Remediation Project and other projects completed at the Fernald Site with a focus on those elements that should be considered in evaluating a removal action at the IWCS. The K-65 residues removed from the Fernald Site were sufficiently similar in form, chemical characteristics and radiological activity so that many of the processing, packaging, environmental controls and secondary or contact waste disposition approaches could be directly applicable to evaluation of various remedial alternatives and development of a preferred remedy for employment at the NFSS. Although the Fernald Site did not contain other byproduct residues like the NFSS, the protocols for addressing these additional residues would likely be the same or very similar.

Lessons learned from the Fernald Site Silos 1 and 2 Remediation Project are presented in tables at the end of Sections 2 through 6 and are collected here as Table 7-1. These lessons learned include notes that describe the potential application to remediation of the IWCS.

The waste disposal options study identifies waste volumes and classifications and assesses various options for waste disposal sites, packaging, transportation modes, and order of magnitude pricing for the packaging, transport and disposal of the wastes involved in IWCS. Based on this evaluation, the following are considered viable waste disposal facilities (subject to meeting the facility's WAC) for the expected waste forms:

- Commercial Facilities
    - Energy*Solutions*, Utah
    - U.S. Ecology, Grand View, Idaho
    - WCS, Andrews County, Texas
    - Wayne Disposal, Incorporated (WDI), Belleville, Michigan
- USDOE Owned Facilities
    - NNSS

The evaluation of these facilities includes an estimate of the disposal costs for a presumed IWCS removal action. These costs are estimates based on the current understanding of the volume of IWCS wastes to be removed, estimated waste volumes assuming downblending to meet disposal and shipping requirements, and current WAC requirements for the selected facilities. These estimated costs should be considered preliminary due to uncertainty in the assumptions and the probability that these assumptions will be modified during the development of alternatives in the feasibility study.

Follow-up discussion with the NNSS and the WIPP is needed to investigate potential modifications that might be made by USDOE to allow receipt of additional waste streams from NFSS. This is based on the fact that the wastes in question have a USDOE pedigree and these are USDOE-owned disposal facilities.

Table 7-1. Lessons Learned Summary

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
2.1.3	Final ARARs in approved FS.	• 40 CFR 191 Subpart B *Environmental Standards for Disposal* identified as a "relevant and appropriate" ARAR by EPA during the OU 4 FS • Impacted plans for on-site disposal at Fernald • Introduced new waste containment requirements and quantitative release limits • Impacted already-completed FS activities based on previously identified ARARs	• USDOE conducted detailed assessment of the impact of this ARAR on the OU 4 silos remediation	• Reconfiguration of OU 4 into sub-OUs • Re-evaluation of new technologies/process options • Investigation of disposal site availability for K-65 residues • Identified off-site temporary storage pending final disposal options • Development of new/revised alternatives • Significant project cost and schedule impacts
Lesson Learned: *The ARAR was identified by EPA after the OU 4 FS was already in development. The resulting requirements significantly impacted the technical requirements, remedial alternatives, and planned on-site disposal options for the K-65 residues. Significant project cost and schedule impacts resulted from the late identification of this ARAR during the remedial process. Although the ARARs at NFSS are determined by the USACE, efforts at the beginning of the FS process need to focus on gaining agreement on the complete set of ARARs to be addressed. Also, the NFSS should consider application of subunits, or a similar approach, should there be K-65 specific ARARs identified for IWCS OU FS that should not be applied to the remainder of materials within the IWCS.*				
2.1.5.3	Interim storage and management of debris and contaminated soils for on-site disposal	• Under Removal Action No. 17, contaminated debris was generated that was suitable for on-site disposal when placed with fill material (soil). Sufficient contaminated soil was excavated under a separate action, but was not available until after the debris was generated.	• An on-site interim storage facility (Engineered Central Storage Facility) was established to store the debris pending excavation and availability of on-site soils from a separate remedial action.	• Waste materials from separate actions stored until sufficient volumes were available to meet on-site disposal requirements. • Wastes managed and disposed on-site, avoiding off-site disposal.
Lesson Learned: *On-site interim management of waste materials can be used to avoid dispositioning wastes off-site when on-site options are available but will require a delay prior to disposal. This allows integration of individual subproject schedules, resulting in cost savings and optimizing disposal methods. During remediation of the IWCS, wastes with varying characteristics will be generated and a similar interim storage strategy may prove cost-effective.*				

Table 7-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
2.1.5.4	Selection of innovative treatment technologies	• Numerous technical and operational problems were encountered in the OU 4 vitrification treatability study process.	• A proven technology, chemical stabilization, was selected as the alternate treatment technology.	• Waste treatment achieved waste certification, licensing, transport, health and safety, and disposal requirements • Technology was proven reliable and fully implementable.
Lessons Learned: *Consideration of innovative treatment technologies should include an understanding of the potential increased level of complexity and potential negative impacts to implementability, cost, and schedule. IWCS FS should balance potential positive and negative impacts when considering innovative treatment technologies.*				
2.2.1.2	Pre-design waste characterization	• Limited waste characterization data for K-65 residues available during pre-design remedial activities • Elevated radiological activities and concerns for worker safety limited the amount of sampling conducted • Limited data set represented an uncertainty in anticipated waste properties	• Fernald utilized a 95% UCL statistical approach to quantify waste characteristics	• Uncertainties remained with respect to K-65 residue characterization throughout the Fernald pre-design • Significant differences between the statistical results and actual results could have represented significant impacts to Fernald Project technical design, schedule, and cost
Lesson Learned: *Pre-design waste characterization data collection should be conducted, to the extent possible, to maximize available data for the K-65 residues and other IWCS waste materials at NFSS. Any reduction in the level of uncertainty associated with waste characterization prior to the start of waste removal/treatment/disposal will mitigate potential negative impacts to project technical, cost, and schedule plans.*				

Table 7-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
2.2.2	Incorporation of subprojects into remedial approach	• Potentially complex, long-term, and high cost remedial implementation	• Consider dividing the remedial project into more manageable subprojects based on significant technical tasks or schedule-based work phases	• More effective management of project implementation • More flexibility to apply varying contract mechanisms based on the scope of activities
Lesson Learned: *Although the incorporation of subprojects for the OU 4 remediation was necessitated by the late identification of an ARAR by EPA (see above), dividing a large and complex project such as the potential NFSS IWCS remediation may provide management and contracting option benefits – even if this approach is not required for other reasons.*				
2.3.3	RCS operation/system design	• K-65 residue radon leakage to surrounding area • The need to adjust system applications as project continued	• Continuous removal of headspace radon • Incorporation of flexible system design	• Effectively negated further leakage • Surrounding area radon concentrations/dose rates reduced to background • Allowed TTA construction without radiological controls • Increased work production in surrounding area • Flexible system design reduced system downtime and maximized incorporation of ALARA
Lesson Learned: *Although the presence of significantly elevated radon levels is anticipated during the potential NFSS IWCS remediation, the waste storage configuration at the IWCS is very different from that used at Fernald. As a result, the configuration of a RCS at the IWCS also is likely to differ from the Fernald design. Even though the system designs are likely to differ, the design of an effective RCS at the IWCS should consider the benefits from generally lower radon concentrations/dose rates in the immediate and surrounding work areas, the elimination of significant off-site radon exposures, reduced radiological controls, and overall increased work productivity during project completion.*				

Table 7-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
2.4.2	AWR operation/system design	• Hardened material encountered during waste retrieval operation • Inconsistent waste form/imbalanced radiological activity	• Utilized center confinement structure for mechanical retrieval device access • Circulation through receiving temporary storage tanks	• Allowed hardened material removal without contamination spread or release of headspace radon to environment • Effectively blended waste material – increasing consistency in resulting waste form and activity • Flexible system design and planning for potential waste form variations minimized project schedule and cost impacts
Lesson Learned: *The waste storage configuration at the IWCS will require an AWR system design that addresses the removal of K-65 residues from an open bay configuration (versus the relatively confined environment within the silos at Fernald). The potential for beneficial waste blending and the resulting consistent waste form and radiological activity should be considered during IWCS system design – as these benefits may represent significant positive impacts to waste packaging, transport, and disposal.*				
2.5.2.2	Inclusion of technology vendors in WT&P process design development	• Potential negative impacts due to improper component compatibility or interfacing • Need to identify specifications from numerous component vendors • Challenges related to development of "first-of-kind" systems	• Process system component vendors included in design • Best value procurement approach utilized • Cooperative efforts among vendors	• Minimized potential complications associated with complex system designs • Best value contracting approach considered technical expertise (not low-cost only).
Lesson Learned: *Including vendors for various complex system and process design activities helped to minimize component interface issues and associated negative impacts to project cost and schedule. The efficient design of complex systems and processes requires close coordination with component vendors to ensure compatibility and effective implementation.*				

Table 7-1. Lessons Learned Summary (continued)

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
2.5.4	Incorporation of redundant systems in remedial processes	• Potential negative impacts to worker safety, project schedule and cost due to excessive delays for equipment maintenance/repair	• Inclusion of redundant capabilities for key system components	• Minimization of overall process downtime due to scheduled/unscheduled equipment maintenance or repairs • Minimization of potential personnel exposures related to maintenance or repairs
Lesson Learned: *The utilization of redundant system components for key applications will minimize overall process schedule delays and potential worker exposures due to required equipment maintenance activities. The presence of redundant system components allows the process to continue operation while the affected components were repaired. Excessive downtime in a single process may result in delays to numerous other processes or operations.*				
2.5.6	Transportation to, and Interim Storage at Off-site Disposal Facility	• Legal issues identified by the State of Nevada concerning the off-site disposal of the treated Fernald silo materials at the ROD designated off-site disposal facility (NNSS) required diversion of waste to alternate interim storage location (WCS).	• Feed batch data, recipe formulation data, and process control data for each container produced was collected to demonstrate compliance with the waste profile. • Each shipment was manifested to ensure that all of the Silos 1 and 2 Remediation Project residues were properly shipped and received by the facility. • Careful, methodical review approach for assuring accuracy of shipping papers to prevent rejection of shipments at the disposal facility. • Earliest possible submittal of shipping papers to disposal facility to facilitate early discovery of discrepancies and sufficient scheduling of shipments.	• Maintained the final remedy of protective, permanent off-site disposal of silo material. • No delay or rejected shipments at the disposal facility. • Approximately 2000 shipments to disposal facility without adverse occurrence or event impacting shipping campaign.

Table 7-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
Lesson Learned: *Process control data for each container produced was collected to demonstrate compliance with the waste profile. Careful, methodical review to ensure accuracy of shipping papers and early submittal of papers to disposal facility facilitated early discovery of discrepancies and sufficient scheduling of shipments.*				
2.6	Consideration of system components/materials in waste disposal volumes at project completion	• Potential negative impacts to project waste volume estimates if all waste streams are not considered	• Ensure consideration of project shutdown waste volumes associated with system demolition, waste line cleanout, infrastructure removal, etc.	• More accurate estimates of final waste volume and associated disposal cost planning • Minimize negative schedule impacts due to insufficient funding
Lesson Learned: *The inclusion of remedial system component shutdown, demolition, or removal waste materials in the overall project waste disposal volumes is essential for accurate waste disposal cost estimates and scheduling. Negative impacts to project schedule and costs may result if additional unplanned waste materials are not identified until project completion. Potential waste types may include: equipment containment, work pads/surfaces, contaminated system components, excess wastewater from process operation or system decontamination, treatment process residues/tailings, etc.*				
3.3	Air monitoring for radon	• Movement of fixed radon monitors requires considerable effort.	• Monitoring program supplemented with portable radon gas monitors	• Rapid evaluation of localized areas made easier, supporting development of corrective actions
Lessons Learned: *Portable gas monitors should be considered for use in the air monitoring system during remediation effort at IWCS remediation. Provides flexible system design and enhances ability to adapt to changing conditions during remedial activities.*				
3.5	Integrated radiological monitoring system	• Waste treatment and packaging required measurement and quantification of Ra-226 concentrations and slurry densities. Collection of samples for laboratory analysis would interrupt operations and increase potential personnel exposures	• In-line Ra-226 Analyzer Systems were developed and installed on a diverter loop (piping) for each of the three slurry feed tanks	• Continuous measurements were available with minimal exposure to workers and without process interruption for laboratory analysis.
Lessons Learned: *The integration of radiological monitoring systems with process operations may minimize down time and worker exposures during IWCS remedial activities. Integrated monitoring systems may apply to numerous process components during the life of the project.*				

Table 7-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
4.1	Feasibility of Radium Recovery	• In-process recovery would increase processing cost and increase potential worker exposure; post-disposal recovery could limit waste disposal options, increase disposal cost and/or decrease stability of the disposed waste form.	• Qualitative evaluation of impact of in-process or post-disposal recovery versus benefits of reuse.	• Ra-226 recovery was not used to affect waste processing or the disposal form or disposal method.
Lessons Learned: *The feasibility of radium recovery for medical purposes or as precious metals for cost recovery will be evaluated in the IWCS FS based on economic conditions at the time.*				
4.2	Waste retrieval systems	• Waste materials varied physical form (grain size, moisture content, and compacted masses).	• Developed waste retrieval tools that addressed the range of waste forms identified.	• Waste retrieval system successfully removed all waste forms encountered.
Lessons Learned: *Potential variations in the physical state of the wastes to be removed from the IWCS may necessitate the incorporation of multiple retrieval components.*				
4.5.1	OSDF Design	• Strict/defined engineering requirements resulted in difficulty in meeting design specifications during construction due to varying field conditions. • Impacts to schedule and cost to expend additional effort or redo work to meet specified criteria	• Proposed additions and revisions to the approved plans and specifications that enhanced constructability of the facility with no impact to worker safety or performance of the OSDF.	• Proposed changes created negative perception by the public and regulators. • Design with specifications with flexibility to increase ease of construction.
Lessons Learned: *Provide flexibility in the engineering requirements indicated on design drawings, detailed in technical specifications and described in the work plan. Perform detailed constructability review by experienced construction professionals to identify elements that may impact construction costs and schedule. This approach will minimize change orders and non-compliance reports (NCRs) and avoid negative perception by the regulators and stakeholders.*				

Table 7-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
4.5.4	OSDF Cell Construction	• Clay borrow material contained an unexpected overabundance of rock • Clay material did not meet moisture content and compaction requirements need to reach the Acceptable Permeability Zone Curve for material acceptability	• Material was screened to remove rocks • Material excavated and stockpiled into smaller piles and tested two to three months ahead of placement	• Mechanical removal of rocks from material was much more effective than manual removal • Screening of material enhanced its workability during compaction • Testing material early enhanced likelihood of material meeting performance standard after placement, by avoiding sub-par materials.
Lessons Learned: *Verify variability of clay material, particularly in glacial till environments, and accordingly develop material preparation, handling, sorting and testing plans to enhance compaction and quality control performance.*				
4.5.5 and 4.5.6	OSDF WAC and Waste Placement	• Regulatory and Public Concerns over waste placement in OSDF meeting regulatory requirements • Inefficient waste placement could result in requiring significantly more soil than planned for layers and covers resulting in increased costs and reduction in cell capacity.	• Development of a Waste Acceptance Organization (WAO) to track excavation, transport and placement of all material in the OSDF • Development of a waste placement optimization plan to plan and track soil needs for the protective, select and intervening layers, placement of D&D and other materials.	• WAO for monitoring and tracking waste at source as an independent oversight organization added value and stakeholder trust. • Waste placement optimization plan and daily placement tracking optimized the OSDF placement capacity.
Lessons Learned: *Planning and tracking of waste from point of generation to point of final disposal provides credibility to the stakeholders and provides ability to address questions or issues after project has been completed. In addition, developing a methodical plan and procedure for waste handling and disposal, whether on-site or off-site, will reduce costs impacts and schedule delays during remedial implementation.*				

Table 7-1. Lessons Learned Summary (continued)

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
5.1	Public Involvement Strategy	• Limited public-facing communication and limited public participation in the decision-making process led to an adversarial relationship between the facility and the public.	• Fernald expanded public communication beyond the CERCLA requirements to develop a participatory relationship with citizen groups. • Expanded feedback pathways (online surveys, surveys in public places) to collect input from a larger cross-section of the public.	• Public participated as a fully engaged member of the Fernald planning and development team, advocated for site future use, and contributed to solution of major issues in Fernald site cleanup. • DOE communications, facility open house tours, public meetings, regular media contact, immediate press releases when events occurred, and public outreach materials (flyers, educational seminars) addressed public concerns, raising public trust in USDOE and site activities.
Lessons Learned: *NFSS could design and implement a public involvement program with elements similar to that developed for Fernald Citizens Advisory Board. The USACE-FUSRAP program does not have the authority to establish a Citizens Advisory Board, but the principles and structure of the FCAB should be considered given financial limitations.*				
5.2	Voluntary Protection Program	• 300 first aid incidents reported in 1992 • Influx of large workforce inexperienced in a radiological work environment.	• Implementation of the VPP • Continuing emphasis on worker involvement and enhanced work planning	• First aid incidents dropped to 50 in 2005 and 19 in 2006. • Ten million safe work hours and 11 years were recorded without a single lost-time accident.
Lessons Learned: *Implementation of a VPP, with management team commitment and a robust health and safety culture, can mitigate potential hazards and incidents that may occur during IWCS remediation.*				

Table 7-1. Lessons Learned Summary (continued)

Section	*Topic*	*Adverse Condition*	*Attempted Correction*	*Result*
5.3	Contracting Strategy	• Subtier FFP/PBC contracts for innovative or specialty services/resources during the design phase resulted in multiple change orders, impacting cost and schedule.	• Contracts were re-evaluated to determine how well the scope of services was defined; services and resources that could not be adequately defined (e.g. innovative or evolving technologies and designs) were procured using time and materials contracts.	• Significant reduction in contract change orders and the cost and schedule for integrated change management, as well as renewed focus on project execution.
Lessons Learned: *In developing the procurement strategy, time and materials or cost-reimbursable contract types could be considered for work packages requiring innovative or specialty services and resources with incentives tied to performance goals for the contract.*				
6.1.2	Potential for cross-contamination of 11e.(2) byproduct material during remediation	• Introduction of non-11e.(2) contaminants into byproduct waste streams may alter waste classification • Cross-contamination due to mixing waste with other on-site waste streams • Cross-contamination due to incidental contact with other site media during waste removal	• Thorough pre-remediation characterization of all site media that may contact waste material during removal or treatment • Confirmation testing of materials on a relatively small batch basis to identify impacts early and minimize the overall volume affected	• Minimize, to the extent possible, the potential for cross-contamination of 11e.(2) byproduct waste streams during remediation • Identify impacts related to waste process options early to ensure the final design accounts for all possible variations in waste composition
Lessons Learned: *The option of using NFSS on-site soil to mix with higher activity IWCS waste streams presents the risk of cross-contamination with constituents that may significantly impact the treatment, classification, and disposal of project waste. Proactive and thorough characterization of site media that may be used as a waste treatment component – or that may incidentally contact waste material during removal – will help to minimize potentially significant changes to waste disposal options, project schedule, and overall cost.*				

Table 7-1. Lessons Learned Summary (continued)

Section	***Topic***	***Adverse Condition***	***Attempted Correction***	***Result***
6.2.4	Relationship between disposal facility WAC and USDOT waste shipping requirements	• Inaccurate identification of the key criteria for waste shipping and disposal acceptance • Inaccurate design of waste treatment processes • Incorrect assumption that meeting one set of criteria guarantees compliance with the other	• Thorough study and consideration of all applicable requirements that may impact waste treatment, packaging, transport, and disposal facility acceptance	• Post-treatment waste materials that meet packaging, transport, and disposal acceptance • Eliminate unanticipated changes in waste packaging and transport configurations • Accurately target design of customized packages or containers
Lessons Learned: *An accurate understanding of the relationship between disposal facility WAC and USDOT (and any other) shipping requirements is essential for determining waste treatment objectives, shipping configuration design, and accurate waste profiles. Either the disposal facility WAC or the USDOT shipping requirements may prove to be a limiting factor with regard to waste material activities and associated dose rates. Both sets of criteria also may prove to be equally restrictive. Limiting criteria may include those associated with: waste concentrations, transport package dose rates, transport package weight. All potentially limiting criteria should be considered during the FS and potential remedial design.*				
6.4.2	Waste Container Design and Testing	• Potential excessive weight of containers designed to meet USDOT requirements and disposal facility WAC • Potential container certification test failure due to design deficiency	• Prototype of truck trailer incorporating aluminum to minimize trailer weight • Performance of preliminary testing prior to certification testing	• Transport vehicle configuration was confirmed prior to full scale operations. • Transport container and vehicle shipping was compliant with USDOT and disposal facility WAC • Container design defect identified and corrected prior to certification testing
Lessons Learned: *Preliminary testing and development of container prototypes should be considered as a key component of a potential IWCS remedial design. Incorporation of preliminary and prototype testing will allow for the identification and correction of process system flaws.*				

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Appendix A

Responses to Public Comments on the Waste Disposal Options and Fernald Lessons Learned Technical Memorandum Fact Sheet

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Niagara Falls Storage Site
Feasibility Study Technical Memorandum Development

U.S. Army Corps of Engineers **Building Strong ®**
Buffalo District

Formerly Utilized Sites Remedial Action Program (FUSRAP)

December 2010

Development of Waste Disposal Options and Fernald Lessons Learned Technical Memorandum

Purpose

The purpose of this fact sheet is to announce that the U.S. Army Corps of Engineers will be developing the *Waste Disposal Options and Fernald Lessons Learned Technical Memorandum* as part of their efforts in conducting the Feasibility Study (FS) for the Interim Waste Containment Structure (IWCS) at the Niagara Falls Storage Site (NFSS). In the FS, the Corps will identify and evaluate remedial alternatives and technologies that can be used to address radiological and chemical contamination resulting from Manhattan Engineer District and Atomic Energy Commission activities at the site. As indicated in the NFSS FS Work Plan published in December 2009, there will be three separate FS documents completed, one for each of the three operable units; IWCS, Balance of Plant (i.e., the entire site not including groundwater and the contents placed in the IWCS) and Groundwater, with the IWCS operable unit being completed first, then the Balance of Plant operable unit and then the Groundwater operable unit. This technical memorandum will address current or foreseeable future waste disposal options for the various IWCS waste streams to be considered for those removal alternatives associated with off-site disposal and lessons learned from all facets of activities related to planning, remedial design, removal, handling, packaging, shipment, and disposal associated with the radioactive K-65 waste residues, similar to those located at the NFSS, during the closure of a former uranium processing facility in Fernald, Ohio. By release of this fact sheet, the Corps seeks input from the public on the objective of the Waste Disposal Options and Fernald Lessons Learned Technical Memorandum so that the Corps can address public concerns during the development and finalization of this technical memorandum. The *Waste Disposal Options and Fernald Lessons Learned Technical Memorandum* is scheduled to be completed and available to the public in the Summer of 2011.

Project Background

The Formerly Utilized Sites Remedial Action Program (FUSRAP) was initiated in 1974 to identify, investigate and clean up or control sites throughout the U.S. that were part of the Nation's early atomic weapons and energy programs during the 1940s, 1950s, and 1960s. The NFSS is a 191-acre Federal property containing the 10-acre IWCS. Radioactive residues and wastes brought to the site by the Manhattan Engineer District and the Atomic Energy Commission during the 1940s and 1950s were consolidated into the IWCS by the U.S. Department of Energy in the 1980s. In 1997, the Corps became the Federal agency responsible for implementing the Formerly Utilized Sites Remedial Action Program (FUSRAP) subject to CERCLA. As previously announced, the Corps has begun transitioning into the feasibility study phase. The Corps will prepare a number of technical memoranda that will be made available to the public prior to the development and release of the FS. In this manner, the public will be given the opportunity for review and comment as we progress through the development of the FS.

Waste Disposal Options and Fernald Lessons Learned Technical Memorandum Objective

The objective of this technical memorandum with respect to waste disposal options will be to:

- Present an inventory, based on available documented information, of the various IWCS waste streams (e.g., K-65 residues, other residues, and other contaminated soils) by volume, activity and generation;
- Identify, for each IWCS waste stream, the potential waste disposal facilities, waste acceptance criteria and licensing requirements, or other factors for each waste facility that may impact shipment and disposal of NFSS wastes;
- Provide an estimate of disposal costs associated with various waste types for each waste facility; and
- Identify transportation modes and associated unit rates available for shipment of waste to the waste facilities.

With respect to the integration of lessons learned from the Fernald Site regarding the successful disposition of K-65 residues similar to those located at the NFSS, the technical memorandum will contrast and compare the Fernald facility and NFSS to highlight similarities and differences including, but not limited to, waste placement and waste inventory. Lessons learned at Fernald will address material excavation, material handling and transfer, packaging, transportation, waste disposal, personnel exposures and associated controls, radon abatement, radiological exposures to the public and environment, and public affairs. The Fernald lessons learned portion of the technical memorandum will also include planning activities such as applicable or relevant and appropriate requirements identification, remedial action objectives, treatability studies, waste characterization, etc. The technical memorandum shall identify the components that need to be addressed in the various FS alternatives involving the removal of the residues from the IWCS.

Public Input Regarding the Technical Memorandum

The Corps encourages input from the public regarding the objective of this specific technical memorandum. Input should be provided to the Corps by January 3, 2011, to allow the Corps to consider the input while developing and finalizing the technical memorandum. Responses to public comments on the objectives of this technical memorandum will be made available on the project website. Input can be sent via e-mail to fusrap@usace.army.mil (please be sure to note "Waste Disposal Options and Fernald Lessons Learned Technical Memorandum" in the subject of the e-mail) or mail your comments to the FUSRAP Team at the address noted below.

Administrative Record File

The Administrative Record File for the NFSS FUSRAP Site contains the Remedial Investigation Report, Baseline Risk Assessment, Groundwater Flow and Contaminant Transport Modeling and other CERCLA-related documentation for the NFSS. Reports and documents in the Administrative Record may be viewed at the following locations:

US Army Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207 (by appointment only)

Town of Lewiston Public Library
305 South 8th Street
Lewiston, NY 14092

Youngstown Free Library
240 Lockport Street
Youngstown, NY 14174

Responses to Public Comments on the Waste Disposal Options and Fernald Lessons Learned Technical Memorandum Fact Sheet

Comment No.	Comment	Response
1	I am a resident of Lewiston, NY (Lower River Road). I have evaluated the documents and encourage you to consider complete removal of the IWCS contents, including all K-65 residues, lower activity residues and contaminated soil.	The feasibility study that is planned for the NFSS IWCS will evaluate various removal alternatives associated with the contents within the IWCS, including the complete removal of the contents of the IWCS. The feasibility study will be made available for public review.
2	I am a resident of Lewiston, NY (The Circle). I have evaluated the documents and encourage you to consider complete removal of the IWCS contents, including all K-65 residues, lower activity residues and contaminated soil.	The feasibility study that is planned for the NFSS IWCS will evaluate various removal alternatives associated with the contents within the IWCS, including the complete removal of the contents of the IWCS. The feasibility study will be made available for public review.
3	The K-65 residues should be regarded as high level radioactive waste; as such the treatment of similar residues at Fernald was not appropriate. Residues of such high activity require encapsulation in a glass medium before being placed in a remote underground repository. Mixing the residues with fly ash, followed by disposal as low level radioactive waste is not appropriate and does not provide the required protection of the environment. There is a growing body of evidence that the Interim Waste Containment Structure at the NFSS is leaking, which necessitates the urgent removal of these dangerous residues. The NFSS has long been recognized as a totally unsuitable location to store radioactive waste: the wet conditions, high water table, close proximity to local populations and the Great Lakes all preclude the continued storage of K65 residues at the site. The residues should be removed from the	The K-65 residues within the IWCS do have high activity levels, however, per the regulations; these residues do not meet the definition of high level waste. These residues, as well as any other waste, that might be removed from the IWCS will be handled, treated and disposed in accordance with disposal facility licensing and other regulatory requirements (e.g., Department of Transportation) in effect at that time. If treatment is necessary to meet the potential disposal facility waste acceptance criteria or regulatory requirements, then the necessary treatment will be included in the development of the specific alternative(s) and their associated costs for the IWCS Feasibility Study The issue regarding the integrity of the IWCS is being addressed in the NFSS RIR Addendum and will not be addressed in this technical memorandum. With respect to the removal of the K-65 residues, the IWCS Feasibility Study will address various alternatives regarding possible remedial actions associated with the K-65 residues, other residues and the entire IWCS contents. The several technical memoranda that are currently under

Comment No.	Comment	Response
	NFSS as soon as possible, vitrified at a remote location and stored at a remote location to await placement in an appropriate repository.	development will provide some of the necessary information to assess the feasibility and protectiveness of any remedial action that may be proposed for NFSS IWCS. The major components of the feasibility study evaluation include effectiveness (i.e. protectiveness; worker protection, public protection and environmental protection) and implementability (site conditions, engineering and administrative controls)
4	Development of Waste Disposal Options and Fernald Lessons Learned Technical Memorandum From the Tech Memo "Lessons learned at Fernald will address material excavation, material handling and transfer, packaging, transportation, waste disposal, personnel exposures and associated controls, radon abatement, radiological exposures to the public and environment and public affairs." * Present an inventory, based on available documented information, of the various IWCS waste streams (e.g., K-65 residues, other residues and other contaminated soil) by volume, activity and generation; * Identify, for each IWCS waste stream, the potential waste disposal facilities, waste acceptance criteria and licensing requirements, or other factors for each waste facility that may impact shipment and disposal of NFSS wastes; * Provide an estimate of disposal costs associated with various waste types for each waste facility and * Identify transportation modes and associated unit rates available for shipment of waste to the waste facilities".	The suggested approach in the comment will be taken into consideration during the detailed development of any removal alternatives in the NFSS IWCS Feasibility Study. The feasibility study will be made available for public review.

Comment No.	Comment	Response
	Response Phased plan for remedial action Phase one: removal of L-50 from bldg 414 & 413, packaging and transportation Phase two: removal of L30 from Bldg 411 Phase 3: remove k-65 from recarbonation pit Phase 4: remove k-65 from 411within 5 years of inception Remove R-10 Phases are in increasing order of accessibility and/or radium content. Starting with the buildings 413 and 414. These are circular concrete tanks,62 feet in diameter and 19 feet deep. The contents were originally 7% uranium ore before processing at Linde. These are the longest in-place residues at NFSS. The goals will be to avoid the problems at Fernald and develop equipment and training for cover removal, residue removal, handling, packaging and shipment of Afrimet ores. If there is a radium separation process, that can also be developed and tested.	

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Appendix B

Assessment of Impacts of Additional ARAR, 40 CFR 191, August 24, 1990

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ASSESSMENT OF IMPACTS OF ADDITIONAL ARAR, 40CFR191 AUGUST 24, 1990

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REPORT

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1747

ASSESSMENT OF IMPACTS OF ADDITIONAL ARAR, 40CFR191

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO

August 24, 1990

U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE

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1.0 INTRODUCTION

At a meeting between the U.S. EPA and DOE at the U.S. EPA Regional Office Chicago on August 7, 1990, U.S. EPA notified DOE that 40CFR191 is considered to be an ARAR for the K-65 residues within Operable Unit 4. This regulation is entitled "EPA Radiation Protection Standards for Managing and Disposing of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes". Inclusion of this regulation as an ARAR requires that remedial alternatives for the K-65 residues must be evaluated for compliance with the provisions of 40CFR191.

1.1 40CFR191 Applicability

Both U.S. EPA and DOE agreed that the K-65 residues do not meet the requirements of applicability of 40CFR191, since K-65 residues are not spent nuclear fuel, high-level radioactive waste, or transuranic waste. The U.S. EPA maintained that the radiological nature of the K-65 residues is similar to transuranic radioactive waste (viz. long half-lives, alpha-particle emitting radionuclides, high radiotoxicity, and a concentration exceeding 100 nCi/g). Because of these similarities, U.S. EPA maintained that 40CFR191 is both "Relevant and Appropriate" as a requirement for management and disposal of the K-65 residues.

1.2 40CFR191 Relevancy and Appropriateness

DOE agrees with the similarities of the stated radiological properties between the K-65 residues and transuranic waste, but does not agree with the determination by U.S. EPA that 40CFR191 is both "Relevant and Appropriate". Although the requirement addresses substances which are similar to those found at the site, DOE and its contractors have maintained that adoption of 10CFR61, 40CFR141, 40CFR192, DOE Order 5400.5, and DOE Order 5820.2A present requirements which provide a sufficient level of protectiveness of human health and the environment.

Inclusion of 40CFR191 as a "Relevant and Appropriate" requirement introduces containment requirements and quantitative release limits which are unnecessary in the presence of the requirements of 40CFR141, DOE Order 5400.5, and DOE Order 5820.2A. Furthermore, disposal system performance assessments upon which containment requirements are based require time frames and financial expenditures which are inconsistent with the RI/FS process. Required performance assessments would, in fact, necessitate either offsite disposal in a previously approved disposal facility or interim on-site monitored retrievable storage until such time that an off-site disposal facility is approved.

1.3 FS Progress To Date

It is not possible to anticipate which regulations the U.S. EPA may choose to include as "Relevant and Appropriate" requirements even though they are not "applicable". Obviously, the U.S. EPA has the responsibility to determine correctly those requirements that are "Relevant and Appropriate" in accordance with their own guidelines (e.g. 53CFR51436-37). We maintain that identification of 10CFR61, 40CFR141, 40CFR192, DOE Order 5400.5, and DOE Order 5820.2A as potential ARARs and TBCs by the RI/FS team satisfies the requirements for such identification under CERCLA, SARA, NCP, and the Consent Agreement (April 1990) and that 40CFR191 should not be included as an ARAR. Nevertheless, with the signing of the Consent Agreement, DOE agreed with U.S. EPA that "The determination of final ARARs by U.S. EPA shall be final and not subject to dispute by U.S. DOE". (Section XII, p. 30)

To date, the FS activities for Operable Unit 4 have proceeded with the premise that 40CFR191 is neither "Applicable" nor "Relevant and Appropriate". The unilateral decision by the USEPA to include 40CFR191 as an ARAR requires that all FS activities performed to date for Operable Unit 4 be repeated to include in light of this new requirement.

1.4 Waste-Type Definitions

40CFR Part 191 specifies standards for management and disposal of spent nuclear fuel, high level wastes, and transuranic wastes.

Spent nuclear fuel is fuel that has been irradiated in a nuclear reactor. High level wastes are wastes resulting from the reprocessing of spent nuclear fuel. The K-65 residues do not fall into either one of these categories.

The various federal agencies have differing definitions of transuranic waste. EPA in 40CFR191 defines transuranic radioactive waste as "waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, with half-lives greater than twenty years, per gram of waste, . . .". EPA also listed three exceptions, the second being of interest: "except for wastes that the Department (of Energy) has determined, with the concurrence of the Administrator (EPA), do not need the degree of isolation required by this part."

DOE's policy is that transuranic waste is waste contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g. Additionally, DOE can determine other alpha-contaminated wastes peculiar to a particular site, must be managed as transuranic waste.

A transuranic isotope has an atomic number greater than 92. There are no known transuranic isotopes in the K-65 residues. The alpha emitting radionuclides in the K-65 residues are thorium-230 and - 232 (atomic number 90), radium - 226 (atomic number 88), uranium - 234, 235, 236, and 238 (atomic number 92).

Tables 1, 2, and 3 list the concentrations of alpha-emitting radionuclides with half-lives greater than 20 years for Silos 1, 2, and 3. EPA has started 40CFR191 to be an ARAR since the K-65

TABLE 1

ALPHA EMITTING RADIONUCLIDE CONCENTRATION IN SILO 1*

NUCLIDE (nCi/g)	S1NE1A	S1NE1B	S1NE1C	SISE1	S1SE2	S1SW1	S1NW1
Th-230	21.412	39.693	30.751	10.569	20.848	40.818	43.771
Th-232	ND	ND	ND	ND	ND	ND	0.766
Ra-226	108.1	192.6	166.4	116.8	89.28	181.2	163.3
U-234	0.815	0.326	0.622	0.633	0.814	0.594	0.897
U-235	ND	ND	ND	ND	ND	ND	ND
U-238	0.920	0.398	0.610	0.545	0.758	0.532	0.687
TOTAL (nCi/g):	131	233	198	129	112	223	209

Mean Concentration (nCi/g) = 176

NOTES:
ND - Not Detected
*Alpha emitters with half-lives greater than 20 years

TABLE 2

ALPHA-EMITTING RADIONUCLIDE CONCENTRATION IN SILO 2*

NUCLIDE (nCi/g)	S2SW1	S2NW1	S2NE2	S2SW2	S2NE1	S2NW2
Th-230	31.825	32.784	8.365	29.716	40.124	25.391
TH-232	ND	ND	ND	851	ND	ND
Ra-226	145.300	61.780	0.657	104.900	65.520	68.310
U-234	0.859	1.107	0.974	0.121	0.848	1.404
U-235	ND	0.074	0.047	ND	0.036	0.070
U-238	0.661	1.069	0.874	0.046	0.0814	1.240
Total (nCi/g):	179	97	11	136	107	96

Mean Concentration (nCi/g) = 104

NOTES:

ND - Not Detected

* Alpha emitters with half lives greater than 20 years

TABLE 3

ALPHA EMITTING RADIONUCLIDE CONCENTRATION IN SILO 3*

Nuclide (nCi/g)	# 21	# 22	# 23	# 24	# 25	# 26
Ac-227	0.007	0.006	0.003	0.019	.007	0.010
Pa-231	0.521	0.401	0.266	NA	0.556	0.889
Th-230	41.911	33.881	21.010	71.650	40.968	41.555
Th-232	1.451	ND	0.815	0.911	0.411	ND
Ra-226	2.589	2.192	0.467	6.435	3.073	1.862
U-234	1.935	1.618	0.348	1.524	1.467	1.910
U-235/236	0.152	0.117	ND	0.127	0.054	0.076
U-238	2.043	1.649	0.320	1.600	1.392	1.860
TOTAL (nCi/g):	50.6	39.9	23.2	82.3 (1)	47.9	48.2

Nuclide (nCi/g)	# 27	# 28	# 29	# 30	# 33
Ac-227	0.006	0.006	0.006	0.011	0.008
Pa-231	0.458	NA	0.564	0.931	0.431
Th-230	53.227	63.649	61.190	68.759	65.488
Th-232	ND	0.755	0.672	0.581	0.672
Ra-226	1.518	3.702	4.169	2.240	4.451
U-234	1.317	1.052	1.843	1.643	1.600
U-235	0.080	0.042	0.158	0.075	0.118
U-238	1.243	0.994	1.951	1.574	1.878
TOTAL (nCi/g):	57.8	70.2 (1)	70.5	75.8	74.6

Mean Concentration = 58 nCi/g

NOTES:

Data validation is currently in progress.

*Alpha emitters with half-lives greater than 20 years.

(1) Pa-231 Not Analyzed for this sample

NA - Not Analyzed

ND - Not Detected

residues in Silos 1 & 2 have alpha activity greater than 100 nCi/g. The mean alpha activity in Silo 3 is 58 nci/g, so there is no reason to believe that Silo 3 would have to be treated as transuranic waste.

From DOE's point of view, the ultimate question is whether or not the K-65 residues have to be managed as transuranic waste. If it does, then by the definition in DOE Order 5820,2A, 1988, the waste is transuranic.

2.0 TECHNICAL IMPACTS AND ISSUES

As a result of the recent EPA statement to invoke 40CFR191 as an ARAR for Operable Unit 4 (OU-4), several technical issues require evaluation and resolution to allow completion of the FS. Some of the issues are the following:

- Reconfiguration of OU-4 into sub-operable units (this was also requested as an action by EPA Comments)
- Reevaluation of technologies and process options to develop new remedial alternatives
- Investigation of the availability of disposal sites for the K-65 material
- Redesigns or new designs of remedial alternatives

Each of these technical issues and a plan for resolving each are described below.

2.1 Reconfiguration of OU-4 Into Sub-Operable Units

Originally, OU-4 consisted of the K-65 silos (Silos 1 and 2) and contents, the metal oxide silo (Silo 3) and contents, the unused silo (Silo 4), the berms around Silos 1 and 2, and the soils beneath the silos. The 40CFR191 ARAR requires that the contents K-65 silo be treated differently than the other materials comprising OU-4. In order to effectively evaluate appropriate alternatives for the different materials and structures to be remediated, OU-4 will be separated into four sub-operable units (SOUs). These SOUs will be the following:

- SOU-4C - Metal oxide silo (Silo 3) contents, structure, and subsoils
- SOU-4A - K-65 residues
- SOU-4B - K-65 silo structures, berms, and subsoils
- SOU-4D - Unused metal oxide silo (Silo 4)

The reasoning for and the impact of separating the one operable unit into four sub-operable units is discussed below.

SOU-4A - K-65 Residues

Since the K-65 residues are the only portion of OU-4 affected by the new ARAR, separation of the material from the rest of OU-4 is appropriate to allow its evaluation in relation to meeting the added ARAR. The universe of technologies and process options will be reinvestigated and new technology/process options will be considered in order to meet the ARAR requirements. Some of the technologies and process options to be considered, possible revised and new alternatives, and relevant technical issues are discussed in subsequent sections.

SOU-4B - K-65 Silo Structures, Berms, and Subsoils

The 40CFR191 ARAR is not "relevant and appropriate" to the K-65 silo structures, berms, and subsoils; therefore, separation of these components of the operable unit from the K-65 residues will allow the remedial alternatives for these portions to be similar to those developed in the previous evaluations. Separation of the K-65 residues from the silo structure, berms, and soils will, however, require revision to the existing alternatives to exclude the K-65 residues from them.

SOU-4C - Metal Oxide Silo (Silo 3) Contents, Structure, and Subsoils

The 40CFR191 ARAR only applies to the K-65 residues present in Silos 1 and 2. As previously presented, the Silo 3 contents contain lower activities of the alpha-emitting radionuclides of concern. Since much evaluation has been performed to date on remediation of the combined Silo 3 contents, structure, and subsoils, this combination will remain intact as SOU-4C to avoid unnecessary re-evaluation of alternatives. Minimal additional evaluation of technologies, process options, or alternatives will be necessary for Silo 3 (SOU-4C).

SOU-4D - Unused Metal Oxide Silo (Silo 4)

SOU-4D covers Silo 4 which was never used.

2.2 New Technologies/Process Options

As a result of treating the K-65 residues as transuranic-like waste, several issues must be addressed concerning waste treatment, waste form, packaging, storage, shipping, and disposal. New technologies/process options will be evaluated. Technologies and process options to be evaluated include the following:

- Investigation of the availability of offsite disposal facilities for the K-65 residues
- Investigation of the availability of offsite facilities for interim retrievable storage of the material
- Evaluation of options for on-site, interim retrievable storage
- Volume reduction, contaminant separation, and contaminant concentration technologies must be identified and evaluated
- Packaging, shipping, and disposal requirements for transuranic-like waste must be investigated and developed

The viable technologies and process options will then be assembled and incorporated into remedial alternatives for the sub-operable units. Tables 4 through 7 list the minimum alternatives for each sub-operable unit, as they have been initially envisioned.

2.3 Disposal Sites Availability

Currently, WIPP appears to be the only facility that meets the requirements for disposal of the K-65 residues. WIPP is intended

TABLE 4

SUB-OPERABLE UNIT 4A MINIMUM REMEDIAL ALTERNATIVES DESCRIPTION AND STATUS

Alternative # (Old #)	*Description*	*Status*
4A-0 (0)	No action	Revision required
4A-1 (1a)	Slurry wall and cap	Not applicable
4A-2 (2a)	Shallow soil mix & cap	Not applicable
4A-3 (6)	Remove, treat (stabilization) on-site disposal	Not applicable
4A-4 (7)	Remove, treat (stabilization), interim storage (if necessary), off-site disposal	Revision required
4A-5 (8)	Remove, volume red./ contaminant separation stabilization, on-site disposal	Not applicable
4A-6 (9)	Remove, volume red./ contaminant separation stabilization, interim storage (if necessary), off-site disposal	Revision required

TABLE 5

SUB-OPERABLE UNIT 4B MINIMUM REMEDIAL ALTERNATIVES DESCRIPTION AND STATUS

Alternative # (Old #)	*Description*	*Status*
4B-0 (0)	No action	Revision required
4B-1	Remove, stabilize, on-site disposal	Revision required
4B-2	Remove, stabilize, off-site disposal	Revision required
4B-3	Remove, package, on-site disposal	Revision required
4B-4	Remove, package, off-site disposal	Revision required
4B-5	Cap	Revision required

TABLE 6

SUB-OPERABLE UNIT 4C MINIMUM REMEDIAL ALTERNATIVES DESCRIPTION AND STATUS

Alternative # (Old #)	*Description*	*Status*
4C-0 (0)	No action	No revision required
4C-1 (1b)	Slurry wall and cap	No revision required
4C-2 (2b)	Shallow soil mix & cap	No revision required
4C-3 (3 modified)	Remove, treat, on-site disposal	Modified to include treatment
4C-4 (4 modified)	Remove, treat, off-site disposal	Modified to include treatment
4C-5 (5 modified)	Rehabilitate silo	No revision required

TABLE 7

SUB-OPERABLE UNIT 4D MINIMUM REMEDIAL ALTERNATIVE DESCRIPTION AND STATUS

Alternative # (Old #)	***Description***	***Status***
4D-0	No action	New

for the disposal of defense-related transuranic waste from ten designated facilities. FMPC presently is not on the intended list.Also, the facility is to undergo an initial five-year testing phase where a limited amount of waste will be accepted. However, WIPP may not be the only option for possible disposal of the K-65 residues.

Per discussions with NTS personnel, NTS has been assessed to accept 40CFR191 material. However, the assessment did not include 40CFR191 material with radium. Therefore, if the K-65 residues are determined to be 40CFR191 material, NTS cannot accept it at this time. However, NTS may be able to accept the K-65 material if the following occurred:

- A policy decision at DOE Headquarters
- A 40CFR191 assessment of the disposal of the K-65 residues at NTS
- EPA concurrence on the 191 assessment methodology

Even if 40CFR191 is not determined to be an ARAR, there is no assurance that NTS would be able to dispose of the waste. Written notification and application to NTS would be required, followed by an NTS evaluation of the K-65 residues. DOE headquarters would also have to approve of the disposal of K-65 residues at NTS.

The availability of other disposal sites will be investigated in detail as part of the required re-evaluation.

2.4 New/Revised Remedial Alternatives

Based upon the reinvestigation of the universe of technologies and process options to find suitable options to handle the K-65 material, and the reconfiguration of Operable Unit 4 into four sub-operable units, new remedial alternatives will be developed and previously developed ones will be revised. The alternatives for SOU-4C will remain unaffected by the new ARAR. All of the previously developed alternatives for SOU-4A and 4B will either be deleted or will require revision. New alternatives will also be developed for SOU-4A, 4B, and 4D based on the additional screening of technologies to be performed.

SOU-4A is expected to require alternatives to include provisions for interim storage of the K-65 residues unless a disposal facility is identified which will be able to accept the waste when it is prepared for disposal. Interim storage capacity may be considered at an on-site facility or an offsite facility, if available.

Also, remedial alternatives for SOU-4A may include additional process technologies for contaminant separation, volume reduction, or contaminant concentration to reduce the volume of transuranic-like waste from the K-65 residues.

2.5 Redesign and New Design of Process Options

Based on the results of the development of new/revised remedial alternatives, additional design or redesign is expected to be necessary. Design items may include:

- Processes for volume reduction, contaminant separation, and/or contaminant concentration
- Various remediation equipment sizing or resizing to accommodate the new or revised alternatives
- Design of interim storage facilities
- Design of packaging, shipping, and disposal hardware and facilities

All design activities will be performed in sufficient detail to provide a concept for the remedial alternative. Construction schedules and cost estimates will be prepared and used in the risk assessment of the alternative. The risk assessment will be performed after the concept is fully defined and will be used in

3.0 SCHEDULE IMPACT AND ISSUES

To document the changes required if 40CFR191 is relevant and appropriate to the K-65 residues, the Initial Screening of Alternatives (Task 12) document and Detailed Analysis of Alternatives (Task 13) presentation will need to be revised. The Selection of Preferred Alternative (Task 14) presentation prepared, and the Feasibility Study (Task 15), of which the first draft was nearing completion, will need to be revised and completed.

3.1 Initial Screening of Alternatives

Revising the Initial Screening of Alternatives would require, as discussed previously, an updated review of the universe of technologies and process options to determine if any additional technologies can be applied to the K-65 residues.

Concurrently with the review of the universe of technologies, various studies need to be performed. These studies include:

- Proper design life of the on-site interim storage facility, if required, per established design criteria, and if designs developed at other locations are applicable
- Acceptance criteria and cost for off-site disposal
- If stabilization could result in a waste form having less than 100 nCi/g
- If vitrification is a viable option for the transuranic-like waste
- If off-site interim storage is available
- If disposal at a facility similar to NTS, or a commercial facility, is an option
- If separation of the radium from the waste is feasible to allow the option to dispose of most of the waste as non-transuranic-like

After completion of the technologies review, Operable Unit 4 will be broken into the four sub-operable units defined previously.

New alternatives will be defined, as necessary, for each SOU. Existing alternatives will be retained if they are applicable to a SOU. The new alternatives, along with the existing alternatives, will be screened for implementability, overall protection of health and environment, and cost.

Major text changes will be required by the addition of any new technologies and/or process options, and defining the resulting new alternatives and revised alternatives for SOUs -4A, and -4B. A minimum of 13 new or revised alternatives are estimated for SOU-4A and SOU-4B (see Tables 4 & 5). Each alternative, under its respective SOU, will be analyzed with respect to the screening criteria for implementability, overall protection of health and environment, and cost. Any alternative not meeting the screening criteria will not be carried on to the detailed analysis of alternatives. These screenings will create major text changes in the existing Initial Screening of Alternatives document.

By leaving the metal oxide material, structure, and subsoil as a separate SOU only minor text changes concerning the metal oxide material and the Silo 3 structure and subsoil will be required to the existing Initial Screening of Alternatives document. However, screening results would not be revised. Table 6 lists the minimum alternatives for SOU-4C.

Text changes will be required by the addition of SOU-4D. Changes include the addition of the SOU definition, description of any alternatives and a screening analysis of the alternatives. Table 7 lists the minimum alternatives for SOU-4D.

3.2 Detailed Analysis of Alternatives

The Detailed Analysis of Alternatives presentation will be revised to encompass each of the SOUs and its respective alternatives.

The revision of the presentation to reflect SOU-4A and SOU-4B requires major modification to existing alternatives and extensive work to develop new alternatives. A minimum of 13 alternatives will be evaluated. These evaluations will include detailed conceptual designs, cost estimates, risk assessment analyses, NEPA analyses, and threshold and balancing criteria analyses. These steps cannot be performed concurrently. The cost estimate and NEPA analysis require input from the detailed design results. A portion of the risk analyses depend on the estimated man-power requirements for construction, operation and maintenance which are developed for the cost estimates. Following these analyses, threshold and balancing criteria analyses must be performed.

As was the case in the Initial Screening of Alternatives document, SOU-4C will require only minor changes. Detailed designs, cost estimates, risk assessment analyses, NEPA analyses, and threshold and balancing criteria analyses will require only minor revisions.

The presentation must also be revised to reflect the addition of SOU-4D. However, this is not considered a major effort since there is no waste material to be handled.

3.3 Selection of Preferred Alternatives

The Selection of Preferred Alternatives had not been presented, however, the selection process was near completion. The process to select the preferred alternative consists of a comparative analysis of the strengths and weaknesses of the alternatives relative to one another with respect to each balancing criterion. As a result of this comparative analyses, the alternatives are "ranked" in order of the most preferred alternative with respect to each criterion. Each criterion is "weighted" to indicate its relative importance. These criterion weights and rankings are entered into the computer software program "Expert Choice". Two runs, one including cost and one excluding cost will be run per sub-operable unit. The selection of preferred alternative for SOU-4C will have minor revisions. However, the selection of preferred alternatives for the other sub-operable units will require a total revision of the existing analyses.

3.4 Feasibility Study

The Feasibility Study is a compilation of the previous tasks. The first draft of the Feasibility Study for Operable Unit 4 was nearing completion when it was stated that 40CFR191 is relevant and appropriate to the K-65 residues. Therefore, due to the extensive rework of the initial screening of alternatives, the detailed analysis of the alternatives, and the selection of preferred alternatives, the Feasibility Study will also require extensive rework to accommodate the 40CFR191 ARAR.

4.0 RECOVERY PLAN

Invoking 40CFR191 will impact the schedule and budget for the OU-4 Feasibilty Study. These impacts are described in Sections 4.1 and 4.2.

4.1 Schedule

The schedule to revise the above mentioned deliverables is given in Appendix A. Please note that only one review cycle for DOE is scheduled for the Initial Screening of Alternatives, Detailed Analysis of Alternatives, and the Selection of Preferred Alternatives. The Feasibility Study is scheduled to have the usual two reviews.

4.2 Cost Estimate

The estimated cost required to complete the above scheduled tasks is given in Appendix B. Please not that the NEPA Analyses and Risk Assessments are not costed. These costs will be provided later.

APPENDIX A

RECOVERY PLAN

Schedule Recap

	WEEKS
• Prepare and Issue Draft Initial Screening of Alternatives Document	8
• Prepare Detailed Analysis of Alternatives Presentation	20
• Prepare Selection of Preferred Alternatives Presentation	4
• Draft FS	8
• DOE Review and Responses	14
ACTUAL WEEKS INCLUDING OVERLAPS, ADDED TO EXISTING FFA DATE	40

SCREENING OF TECHNOLOGIES & PROCESS OPTIONS

Task	WEEKS
• Examine Universe of Technologies • Write up New Applicable Technologies • Establish Screening Factors for New Technologies	1
• Assemble Process Options • Assemble New or Modified Alternatives	1
• Screen for Implementability, Overall Protection of Health & Environment, and Cost	2
• Prepare and Deliver Draft Initial Screening of Alternatives Document	4
TOTAL	8

DETAILED ANALYSIS

	WEEKS
• Develop Detailed Conceptual Designs • Develop Cost Estimates • Evaluate Against 2 Threshold Factors & 5 Balancing Factors	17
• Prepare Detailed Anaylsis of Alternatives Presentation	3
TOTAL	20

SELECTION OF PREFERRED ALTERNATIVES

	WEEKS
Compare Alternatives Using EXPERT CHOICE:	
- 2 EXPERT CHOICE Models will be run per SOU - 1 run including cost, 1 run excluding cost	1
- Prepare Selection of Preferred Alternatives Presentation	3
TOTAL	4

DRAFT FS

	WEEKS
• Prepare Draft for Internal Review	4
• Internal Review	2
• Comment Resolution & Incorporation	2
• Deliver Draft FS	
TOTAL	8

DOE REVIEW AND RESPONSES

	WEEKS
• DOE Review	4
• Resolve & Incorporate Comments	4
• DOE Review (II)	4
• Resolve & Incorporate Comments	2
TOTAL	14

APPENDIX B

IMPACT OF NEW ARAR, FERNALD OU4
ESTIMATED ADDITIONAL COST
(NEPA AND RISK ASSESSMENT NOT INCLUDED)

DIRECT LABOR

Labor Categories	Hours	Average Rate	Cost ($)
Project Manager/Senior Staff (E-11)	1500	32.08	48113.40
Senior Project Engineer (E-9)	1936	25.29	48964.54
Project Engineer (E-7)	3872	20.29	78562.88
Secretary/Word Proc (N-7)	340	8.51	2894.01
DIRECT LABOR SUBTOTAL	7648		178534.83
LABOR OVERHEAD			
Overhead at 130% of direct labor			232095.28
SUBTOTAL -- LABOR INCLUDING OVERHEAD			410630.11
OTHER DIRECT COSTS - UNBURDEDED			
Travel expense			0.00
Sampling Equipment (List Attached)			0.00
OTHER DIRECT COSTS - BURDENED			
Computer Time			300.00
TOTAL OTHER DIRECT COSTS			300.00
SUBTOTAL -- TOTAL DIRECT COSTS AND OVERHEAD			410930.11
G&A BASE (EXCLUDES BURDENED DIRECT COSTS)			410630.11
G&A EXPENSE @ 16.75%			68780.54
SUBTOTAL -- THROUGH G&A			479710.65
FEE BASE (EXCLUDES BURDENED DIRECT COSTS)			479410.65
FEE/PROFIT @ 8%			38352.85
SUBTOTAL -- THROUGH FEE/PROFIT			518063.50
FCCOM			
OH FCCOM = 1.866% OF DIRECT LABOR			3331.46
G&A FCCOM = 0.071% OF G&A BASE			291.55
FCCOM SUBTOTAL			3623.01
TOTAL COST			521686.51

Appendix C
Fernald Radon Model

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The Fernald Radon Model was presented as a component of the Accident Analysis in Appendix G of the *Accelerated Waste Retrieval (AWR) Nuclear Health and Safety Plan* (Fluor Fernald 2004). The purpose of the Accident Analysis was to determine if the AWR Project needs any safety-class structures, systems, and components (SSCs) or technical safety requirements for protection of the public. Safety-class SSCs are not normally associated with Hazard Category 2 or 3 facilities due to their limited potential for off-site impact. This document also quantifies the consequences of the bounding accidents associated with the operation of the Waste Retrieval and Transfer Tank Area (TTA), and Radon Control System (RCS). The dose consequence calculations in this accident analysis also support final hazard categorization used to develop health and safety plans for the remediation activities.

Analysis of five accident scenarios, Evaluation Basis Accidents (EBA) 1 through 5 produced the radiological dose estimates for workers and off-site populations. The scope of the analysis is focused on the accidents most likely to be encountered during AWR operation and maintenance. The five accidents analyzed include; EBA 1: failure of the RCS during retrieval operations; EBA 2: carbon bed failure [elution of adsorbed radon], EBA 3: failure of silo containment due to over-pressurization or under-pressurization during waste retrieval, EBA 4: breach of a transfer line, and EBA 5: failure of a TTA tank.

Safety-class SSCs are required for consequences exceeding an EG of 25 rem total effective dose equivalent to a maximally exposed off-site individual (MOI). Safety-significant SSCs are those important to defense in depth or on-site worker safety. Although EGs are not used for designating safety-significant SSCs, the on-site impacts are determined in this analysis. Within this analysis, consequences are determined for the following:

- Workers at 30 meters (m), which represents the distance for determining the dose threshold criteria of USDOE Hazard Category (HC) 3 facilities;

- Workers at 100 m, which represents the distance for determining the dose threshold criteria of USDOE HC-2 facilities. Note: Co-located workers are at 70 m or 120 m. These distances represent the distance from either of two release points (silo or stack) to the control room;

- Public at 330 m, which is defined as the distance to the MOI. The nearest off-site point on the Fernald Environmental Management Project site boundary is approximately 330 m west of the silos. Therefore, the maximally exposed off-site individual (MOI) is assumed to be located 330 m downwind of the accident location. The estimated values at 330 m are compared to the Evaluation Guidelines (EGs) established by DOE-STD-3009-94 Evaluation Guidelines for Accident Analysis and Safety Structures, Systems, and Components, USDOE; January 2000.

Fluor Fernald developed a predictive tool, the *Fernald Radon Model*, to estimate radon air concentrations at different site locations for various release scenarios. The model, which reasonably fit the site monitoring data, is described in the *Radon Modeling Report for the OU4 Safety Analysis Plan* [40000-RP-0030, *Radon Modeling Report for OU4 Safety Analysis Plan*, Parsons; Cincinnati, Ohio; February, 1998]. The model predicts the radon concentrations downwind from a release and allows inclusion of a "lag" term. The "lag" model is more complex and provides a more accurate depiction of radon transport when compared to existing monitoring data. This is because the model accounts for the persistence of radon in the vicinity closest to the release point. The non-lag model is used for the accident analyses. The model is based on F Class meteorological stability. A wind speed of 1.8 m/sec is used at 30 m and 330 m, which is a basic assumption of the model. A wind speed of 4.5 m/sec was used at 100 m, which is consistent with guidance in DOE-STD-1027-92 for HC-2 calculations. For a continuous release, the receptor is assumed to be exposed for 24 hrs at 30 m and 2 hrs at 100 m and 330 m. For an instantaneous release, the material is assumed to be completely released within 1 hour. The receptor is exposed during this hour to the instantaneous release, and for the entire exposure period to radon that is emitted continuously. Exceptions to these values are used for EBA 2. For EBA 2, the concentrations of radon progeny are calculated in working levels (WL). Exposures to these radionuclides are expressed in WL month. For releases of pure radon, the ingrowth time for radon progeny is a function of wind speed and receptor distance. To compare thresholds and limits, the dose equivalence of working levels must be determined. As shown in 10 CFR 835, the Derived Air Concentration for Rn is 30 pCi/L, corresponding to 5 rem in 1 year, which is equivalent to 2.5 mrem in 1 hour. Therefore, an individual exposed to 100 pCi/L Rn (or 1 WL) for 1 hour would receive a dose of 7.5 mrem, assuming 100 percent progeny equilibrium.

For EBA-3, radon is released to the environment via the 150-ft stack. To estimate the upper bound of the effect of such releases, a "fumigation" condition was considered. The upper bound for the fumigation condition is defined in Reg. Guide 1.145, Section 1.3.2, which states that the concentrations "cannot be higher than those produced by non-fumigation, stable atmospheric conditions with he = 0, for the fumigation case that assumes F stability and a wind speed of 2 meters per second." Therefore, to bound the fumigation condition, the radon release by way of the stack, was modeled as a ground level release with a wind speed of 2 meters per second, using the Fernald Radon Model.

The consequences of a mechanical failure of the stack (EBA 3) are similar to and less than the effects of a failure of the RCS during retrieval operations and hence have not been singled out for analysis. This accident and the five accidents analyzed are considered to be independent because the initiating mechanisms are independent of each other, i.e., dropped load, total electrical failure, flow control/lower failure, getting water in the carbon beds, fire in the carbon beds, and mechanical failure of the stack.

Analysis of five accident scenarios provided calculated internal dose estimates for individuals located at 30, 100, and 330 m from the point of the release and is presented in Table C-1. The off-site dose estimate was compared to the 25 rem EG established by DOE-STD-3009-94. The conclusions that can be drawn from the analyses are:

- None of the analyzed RCS accident scenarios yield results that are inconsistent with designating the AWR as a Radiological Facility.
- None of the accident scenarios analyzed yield consequences that would require "safety-class" controls as defined in DOE-STD-3009-94.
- None of the RCS initiated accident scenarios would yield consequences that would require "safety -significant" controls, as defined in DOE-STD-3009-94.

Table C-1. Comparison of Dose to Emergency Guidelines[1]

Evaluation Basis Accident (EBA)[2]	*Radiological Dose (CEDE*[3]*) in mrem*		
	Distance to Receptor Point		
	30 m	*100 m*	*330 m*
EBA-1: Failure of RCS during retrieval	1,030	6.3	3.7
EBA-2: Carbon bed failure (elution)	733	31.6	15.5
EBA-3: Silo over- or under-pressurization	1,279	71	88
EBA-4: Breach of transfer line	83	4.2	6.1
EBA-5: Failure of TTA tank	50	0.3	1.8

[1] From Table G.4-1 of the AWR Nuclear Health and Safety Plan (Fluor-Fernald 2004).

[2]EBA - Evaluation basis accident

[3]CEDE - Committed effective dose equivalent

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Appendix D
Estimates of Waste Volumes and Associated Radiological Concentrations within the NFSS IWCS

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The purpose of this appendix is to inventory the waste streams that are present in the NFSS IWCS and provide an estimated volume for each waste stream. The inventory is based on available information regarding the NFSS IWCS and previous waste management that has been conducted at the site. The inventory is used as the basis for a waste disposal options evaluation (see section 6), in which it is assumed that the remedy is waste removal and offsite disposal of the NFSS IWCS. The configuration of any potential removal action will be further defined and evaluated in the NFSS IWCS FS.

Table D-1 shows volumes of the residues, contaminated soil, and rubble present in the IWCS. It also shows the assumed waste classification for the purposes of the waste disposal options analysis and disposal cost estimate presented in Section 6 of this TM.

Table D2 provides the radionuclide concentrations for the various residues and soils buried within the IWCS. These data provide a basis for evaluation of waste treatment, packaging, transport, and disposal at the potential disposal facilities as described in section 6 of this TM.

The information in tables D-1 and D-2 were based on the NFSS Remedial Investigation Report (USACE 2007) and the associated references in the footnotes for Table D-1 and D-2.The information provided in this Appendix is a preliminary estimate of waste volumes and waste segregation. A more detailed analysis will be conducted for the NFSS IWCS FS.

The waste volumes shown in Table D-1 are derived from a number of sources, as defined in the footnotes to the table. The assumed waste classification for each waste volume correlates to the waste classes described in section 6.1.

- K-65 Residues and Other IWCS Residues/Wastes: as discussed in sections 6.1.2 and 6.1.3, these materials are assumed to be 11e.(2) wastes. These constitute the K-65 Residues waste stream and the Other IWCS Residues/Wastes as reported on Table 6-1 in this TM.
- Tower Soil: as discussed in section 6.1.4, these soils are assumed to be 11e.(2) wastes because they were contaminated by the K-65 residues in the Building 434 silo used for waste storage.
- Contaminated Rubble/Waste: as discussed in section 6.1.5, these materials are assumed to be 11e(2) wastes. This determination assumes that the rubble is physically segregated from the other IWCS wastes so that it is not contaminated by non-11e.(2) materials. If these wastes have been impacted by non-11e.(2) wastes, then it may have to be disposed as LLRW and/or LLMW.
- R-10 Residues and Soil: as discussed in section 6.1.6, these materials are assumed to be 11e.(2) wastes. Below grade soils contaminated by leaching through the R-10 pile are to be managed under the Balance of Plant OU. However, for the purposes of this cost estimate the below grade soils are included (Table D-1). They are included because it is assumed that removal of the R-10 spoil pile would continue until the contamination is removed rather than be terminated at an administrative boundary.
- Contaminated Soil: As discussed in section 6.1.7, this consists of soils from various sources and corresponding waste classifications.
    - For most of these materials, the waste is expected to be designated LLRW with a minor component of LLMW. The LLMW is assumed to be 10% of the total waste volume; it is assumed to be generated by contact with hazardous contamination in the removed soils or through contamination prior to the remedial action that generated the soils. The use of a 10% level for LLMW is a conservative assumption, and is made for cost estimating purposes only.

- Sand/clay separating layers within the IWCS in the foundation of Building 411: these soils are assumed to be 11e.(2) waste because they have been in contact with the NFSS IWCS residues over a significant time period.
- Contaminated Dike Material: the soil volume included here constitutes the 0.6 m (2 ft) that are closest to the contaminated materials in the NFSS IWCS. For the purposes of the pricing estimate, this is assumed to be a mixture of LLRW (90% of total volume) and LLMW (10%).
- Contaminated Cap Material: the soil volume included here constitutes only the 0.6 m (2 ft) that lies on top of the NFSS IWCS waste. The rest of the cap is assumed to be uncontaminated. For the purposes of the pricing estimate, this is assumed to be a mixture of LLRW (90% of total volume) and LLMW (10%).
- Soil beneath the IWCS: for the purposes of this price estimate, a total thickness of 3 m (10 ft) of soil is assumed to be contaminated beneath the IWCS. This estimated soil depth is used for cost estimating purposes only; it is intended to overestimate the actual depth of contamination. In addition, these soils are assumed to constitute 11e.(2), LLRW, and LLMW. The soils beneath the footprint of the former Buildings 411, 413, and 414 are assumed to be 11e.(2) waste because the buildings predated waste operations at NFSS and the source of contamination is the K-65 materials in the NFSS IWCS. The remaining volume is assigned to a mixture of LLRW (90% of remaining volume) and LLMW (10%).

Table D-1. Volumes and Densities of Materials in the NFSS IWCS

	Source	Concentration of U_3O_8 in Ore	*Total Waste Volume*		*11e.(2) Waste Volume*		*LLRW Volume*		*LLMW Volume*		*Density Damp* [g]	
			yd³	*m³*	*yd³*	*m³*	*yd³*	*m³*	*yd³*	*m³*	*lbs/yd³*	*kg/m³*
K-65 Residues												
K-65	Afrimet	35-60%	4,030[d,l]	3,080	4,030	3,080	0	0	0	0	3,000	1,800
Other IWCS Residues/Wastes												
L-30	Afrimet	approx 10%	7,960[m]	6,090	7,960	6,090					3,000	1,800
L-50	Afrimet	approx 7%	2,150[n]	1,640	2,150	1,640						
F-32	Afrimet	Unknown	440[p]	340	440	340						
Subtotal Other IWCS Residues/Wastes			10,550	8,070	10,550	8,070	0	0	0	0		
Tower Soil												
Higher activity tower soils in Building 411			4,115	3,150	4,115	3,150	0	0	0	0	3,000	1,800
Contaminated Rubble/Waste												
Building 410 and grouted piping			4,210	3,220	4,210	3,220					3,200	1,898[k]
Building 415			100	80	100	80						
Building 434			1,400	1,070	1,400	1,070						
Thaw House Foundation			200	150	200	150						
K-65 Slurry transfer piping			170	130	170	130						
1991--Hittman tanks, misc. debris[c]			300	230	300	230						
Middlesex Sands			230	180	230	180						
Existing Structures Prior to IWCS			15,000	11,470	15,000	11,470						
Misc materials and materials added to 413 and 414			25,000	19,120	25,000	19,120						
Subtotal Rubble			46,610	35,650	46,610	35,650	0	0	0	0		
R-10 Residues and Soil												
R-10 Residues and Soil (includes 1972 - Remedial Action[a])			59,500[f,o]	45,500	59,500	45,500	0	0	0	0	3,000	1,800
Contaminated Soil												
1982 Remedial Action[a,e]			15,700	12,000			14,130	10,800	1,570	1,200	3,000	1,800
1983 Remedial Action												
Onsite Cleanup			39,850	30,470			35,870	27,420	3,980	3,050		
Off-site Cleanup			14,150	10,820			12,740	9,740	1,410	1,080		
1984 Remedial Action[a]												
Onsite Cleanup[e]			4,640	3,550			4,180	3,200	460	350		
Off-site Cleanup			23,260	17,780			20,930	16,000	2,330	1,780		

Table D-1. Volumes and Densities of Materials in the NFSS IWCS (continued)

	Source	Concentration of U_3O_8 in Ore	Total Waste Volume		11e.(2) Waste Volume		LLRW Volume		LLMW Volume		Density Damp [g]	
			yd^3	m^3	yd^3	m^3	yd^3	m^3	yd^3	m^3	lbs/yd^3	kg/m^3
1985 Remedial Action[a,b]												
On-Site Cleanup			8,300	6,350			7,470	5,720	830	630		
Vicinity Properties			1,000	760			900	680	100	80		
Hot Spot			3,000	2,290			2,700	2,060	300	230		
1991 Remedial Action[c]												
Miscellaneous Soils			3,200	2,450			2,880	2,210	320	240		
Sand/clay separating layers in 411			3,900	2,980	3,900	2,980						
Contaminated Dike Material (2 ft on inside face of walls)			3,600[h]	2,750			3,240	2,480	360	270		
Contaminated Cap Material (2 ft that lies next to waste)			40,000[i]	30,580			36,000	27,520	4,000	3,060		
Soil beneath IWCS (assume 10 ft for costing)			87,500[j]	66,900	16,846	12,880	63,590	48,620	7,064	5,400		
Subtotal Soils			248,100	189,680	20,746	15,860	204,630	156,450	22,724	17,370		
Total Waste Volume			372,905	285,130	145,551	111,310	204,630	156,450	22,724	17,370		

[a] Bechtel National, Inc., 1986. Closure/Post-Closure Plan for the Interim Waste Containment Facility at the Niagara Falls Storage Site. Prepared for the U.S. Department of Energy. DOE/OR/20722-85. May 1986.

[b] Includes 3600 yd^3 excavated from Central Drainage Ditch and placed on bank in 1984, but not transported to Waste Containment Area until 1985.

[c] Bechtel National, Inc., 1991. Geotechnical Post-Construction Report for NFSS Contaminated Waste Pile Consolidation, July-October, 1991.

[d] Anderson et al 1981. Comprehensive Characterization and Hazard Assessment of DOE-Niagara Falls Storage Site. Battelle Columbus Laboratories. Anderson et al 1981 references two documents: 1) NLO, Inc. and Battelle Columbus Laboratories, 1980. Scoping Investigations of Short-Term and Long-Term Storage Costs for Afrimet Residues – NFSS and FMPC

[e] Potentially contaminated with cesium. These soils were from areas reported to have stored wastes from Knolls Atomic Power Lab

[f] Based on core samples in 1980. From Department of Energy, April 1986. Final Environmental Impact Statement – Long Term Management of the Existing Radioactive Wastes and Residues at the NFSS, DOE/EIS-0109F.

[g] USDOE 1986, Final Environmental Impact Statement, Table 3.5. Soil densities are assumed to be approximately equal to the dry and wet densities of clay.

[h] The total volume of clay in the perimeter dikes and cutoff walls is approximately 54,000 cubic yards. The dikes and cutoff walls are approximately 30 ft thick on average. Assuming 2 ft of clay on the inside face of the cutoff walls and dike are contaminated results in about 6.7% (2 out of 30) of the total volume being contaminated.

[I] Assumes 2 ft of the clay cap that lies next to the waste is contaminated.

[j] Assumes that 10 ft of the brown clay that lies beneath the waste within the IWCS is contaminated for the purposes of cost estimating. The actual extent of contamination is expected to be much less. The area within the dikes is approximately 331,000 ft^2, which results in approximately 122,500 yd^3. Then subtracting the 35,000 yd^3 of contaminated below grade soil accounted for in the R-10 spoils pile (see footnote d) results in 87,500 yd^3.

[k] Assumes contaminated rubble consists of concrete with some rebar.

[l] Different volumes are presented by different documents: Battelle Columbus lists 4,074 yd^3 in the May 1981 document and 4,030 yd^3 in the June 1981 document. The DOE 1986 (EIS) lists 3,923 yd^3. Internal documentation by Bechtel personnel compiled after construction of the IWCS indicate that the volume could be as little as 3,200 yd^3 based on visual observation inside Building 434 during the slurrying process.

[m] Different volumes are presented by different documents: Battelle Columbus lists 7,960 yd^3 in the May 1981 document and 7,873 yd^3 in the June 1981 document. DOE 1986 (EIS) lists 7,848 yd^3.

[n] Different volumes are presented by different documents: Battelle Columbus lists 2,148 yd^3 in the May 1981document and 2,124 yd^3 in the June 1981 document. DOE 1986 (EIS) lists 1962 yd^3.

[o] From the DOE Phase II planning Document. The EIS indicates that the R-10 spoils pile consists of 9,500 yd^3 residues, 15,000 yd^3 contaminated soils from 1972 remedial actions placed on top of the R-10 pile. The resulting R-10 spoil pile subsequently leached into the underlying soil, contaminating an additional 35,000 yd^3 of below grade soils for a total of 59,500 yd^3 (Battelle's June 1981document indicates that there are 9,266 yd^3 residues and the R-10 area consists of 69,876 yd^3 of contaminated material).

[p] Different volumes are presented by different documents: Battelle Columbus lists 440 yd^3 as the maximum volume in the May 1981 document and 439 yd^3 in the June 1981 document, DOE 1986 (EIS) cites a value of 654 yd^3.

Table D-2. Estimated Source Term (pCi/g) for Residues and Contaminated Soils at the NFSS

Radionuclide	Half-life (yrs)	Activities in pCi/g						
		K-65	L-30	F-32	L-50	R-10 [1]	Tower Soils [6]	Contaminated Soils
Uranium Series								
U-238	$4.47x10^{9}$	**650**	**970**	**1750**	**515**	**1.7**	13	**4.8**
Th-234	24.1 d	650	**1000**	1750	515	1.7	13	4.8
Pa-234m	1.17 m	650	1000	1750	515	1.7	13	4.8
Pa-234	6.7 h	1	1.3	2.3	0.7	0.002	0.02	0.006
U-234	$2.44\ x10^{5}$	650	970	1750	515	1.7	13	4.8
Th-230	77,000	**54000**	12000	300	3300	50	1080	16
Ra-226	1600	**520000**	**12000**	**300**	**3300**	**95**	10400	**16**
Rn-222	3.82 d	520000	12000	300	3300	95	10400	16
Po-218	3.05 m	520000	12000	300	3300	95	10400	16
Pb-214	26.8 m	520000	**15000**	300	3300	95	10400	16
Bi-214	19.9 m	520000	**14000**	300	3300	95	10400	16
Po-214	$1.64x\ 10^{-6}$	519896	13997	300	3299	95	10398	16
Tl-210	1.3 m	104	2.8	0.1	1	0.02	2.1	0.003
Pb-210	22.3	**155000**	**18000**	450	4950	143	3100	24
Bi-210	5.01 d	**155000**	18000	450	4950	143	3100	24
Po-210	138 d	**155000**	18000	450	4950	143	3100	24
Thorium Series								
Th-232	$1.41\ x\ 10^{10}$	1210	24 [2]	1	7	0.2	24.2	0.03
Ra-228	5.75	1210	24	1	7	0.2	24.2	0.03
Ac-228	6.13 h	1210	24	1	7	0.2	24.2	0.03
Th-228	1.91	1210	24	1	7	0.2	24.2	0.03
Ra-224	3.66 d	1210	24	1	7	0.2	24.2	0.03
Rn-220	55.6 s	1210	24	1	7	0.2	24.2	0.03
Po-216	0.15 s	1210	24	1	7	0.2	24.2	0.03
Pb-212	10.64 h	1210	24	1	7	0.2	24.2	0.03
Bi-212	60.55 m	1210	24	1	7	0.2	24.2	0.03
Po-212	$3.05x10^{-9}$	775	15	0.4	4	0.1	15.5	0.02
Tl-208	3.07 m	435	9	0.2	2	0.07	8.7	0.01
Actinide Series								
U-235	$7.04\ x\ 10^{8}$	33	**70** [3]	126	37	0.1	0.7	0.3
Th-231	25.5 h	33	70	126	37	0.1	0.7	0.3
Pa-231	32,760	**5000** [4]	82 [5]	147	43	0.1	100	0.4
Ac-227	21.77	10000	82	147	43	0.1	200	0.4
Th-227	18.72 d	**10000**	**80**	144	42	0.1	200	0.4
Fr-223	21.8 m	138	1	2	1	0.0	2.8	0.0
Ra-223	11.43 d	**10000**	**850**	1534	451	1.5	200	4.2
Rn-219	3.96 s	**10000**	**800**	1443	425	1.4	200	4.0
Po-215	$1.78x10^{-3}$ s	10000	850	1534	451	1.5	200	4.2
Pb-211	36.1 m	10000	850	1534	451	1.5	200	4.2
Bi-211	2.14 m	10000	850	1534	451	1.5	200	4.2
Tl-207	4.77 m	9973	848	1529	450	1.5	199	4.2
Po-211	0.516 s	27	2	4	1.2	0.004	0.5	0.01

Table D-2. Estimated Source Term (pCi/g) for Residues and Contaminated Soils at the NFSS (continued)

Radionuclide	Half-life (yrs)	K-65	L-30	F-32	L-50	R-10 [1]	Tower Soils [6]	Contaminated Soils
Waste Volumes (cubic yards)								
K-65		4,030						
L-30			7,960					
F-32				440				
L-50					2,150			
R-10 soils						59,500		
Tower soils in 411							4,115	
Contaminated soils								113,100
Dike, cap, bottom of IWCS								131,100
Clay, sand in 411								3,900
Totals								326,295

Numbers in bold are measured values.
Activities based on assumptions of secular equilibrium or natural abundance.
Activities based on ratio's from the L-30 analyses in Battelle 6/81.
Activities based on ratio's from the FEMP Silo 1 Data.

1 Based on the EIS (USDOE 1986), the R10 soils pile represents 11,500 m^3 (15,000 yd^3) of contaminated soils from 1972 cleanup, 26,500 m^3 (35,000 yd^3) below ground, and 7,000 m^3 (9,500 yd^3) of the original residues. The reported concentrations are results of sampling the soils pile and subsurface.

2 The italic values for the Th-232 activity in the Linde Residues is based on the ratio of Ra-226/Th-232 found in the sample with the highest concentration of Ra-226 from the Linde Site RI data.

3 The Actinide actual values (Bold) are from the June 1981 Battelle Document as are the L-30 values for Th-234, Pb-214, Bi-214 and Pb-210.

4 The Pa-231 value is probably based on the Th-227 analysis, and if the FEMP measured data is correct, is about half the value.

5 Pa-231 is assumed to be in equilibrium with the measured value for Th-227 for the Linde residues.

6 "Tower soils" represents the K-65 contaminated material that was added to the north end of Bay D. Assumed to have 2% of K-65 contaminant levels. These soils are included in the source term for consolidation of Building 411 materials.

Appendix E
Viable Waste Disposal Options Summary for IWCS Waste Streams

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Table E-1. Viable Waste Disposal Options Summary for IWCS Waste Streams

Item		*EnergySolutions (Utah)*	*U.S. Ecology (Idaho)*	*Waste Control Specialists (Texas)**	*Wayne Disposal Landfill (Michigan)*	*Nevada National Security Site (Nevada)**
Waste Classification		• LLRW • LLMW • 11e.(2) byproduct material	• NORM/TENORM • NRC exempted waste • RCRA Part B	• Class A/B/C USDOE landfill • 11e.(2) by-product material	• NORM/TENORM • NRC exempted waste	• LLRW • LLMW
WAC Limits/Constraints		• Ra-226: 10,000 pCi/g • Ra-226: 4,000 pCi/g (11e.(2) byproduct material) • Certification of 11e.(2) byproduct material required	• Ra-226: 500 pCi/g • Sum of concentration values for individual radionuclides (parents and progeny)	• Ra-226: 100,000 pCi/g (11e.(2) byproduct material, based on Fernald waste acceptance) • Total curie and volume specifications only (Class A/B/C)	• Ra-226:50 pCi/g. • Numerical concentration limits for additional radionuclides	• Plutonium equivalent gram limits per shipment and package • Must have an approved Waste Program prior to NTS disposal. • Not regulated or licensed by NRC or through Agreement State licensing.
Packaging Types	Custom IP-2	Yes	Yes	Yes	Yes	Yes
	Gondola	Yes	Yes	No	Yes	No
	Intermodal	Yes	Yes	Yes	Yes	Yes
	Soft Sided Bags	Yes	Yes	Yes	Yes	No
Transportation	Direct Truck	Yes	Yes	Yes	Yes	Yes
	Direct Rail	Yes	Yes	No	Yes	No
	Bi-Modal	No	Yes	Yes	Yes	Yes
Waste Form		• No liquid exceeding 1% of volume • Waste packages should minimize void space • Must packaging must comply with WAC and USDOT	• Bulk material for trans-loading should be less than 1 yd^3 in size • Over-sized debris may be received with prior notification • Notice required if incidental free liquids may be present that require management upon receipt • Packaging must comply with WAC and USDOT	• No liquid exceeding 1% of volume. • Waste packages should minimize void space • Packaging must comply with WAC and USDOT	• Solids only, no free liquids • Bulk containers must be lined during winter (frozen loads) • Packaging must comply with WAC and USDOT	• No liquid exceeding 1% of volume • Waste packages should minimize void space • Packaging must comply with WAC and USDOT
Permit Modifications		None currently planned	None currently planned	Additional LLMW cell approval expected within one year	Currently negotiating with the State of Michigan regarding the future management of liquid radiological waste.	Additional LLRW cell approved

* USDOE Orders apply to facilities which USDOE owns or operates under its jurisdiction

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