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MODIFIED R1 FEASIBILITY STUDY REPORT FOR THE INTERIM WASTE CONTAINMENT STRUCTURE AT THE NIAGARA FALLS STORAGE SITE, LEWISTON, NEW YORK

February 2014

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MODIFIED R1

FEASIBILITY STUDY REPORT
FOR THE
INTERIM WASTE CONTAINMENT STRUCTURE
AT THE
NIAGARA FALLS STORAGE SITE,
LEWISTON, NEW YORK

Prepared for:

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ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
°C	degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
Ci	curie
cm	centimeter
cm/sec	centimeters per second
D&D	decontamination and demolition
DOE	U. S. Department of Energy
DOT	U. S. Department of Transportation
EPA	U. S. Environmental Protection Agency
°F	degrees Fahrenheit
FS	feasibility study
ft	feet
g	gram
gal	gallon
GRA	general response action
ha	hectare
HVAC	heating, ventilation, and air conditioning
in.	inch
IWCS	Interim Waste Containment Structure
KAPL	Knolls Atomic Power Laboratory
kg	kilogram
km	kilometer
lb	pound
LLMW	low-level mixed waste
LLRW	low-level radioactive waste
LOOW	Lake Ontario Ordnance Works
LUC	land-use control
LWBZ	lower water-bearing zone
m	meter
m^3	cubic meter
mi	mile
mrem/year	millirems per year
NFSS	Niagara Falls Storage Site
O&M	operation and maintenance
OU	operable unit
%	percent
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/m^2	picocuries per square meter
pCi/m^2/sec	picocuries per square meter per second
Ra-226	radium-226
RAO	remedial action objective
RCS	radon control system
RI	remedial investigation
$	U. S. dollar

S/S	solidification/stabilization
TM	Technical Memorandum
U-238	uranium-238
USACE	U. S. Army Corps of Engineers
UWBZ	upper water-bearing zone
WAC	waste acceptance criteria
WCS	Waste Control Specialists
yd^3	cubic yard

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

This report presents the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Feasibility Study (FS) prepared to evaluate remedial action alternatives for the Interim Waste Containment Structure (IWCS) at the Niagara Falls Storage Site located in the township of Lewiston, New York. The lead Federal agency responsible for this effort is the U. S. Army Corps of Engineers, Buffalo District under the Formerly Utilized Sites Remedial Action Program. This FS Report does not recommend or select a preferred alternative; rather, it provides information to support subsequent steps of the CERCLA process.

The IWCS was constructed from 1982 to 1986 to consolidate and contain radiological waste generated by the Manhattan Engineer District and its successor, the Atomic Energy Commission. Beginning in 1944 and until it was placed into the IWCS, the radiological waste was stored on portions of the Lake Ontario Ordnance Works presently referred to as the Niagara Falls Storage Site and its vicinity properties. The wastes placed in the IWCS include pitchblende uranium ore residues, debris from site operations, rubble from building demolition, and soil and other materials contaminated by the ore and operations at the Niagara Falls Storage Site. The IWCS is a 4-hectare (ha) (10-acre) engineered landfill surrounded by a dike/groundwater cut-off wall and covered with a clay cap (Figure ES-1). A comprehensive monitoring and maintenance program confirms the IWCS is intact and continues to operate as designed.

The IWCS is engineered to retard radon emissions, infiltration from precipitation, and migration of contamination to groundwater. It was constructed by covering the most radioactive waste (the ore residues) with lower-activity waste and a multi-layer cap. This configuration serves to retard radiological emissions and infiltration of precipitation. The ore residues emit high levels of gamma radiation and produce radon gas from the decay of radium-226 (Ra-226), both of which present a potential risk to human health and the environment. The IWCS is performing as designed and presents no current risk to human health or the environment. The design life of the existing IWCS cap is 25 to 50 years, and the design life of the bottom, dike, and cut-off walls is 200 to 1,000 years.

The IWCS Operable Unit was divided into subunits for the purpose of evaluating remedial action alternatives in this FS (Figure ES-1). The subunits were defined based on waste type and level of radiological contamination, as well as the location and placement of the wastes. The three subunits are:

- **Subunit A: Residues and Commingled Wastes Within Buildings 411, 413, and 414.** This subunit includes all of the high-activity residues (K-65, L-30, L-50, and F-32) placed in Buildings 411, 413, and 414. Additionally, this subunit includes other wastes placed within Buildings 411, 413, and 414, including contaminated soil (Tower Soil and other contaminated soil and clay) and contaminated rubble/debris that are commingled with the residues in Building 411. The Ra-226 concentration of the ore residues in Subunit A ranges from 300 picocuries per gram (pCi/g) (in the F-32 residues) to 520,000 pCi/g (in the K-65 residues).

- **Subunit B: Debris and Wastes in the South End of the IWCS.** Subunit B is defined as the wastes placed south of the IWCS dike/cut-off wall that abuts Building 411 on both its east and west sides, except for those wastes defined as part of Subunit A. This subunit includes the Buildings 411, 413, and 414 structures; other contaminated rubble/debris that was placed outside of Buildings 411, 413, and 414 that was associated with storage, handling, and transfer of K-65 residues; and contaminated rubble/debris from the former K-65 storage silo and other Niagara Falls Storage Site buildings used to store residues or wastes. Additionally, Subunit B includes contaminated soil that was placed

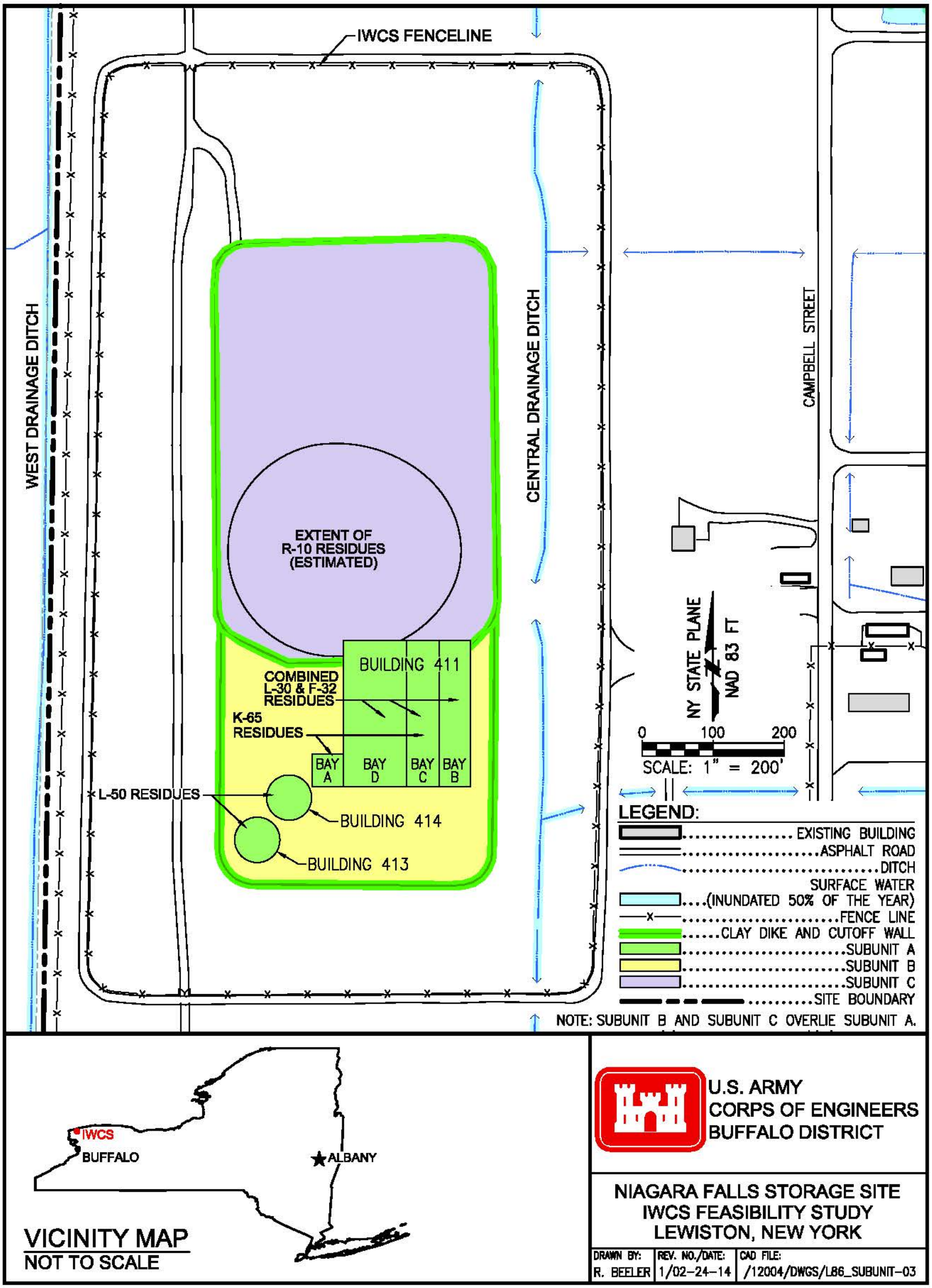

Figure ES-1. Interim Waste Containment Structure, Niagara Falls Storage Site

surrounding the debris within the south end of the IWCS. The Ra-226 concentrations in Subunit B are highly variable; the estimated concentrations range from 16 pCi/g (in contaminated soil) up to levels similar to the ore residues where debris or soil is in contact with the ore residues.

- **Subunit C: Residues and Wastes in the North End of the IWCS.** This subunit includes the majority of the volume of waste categorized as contaminated soil. It includes lesser volumes of miscellaneous waste and about 7,400 cubic meters (m^3) (9,700 cubic yards [yd^3]) of R-10 residues. The average Ra-226 concentration of wastes in the north end of the IWCS ranges from approximately 16 to 95 pCi/g.

This FS follows the process outlined by the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a):

- identification of applicable or relevant and appropriate requirements (ARARs),
- identification of remedial action objectives,
- identification and screening of remediation technologies,
- development of remediation alternatives, and
- a detailed analysis of the alternatives and comparative analysis of the alternatives.

ES.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

For the IWCS, the following environmental laws are relevant and/or appropriate to the remedy selection process (see Appendix D). These laws provide requirements that must be met to ensure any remedial alternative is protective of human health and the environment:

- **10 *Code of Federal Regulation* 40, Appendix A:** Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content:
    - Criteria 5B(1), 5B(2), 5B(3), 5B(5), and 5C, Groundwater Protection Standards;
    - Criterion 6(1), 6(2), 6(3), 6(5), 6(6), and 6(7), Closure of Waste Disposal Areas;
    - Criterion 12, Long-term Site Surveillance; and
    - Criterion 13, Hazardous Constituents.

- **40 *Code of Federal Regulations* 61:** National Emission Standards for Hazardous Air Pollutants:
    - Subpart H – National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities, and
    - Subpart Q – National Emission Standards for Radon from Department of Energy Facilities.

ES.2 REMEDIAL ACTION OBJECTIVES

Remedial action objectives are goals developed to specify requirements that remedial alternatives must fulfill to be protective of human health and the environment. The remedial action objectives for the IWCS were defined in the *Interim Waste Containment Structure Remedial Alternatives Technologies Development and Screening Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (USACE 2013a) and include the following:

- Prevent unacceptable exposure of receptors to the hazardous substances associated with uranium ore mill tailings (e.g., Ra-226 and its short-lived decay products) inside the IWCS.

- Minimize/prevent the transport of hazardous substances within the IWCS to other environmental media (e.g., soil, groundwater, surface water, sediment, and air) outside of the IWCS.

- During implementation of the remedial alternatives(s), minimize/prevent releases and other impacts that could adversely affect human health and the environment, including ecological receptors.

ES.3 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Table ES-1 summarizes the general response actions, remedial technologies, and process options identified and retained for consideration after an initial technical implementability screening step. The table also indicates the outcome of the ranking of the technologies for effectiveness, implementability, and cost. Technologies assigned "moderate" or "high" rankings for effectiveness and implementability were retained to be used in the development of remedial alternatives. The cost criterion was not used to eliminate any of the technologies at this step in the FS.

Table ES-1. Summary of Ratings for Technologies

General Response Action/Technology/Process Option	Effectiveness	Implementability	Cost	Subunits	Retained?
Land-use controls	Moderate	High	Moderate	A, B, C	Yes
Containment	Moderate	High	Moderate	A, B, C	Yes
Removal (mechanical)	Low to high	Moderate	Moderate	A, B, C	Yes
Removal (hydraulic)	Moderate	Low	High	A	No
Removal (demolition)	Moderate to high	Moderate to high	Low to moderate	A, B	Yes
Treatment (S/S)	Moderate	High	Moderate	A	Yes
Treatment (vitrification)	Moderate	Low	High	A	No
Treatment (metals recovery)	Moderate	Low	High	A	No
Treatment (physical processes)	High	Moderate to high	Low	A, B, C	Yes
Disposal (on-site)	Moderate	Low	Moderate	A, B, C	No
Disposal (off-site)	High	High	High	A, B, C	Yes

Gray shading denotes technologies that are not retained.
S/S = Solidification/stabilization.

ES.4 DEVELOPMENT OF ALTERNATIVES

Remedial alternatives were identified by combining the retained technologies from the screening process. Table ES-2 presents the five remedial alternatives carried forward for the IWCS FS. These alternatives include no action, enhanced waste containment, waste removal with off-site disposal, and two alternatives that remove portions of the waste for off-site disposal and contain the remaining wastes left in place.

The No Action alternative is evaluated as part of the FS process as a baseline for comparison to the other alternatives being considered. All of the action alternatives (2 through 4) are designed to ensure adequate protection of human health and the environment; achieve remedial action objectives; achieve ARARs identified for the IWCS; and permanently and significantly reduce the volume, toxicity, and/or mobility of site-related contaminants, as appropriate.

The removal-based alternatives (3A, 3B, and 4) include cement stabilization treatment of the K-65 residues as well as specialized packaging and transportation due to their high level of radioactivity. Land-use controls (LUCs) are inherent in each alternative where IWCS wastes would remain on-site.

Table ES-2. Remedial Alternatives for the IWCS

Alternative Type	Alternative Identifier	Alternative[a]
No Action	1	No Action
Enhanced Containment	2	Enhanced Containment of Subunits A, B, and C
Partial Removal with On- and Off-Site Disposal	3A	Removal, Treatment, and Off-site Disposal of Subunit A and Enhanced Containment of Subunits B and C
	3B	Removal, Treatment, and Off-site Disposal of Subunits A and B and Enhanced Containment of Subunit C
Complete Removal	4	Removal, Treatment, and Off-site Disposal of Subunits A, B, and C

[a] All alternatives that involve removal (3A, 3B, and 4) assume treatment of the K-65 residues in Subunit A. Land-use controls are assumed for any alternative where IWCS waste would remain on-site.
IWCS = Interim Waste Containment Structure.

ES.5 DETAILED AND COMPARATIVE ANALYSIS OF ALTERNATIVES

The detailed analysis of IWCS alternatives listed in Table ES-2 was performed by evaluating each remedial alternative against seven criteria according to the statutory requirements of CERCLA Section 121, as well as technical and cost considerations deemed appropriate for use in the remedy selection. The criteria include:

- threshold criteria:
    - overall protection of human health and the environment, and
    - compliance with ARARs.
- balancing criteria:
    - long-term effectiveness and permanence;
    - reduction in toxicity, mobility, or volume through treatment;
    - short-term effectiveness;
    - implementability; and
    - cost.

An alternative must be compliant with the threshold criteria to be carried forward for further evaluation. The balancing criteria are used to weigh each remedial alternative relative to the criteria. The level of detail provided in the conceptual designs of the alternatives and the detailed analysis is consistent with the nature of the waste.

As detailed in the *Waste Disposal Options and Fernald Lessons Learned Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (USACE 2011a), the K-65 residues in the IWCS are similar to the K-65 residues that were stored at the Fernald Site in Ohio. The lessons learned from that project are applied to the technology selection and remedial alternative designs in this FS.

After the detailed analysis, the remedial alternatives were evaluated relative to each other in a comparative analysis. A summary of the comparative analysis is presented below.

ES.5.1 Overall Protection of Human Health and the Environment

Alternative 1, No Action, serves as the baseline for comparison to the other alternatives being considered. Because no remedial activities or long-term maintenance and monitoring would be implemented, the alternative is considered not protective and, therefore, does not meet the threshold criterion. Alternatives 2, 3A, and 3B comply with this criterion by preventing unacceptable exposures to the waste by maintaining perpetual, active, LUCs and maintaining the integrity of the cap. Alternatives 3A and 3B also include removal of some wastes. Alternative 4 complies with this criterion by removing all waste from the site and thereby eliminating future risk to human health and the environment.

ES.5.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 1, No Action, does not comply with the identified ARARs selected for the IWCS because current maintenance activities that help ensure compliance with ARARs would cease, resulting in conditions that could reduce the effectiveness of the cap to a point that releases exceed the radon emanation and other contaminant limits defined by ARARs. Alternative 4 complies with all ARARs by removing all IWCS wastes and soils and disposing off-site, allowing unrestricted use. Alternatives 2, 3A, and 3B comply with ARARs by containing remaining wastes under an enhanced containment system and implementing system maintenance and LUCs. Alternatives 3A and 3B combine enhanced containment of remaining wastes with removal of different portions of the waste.

ES.5.3 Long-Term Effectiveness and Permanence

Alternative 1, No Action, does not provide long-term protectiveness due to lack of LUCs and ongoing maintenance to prevent degradation of the multi-layer cap and containment system. For these reasons, the Alternative 1 ranking for this criterion is "low." Alternatives 2, 3A, 3B, and 4 provide effective and permanent protectiveness by preventing contaminant releases and receptor exposure to within acceptable limits.

This criterion also evaluates the adequacy and reliability of controls. There are no controls required for Alternative 4 because all IWCS waste is removed from the site. Because Alternative 4 provides protectiveness throughout the compliance period and requires no site controls, it is assigned a ranking of "high." Alternatives 2, 3A, and 3B rely on an enhanced containment system and LUCs to prevent receptor intrusion and future exposure to IWCS wastes left on-site. As a result, these alternatives require LUCs throughout the compliance period (1,000 years). Because Alternatives 2, 3A, and 3B are effective but require LUCs, each is assigned a ranking of "moderate."

ES.5.4 Reduction in Toxicity, Mobility, or Volume through Treatment

This criterion is evaluated on the amount of untreated residual waste left on-site under the alternative. The greatest amount of untreated residuals is associated with Alternative 1 (No Action) and Alternative 2 (Enhanced Containment); therefore, these alternatives receive a "low" ranking for this criterion. Alternative 4 (Removal) leaves no untreated residuals on-site; thus, Alternative 4 receives a "high" ranking. Alternatives 3A and 3B receive a "moderate" ranking because these alternatives leave untreated residual waste on-site, but the most contaminated materials (the K-65 residues) are removed, treated to decrease toxic effects and mobility, and transported to an off-site disposal facility.

ES.5.5 Short-Term Effectiveness

Alternative 1, No Action, has no potential short-term impact to the community, workers, and the environment during remedial action because no action is taken. Thus, Alternative 1 receives a ranking of "high." The greatest potential short-term impact is related to exposure to the ore residues and other wastes during excavation. Alternatives 2, 3A, 3B, and 4 include control measures to mitigate releases and short-term impacts. Because all short-term impacts can be controlled, none of the alternatives receive a "low" ranking. The short-term effectiveness of Alternative 2 is greater than Alternatives 3A, 3B, and 4 given this alternative does not involve opening the IWCS cap and handling and transporting the IWCS wastes, including the ore residues. Therefore, Alternative 2 receives a "high" ranking, and Alternatives 3A, 3B, and 4 receive a "moderate" ranking.

ES.5.6 Implementability

Each of the identified alternatives has proven to be implementable; therefore, none of the alternatives receive a "low" ranking. There is no action proposed for Alternative 1; therefore, it receives an "NA" for this criterion. The alternative proven to be the most implementable is Alternative 2, because the alternative uses standard capping construction practices and readily available resources to complete the remedial action. Therefore, Alternative 2 receives a "high" ranking. Alternatives 3A, 3B, and 4 require specialty resources (some of which have been proven at only one other site) to remove and treat the contents of Subunit A in combination with standard resources to remove, transport, and dispose of portions of Subunits B and C. Therefore, Alternatives 3A, 3B, and 4 receive a ranking of "moderate."

ES.5.7 Cost

The estimated cost for each alternative is presented in Table ES-3. These costs are based on the conceptual design for each alternative. The conceptual designs in this FS provide a greater level of detail than is commonly provided in an FS, with additional emphasis on the estimation of construction materials quantities and definition of work control requirements. In addition, the cost estimates include a formal analysis of cost and schedule risk and necessary contingencies to address those risks.

Table ES-3. Estimated Costs of IWCS Remedial Alternatives

CERCLA Cost Component[a]	Alternative 1 – No Action	Alternative 2 – Enhanced Containment of Subunits A, B, and C	Alternative 3A – Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C	Alternative 3B – Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C	Alternative 4 – Removal, Treatment (Subunit A only), and Off-Site Disposal of Subunits A, B, and C
Non-Discounted Costs					
Capital cost	Zero cost	$23.4M	$259.6M	$318.4M	$490.6M
O&M	Zero cost	$1,450M	$1,450M	$1,450M	Zero cost
Total alternative cost	Zero cost	$1,473M	$1,710M	$1,768M	$490.6M
Discounted Costs[b,c]					
Capital cost	Zero cost	$23.4M	$259.6M	$318.4M	$490.6M
O&M (discounted)	Zero cost	$44.0M	$43.8M	$43.8M	Zero cost
Total alternative cost	Zero cost	$67.4M	$303.4M	$362.2M	$490.6M

[a] All costs (capital and O&M) include contingency.
[b] Discounted cost is used to evaluate expenditures that occur over different timeframes by turning all future dollar expenditures into a current dollar value. The discounted cost is the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life.
[c] Discount rate of 3.5 percent (%) applied over the duration of O&M for the alternative. O&M duration of Alternative 1 is 0 years; O&M duration of Alternatives 2, 3A, and 3B is 1,000 years; and O&M duration of Alternative 4 is 0 years.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
IWCS = Interim Waste Containment Structure.
O&M = Operation and maintenance.

In Table ES-3, capital costs are inclusive of the costs from implementing an alternative; they include such costs as planning, design, remedial activities, waste packaging and transport, waste disposal, and site restoration. Operation and maintenance costs are the post-remediation costs for maintaining and operating the action throughout its lifetime. Operation and maintenance costs in Table ES-3 are shown as both non-discounted and net present value (discounted). The discounted cost is presented in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (40 *Code of Federal Regulations* Part 300.430[2][e][9][iii][G][3]). This allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year, would be sufficient to cover all costs associated with the remedial action over its planned life. For Alternatives 2, 3A, and 3B, the discounted cost is significantly lower than the non-discounted cost due to the 1,000-year period for operation and maintenance activities. Capital costs in Table ES-3 are not discounted due to the relatively short durations (6 years or less) associated with construction activities under each alternative.

ES.5.8 Summary

Table ES-4 depicts the comparison of the five alternatives relative to each of the seven CERCLA criteria.

Table ES-4. Comparative Analysis of Alternatives for the IWCS FS

Criterion	Alternative 1 – No Action	Alternative 2 – Enhanced Containment of Subunits A, B, and C	Alternative 3A – Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C	Alternative 3B – Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C	Alternative 4 – Removal, Treatment (Subunit A only), and Off-Site Disposal of Subunits A, B, and C
Threshold Criteria					
Overall Protection of Human Health and the Environment	No	Yes	Yes	Yes	Yes
Compliance with ARARs	No	Yes	Yes	Yes	Yes
Balancing Criteria					
Long-Term Effectiveness and Permanence	Low	Moderate	Moderate	Moderate	High
Reduction of Toxicity, Mobility, and Volume through Treatment	Low	Low	Moderate	Moderate	High
Short-Term Effectiveness	High	Moderate	Moderate	Moderate	Moderate
Implementability	NA	High	Moderate	Moderate	Moderate
Cost (discounted)[a]	Zero cost	$67.4M	$303.4M	$362.2M	$490.6M

[a] Discounted cost is used to evaluate expenditures that occur over different timeframes by turning all future dollar expenditures into a current dollar value. The discounted cost is the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life.
ARAR = Applicable or relevant and appropriate requirement.
FS = Feasibility study.
IWCS = Interim Waste Containment Structure.
NA = Not applicable.

This FS Report does not recommend or select a preferred alternative. The information in this FS, including the detailed and comparative analysis of alternatives, will be used by the U. S. Army Corps of Engineers to identify the preferred remedial alternative in the Proposed Plan. The U. S. Army Corps of Engineers will review state and community input (consistent with CERCLA modifying criteria) to determine if the preferred alternative remains the most appropriate remedial action for the site. The U. S. Army Corps of Engineers will then make the final remedy selection decision, which will be documented in the Record of Decision.

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1.0 INTRODUCTION

This report presents the Feasibility Study (FS) for the Interim Waste Containment Structure (IWCS) Operable Unit (OU) at the Niagara Falls Storage Site (NFSS) located in the township of Lewiston, New York (Figure 1-1). This FS evaluates remedial action alternatives in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedy selection process. The lead Federal agency responsible for CERCLA actions at the NFSS is the U. S. Army Corps of Engineers (USACE), Buffalo District. Remedial actions at the NFSS are being addressed as part of the Formerly Utilized Sites Remedial Action Program.

The NFSS is a 77.3-hectare (ha) (191-acre) property that occupies a portion of the former Lake Ontario Ordnance Works (LOOW). In 1944, the Manhattan Engineer District was granted use of a portion of the LOOW (designated the NFSS) for the storage of radioactive uranium ore residues generated through the processing of uranium ore for development of the atomic bomb. During the 1940s and 1950s, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), brought various radioactive wastes and uranium processing byproducts (residues) to the NFSS for storage. In 1982, the U. S. Department of Energy (DOE) began cleanup and consolidation of the radioactive residues, wastes, and debris. These were placed into the IWCS, a 4.0-ha (10-acre) engineered structure on the west side of the NFSS property (Figure 1-2). The IWCS contains radioactive residues, contaminated rubble and debris from demolition of buildings, and contaminated soil from the NFSS and vicinity properties. To manage the CERCLA activities at the NFSS, USACE has established three separate OUs:

- IWCS OU – The waste material (i.e., uranium ore residues and other remedial action waste) placed in the disposal cell within the diked area at the NFSS.

- Balance of Plant OU – All material at the NFSS not placed within the IWCS, excluding groundwater.

- Groundwater OU – Groundwater remaining in both the upper water-bearing zone (UWBZ) and the lower water-bearing zone (LWBZ) after implementation of the selected remedial actions for the IWCS and Balance of Plant OUs.

The OU approach is commonly used under CERCLA to define logical groupings of environmental issues at a single site to incrementally address site problems. By employing the OU approach at the NFSS, decisions about the primary sources of contamination at the site can be incorporated into the final site-wide groundwater approach.

The IWCS OU is the first OU to proceed through the FS stage of the CERCLA process because it poses the greatest potential risk of the three OUs. The IWCS is a constructed landfill that contains the following below-grade waste components (Figure 1-3):

- Uranium ore residues (K-65, L-30, L-50, and F-32) placed within the former LOOW Freshwater Treatment Plant buildings (Buildings 411, 413, and 414), along with contaminated soil, rubble, and debris that are commingled with the residues in Building 411. These wastes have significantly higher levels of radioactivity than the other wastes within the IWCS.

- A large pile of uranium ore residues, referred to as R-10 residues, commingled with residue-contaminated soil, forming what is called the R-10 pile. The R-10 pile has lower concentrations of radioactivity than the residues placed in the buildings.

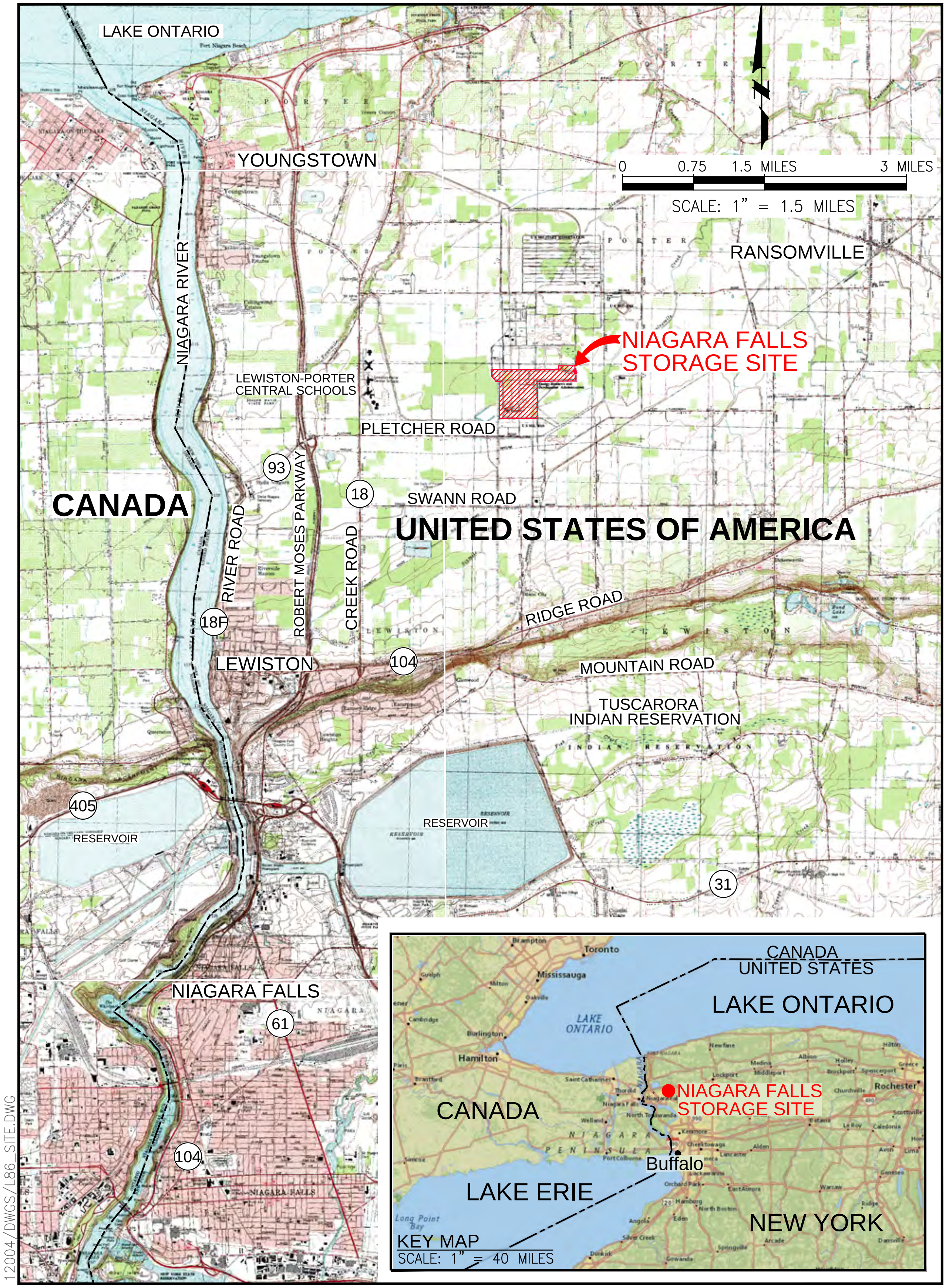

Figure 1-1. Location of the NFSS, Lewiston, New York

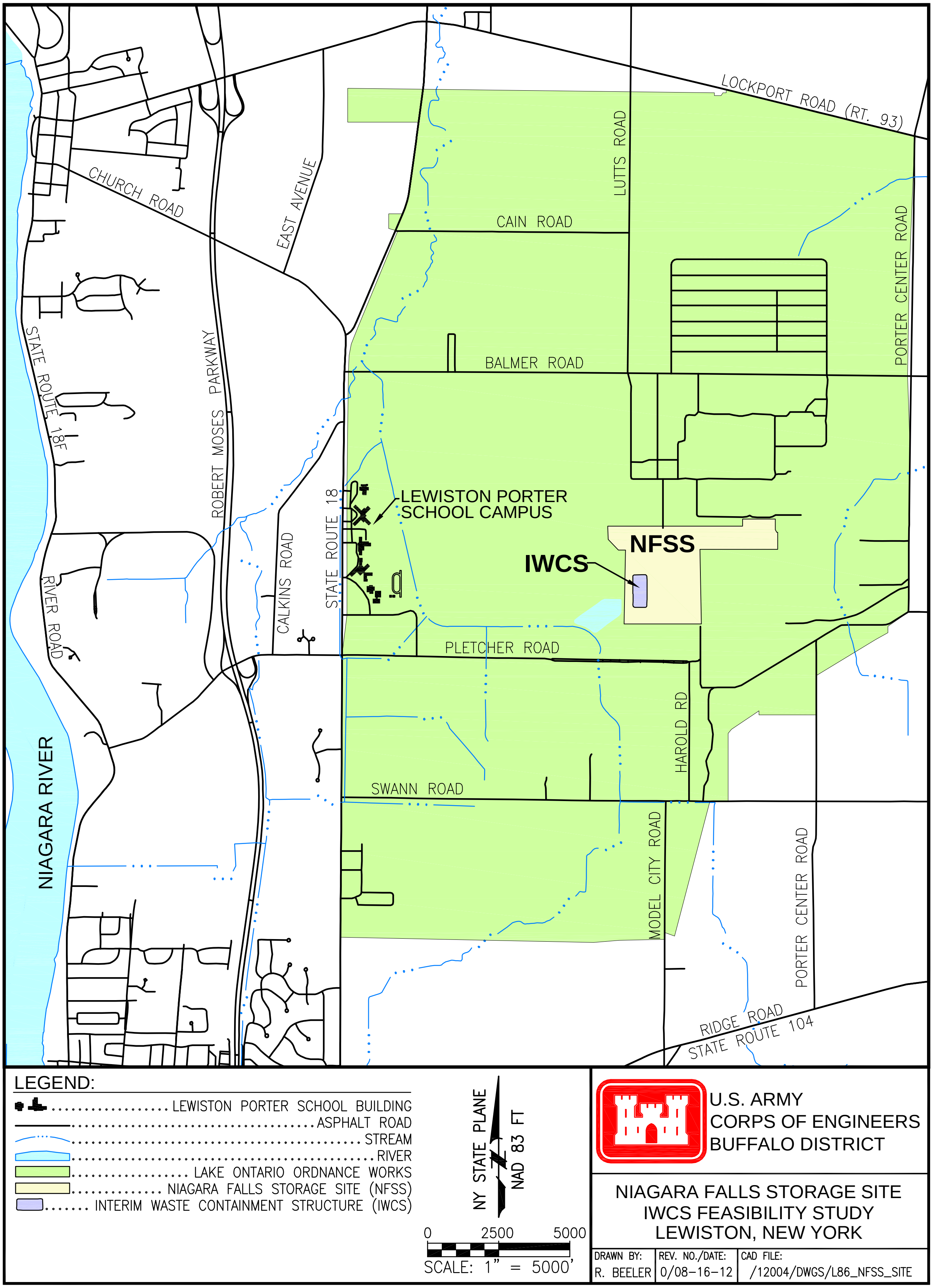

Figure 1-2. Relationship of the LOOW and the NFSS

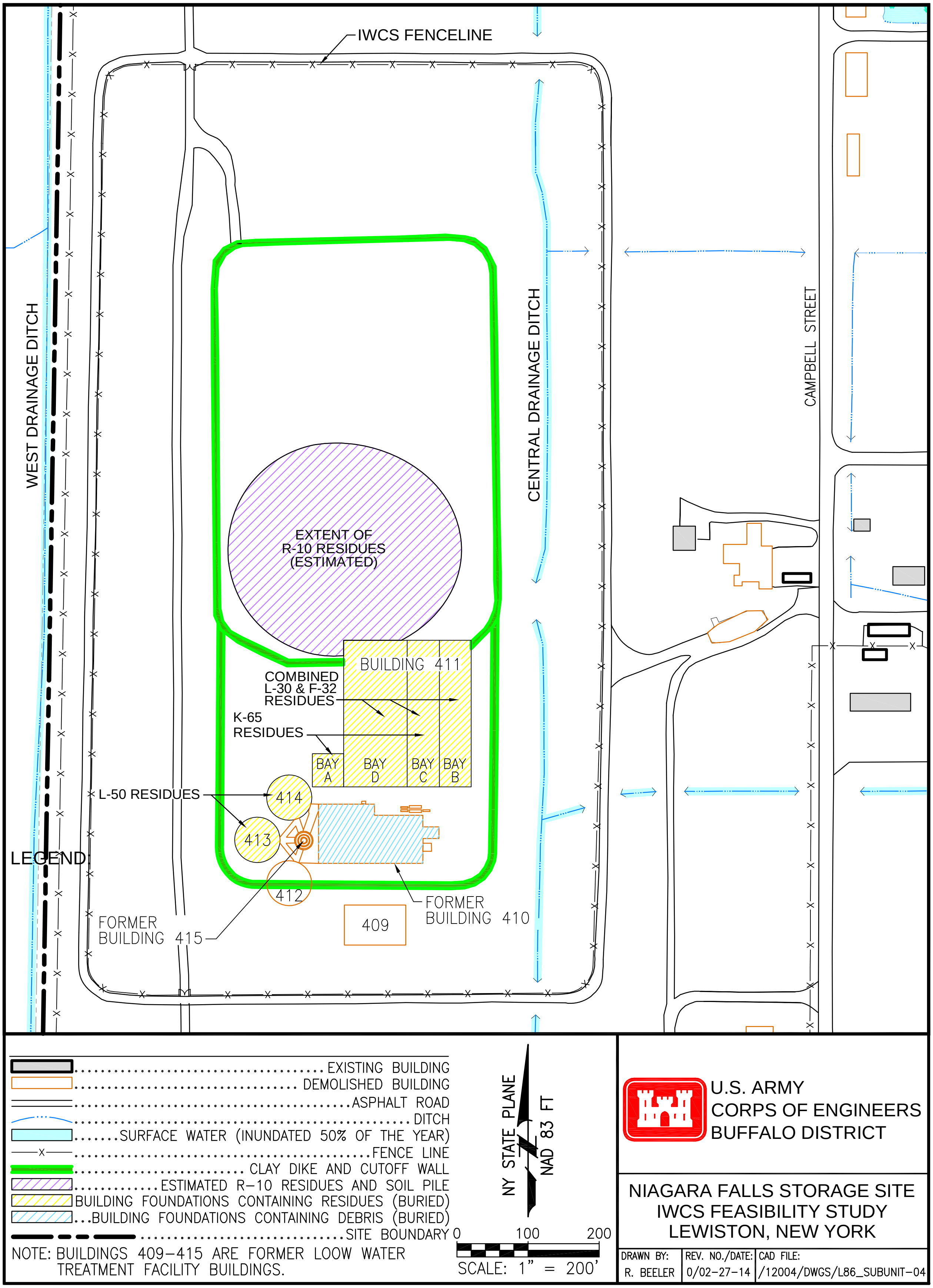

Figure 1-3. Waste Components Within the IWCS

- Contaminated rubble/debris in the south end of the IWCS associated with storage, handling, and transfer of K-65 residues from the former K-65 storage silo (Building 434) and Thaw House foundation and from the former LOOW Freshwater Treatment Plant buildings that were in the area prior to the development of the IWCS.

- Large volumes of contaminated soil and miscellaneous waste from historical remediation activities at the NFSS vicinity properties, placed primarily in the north end of the IWCS above the R-10 pile. These generally have low levels of radioactivity.

1.1 PURPOSE AND ORGANIZATION OF THE DOCUMENT

This IWCS FS identifies potential remedial alternatives and presents a detailed and systematic analysis of the alternatives. These steps are performed following the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988).

The first steps of the FS process identified in Figure 1-4 were performed in the *Interim Waste Containment Structure Remedial Alternatives Technologies Development and Screening Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (USACE 2013a), hereafter referred to as the Remedial Alternatives Technical Memorandum (TM). The steps are summarized in this FS, and the TM is included as Appendix E of this FS Report. Figure 1-4 also provides a road map for the location of information in this FS. The body of this FS Report follows the CERCLA FS outline (EPA 1988):

- Chapter 1.0 – Introduction, including site background information;
- Chapter 2.0 – Identification and Screening of Technologies;
- Chapter 3.0 – Development of Alternatives;
- Chapter 4.0 – Detailed Analysis of Alternatives;
- Chapter 5.0 – Comparative Analysis of Alternatives;
- Chapter 6.0 – Summary; and
- Chapter 7.0 – References.

However, due to the extensive history of the site and large volume of information consolidated for this FS Report, much of the additional detailed information on individual topic areas is presented in the following appendices:

- Appendix A – Interim Waste Containment Structure Waste Description.

- Appendix B – *Groundwater Flow and Contaminant Transport Modeling, Formerly Utilized Sites Remedial Action Program, Niagara Falls Storage Site, Lewiston, New York*.

- Appendix C – Long-term Risk Evaluation for the Interim Waste Containment Structure Feasibility Study.

- Appendix D – Applicable or Relevant and Appropriate Requirements for the Interim Waste Containment Structure Operable Unit.

- Appendix E – *Interim Waste Containment Structure Remedial Alternatives Technologies Development and Screening Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (USACE 2013a).

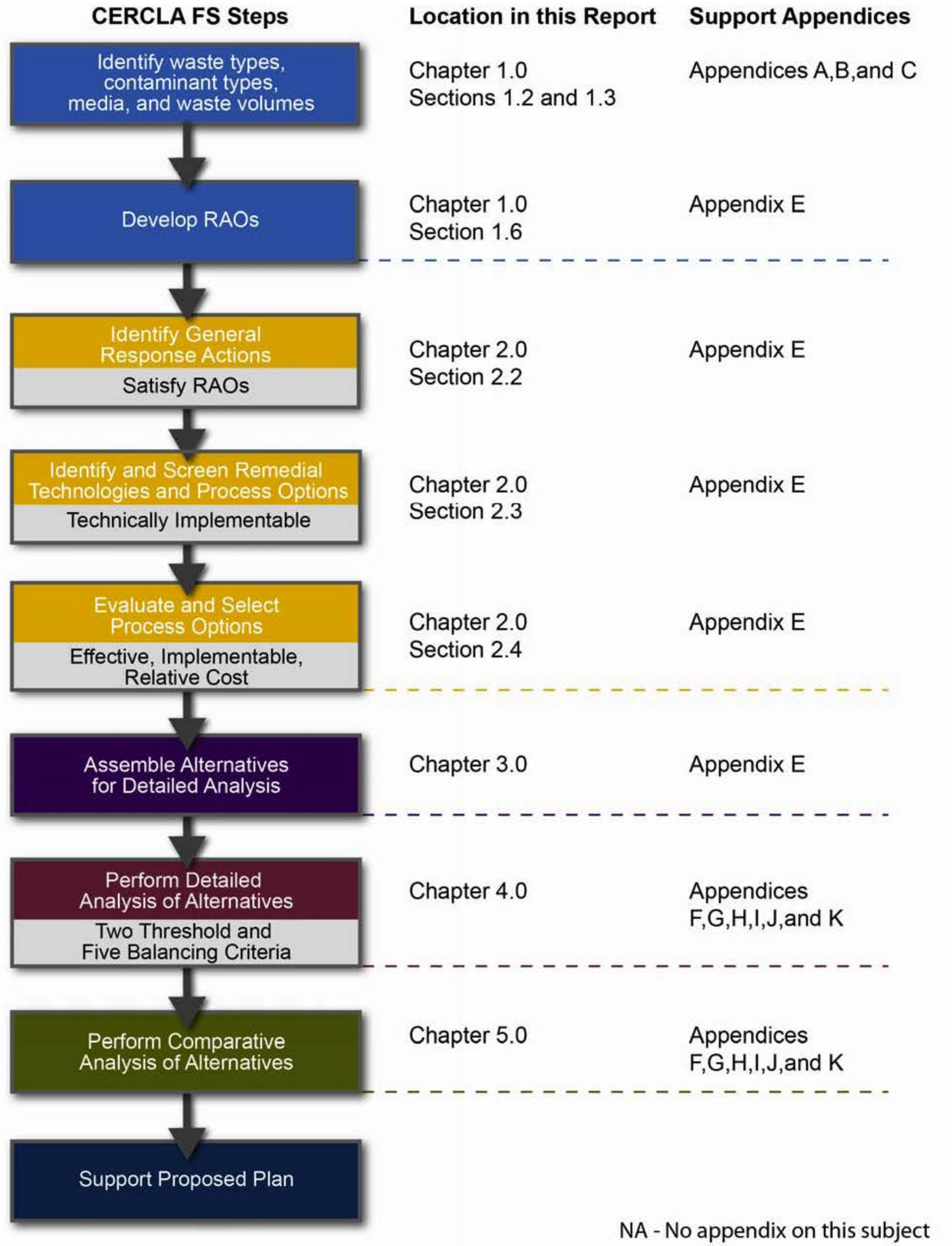

Figure 1-4. Implementation of the CERCLA Process for the IWCS

- Appendix F – Conceptual Remedial Design – Retrieval, Treatment, and Disposal of Subunit A Materials.

- Appendix G – Conceptual Remedial Design – Enhanced Containment.

- Appendix H – Conceptual Remedial Design – Excavation and Off-site Disposal of Subunits B and C.

- Appendix I – Waste Disposal Options and Transportation Assessment.

- Appendix J – Detailed Cost Estimates for the Interim Waste Containment Structure at the Niagara Falls Storage Site Feasibility Study.

- Appendix K – Conceptual Design Drawings for the Interim Waste Containment Structure Feasibility Study.

The detailed analysis of alternatives in Chapter 4.0, combined with the comparative analysis in Chapter 5.0, provides information for evaluating potential remedial options for the IWCS. This analysis is prescribed by the CERCLA statute (Section 121[b][1][A]) and includes consideration of the following evaluation criteria:

- overall protection of human health and the environment;
- compliance with applicable or relevant and appropriate requirements (ARARs);
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, or volume through treatment;
- short-term effectiveness;
- implementability; and
- cost.

This FS Report does not select the proposed alternative; rather, it provides information for the subsequent stages of the CERCLA process—the Proposed Plan that proposes the preferred remedial alternative, and the Record of Decision that documents the selected alternative.

1.2 INTERIM WASTE CONTAINMENT STRUCTURE BACKGROUND

1.2.1 Site History

In 1942, during World War II, the Federal Government built several facilities across the United States to manufacture munitions for the US Army. The government acquired 3,035 ha (7,500 acres) of agricultural land in northwestern New York State to construct a trinitrotoluene production facility in the east-central portion of the LOOW. Facilities constructed included trinitrotoluene production lines, several storage and support facilities, and a freshwater treatment facility. Trinitrotoluene production ceased at the LOOW at the end of July 1943 (USACE 2007a), and in 1944, a portion of the land was transferred to the Manhattan Engineer District. In 1947, the Manhattan Engineer District became AEC.

During this timeframe, AEC was overseeing the separation and processing of uranium ores to develop uranium metal for use in atomic weapons. Ore processing occurred at the Linde Ceramic Plant in nearby Tonawanda, New York, and at the Mallinckrodt operations in St. Louis, Missouri. The facilities processed uranium-rich—or pitchblende—ores to extract uranium. Residues left over from the separation processes were highly radioactive. The residues contained uranium decay products, primarily radium and thorium, that had been in secular equilibrium with the uranium prior to separation. Residual uranium also was present in the material. The residues were typically drummed and removed from the processing facility for disposition. From April 1949 until 1953, drummed residues were shipped to the LOOW for storage (Battelle 1981b; USACE 2007a).

The residues were thought to have sufficient future value to warrant retrievable storage; some were placed in the former LOOW Freshwater Treatment Plant buildings (Buildings 411, 413, and 414); the most radioactive residues (designated K-65 residues) were eventually placed in a concrete silo (Building 434) in the northeastern part of the NFSS; and some of the less-radioactive residues (designated R-10 residues) were placed on the ground just north of the freshwater treatment plant facilities. When Building 434 (the concrete silo) was full, additional K-65 residues were shipped to the Feed Materials Production Center in Fernald, Ohio (hereafter referred to as the Fernald Site). Lessons learned from managing K-65 residues at the Fernald Site were identified by USACE (USACE 2011a) and are integrated into this FS.

During subsequent years, additional AEC wastes were sent to the NFSS for storage and disposal, including wastes from the University of Rochester, Knolls Atomic Power Laboratory (KAPL), Union Carbide's Electrometallurgical Operations, the Middlesex Sampling Plant, and DOE Oak Ridge Operations (DOE 2012). These materials were stored using existing facilities at the LOOW.

In 1974, AEC initiated the Formerly Utilized Sites Remedial Action Program to identify, remediate, or otherwise control sites where residual radioactivity remains from operations conducted for AEC. In 1977, DOE assumed responsibility for the NFSS and, during the 1980s, initiated interim measures to consolidate and store all radioactive materials at the site and on adjacent properties.

In 1982, DOE initiated the effort to consolidate the R-10 residues within a diked area and also began the process of readying the former freshwater treatment plant buildings for long-term storage and containment of the residues, also to be contained within a diked area. By 1986, all residues, and the majority of all contaminated material at the NFSS, were contained, covered with a cap, and designated the Waste Containment Structure, which was later designated the IWCS.

The regulatory documentation completed in support of the IWCS addressed National Environmental Policy Act documents and processes, including the *Environmental Impact Statement, Long-Term Management of the Existing Radioactive Wastes and Residues at the Niagara Falls Storage Site* (DOE 1986a) and *Department of Energy, Office of Secretary: Record of Decision for Remedial Actions at the Niagara Falls Storage Site, Lewiston, New York* (Office of Federal Register 1986). The Record of Decision indicated that, for the radioactive wastes at the NFSS, DOE selected long-term, in-place management consistent with the guidance provided in the Environmental Protection Act regulation for uranium mill tailings (40 *Code of Federal Regulations [CFR]* 192). For the radioactive residues at the NFSS, it was DOE's intent to provide for long-term, in-place management consistent with future applicable U. S. Environmental Protection Agency (EPA) guidance. DOE indicated that, if future analysis showed that in-place management could not meet EPA guidance, long-term, in-place management of the residues would need to be replaced by another option that meets EPA guidance and is environmentally acceptable.

In 1994, DOE published the *Failure Analysis Report for the Niagara Falls Storage Site, Lewiston, New York* (BNI 1994) to further assess the long-term protectiveness of the IWCS with additional enhancements to the existing cap and cover. The analysis looked at eight hypothetical failure scenarios. The report determined that the IWCS is protective against potential future unacceptable indirect exposures (e.g., leaching to groundwater) but that someone drilling into the waste could receive unacceptable doses via direct exposure. The final published conclusion stated "the analysis showed that the proposed final WCS would be protective for the 10,000-yr period."

Subsequently, DOE requested an independent review of the site by the National Academy of Sciences/National Research Council Committee on Remediation of Buried and Tank Wastes. The National Academy of Sciences/National Research Council published its findings in the *Safety of the High-level Uranium Ore Residues at the Niagara Falls Storage Site, Lewiston, New York* in 1994 (NAS/NRC 1995). The report conclusions indicated:

- Site sampling and monitoring information indicated that there was no immediate hazard to the off-site public from the residues in their present configuration.

- The high-level residues could pose a potential long-term risk to the public if conditions, including land and water use and physicochemical setting within the IWCS, are not maintained to prevent receptor exposure.

A number of studies (USACE 2007a, 2007b, 2011b) have been conducted to investigate the uncertainties identified in the National Academy of Sciences/National Research Council (1995) report. The study results are integrated into this FS.

Since the mid-1990s, DOE, and then USACE (after transfer of the Formerly Utilized Sites Remedial Action Program), has implemented a monitoring program that demonstrates that the IWCS has been functioning as designed.

1.2.2 Site Description

A description of current site conditions at the IWCS and the NFSS and the surrounding land area follows.

1.2.2.1 Current demographics and land use

The 77.3-ha (191-acre) NFSS is located in the township of Lewiston, Niagara County, New York, which lies in western New York State on the south shore of Lake Ontario (Figure 1-1).The population of Niagara County in 2010 was 216,469 (U. S. Census Bureau 2011a), with a population density of 414 persons per square mile. The town of Lewiston is located in the westernmost portion of the county. The population estimate for Lewiston in 2009 was 16,750 (U. S. Census Bureau 2011b). The Village of Youngstown and the Hamlet of Ransomville, located approximately 4.8 kilometers (km) (3 miles [mi]) northwest and northeast of the NFSS, respectively, comprise the nearby Town of Porter. The Town of Porter had a population of approximately 6,770 in 2010 (Town of Porter 2011).

Land use in the vicinity of the NFSS is shown on Figure 1-5. The NFSS property is bordered on the north and northeast by the CWM Chemical Services, LLC hazardous waste disposal facility; on the east and south by the Modern Landfill, Inc. solid waste disposal facility; and on the west by a transmission corridor owned by National Grid (USACE 2007a). All of the aforementioned properties were once part of the LOOW, including an 8.9-ha (22-acre) portion (former waste water treatment plant) located north of the NFSS that was transferred to the town of Lewiston (USACE 2007a).

To the south is a second facility owned by Modern Corporation, the H_2Gro Greenhouses, 5 ha (12.5 acres) of Hydroponic greenhouse that produces over 1.3 million kilograms (kg) (3 million pounds [lb]) of tomatoes per year using generators powered by methane gas collected from Modern Landfill, Inc.

The nearest residences to the NFSS are located on Pletcher Road, approximately 0.8 km (0.5 mi) west-southwest of the site (USACE 2007a). Other residents are located along the roadways that run north-south and east-west around the site. During summers, visitors use a Kampground of America campground located on Pletcher Road. The campground entrance is approximately 0.3 km (0.2 mi) from the entrance to the NFSS.

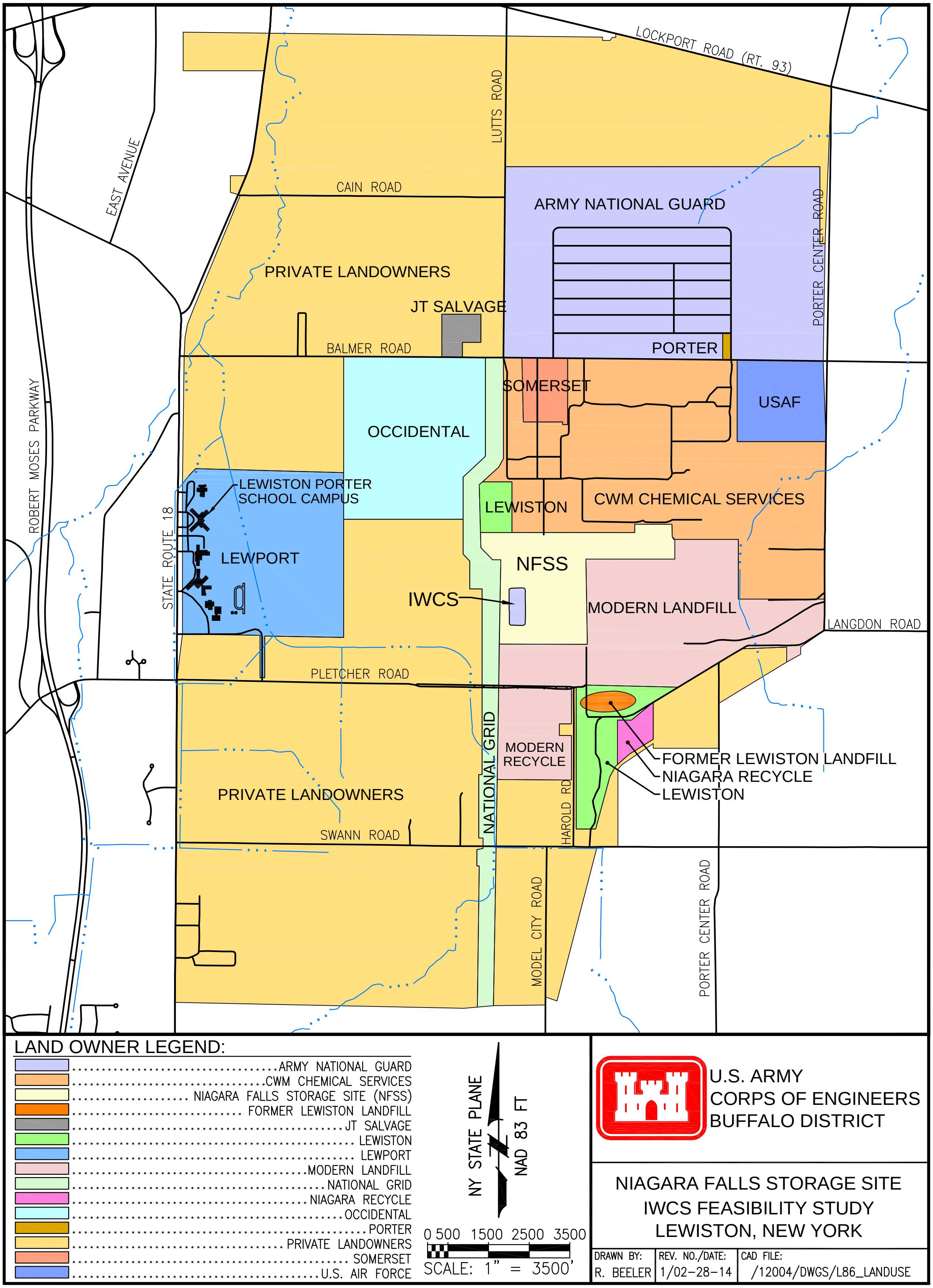

Figure 1-5. Land Use in the Vicinity of the NFSS

The Lewiston Porter public school complex is approximately 2.4 km (1.5 mi) due west of the site at 4061 Creek Road. The complex covers approximately 64.8 ha (160 acres) and consists of five buildings: District Offices, the Primary building (grades K through 2), the Intermediate building (grades 3 through 5), the Middle School (grades 6 through 8), and the High School (grades 9 through 12). Enrollment is approximately 2,500 students and 200 faculty (as of 2012) (http://www.lew-port.com/Page/1). There are two stadiums behind the high school.

Public water is supplied to county residents from the upper Niagara River, which has been utilized by almost all county residents for several decades (Niagara County Department of Health 2006). The Niagara County Water District obtains water from the west branch of the Niagara River and supplies water to the residents of nearby Lewiston and Porter (USACE 2007a).

1.2.2.2 Meteorology

Niagara County experiences a fairly humid, continental-type climate but with a definite maritime flavor due to strong modification from the Great Lakes. The temperature in this area is typically cool, with an average daily maximum temperature of about 27 degrees Celsius (°C) (81 degrees Fahrenheit [°F]) in July and an average daily minimum temperature of about -7.2°C (19°F) in January and February.

Annual precipitation is about 97 centimeters (cm) (38 inches [in.]), which includes both rainfall and snow melt (USACE 2007a), and is fairly evenly distributed throughout the year. Thunderstorms occur 33 days a year on average, primarily during June through August. The highest rainfall month is November with an average of 9.1 cm (3.6 in.) of precipitation, while February is the lowest rainfall month with an average of 6.3 cm (2.5 in.); however, precipitation in the form of snowfall occurs at this time of year. The annual average snowfall in this area is approximately 226 cm (89 in.), with a record maximum of nearly 447 cm (176 in.) reported. Snowfall is generally highest in January, averaging about 61 cm (24 in.) (USACE 2007a).

Meteorological data from the adjacent CWM Chemical Services, LLC landfill indicate prevailing winds are from the west-southwest and the average wind speed is 10.1 km (6.7 mi) per hour (USACE 2011c).

1.2.2.3 Geology

The NFSS and surrounding region is in the Ontario Lake Plain and is generally flat to gently rolling. The Niagara Escarpment sits about 5.2 km (2 mi) south of the site and is the result of a division in bedrock stratigraphy in the region. North of the escarpment, where the NFSS is located, erosion wore away the upper 300 meters (m) (1,000 ft [feet]) of Silurian deposits, leaving the Queenston Formation as the uppermost bedrock layer. This formation, composed of shale, siltstone, and sandstone, is approximately 300 m (1,000 ft) thick and overlies thick layers of other Ordovician shale and limestone units (Acres American, Inc. 1981; BNI 1986a; USACE 2007b).

Overlying the bedrock is approximately 15 m (50 ft) of unconsolidated glacial sediment. The sediment is dominated by clay and silt, although gravel and sand deposits, along with occasional boulders, are found throughout the region. At the NFSS, surficial materials underlain by five major stratigraphic units were identified within the interval from zero to approximately 27 m (90 ft) below ground surface. In order of increasing depth, these units are: surficial soil and fill, brown clay till, glacio-lacustrine clay (or gray clay), alluvial sand and gravel, basal red till, and the Queenston Formation (Figure 1-6). These are described in more detail below.

The surficial soil and fill at this site is made up of unconsolidated materials that have been altered or deposited by human activities, such as site grading. Sand and gravel also are generally found in this unit.

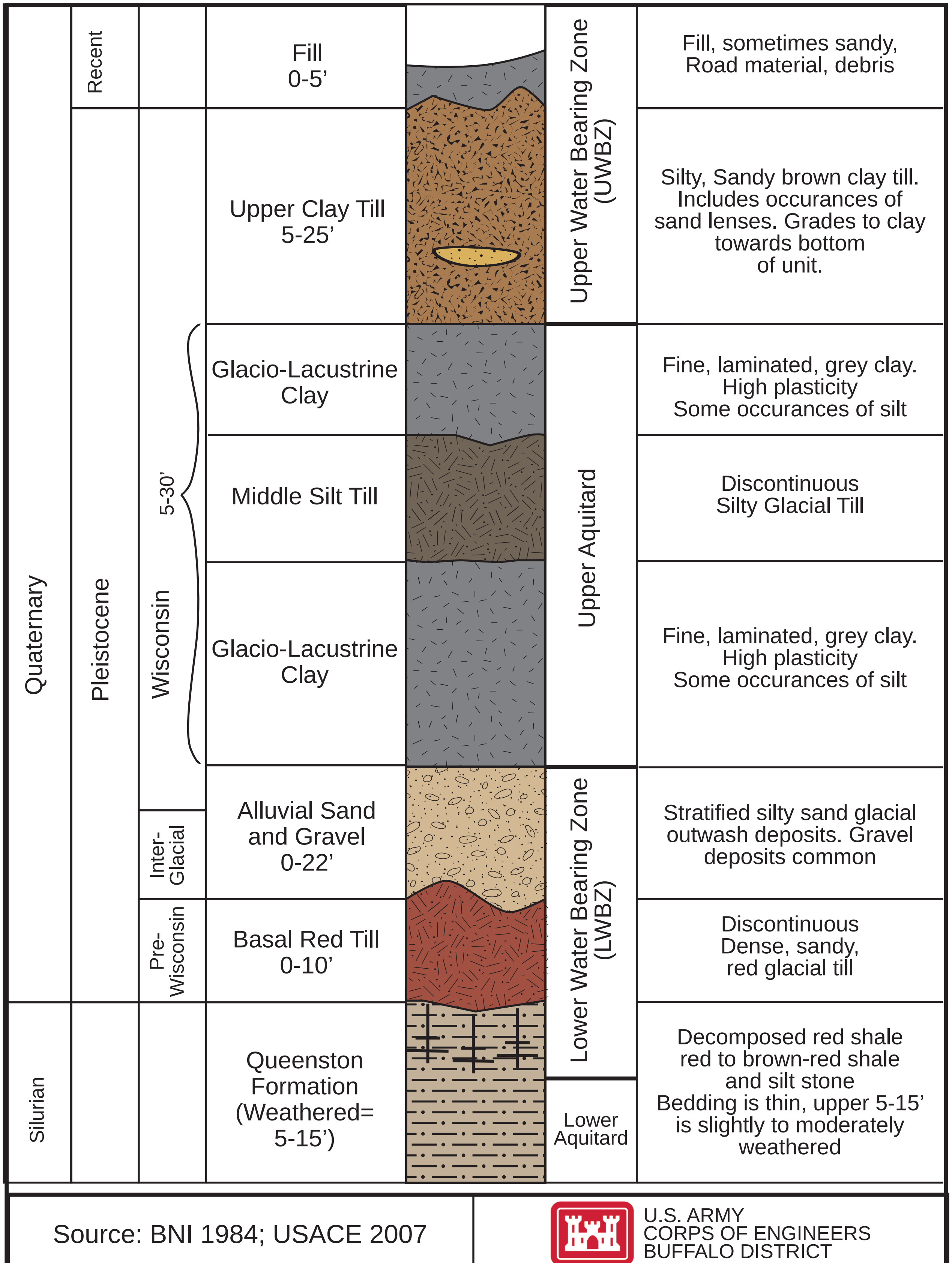

Figure 1-6. NFSS Near-Surface Geologic Units

The thickness of this unit varies between 0 and 1.5 m (0 and 5 ft), with an average of 0.3 to 0.6 m (1 to 2 ft). Generally, the unit is dry to moist, but sometimes it may be saturated.

Underlying the surficial soil is the brown clay till, which is predominantly brown or reddish brown clay. This unit also is referred to as the upper clay till in various sources. The thickness of this unit near the IWCS varies between 1.8 and 7.0 m (6 and 23 ft). Sand and gravel lenses are common within the brown clay till and vary in thickness from 0.3 to 6 m (1 to 20 ft). A 2007 lithologic study of the Bechtel National, Inc. geotechnical logs found that the sand lenses within the brown clay till are discontinuous features (USACE 2007b).

Underlying the brown clay till is the glacio-lacustrine clay unit, also referred to as the gray clay unit. This unit typically consists of a homogeneous gray clay, with occasional laminations of red-brown silt and minor amounts of sand and gravel. The clay is saturated and softer than the overlying unit. In some locations, there is a discontinuous silty layer within the gray clay called the middle silt till. Within the IWCS, it is thought that the gray clay unit varies in thickness from less than 0.3 m (1 ft) to a maximum of 9 m (30 ft) (USACE 2007b). The top surface elevation topography and thickness are highly irregular in the area (BNI 1986a).

The alluvial sand and gravel unit consists of stratified coarse sands; non-stratified coarse silt and sand; or interlayered silt, sand, and clay. It is saturated and usually compact to very dense. In some parts of the NFSS, the basal red till underlies the alluvial sand and gravel unit. This unit is discontinuous throughout the NFSS and, where present, is generally thin. The thickness of this unit varies from 0 to 3 m (0 to 10 ft) and is not thought to be present under the IWCS.

The Queenston Formation is the uppermost bedrock unit that underlies the glacial overburden deposits. It consists of a reddish brown fissile shale. The alluvial sand and gravel unit, basal red till, and Queenston Formation make up the LWBZ underlying the IWCS.

1.2.2.4 Hydrology

There is limited surface water at the site; there are no perennial natural streams, navigable waterways, or impoundments. Over most of the site, several east-west ditches collect surface water runoff that empties into the Central Drainage Ditch. The Central Drainage Ditch traverses the entire north-south length of the NFSS property. Surface water runoff from the western periphery of the site flows to the West Drainage Ditch (Figure 1-3).

Surface water also flows onto the site from the east from the Modern Landfill, Inc. property and from the north and east from the adjacent CWM Chemical Services, LLC site. In addition, surface water flows onto the NFSS from the properties to the south of the site via ditches that are connected to the Central and West Drainage Ditches. Surface water is present during only part of the year in some of these drainage ways.

The Central and West Drainage Ditches flow north and join approximately 0.8 km (0.5 mi) north of the NFSS. The Central Drainage Ditch joins Four Mile Creek about 2.4 km (1.5 mi) north of the NFSS. Four Mile Creek, in turn, empties into Lake Ontario.

Groundwater at the site is defined in terms of the unconsolidated geologic units and one bedrock unit split into three principal hydrostratigraphic zones (listed from top to bottom):

- the UWBZ (surface fill and upper brown clay till unit),
- an aquitard or confining unit (the gray clay and middle silt till units), and
- the LWBZ (alluvial sand and gravel, basal red till, and Upper Queenston Formation).

The UWBZ is composed of two hydrogeologic media: (1) continuous, low-permeability clays and silts; and (2) embedded, discontinuous pockets of sand and gravel. The sand lenses in the UWBZ could not be correlated over distances greater than 6.1 m (20 ft) and, thereby, it was concluded that the sand lenses underlying the IWCS are probably spatially discontinuous (USACE 2007b). The discontinuity of sand lenses creates immobilized pockets of water resulting in a low yield from a water supply perspective.

Generally, groundwater flows northwestward across the NFSS at a gradient of about 0.004 to 0.03 m/m in the area around the IWCS. However, there are localized variations. Groundwater flow in the UWBZ near the Central Drainage Ditch is influenced seasonally by deep-rooted wetland vegetation (phreatophytes) that grows in the ditch during the late-spring, summer, and early-fall periods. The vegetation absorbs groundwater below and along the ditch via evapotranspiration, which lowers groundwater levels and interrupts the gradual flow across the site. In general, water levels are highest in February and lowest in October. During high water level conditions, there is greater downward flow from the UWBZ to the LWBZ than during low water level conditions due to a greater downward hydraulic gradient (USACE 2007b). Recent findings for the UWBZ groundwater flow system are presented in the *2011 Environmental Surveillance Technical Memorandum, Niagara Falls Storage Site* (hereafter referred to as the Environmental Surveillance TM) (USACE 2012d).

Another feature of this zone is the system of underground piping that was developed during construction of the LOOW Freshwater Treatment Plant. However, the extent of the effect from the pipelines is limited. Prior to construction of the IWCS in the 1980s, pipelines connecting the former LOOW Freshwater Treatment Plant buildings were removed or filled and the ends plugged to eliminate pathways for possible migration of radionuclides and to prevent future subsidence of compacted wastes (DOE 1986a). Historical documents and as-built construction drawings indicate subsurface piping within the planned confines of the IWCS was excavated from the area extending from the building perimeters to immediately outside of the planned cut-off wall. The piping outside of the cut-off wall was sealed with concrete or grout (BNI 1984b).

The UWBZ is separated from the LWBZ by an aquitard that corresponds to the gray clay and the middle silt till units. This aquitard underlies the brown clay till and overlies the alluvial sand and gravel unit. It ranges from 0.3 to 9 m (1 to 30 ft) thick (USACE 2007b). This unit acts as a confining layer for the LWBZ (Acres American, Inc. 1981; BNI 1984a; USACE 2007b). Descriptions of sand lenses in the gray clay show the lenses generally are unsaturated and some are dry.

A confined groundwater condition occurs in the LWBZ. The LWBZ is associated with the alluvial sand and gravel unit, the basal red till/red silt unit, and the upper fractured/weathered portion of the Queenston Formation. Groundwater flow in the LWBZ is generally toward the north to northwest with a gradient of 0.002 to 0.004 m/m. The depth to water in the LWBZ ranged from 0.7 to 2.9 m (2.3 to 9.4 ft) below ground surface during Calendar Year 2009 and to 0.1 to 4.1 m (0.4 to 13.5 ft) below ground surface in Calendar Year 2010. Quarterly water level fluctuations showed high and low elevations in May and February, respectively, during Calendar Year 2009. The high and low elevations were in May and October, respectively, during Calendar Year 2010.

1.2.3 Interim Waste Containment Structure Design and Construction

The design and construction of the IWCS is thoroughly documented in an initial design report and in annual construction reports developed by the contractor, Bechtel National, Inc. (BNI 1982 – 1986, 1983, 1984b, 1986b, 1986c, 1987, 1989). A schematic of the final constructed IWCS is shown in Figure 1-7 and includes the following layers (from upper to lower):

- A seeded, shallow-rooted turf cover to control erosion and minimize frost heave damage.

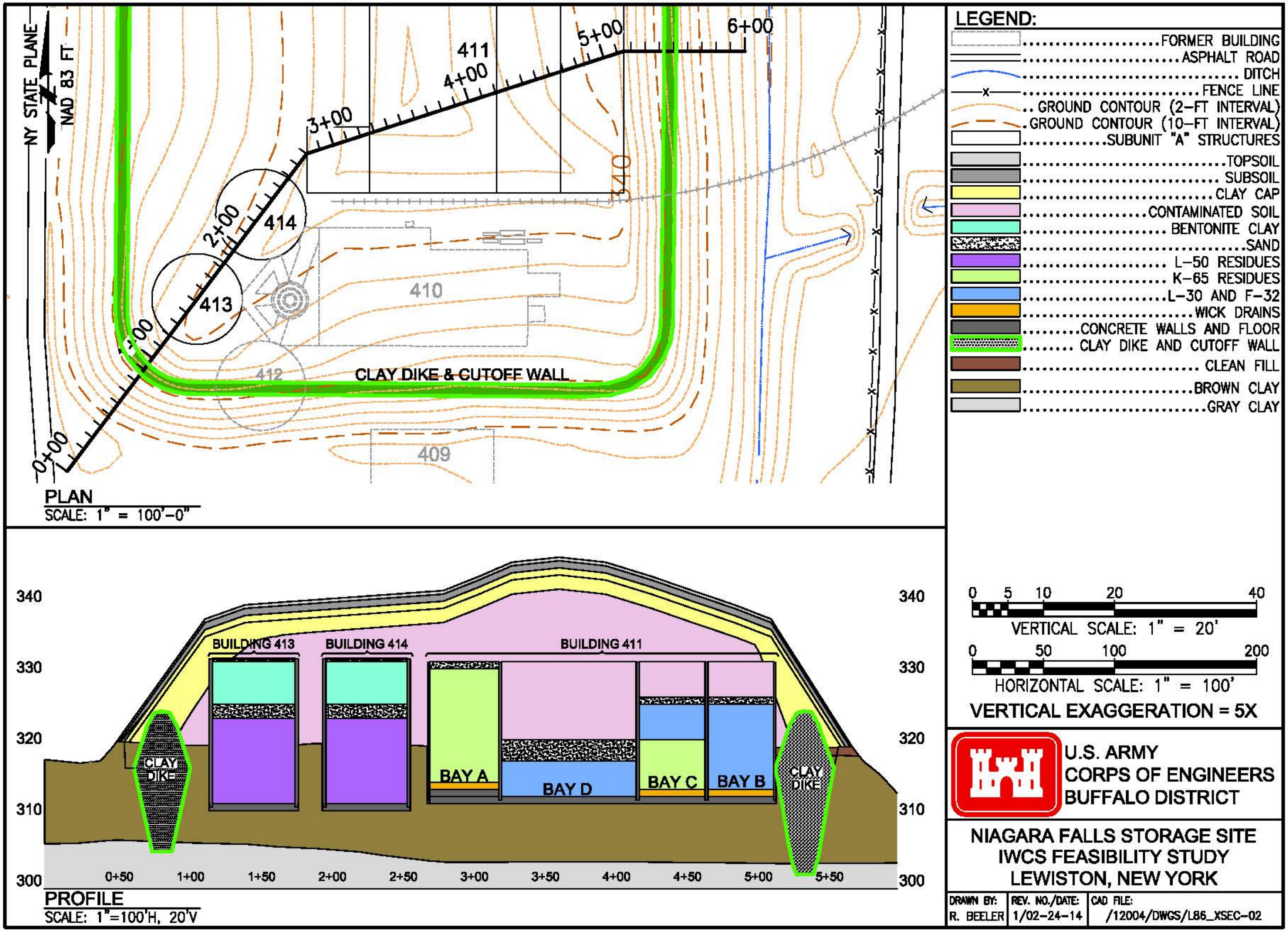

Figure 1-7. IWCS and Waste Placement East-West Cross-Section

- A seeded, shallow-rooted turf cover to control erosion and minimize frost heave damage.

- A 15-cm (6-in.) layer of topsoil.

- A 30.5-cm (12-in.) layer of loosely compacted soil to act as a protective cover to the clay layer.

- A 0.9-m (3-ft) compacted, low-permeability clay cap (constructed to meet 1 x 10^{-7}-centimeter per second [cm/sec] hydraulic conductivity). The sides of the cap were constructed to a maximum slope of 3:1 horizontal to vertical ratio (33 percent [%] slope), and the top of the cap was constructed with 5 to 10% slope to promote runoff while limiting moisture retention and erosion. The cap slopes at approximately 8% from the center to the vicinity of the clay dikes. At this point, the side slopes increase to 3:1 (33%).

- A large and varying layer of waste, comprised of contaminated soil and debris, placed around and over Buildings 411, 413, and 414 and on the original open ground surface.

- Ore residues, located within Buildings 411, 413, and 414 in the southern portion of the IWCS, and the R-10 residues on the original open ground surface in the northern portion of the IWCS.

- Sidewalls made of a compacted clay dike and cut-off wall constructed around the waste containment area. The dike has a minimum width of 2.4 m (8 ft) and extends approximately 1.5 m (5 ft) above the original grade. It rests on the cut-off wall, which has a minimum width of 3.6 m (12 ft) and extends at least 0.5 m (1.6 ft) into the gray clay unit.

- Approximately 1.8 to 7.0 m (6 to 23 ft) of naturally occurring brown clay.

- Less than 0.3 to 9.1 m (1 to 30 ft) of naturally occurring gray clay.

This facility reaches a maximum height of 10 m (34 ft) above ground surface (BNI 1991, 1986b). In the years since the closure of the cap over the IWCS, several investigations, as detailed in the *Remedial Investigation Report Addendum for the Niagara Falls Storage Site* (USACE 2011b), have been conducted to review the physical integrity of the cap and sidewalls and have found that the IWCS is functioning as designed.

1.2.4 Contents of the Interim Waste Containment Structure

Process knowledge and construction records provide indications of the waste types and waste quantities within the IWCS. Although radiological concentrations and waste characterization data were not collected after placement in the IWCS, pre-construction records can be used to characterize the composition and characteristics of the wastes within the IWCS. The waste sources of primary interest at the IWCS are the ore residues from historical uranium processing operations (Table 1-1).

The high-activity ore residues comprise 8% by volume of all materials placed within the IWCS. In addition to the ore residues, other waste streams placed in the IWCS include contaminated soil from historical excavation efforts at the NFSS and vicinity properties, as well as construction and building debris.

Table 1-1. Ore Residues Within the IWCS

Residue	Source	Location Within the IWCS
K-65	From processing ore at the Mallinckrodt facility that contained 35 to 65% uranium oxide	Building 411, Bay A and bottom of Bay C
L-30	From processing ore at the Linde Ceramics Facility that contained 10% uranium oxide	Building 411, bottom and Bays B and D; Bay C (above the K-65 residues)
L-50	From processing ore at the Linde Ceramics Facility that contained 7% uranium oxide	Buildings 413 and 414
F-32	From Middlesex Plant, New Jersey that contained 0.4 to 0.65% uranium oxide	Mixed in with the L-30 residues
R-10	From processing ore at the Linde Ceramics Facility that contained 3.5% uranium oxide	Large pile in the northern portion of the IWCS, north of Building 411 and north of the dike wall that separates the IWCS

IWCS = Interim Waste Containment Structure.
% = Percent.

1.2.5 Definition of Interim Waste Containment Structure Feasibility Study Subunits

The IWCS OU was divided into subunits for this FS. The subunits were defined based on waste type and contaminant concentrations of the residues and the other wastes in the IWCS, as well as the location and placement of the wastes. A detailed discussion regarding the placement of wastes within the IWCS is presented in Appendix A. The locations of the subunits with respect to the plan view of the IWCS are shown on Figure 1-8:

- **Subunit A: Residues and Commingled Wastes Within Buildings 411, 413, and 414.** This subunit includes all of the high-activity residues (K-65, L-30, L-50, and F-32) placed in Buildings 411, 413, and 414. Additionally, this subunit includes other wastes placed within Buildings 411, 413, and 414, including contaminated soil (Tower Soil and other contaminated soil and clay) and contaminated rubble/debris that are commingled with the residues in Building 411.

- **Subunit B: Debris and Wastes in the South End of the IWCS.** The wastes comprising Subunit B are defined as the wastes placed south of the IWCS dike/cut-off wall that abuts Building 411 on both its east and west sides, except for those wastes defined as part of Subunit A. This subunit includes the Buildings 411, 413, and 414 structures. It also includes other contaminated rubble/debris that was placed outside of Buildings 411, 413, and 414 that was associated with storage, handling, and transfer of K-65 residues. Subunit B also includes contaminated rubble/debris from the former K-65 storage silo (Building 434), the Thaw House Foundation, Building 415, Building 410, and the Middlesex Sands that was placed into the basement of Building 410. Additionally, Subunit B includes contaminated soil that was placed surrounding the debris within the south end of the IWCS.

- **Subunit C: Residues and Wastes in the North End of the IWCS.** This subunit includes the majority of the volume of waste categorized as contaminated soil; miscellaneous waste; and about 7,400 cubic meters (m^3) (9,700 yd^3 [cubic yards]) of R-10 residues. The radium-226 (Ra-226) concentrations of wastes in the north end of the IWCS range from approximately 16 to 95 picocuries per gram (pCi/g).

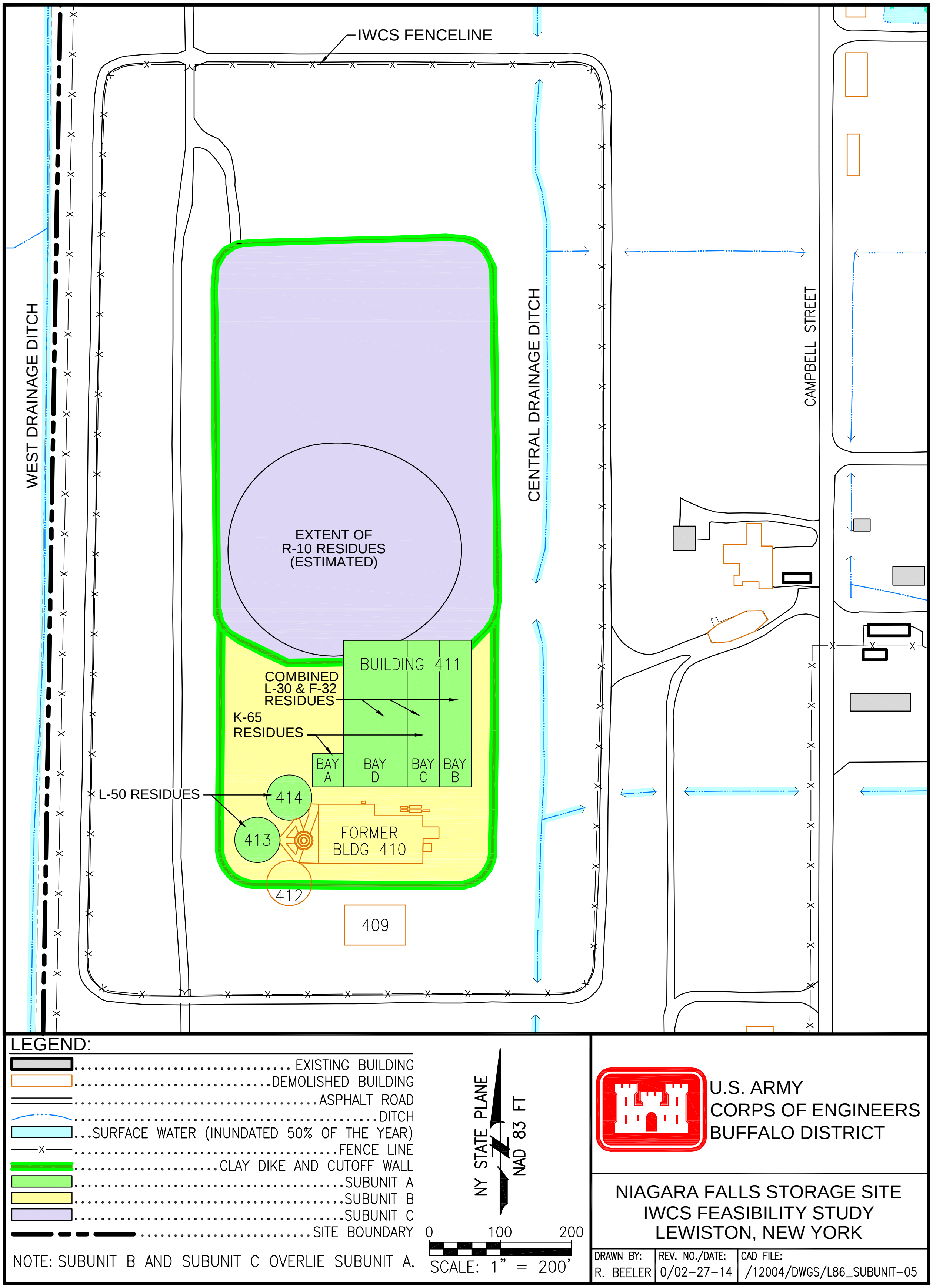

Figure 1-8. IWCS Subunits Identified for the FS

Table 1-2 presents the estimated volume of wastes, building rubble, and other materials within each of the IWCS subunits. A more detailed discussion regarding the characteristics of the wastes contained within the IWCS is presented in Appendix A.

Some wastes at the NFSS came from the KAPL Separations Process Research Unit, located in Schenectady, New York. Separations Process Research Unit was a pilot plant that conducted laboratory-scale research on non-irradiated and slightly irradiated test specimens for development of processes later used at other facilities to extract uranium and plutonium from irradiated uranium (DOE 2012). Separations Process Research Unit commenced operation at KAPL in 1950. Records indicate that approximately 317,000 kg (700,000 lb) of contaminated wastes were shipped from KAPL to the NFSS. The processing wastes contained some residual plutonium and fission product radioactivity (cesium-137 and strontium-90). These materials were transferred to the Oak Ridge Burial Grounds during the late 1950s, and most of the buildings where they were stored were later destroyed (EA 1998).

An investigation of the former storage sites (DOE 2012) concluded that all suspect areas were remediated for unrestricted use, and that "although minor KAPL residuals remain, particularly cesium-137, they are less than a risk-based screening benchmark. Therefore, they do not pose an unacceptable risk and do not require further remediation."

1.2.6 Waste Characterization Data

Waste characterization of the IWCS is based on historical information, analytical records, and process knowledge. No intrusive sampling of the IWCS materials was conducted for the remedial investigation (RI) phase (USACE 2007a). It was determined that sampling would require a breach of the clay cap, and this breach was considered unacceptable. The available data were reviewed and determined to be sufficient for the purpose of conducting the FS.

The historical waste characterization activities that were conducted by DOE over the years largely focused on the key radionuclides in the uranium-238 (U-238), uranium-235, and thorium-232 decay series found in the naturally occurring ores. For context, Figure 1-9 shows the decay chain of the primary U-238 series. This decay chain provides an overview of the radionuclides by decay of U-238 and their half-lives. In nature, the radionuclides in these three decay series are in a state of secular equilibrium, and the activities of all radionuclides within each series are equal.

However, as indicated in the *Preliminary Health Effects for Hypothetical Exposures to Contaminants from the Interim Waste Containment Structure Technical Memorandum* (USACE 2012b) (hereafter referred to as the Health Effects TM), "this natural state is altered during the processing of uranium and thorium ores. The rate at which equilibrium conditions are reestablished depends on the half-lives of the decay products. Radioactive decay products with half-lives of less than six months to one year will reestablish equilibrium conditions with their longer-lived parent radionuclides within ten years. Thus, because the residues and other wastes in the IWCS are associated with uranium processing activities that occurred more than 50 years ago, it can be assumed that all radionuclides with half-lives of less than one year have reestablished equilibrium conditions."

Table 1-3 summarizes the estimated concentrations for radionuclides of interest in the various ore residues and soil wastes in the IWCS. These concentrations are based on sampling under previous studies because the materials could not be sampled in-situ (USACE 2012b). In general, the K-65 residues contain one to two orders of magnitude higher concentrations of radionuclides than the other residues, and the average level of radioactivity for contaminated soil is relatively low. Additional details regarding the waste types and levels of contamination are provided in Appendix A, which also contains concentration data for non-radiological constituents of interest.

Table 1-2. Volumes of Materials Within the IWCS

NFSS IWCS Subunit	Waste Inventory Volume[a,b] (yd^3)
Subunit A – Residues and Commingled Waste Within Buildings 411, 413, and 414	
K-65 residues	4,030
L-30 residues	7,960
L-50 residues	2,150
F-32 residues	440
Tower Soil	4,115
Sand/clay separating layers in Building 411	3,900
Contaminated soil (1984 – 1985 on- and off-site remedial actions)	3,901
Miscellaneous materials and materials added to Buildings 411, 413, and 414	1,944
Total volume Subunit A	***28,440***
Subunit B – Debris and Wastes in the South End of the IWCS	
Middlesex sands	230
Buildings 411, 413, and 414 concrete walls, beams, and foundations	4,950
Building 410 and grouted piping	4,210
Building 415	100
Building 434	1,400
Buildings 409 and 412 debris	3,500
Thaw House Foundation	200
K-65 slurry transfer piping	170
Contaminated soil (1984 – 1985 on- and off-site remedial actions)	15,900
Miscellaneous materials and materials outside of Buildings 411, 413, and 414	12,130
Contaminated clay cap material[c]	8,750
Contaminated clay dike[c]	2,390
Contaminated soil beneath the IWCS[d]	9,200
Total volume Subunit B	***63,130***
Subunit C – Residues and Wastes in the North End of the IWCS	
Original R-10 residues	9,500
Contaminated soil in the R-10 pile (1972 remedial action)	15,000
1982 remedial action – placed on R-10 pile	15,700
1983 remedial action (on- and off-site) – placed north of Building 411	54,000
1991 miscellaneous soil – placed north of Building 411	3,200
1991 – Hittman Tanks and miscellaneous debris – placed north of Building 411	300
Contaminated soil (1984 on- and off-site remedial actions)	24,300
Contaminated dike material[c]	2,450
Contaminated cap material[c]	15,200
Contaminated soil beneath the IWCS[d]	46,852
Total volume Subunit C	***186,502***

[a] The volumes presented in this table were derived from the *Waste Disposal Options and Fernald Lessons Learned Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (USACE 2011a) and construction records. Additional information on assumptions for the waste volumes is provided in Appendix A of this Feasibility Study Report.
[b] The volumes in the table represent in-situ volumes. Records associated with the general waste types of "contaminated soils" and "miscellaneous materials" contain a degree of uncertainty as is typical with old landfills. Numerous assumptions had to be made about the volumes of these materials in each subunit. In general, construction records for other waste streams (e.g., residues) are more detailed because of the level of radioactivity of the material and focus on worker and public safety. The approach for estimating contaminated soil volume and miscellaneous materials is: total capacity of the subunit minus the volume of known residues, waste streams, and structures equals the maximum amount of contaminated soil and miscellaneous materials. Construction records were used to estimate the split between miscellaneous materials and contaminated soil.
[c] Clay dike and cap material are assumed to be contaminated by extended contact with IWCS waste to a depth of 0.6 meters (m) (2 feet [ft]). Resulting volumes are allocated to Subunits B and C based on footprint.
[d] Contaminated soil beneath the IWCS is based on soil boring sampling results at the R-10 pile and an assumption of 0.6-m (2-ft) contamination by leaching under the remainder of the IWCS. Resulting volumes are allocated to Subunits B and C based on footprint.
IWCS = Interim Waste Containment Structure.
NFSS = Niagara Falls Storage Site.
yd^3 = Cubic yard.

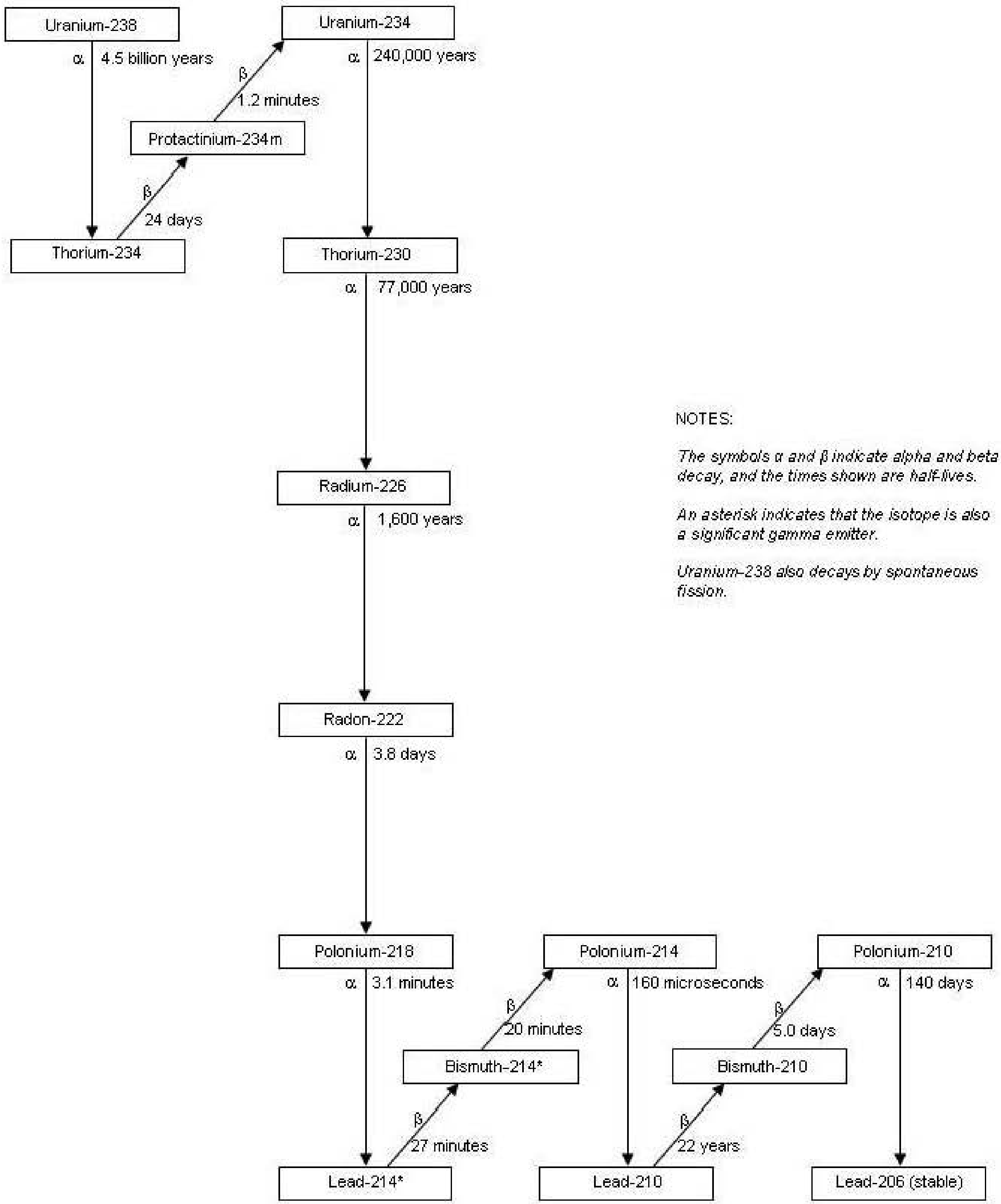

Figure 1-9. U-238 Decay Series (from USACE 2012b)

Table 1-3. Radionuclide Measured Concentrations (pCi/g) for Residues and Contaminated Soil at the NFSS

Radionuclide	Half-Life (year)	Activities (pCi/g)[a]						
		K-65	L-30	F-32	L-50	R-10	Tower Soil[b]	Contaminated Soil
Uranium-238 Decay Series								
Uranium-238	4.47E+9	650	970	1,800	520	1.7	13	4.8
Uranium-234	4.47E+9	650	970	1,800	520	1.7	13	4.8
Thorium-230	77,000	54,000	12,000	300	3,300	50	1,100	16
Radium-226	1,600	520,000	12,000	300	3,300	95	10,000	16
Lead-210	22.3	520,000	18,000	450	5,000	140	10,000	24
Uranium-235 Decay Series								
Uranium-235	7.04E+8	33	70	130	37	0.1	0.7	0.3
Protactinium-231	3.3E+4	10,000	82	150	43	0.1	200	0.4
Actinium-227	22	10,000	82	150	43	0.1	200	0.4
Thorium-232 Decay Series								
Thorium-232	1.4E+10	1,210	24	1.0	7.0	0.2	24	0.03
Radium-228	5.8	1,210	24	1.0	7.0	0.2	24	0.03
Thorium-228	1.9	1,210	24	1.0	7.0	0.2	24	0.03

[a] Concentrations are from Table 2.2 of the *Preliminary Health Effects for Hypothetical Exposures to Contaminants from the Interim Waste Containment Structure Technical Memorandum* (USACE 2012b) and are generally rounded to two significant figures, except for Tower Soil (not quantified in the *Environmental Impact Statement, Long-Term Management of the Existing Radioactive Wastes and Residues at the Niagara Falls Storage Site* [DOE 1986a]).
[b] For the Tower Soil, radionuclide concentrations are assumed to be 2 percent (%) of those for the K-65 residues. For the other soils, the volume addresses that placed in the Interim Waste Containment Structure (IWCS) by the U. S. Department of Energy; it does not include subsurface soils beyond the IWCS contents, such as those considered part of the containment system.
NFSS = Niagara Falls Storage Site.
pCi/g = Picocuries per gram.

1.2.7 Surveillance and Monitoring

Environmental surveillance activities at the NFSS began in 1981, about the time IWCS construction began. These activities included air, surface water/sediment, and groundwater monitoring. Following completion of the IWCS cap in 1986, DOE installed 36 additional groundwater wells along the perimeter of the IWCS. Over time, IWCS monitoring activities became part of the broader environmental monitoring program DOE maintained for the NFSS. In 1997, USACE adopted and continued the monitoring program begun by DOE, which is now referred to as the Environmental Surveillance Program.

In 2007, USACE issued the *Remedial Investigation Report for the Niagara Falls Storage Site* (USACE 2007a). The RI was conducted to define the identity, amount, and location of chemicals and radionuclides of concern at the NFSS and to provide data for the FS. Based on public comments on the RI, USACE performed a supplemental RI (USACE 2011b) that focused on specific data needs around the IWCS. Based on this supplemental RI work, the ongoing Environmental Surveillance Program was reassessed and enhanced (USACE 2010, 2013b). A full description of the current monitoring program can be found in the Environmental Surveillance TM (USACE 2012d). Below is a brief summary of the published findings from the 2011 environmental monitoring effort related to the IWCS area of the site.

1.2.7.1 IWCS external gamma radiation and radon gas

As reported in the 2011 Environmental Surveillance TM (USACE 2012d), radon-222 air concentrations on the IWCS were below the DOE off-site limit of 3.0 picocuries per liter (pCi/L) specified in DOE Order 458.1. Radon-222 flux measurements were below the radon flux standard of 20 picocuries per square meter per second (pCi/m^2/sec) specified by the National Emission Standards for Hazardous Air Pollutants requirements in 40 *CFR* Part 61 Subpart Q. The calculated dose to a receptor from external gamma radiation and airborne particulates was below the DOE guideline of 25 millirems per year (mrem/year) (excluding radon) for all pathways. In addition, the dose from airborne particulates to a receptor was below 10 mrem/year, the maximum individual dose specified by EPA in 40 *CFR* Part 61 Subpart H.

1.2.7.2 Surface water/sediment

Surface water and sediment are sampled across the NFSS as part of the environmental monitoring program. As in previous years, radionuclide concentration results from the 2011 sampling were in background range and below New York State Class B surface water criteria and drinking water criteria. Radionuclides were detected in sediment at levels seen historically. All of the sediment sampling results were below identified criteria, with the exception of two tritium samples with levels greater than the DOE Order 458.1 criterion (3.0 pCi/L).

1.2.7.3 Groundwater

Radionuclides are present in groundwater at the NFSS from historical waste handling activities. Monitoring results from 2011 showed five wells in the vicinity of the IWCS with uranium detections that exceeded the state drinking water standard (a comparison made even though groundwater in this area is not used as drinking water). Generally, these results are consistent with historical data and are "indicative of attenuating legacy sources (i.e., surface stored wastes)" (USACE 2012d). Groundwater will be addressed under the Groundwater OU.

1.2.8 Interim Waste Containment Structure Performance

This section provides a focused assessment of the current IWCS in terms of its effectiveness in protecting human health and the environment. As discussed previously, the IWCS was designed and constructed as a waste containment system with a natural clay bottom and engineered cap, dike, and sidewalls. These features work together to retard radon emissions, infiltration from precipitation, and migration of contamination to groundwater. The design requirements for the existing cap assumed a 25- to 50-year service life, and the bottom, dike, and cut-off walls support a service life of 200 to 1,000 years (BNI 1986c). In the years since closure of the cap over the IWCS, several investigations, as detailed in the RI Report Addendum (USACE 2011b), have been conducted to review the physical integrity of the cap and sidewalls. These investigations have found that the IWCS is intact and functioning as designed. The Environmental Surveillance Program (see Section 1.2.7) confirms that IWCS site controls are continuing to perform as designed and are fully protective of human health and the environment (USACE 2012d).

Another way to evaluate the IWCS in its current configuration is to compare its attributes to pertinent regulatory requirements. The appropriate and/or relevant regulatory requirements that must be met for closure of a waste disposal area like the IWCS are defined in Section 1.5 and detailed in Appendix D. These requirements set groundwater protection standards, limits on the emission of radionuclides and radon to the ambient air, and closure requirements for uranium ore processing waste disposal areas. The IWCS, in its current configuration and as currently operated by USACE, matches the appropriate and/or relevant requirements as follows:

- Prevents hazardous constituents from entering the groundwater at levels above the specified concentration limits, including at the compliance point (10 *CFR* 40 Appendix A, Criterion 5B[1], 5B[2], 5B[3], 5B[5], and 5C).

- Includes an earthen cover, which provides reasonable assurance of control of radiological hazards to be effective for 1,000 years or at least 200 years (10 *CFR* 40 Appendix A, Criterion 6[1]).

- Limits releases of radon-222 from the IWCS to the atmosphere so as not to exceed an average release rate of 20 pCi/m^2 sec (10 *CFR* 40 Appendix A, Criterion 6[1] and 40 *CFR* 61.192).

- Includes a multi-layer cap constructed of natural clay and soil that do not contain elevated levels of radium (10 *CFR* 40 Appendix A, Criterion 6[5]).

- Addresses non-radiological hazards by isolating the wastes within the IWCS containment system, which continues to demonstrate control over the escape of non-radiological hazardous constituents, leachate, contaminated rainwater, or waste decomposition products to the ground or surface waters or to the atmosphere (10 *CFR* 40 Appendix A, Criterion 6[7]).

- Meets secondary groundwater protection standards for constituents reasonably expected to be in or derived from the byproduct materials that have been detected in groundwater because no releases from the IWCS to groundwater have been identified (10 *CFR* 40 Appendix A, Criterion 13).

- Prevents emissions of radionuclides to the ambient air that would cause any member of the public to receive, in any year, an effective dose equivalent of 10 mrem/year (40 *CFR* 61.92), as demonstrated by the Environmental Surveillance Program (USACE 2012d).

Based on this focused assessment, the IWCS in its current configuration continues to be fully protective of human health and the environment and meets many of the regulatory requirements for groundwater protection, emission of radionuclides and radon, and closure of uranium ore processing waste disposal areas.

1.3 DETERMINATION OF CONSTITUENTS OF POTENTIAL CONCERN FOR THE INTERIM WASTE CONTAINMENT STRUCTURE

The evaluations conducted in support of the FS rely primarily on historical process information, site data from previous characterization activities, and ongoing environmental monitoring at NFSS. The contaminants of potential concern for the IWCS were determined through a risk-based assessment as described in the Health Effects TM (USACE 2012b). Radionuclides of potential concern were identified based on process knowledge. The list of constituents of potential concern for the IWCS is shown in Table 1-4.

Radium-226 is the most significant radionuclide in terms of dose in the IWCS. Radium-226 is a decay product of uranium and, therefore, is found in all uranium-bearing ores and any natural rocks containing uranium. The standard unit of measure for radioactivity, the curie (Ci), is defined as the amount of radioactive material that has the same disintegration rate as 1 gram (g) of Ra-226. Radium-226 is the most stable isotope of radium. It decays to radon gas (Figure 1-9) and then further decays to a series of other short-lived alpha- and beta-particle emitting radionuclides, eventually reaching stable lead (lead-206). Radon is a colorless and odorless gas and, therefore, is not detectable by human senses alone. It is approximately eight times denser than air and, therefore, remains low in the atmosphere in the absence of wind movement. Radon is usually measured as picocuries of radon per liter of air (pCi/L). In occupational assessments, it is often measured and reported in working levels, which are related to the radiological dose received per liter of air. Radon is classified as a human carcinogen and linked to lung cancer.

Table 1-4. Constituents of Potential Concern for the IWCS

Radionuclide	Chemical
Actinium-227	Arsenic
Lead-210	Barium
Protactinium-231	Cobalt
Radium-226	Lead
Radium-228	Lithium
Thorium-228	Manganese
Thorium-230	Molybdenum
Thorium-232	Nickel
Uranium-234	Uranium
Uranium-235	Vanadium
Uranium-238	Polychlorinated biphenyls

Source: *Preliminary Health Effects for Hypothetical Exposures to Contaminants from the Interim Waste Containment Structure Technical Memorandum* (USACE 2012b).
IWCS = Interim Waste Containment Structure.

In addition to the radionuclides, DOE (1986a) identified 35 non-radioactive chemicals (mostly metals) as being present in the K-65, L-30, and L-50 residues. In addition, soil from on- and off-site cleanups was placed into the IWCS. Chemicals identified in contaminated soil included volatile organic compounds and polychlorinated biphenyls, pesticides, polycyclic aromatic hydrocarbons, nitroaromatic compounds, and other semivolatile organic compounds (BNI 1991). These data, as well as information from other studies, were assessed, and the non-radiological chemicals of potential concern were identified in the Health Effects TM (USACE 2012b). Additional detail on the non-radiological chemicals that may be present in the IWCS is provided in Appendix A.

1.3.1 Contaminant Fate and Transport

The results of the ongoing Environmental Surveillance Program at the NFSS confirm that the IWCS is performing as designed to prevent contaminant migration away from the landfill. USACE has utilized historical aerial photographs, a 32-year sampling record, and prior remediation reports to determine that the IWCS is performing as designed and built. These conditions will persist as long as government maintenance activities are in place.

Active maintenance activities are in place and control the following potential environmental transport mechanisms:

- radon gas emanation with subsequent diffusion and dispersion through the air;
- emanation of gamma rays;
- soil particulate emissions via dust, winds, and redeposition;
- surface runoff with overland flow to nearby creeks; and
- infiltration to groundwater.

1.4 SUMMARY OF SITE RISKS

A CERCLA baseline risk assessment identifies risks related to the No Action alternative and serves as the baseline against which remedial alternatives can demonstrate reductions in risk. Within a baseline risk assessment, risks are defined as the probability that a person could contract cancer or be exposed to a substance that would cause toxic effects and illness. Estimated cancer risk can be expressed in terms of one chance in a million, or 1 in a 1,000,000, or 1×10^{-6}. EPA uses a 1×10^{-4} to 1×10^{-6} risk range as a target range to manage CERCLA cleanups. In addition, a CERCLA ecological risk assessment typically identifies any ecological risk concerns at a site.

A CERCLA baseline risk assessment was performed as part of the 2007 RI (USACE 2007a). The assessment used data collected for the RI to assess potential risk to soil, groundwater, and surface water/sediment across the NFSS. The long-term risks related to the contents of the IWCS were not quantitatively assessed in the study. To quantitatively evaluate the baseline risks associated with the IWCS (the No Action alternative), and the potential residual risks associated with the proposed remedial alternatives, a risk evaluation was performed for this FS using available information. This evaluation is presented in Appendix C and summarized below.

The risk evaluation considered the following two land-use scenarios:

- Termination of current, active site controls in the future. This would cancel monitoring and maintenance activities that prevent excavation into the landfill and degradation of cap integrity. This land-use scenario represents potential risks under a CERCLA No Action alternative.

- Maintenance of land-use controls (LUCs) in perpetuity by the Federal Government to prevent access to the materials in the landfill and to prevent degradation of the containment system. LUCs include institutional and engineering controls that help prevent human or ecological exposure to contaminants, as well as a program of site monitoring and maintenance. This land-use scenario applies to remedial Alternatives 2, 3A, and 3B.

The conceptual exposure model for the scenario assuming an absence of LUCs is for a future on-site resident. The resident "intrudes" into the waste and is referred to as a Resident Intruder. This intruder could either build a house with a basement into the residues, or build a residence at such a time that the cap materials have eroded and the residues are exposed. The Resident Intruder was quantitatively evaluated in the environmental impact statement (DOE 1986a) and, although this receptor could be exposed via multiple pathways, the only pathway for which risk was quantified was inhalation of radon gas due to proximity to the Ra-226 in the residues. As will be shown, the risk associated with this single pathway was sufficiently high to preclude the need to evaluate additional pathways.

The conceptual exposure model associated with perpetual maintenance of LUCs and the cap layer includes two receptors: an On-Site Maintenance Worker and an Off-Site Resident.

The On-Site Maintenance Worker maintains site controls and the cap. This receptor is an individual who spends the workday on and around the IWCS performing light physical labor, such as mowing or inspecting the IWCS cap. The worker is expected to be directly on top of the IWCS cap for a portion of the day and is likely to be exposed through the following pathways:

- inhalation of radon gas and daughter products emitted from the IWCS source materials, and
- external exposure to gamma radiation emitted from the IWCS source materials.

Exposure to other contaminants and to particulate radionuclide releases is not quantified because these contaminants are under the multi-layer cap and there is no release pathway for them.

The Off-Site Resident is located at an assumed point along the site boundary where LUCs are no longer in place. The Off-Site Resident is conservatively assumed to spend 30 years outside the IWCS fence line in the direction of prevailing winds, located approximately 185 m (607 ft) to the west. The IWCS cap is intact, and the Off-Site Resident is assumed to be exposed through the following pathways:

- inhalation of radon gas and daughter products emitted from the IWCS source materials with subsequent migration to the IWCS surface and to the fence line, and

- external exposure to gamma radiation emitted from the IWCS source materials and reaching the fence line.

Additional pathways, such as inhalation of particulates or ingestion of groundwater, were not quantified because the intact IWCS prevents migration of source material to air (as particulates) or groundwater (see Appendix B for further discussion on contaminant migration through groundwater).

The process for estimating dose and risk via the above pathways is discussed in Appendix C, which also presents the exposure parameters and assumptions used to quantify each exposure pathway-receptor risk. The results of the risk evaluation are presented in Table 1-5.

Table 1-5. Summary of Risk Evaluation Results for the IWCS FS

Receptor	Radon Air Concentration (pCi/L)	Radon Cancer Risk[a]	External Gamma Dose Rate (mrem/year)	Gamma Exposure Cancer Risk[a]	Total Cancer Risk[a]
Absence of LUCs					
Resident Intruder	NE	4.0×1^{-1}	NE	NE	4.0×10^{-1}
Maintenance of LUCs and Containment System					
On-Site Maintenance Worker	0.0014	1.0×10^{-6}	1.2	2.5×10^{-5}	2.6×10^{-5}
Off-Site Resident	0.000034	1.0×10^{-7}	0.018	3.3×10^{-7}	4.4×10^{-7}

[a] Risks are for lifetime exposure.
FS = Feasibility study.
IWCS = Interim Waste Containment Structure.
LUC = Land-use control.
mrem/year = Millirems per year.
NE = Not estimated.
pCi/L = Picocuries per liter.

Based on this analysis, the estimated total cancer risk to the Resident Intruder is 0.4, or 4×10^{-1}. The risk is three orders of magnitude above the acceptable risk range, thus, if active site controls are terminated and the IWCS containment system is not maintained, there is the potential for unacceptable risks associated with the IWCS.

If LUCs are implemented and the containment system is maintained, the estimated cancer incidence risk to the On-Site Maintenance Worker is 2.6×10^{-5} and the estimated risk to the Off-Site Resident is 4.4×10^{-7}. These risks are within and below the target risk range. Thus, under current conditions, and under the scenario that the Federal Government retains ownership and control of the IWCS and, therefore, maintains the current site conditions in perpetuity, there are no unacceptable risks associated with the IWCS.

The 2007 RI Report (USACE 2007a) included a screening-level ecological risk assessment. The ecological assessment concluded that no further action is required because there are no significant or unique ecological resources, there is no critical habitat for threatened or endangered species, and scattered wetlands and ditches are of low quality as a result of prior construction activities at the site.

For the purposes of this FS, two assumptions have been made concerning the ecological risk assessment:

- If active site controls (maintenance and monitoring) are terminated (a No Action scenario), the IWCS containment system may be degraded and ecological receptors may be exposed to the contents of the IWCS. Because of the lack of unique ecological receptors, the human health risk associated with inhalation exposure would dominate the risk-management process.

- Under a scenario where LUCs are implemented and maintained, there are no ecological risk concerns, as outlined in the RI (USACE 2007a).

Based on these assumptions, ecological risk is not the driver for risk-management decisions in this FS.

1.5 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CERCLA Section 121(d) "Degree of cleanup" directs that any remedial action selected must attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment, or control of further release, that, at a minimum, assures the protection of human health and the environment. It also mandates that such remedial actions be relevant and appropriate under the circumstances presented by the release or threatened release of such substance, pollutant, or contaminant. With respect to any hazardous substance, pollutant, or contaminant that will remain on-site, the remedy selected must attain a standard, requirement, criterion, or limitation under any Federal environmental law that is legally applicable to the hazardous substance, pollutant, or contaminant or is relevant and appropriate under the circumstances of the release or threatened release. The selected remedy must also, or in the alternative, attain any promulgated standard, requirement, criterion, or limitation under a State environmental or facility citing law that is more stringent than the Federal standard and has been identified by the State in a timely manner, if it is legally applicable or is relevant and appropriate to the hazardous substance or pollutant or contaminant concerned or the circumstances of the release or threatened release of such hazardous substance or pollutant or contaminant. The statute puts the emphasis on the degree of cleanup, or in other words, how clean is clean enough if a remedy leaves a hazardous substance, pollutant, or contaminant at the site.

For the IWCS, USACE has identified the following environmental laws that are relevant and/or appropriate for consideration in the remedy selection process:

- **10 *CFR* 40, Appendix A:** Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content:

    - Criteria 5B(1), 5B(2), 5B(3), 5B(5), and 5C, Groundwater Protection Standards;
    - Criteria 6(1), 6(2), 6(3), 6(5), 6(6), and 6(7), Closure of Waste Disposal Areas;
    - Criterion 12, Long-term Site Surveillance; and
    - Criterion 13, Hazardous Constituents.

- **40 *CFR* 61:** National Emission Standards for Hazardous Air Pollutants:

    - Subpart H – National Emission Standards for Emissions of Radionuclides other than Radon from DOE Facilities, and

- Subpart Q – National Emission Standards for Radon from DOE Facilities.

A discussion of the rationale for selecting these laws is provided in Appendix D. Table 1-6 summarizes the significant requirements of these laws and their relevance to the IWCS FS.

1.6 REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) are goals developed to specify requirements remedial alternatives must fulfill to be protective of human health and the environment. RAOs provide the basis for selecting remedial technologies (Chapters 2.0 and 3.0) and developing and evaluating remedial alternatives (Chapter 4.0).

The RAOs for the IWCS OU are designed to provide short- and long-term protection of human health and the environment based on plausible future land uses for the NFSS. CERCLA requires that any action taken be protective of human health and the environment, as well as be compliant with identified ARARs.

The RAOs for the IWCS OU follow:

- Prevent unacceptable exposure of receptors to the hazardous substances associated with uranium ore mill tailings (e.g., Ra-226 and its short-lived decay products) inside the IWCS.

- Minimize/prevent the transport of hazardous substances within the IWCS to other environmental media (e.g., soil, groundwater, surface water, sediment, and air) outside of the IWCS.

- During implementation of the remedial alternative(s), minimize/prevent releases and other impacts that could adversely affect human health and the environment, including ecological receptors.

If selected as a remedial action, removal of IWCS material would be based on cleanup criteria derived from the specified ARARs. If all of the waste material in the IWCS is removed, then any remaining IWCS structures (e.g., dike and cut-off walls, residual soil that had waste placed on them, etc.) would be addressed within the scope of the Balance of Plant OU and its associated cleanup criteria.

Table 1-6 Summary of ARARs for the IWCS FS Analysis

Citation	Requirement	Note
10 *CFR* 40, Appendix A: Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content		
Criterion 5B(1)	Hazardous constituents entering the groundwater from a licensed site must not exceed the specified concentration limits in the uppermost aquifer beyond the point of compliance during the compliance period: • Specified concentration limits are those limits established by the Commission as indicated in paragraph 5B(5) of this criterion • The point of compliance must be selected to provide prompt indication of groundwater contamination on the hydraulically downgradient edge of the disposal area	Establishes a groundwater point of compliance at the downgradient edge of the disposal facility
Criterion 5B(2)	A constituent becomes a hazardous constituent subject to paragraph 5B(5) only when the constituent meets all three of the following tests: • The constituent is reasonably expected to be in or derived from the byproduct material in the disposal area • The constituent has been detected in the groundwater in the uppermost aquifer • The constituent is listed in Criterion 13 of 10 *CFR* 40 Appendix A	Establishes the requirements for determining if a constituent becomes a hazardous substance (5B[2] – 5B[5])
Criterion 5B(3)	Even when constituents meet all three tests in paragraph 5B(2) of this criterion, the Commission may exclude a detected constituent from the set of hazardous constituents on a site-specific basis if it finds that the constituent is not capable of posing a substantial present or potential hazard to human health or the environment.	
Criterion 5B(5)	At the point of compliance, the concentration of a hazardous constituent must not exceed: • The Commission-approved background concentration of that constituent in the groundwater • The respective value given in the table in paragraph 5C if the constituent is listed in the table and if the background level of the constituent is below the value listed • An alternate concentration limit established by the Commission	

Table 1-6 Summary of ARARs for the IWCS FS Analysis (continued)

Citation	Requirement	Note
Criterion 5C	Maximum values for groundwater protection, including: • Combined radium-226 and radium-228 – 5 pCi/L • Gross alpha-particle activity (excluding radon and uranium) – 15 pCi/L	
Criterion 6	(1) In disposing of waste byproduct material, licensees shall place an earthen cover (or approved alternative) over tailings or wastes at the end of milling operations and shall close the waste disposal area in accordance with a design that provides reasonable assurance of control of radiological hazards to (i) be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years; and (ii) limit releases of radon-222 from uranium byproduct materials, and radon-220 from thorium byproduct materials, to the atmosphere so as not to exceed an average release rate of 20 pCi/m^2 sec to the extent practicable throughout the effective design life determined pursuant to (1)(i) of this Criterion. In computing required tailings cover thicknesses, moisture in soils in excess of amounts found normally in similar soils in similar circumstances may not be considered. Direct gamma exposure from the tailings or wastes should be reduced to background levels. The effects of any thin synthetic layer may not be taken into account in determining the calculated radon exhalation level. If non-soil materials are proposed as cover materials, it must be demonstrated that these materials will not crack or degrade by differential settlement, weathering, or other mechanism, over long-term intervals. (2) As soon as reasonably achievable after emplacement of the final cover to limit releases of radon-222 from uranium byproduct material and prior to placement of erosion protection barriers or other features necessary for long-term control of the tailings, the licensee shall verify through appropriate testing and analysis that the design and construction of the final radon barrier is effective in limiting releases of radon-222 to a level not exceeding 20 $pCi/m^2/sec$ averaged over the entire pile or impoundment using the procedures described in 40 *CFR* Part 61, Appendix B, Method 115, or another method of verification approved by the Commission as being at least as effective in demonstrating the effectiveness of the final radon barrier	Establishes a 1,000-year design specification and establishes a 20-$pCi/m^2/sec$ release rate goal for containment alternatives

Table 1-6 Summary of ARARs for the IWCS FS Analysis (continued)

Citation	Requirement	Note
	(3) When phased emplacement of the final radon barrier is included in the applicable reclamation plan, the verification of radon-222 release rates required in paragraph (2) of this criterion must be conducted for each portion of the pile or impoundment as the final radon barrier for that portion is emplaced	
	(5) Near-surface cover materials (i.e., within the top 3 m) may not include waste or rock that contains elevated levels of radium; soils used for near-surface cover must be essentially the same, as far as radioactivity is concerned, as that of surrounding surface soils. This is to ensure that surface radon exhalation is not significantly above background because of the cover material itself	Requires that the final cover material contains radioactivity equal to background levels
	(6) The design requirements in this criterion for longevity and control of radon releases apply to any portion of a licensed and/or disposal site unless such portion contains a concentration of radium in land, averaged over areas of 100 m^2, which, as a result of byproduct material, does not exceed the background level by more than: (i) 5 pCi/g of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over the first 15 cm below the surface, and (ii) 15 pCi/g of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over 15-cm thick layers more than 15 cm below the surface. Byproduct material containing concentrations of radionuclides other than radium in soil, and surface activity on remaining structures, must not result in a TEDE exceeding the dose from cleanup of radium-contaminated soil to the above standard (benchmark dose) and must be at levels that are as low as is reasonably achievable. If more than one residual radionuclide is present in the same 100-m^2 area, the sum of the ratios for each radionuclide of concentration present to the concentration limit will not exceed “1” (unity). A calculation of the potential peak annual TEDE within 1,000 years to the average member of the critical group that would result from applying the radium standard (not including radon) on the site must be submitted for approval	Provides the final cleanup goal for the excavation alternative

Table 1-6 Summary of ARARs for the IWCS FS Analysis (continued)

Citation	Requirement	Note
	(7) The licensee shall also address the non-radiological hazards associated with the wastes in planning and implementing closure. The licensee shall ensure that disposal areas are closed in a manner that minimizes the need for further maintenance. To the extent necessary to prevent threats to human health and the environment, the licensee shall control, minimize, or eliminate post-closure escape of non-radiological hazardous constituents, leachate, contaminated rainwater, or waste decomposition products to the ground or surface waters or to the atmosphere	
Criterion 12	The final disposition of tailings, residual radioactive material, or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation. As a minimum, annual site inspections must be conducted by the government agency responsible for long-term care of the disposal site to confirm its integrity and to determine the need, if any, for maintenance and/or monitoring. Results of the inspections for all the sites under the licensee's jurisdiction will be reported to the Commission annually within 90 days of the last site inspection in that calendar year. Any site where unusual damage or disruption is discovered during the inspection, however, will require a preliminary site inspection report to be submitted within 60 days. On the basis of a site-specific evaluation, the Commission may require more frequent site inspections if necessary due to the features of a particular disposal site. In this case, a preliminary inspection report is required to be submitted within 60 days following each inspection	Inspections conducted twice per year
Criterion 13	Secondary groundwater protection standards required by Criterion 5 of 10 *CFR* 40 Appendix A are concentration limits for individual hazardous constituents. The list of constituents in 10 *CFR* 40 Appendix A identifies the constituents for which standards must be set and complied with if the specific constituent is reasonably expected to be in or derived from the byproduct material and has been detected in groundwater. For purposes of 10 *CFR* 40 Appendix A, the property of gross-alpha activity will be treated as if it is a hazardous constituent. Thus, when setting standards under paragraph 5B(5) of Criterion 5, the Commission will also set a limit for gross-alpha activity. The Commission does not consider the list imposed by 40 *CFR* Part 192 to be exhaustive and may determine other constituents to be hazardous on a case-by-case basis, independent of those specified by EPA in Part 192	EPA groundwater provisions of 40 *CFR* 192 are considered relevant and appropriate in lieu of those standards promulgated by the NRC, which simply implement the EPA provisions

Table 1-6 Summary of ARARs for the IWCS FS Analysis (continued)

Citation	Requirement	Note
40 CFR 61: National Emissions Standards for Hazardous Air Pollutants		
Subpart H, 61.92	Emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive, in any year, an effective dose equivalent of 10 mrem/year	Establishes the allowable radiation dose limit
Subpart Q, 61.192	No source at a DOE facility shall emit more than 20 pCi/m^2/sec (1.9 pCi/ft^2/sec) of radon-222 as an average for the entire source, into the air. This requirement will be part of any Federal Facilities Agreement reached between EPA and DOE	Establishes the allowable radon flux limit

ARAR = Applicable or relevant and appropriate requirement.
CFR = Code of Federal Regulations.
cm = Centimeter.
DOE = U. S. Department of Energy.
EPA = U. S. Environmental Protection Agency.
FS = Feasibility study.
IWCS = Interim Waste Containment Structure.
m = Meter.
m^2 = Square meter.
mrem/year = Millirem per year.
NRC = U. S. Nuclear Regulatory Commission.
pCi/g = Picocuries per gram.
pCi/L = Picocurries per liter.
pCi/m^2/sec = Picocuries per square meter per second.
TEDE = Total effective dose equivalent.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 INTRODUCTION

Remedial action alternatives are identified through the CERCLA remedy selection process based on their ability to reduce potential risks to human health and the environment. This selection process is a series of steps that include the identification of remedial technologies, screening of the technologies, and the development of remedial action alternatives to undergo further analysis and evaluation. Appendix E provides the detailed screening of general response actions (GRA), technologies, and process options used to develop the remedial alternatives for this FS Report. The screening was originally performed in the Remedial Alternatives TM (USACE 2013a); the document is included as Appendix E of this FS Report.

Identification and screening of alternatives involves the following activities:

- identification of waste types, contaminants, media, and waste volumes (Section 1.3 and Appendix A);
- identification of RAOs (Section 1.6);
- identification of GRAs;
- identification and screening of technology types and process options; and
- evaluation and selection of technology types and process options.

Due to the differences in the waste types and contaminant levels between the uranium ore residues and the other wastes within the IWCS (as described in Chapter 1.0), the IWCS OU was subdivided for the purpose of identifying GRAs, technologies, and process options. The three subunits are (Figure 1-8):

- Subunit A: Residues and Commingled Wastes Within Buildings 411, 413, and 414.

- Subunit B: Debris and Wastes in the South End of the IWCS (including the Buildings 411, 413, and 414 structures).

- Subunit C: Residues and Wastes in the North End of the IWCS.

Below is a summary of the screening process presented in Appendix E.

2.2 GENERAL RESPONSE ACTIONS

GRAs are defined as broad response actions that satisfy the RAOs for the IWCS, such as containment, removal, disposal, and treatment. The following GRAs were identified and retained for further screening:

- LUCs;
- containment, or in the case of the IWCS, enhanced containment;
- removal;
- treatment; and
- disposal.

2.3 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

For each retained GRA, remedial technologies, such as capping, subsurface barriers, or vertical trenches, and process options, which are specific processes, were identified. This effort was conducted using several available technology reference guides and screening tools, including the *Remediation Technologies Screening Matrix and Reference Guide* (FRTR 2009), the *Technology Screening Guide for Radioactively Contaminated Sites* (EPA 1996), and the *Technology Reference Guide for Radiologically Contaminated Surfaces* (EPA 2006). Experts were consulted and available literature on remediation technologies and process options was researched to determine the innovative technologies that may be feasible for implementation at the IWCS.

The identification of technologies for addressing the higher-activity residues, particularly the K-65 residues, relied heavily on the lessons learned from the Fernald Site K-65 Silos 1 and 2 Remediation Project (hereafter referred to as the Fernald K-65 Project). Some lessons learned are documented in the *Waste Disposal Options and Fernald Lessons Learned Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (hereafter referred to as the WDO/Fernald LL TM) (USACE 2011a); others have been identified since the development of that TM and in preparation of this FS Report.

A broad range of remedial technologies and process options was identified for the IWCS, and all are presented and described in detail in Appendix E. The list of technologies was initially screened against a single criterion, implementability. If the technology or process option was determined not implementable due to IWCS waste characteristics, site-specific physical factors, or if implementing the technology provided no additional benefit over current site conditions, the technology and process option were screened from further consideration in the FS. Table 2-1 identifies the technologies retained by the initial screening.

Table 2-1. Remedial Technologies and Process Options Retained After Initial Screening

GRA	Remedial Technology	Process Option
LUCs	Institutional controls	Proprietary controls, government controls, and informational tools
	Engineering controls	Physical barriers and permanent markers, and/or security systems
	Environmental monitoring	Air, surface water/sediment, and groundwater monitoring
	Surveillance and maintenance	Surveillance activities and maintenance activities
Containment	Engineered cap	Multi-layered engineered cap
Removal	Mechanical removal	Conventional earthmoving equipment, overhead (clamshell) removal, dragline systems, remotely operated equipment, and auger mining
	Hydraulic and pneumatic removal	Hydraulic mining (Subunit A only)
	Demolition	Concrete cutting and mechanical demolition
Treatment	Physical processes	Conventional S/S, encapsulation, ex-situ vitrification, surface decontamination, surface removal, and surface barriers (sealants)
	Chemical processes	Chemical extraction/metals recovery
Disposal	On-site engineered disposal facility	Engineered disposal facility
	Off-site disposal facility	Licensed disposal facility

GRA = General response action.
LUC = Land-use control.
S/S = Solidification/stabilization.

2.4 EVALUATION OF TECHNOLOGIES AND SELECTION OF REPRESENTATIVE TECHNOLOGIES

Following the initial screen, a qualitative evaluation was performed on the retained technologies using three criteria: effectiveness, implementability, and relative cost. For each technology, ratings of high, moderate, or low were determined for the three criteria. The ranking for each technology is provided in

Appendix E. A description of the basis for the rankings and a summary of the evaluation is provided below.

Effectiveness is evaluated based upon the potential long-term effectiveness and permanence in meeting the goals identified in the RAOs, compliance with ARARs, reduction in the mobility or volume of contaminated materials, the adequacy and reliability of controls in handling the estimated volumes of contaminated waste, and the ability of the technology process to minimize risks and exposure levels to human health and the environment during construction and implementation. Those technology and process options that have demonstrated effectiveness in treating wastes and contaminants similar to the IWCS were rated high or moderate. Process options providing significantly less effectiveness than other more-promising options, as well as those that do not provide adequate protection of human health and the environment, were rated as low. Ratings for individual technologies are summarized in the following sections and detailed in Appendix E.

The implementability evaluation places emphasis on the conventional aspects of implementability, such as the ability to construct and operate the technology; the availability and capacity of treatment, storage, and disposal services; the availability of necessary equipment and skilled workers; the ease of undertaking additional steps that may be required to implement a technology, such as pre-treatment or management of residual wastes; and the ability to monitor remedial effectiveness. Process options that are infeasible or require equipment, specialists, or facilities that are not available within a reasonable period of time are rated as low.

In accordance with EPA guidance (EPA 1988), cost plays a limited role in the screening of remedial technologies and process options. Relative cost may include capital costs and operation and maintenance (O&M) costs based on readily published information rather than detailed cost estimates. Costs for each technology are rated qualitatively on the basis of engineering judgment and relative to the other process options in the same technology type. The average reported or estimated cost of a process option is rated as low (less than 150 U. S. dollars [$]/yd^3), moderate (between $150/yd^3 and $300/yd^3), or high (greater than $300/yd^3). Costs that are grossly excessive compared to the overall effectiveness of technologies are rated as high.

Remedial technologies or process options were eliminated from further consideration if they received the following ratings:

- low effectiveness and low implementability,
- low effectiveness and moderate implementability, and
- moderate effectiveness and low implementability.

Table 2-2 summarizes the ratings for each of the retained technologies and process options and identifies those retained for further consideration. The following sections summarize the rationale for ranking each technology.

2.4.1 Land-Use Controls

LUCs include institutional and engineering controls that help prevent human or ecological exposure to contaminants. Three types of institutional controls (proprietary, governmental, and informational), as well as various types of engineering controls (e.g., fences or other physical barriers, signs, and security measures), were retained. Maintenance and surveillance activities and environmental monitoring were retained as components of any remedial actions for Subunits A, B, and C where waste would remain on-site.

Table 2-2. Summary of Ratings[a] for Technologies

GRA/Technology/ Process Option	Effectiveness	Implementability	Cost	Retained?	Note
LUCs	Moderate	High	Moderate	Yes	LUCs are rated when used in conjunction with other GRAs; they are not considered as a stand-alone option; the moderate rating for cost reflects the long period of time they would need to be maintained
Enhanced Containment	Moderate	High	Moderate	Yes	The high rating for implementability reflects successful implementation of this technology throughout the industry
Removal (mechanical)	Low to high	Moderate	Moderate	Yes	Rating for effectiveness depends on technology method and IWCS subunit
Removal (hydraulic)	Moderate	Low	High	No	Applies to Subunit A only
Removal (demolition)	Moderate to high	Moderate to high	Low to moderate	Yes	Applies to structure demolition only (Subunit B); different technologies received different ratings (see Appendix E for detail)
Treatment (S/S)	Moderate	High	Moderate	Yes	Applies to Subunit A only
Treatment (vitrification)	Moderate	Low	High	No	Applies to Subunit A only
Treatment (metals recovery)	Moderate	Low	High	No	Applies to Subunit A and Subunit C (R-10 residues) only
Treatment (physical processes)	High	Moderate to high	Low	Yes	Applies to structure demolition only (Subunit B); different technologies received different ratings (see Appendix E for detail)
Disposal (on-site)	Moderate	Low	Moderate	No	The low rating for implementability reflects concerns about siting a new waste cell
Disposal (off-site)	High	High	High	Yes	Implementability was rated high based on the evaluation of off-site disposal facilities in the *Waste Disposal Options and Fernald Lessons Learned Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (USACE 2011a)

[a] This table summarizes the evaluation of a range of technologies and process options and, as a result, a range of ratings (i.e., moderate to low) is presented. The evaluation and rating for each specific technology or process option is summarized in Appendix E and detailed in the *Remedial Action Objectives and Applicable or Relevant and Appropriate Requirements for the Interim Waste Containment Structure Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York* (USACE 2012a).
Gray shading denotes technologies that are not retained.
GRA = General response action.
IWCS = Interim Waste Containment Structure.
LUC = Land-use control.
S/S = Solidification/stabilization.

LUCs were not retained as a stand-alone option; however, they were retained for use in combination with other GRAs. In combination with other GRAs, they were rated as high for implementability and moderate for effectiveness. They were not rated high against these criteria because the IWCS LUC(s) would have to remain effective for up to 1,000 years. The cost of LUCs, in general, is relatively low. However, because the O&M activities associated with LUCs are long term, the overall cost is rated moderate.

2.4.2 Enhanced Containment

The existing IWCS is a containment system that includes an engineered cap (multi-layer cap), vertical barriers (clay trench walls and dikes), and horizontal barriers (two natural clay layers). The additional containment technologies considered for potential use at the IWCS are enhancements to the existing structures that extend the functional life of the cap. Therefore, this technology is evaluated as an enhanced containment action. Containment enhancements evaluated include an enhanced cap and sidewalls to minimize radionuclide migration, inadvertent intrusion, and soil erosion. Some of the enhancements to existing barriers may include previously evaluated design details for a longer-term cap, such as an increase in multi-layer cap clay layer thickness, adding a geomembrane directly above the clay to further resist infiltration through the waste, adding a rock rip-rap layer between the clay and topsoil layers to restrict inadvertent intrusion and to act as a biobarrier, and adding clay fill material to the existing side slopes to reduce the maximum surface slope (DOE 1986a, 1986b). Enhanced containment was retained for further consideration for Subunits A, B, and C, rating moderate for effectiveness, high for implementability, and moderate for relative cost.

2.4.3 Removal

Mechanical removal (e.g., excavators, a crane and dredging clamshell, and a dragline system) was evaluated for all three subunits, while two additional technologies, hydraulic and auger mining, were evaluated for Subunit A only.

Effectiveness for individual removal technologies was rated low to high depending on the technology method and the associated IWCS subunit. Overall, removal technologies were rated as moderate to high for effectiveness because they result in permanent removal of the waste.

Demolition rated moderate to high for implementability. Mechanical removal rated moderate. Mechanical removal actions include the use of equipment to excavate contaminated media from its current location and place it for subsequent transport to another location. Conventional earthmoving equipment includes bulldozers, scrapers, excavators, loaders, and backhoes.

Hydraulic mining was used as the removal technique for the K-65 residues during the Fernald K-65 Project. Hydraulic mining received a low rating for implementability. One of the key lessons learned during the Fernald K-65 Project was that the large volume of water needed to power jet the residues and transfer and manage them in the slurry form resulted in a large amount of process water that resulted in large storage and treatment costs. The Fernald K-65 Project approach required the following:

- A silo waste retrieval system – This system 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.

- Four temporary storage tanks and associated building – The temporary storage tanks consisted of four, approximately 2,800-m^3 (750,000-gallons [gal]) American Petroleum Institute 650 carbon steel storage tanks located in a shielded concrete vault identified as the transfer facility.

- A water treatment system – This system was costly and was needed for the large volume of waste water that was generated during the process.

The need for these additional components added approximately $35 to $45M to construction costs and extended the project schedule. As a result, hydraulic mining received a high rating for cost. The other removal technologies rated low to moderate for cost.

2.4.4 Treatment

Treatment was retained for only two waste types within the IWCS: the high-activity ore residues within Subunit A, and the building structures within Subunit B. Treatment by solidification/stabilization (S/S) was retained for Subunit A and by physical processes (demolition) for Subunit B.

2.4.4.1 Subunit A ore residues

A single technology, S/S, was retained for treating the Subunit A residues. Rationale for screening of other technologies is provided in Appendix E. S/S is a technology that physically binds or encloses contaminants within a stabilized mass (solidification) and/or induces chemical reactions between a stabilizing agent and contaminants to reduce their mobility (stabilization). For the Fernald K-65 Project, conventional S/S using cement and/or fly ash was used to successfully treat the K-65 residues that were formerly contained in Silos 1 and 2 (USACE 2011a).

Although successfully applied for the Fernald K-65 Project, S/S received a moderate rating for effectiveness because (1) although it stabilizes materials to prevent leaching, it does not eliminate external radiation effects (EPA 1996); (2) it can significantly increase the total volume of contaminated material (up to double the original volume) that would require disposal because of the addition of stabilizing agents such as Portland cement or fly ash (EPA 2007); and (3) the long-term effectiveness of cement S/S on the Fernald K-65 Project residues is yet to be determined.

S/S received a high rating for implementability because issues that could occur during implementation were identified and mitigated during the Fernald Site remediation, thus indicating this technology can be successfully and safely implemented. The cost for this technology was rated moderate.

Of note for the IWCS FS is that the ex-situ vitrification technology has not been retained for the detailed analysis. This is due to lessons learned (DOE 1999) regarding the failed implementation of vitrification at the Fernald K-65 Project (USACE 2011a). This technology remains difficult to implement, particularly on solid waste streams, and would require extensive testing prior to implementation.

Also of note is the metals recovery process was not retained for detailed analysis. In addition to uranium, the pitchblende ores were rich in precious metals, such as gold, platinum, palladium, and silver. Most of the uranium was removed from the K-65 residues, and the radium was precipitated out as radium sulfate. Several metal hydroxides (e.g., iron, aluminum, and manganese) and other impurities, such as precious metals, also were precipitated. Some precious metals were extracted from some shipments of the ore prior to processing for uranium (DOE 1986a). Although these ores were processed to extract uranium and precious metals, the residues still contain appreciable quantities of these materials (Battelle 1981a). The K-65 residues have much less cobalt, nickel, and copper and more rare earths, palladium, molybdenum, and lead than do the other residues. The L-30 residues have more uranium. All of the residues have a small amount of gold, platinum, and other noble metals (DOE 1986a).

2.4.4.2 Building structures

For decontamination of building structures (primarily in Subunit B), two technologies were retained: surface removal (e.g., abrasive blasting, scarification, grinding, planning, spalling, and vibratory finishing) and surface decontamination (e.g., high-pressure steam and water). In addition, surface barriers, such as surface sealants, were retained for Subunit B and could be applied to the structural surfaces of Buildings 411, 413, and 414 prior to demolition. Each of these technologies is proven to be moderately to highly implementable, highly effective, and low cost for decontamination and demolition (D&D) support.

2.4.5 Disposal

Disposal of IWCS residues and wastes at a new on-site disposal facility is not retained for further analysis because of the administrative challenges related to implementability. For any alternative that requires excavation and generation of waste that would require treatment of some or all of the waste stream, the regulations and practical considerations suggest disposal should take place at an existing off-site disposal facility.

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3.0 DEVELOPMENT OF ALTERNATIVES

Remedial alternatives for the IWCS to be carried forward into a detailed analysis have been developed using a two-step process. First, technologies and process options retained from the screening step presented in Chapter 2.0 were assembled into potential remedial actions for each of the IWCS subunits. Second, the individual subunit actions have been assembled into a set of remedial alternatives. This section describes the set of five alternatives for the IWCS to be carried forward into the detailed analysis of alternatives (Chapter 4.0) and subsequent comparative analysis (Chapter 5.0).

3.1 IDENTIFICATION OF SUBUNIT REMEDIAL ACTIONS

Through the identification and evaluation of remedial technologies and process options, the following remedial actions for each subunit were identified. The No Action alternative is evaluated as part of the FS process as a baseline for comparison to the other alternatives being considered (40 *CFR* 300.430[e][6]):

Subunit A: Residues and Commingled Wastes Within Buildings 411, 413, and 414:

- A1: No Action;
- A2: Enhanced Containment with LUCs; and
- A3: Removal, Treatment, and Off-site Disposal.

Subunit B: Debris and Wastes in the South End of the IWCS:

- B1: No Action,
- B2: Enhanced Containment with LUCs, and
- B3: Removal and Off-site Disposal.

Subunit C: Low-Activity Residues and Wastes in the North End of the IWCS:

- C1: No Action,
- C2: Enhanced Containment with LUCs, and
- C3: Removal and Off-site Disposal.

3.2 IDENTIFICATION OF REMEDIAL ALTERNATIVES FOR THE INTERIM WASTE CONTAINMENT STRUCTURE FEASIBILITY STUDY

Combinations of remedial actions for each subunit were identified and evaluated. Table 3-1 summarizes each combination. A combined alternative was not retained if Subunit A (with its higher level of radioactivity) was dealt with less aggressively than Subunit B or C (with lower levels of radioactivity). For example, combinations, such as Subunit A residues remaining in the IWCS but Subunit C being disposed off-site, were screened out.

As a result of the consolidation of remedial actions, No Action (required for all assessments) and four IWCS remedial alternatives are retained for the detailed analysis (Table 3-2).

All of the removal-based alternatives (3A, 3B, and 4) include treatment of the Subunit A waste but do not include planned treatment of the wastes in Subunits B and C. Treatment of the wastes in Subunits B and C is not proposed unless pre-design sampling indicates treatment is necessary to meet the waste acceptance criteria (WAC) at a disposal facility or to meet U. S. Department of Transportation (DOT) requirements. LUCs are inherent in each alternative where IWCS wastes would remain on-site.

Table 3-1. IWCS Alternatives Assembly

Combination	Alternative Description	Retained?
A1, B1, C1	No Action	Yes
A2, B2, C2	Enhanced Containment	Yes
A2, B2, C3	Enhanced Containment of Subunit A Enhanced Containment of Subunit B Removal and Off-site Disposal of Subunit C	No
A2, B3, C2	Enhanced Containment with LUCs of Subunit A Removal and Off-site Disposal of Subunit B Enhanced Containment with LUCs of Subunit C	No
A2, B3, C3	Enhanced Containment with LUCs of Subunit A Removal and Off-site Disposal of Subunit B Removal and Off-site Disposal of Subunit C	No
A3, B2, C2	Removal, Treatment, and Off-site Disposal of Subunit A Enhanced Containment and LUCs of Subunit B Enhanced Containment and LUCs of Subunit C	Yes
A3, B2, C3	Removal, Treatment, and Off-site Disposal of Subunit A Enhanced Containment and LUCs of Subunit B Removal and Off-site Disposal of Subunit C	No
A3, B3, C2	Removal, Treatment, and Off-site Disposal of Subunit A Removal and Off-site Disposal of Subunit B Enhanced Containment and LUCs of Subunit C	Yes
A3, B3, C3	Removal, Treatment, and Off-site Disposal of Subunit A Removal and Off-site Disposal of Subunit B Removal and Off-site Disposal of Subunit C	Yes

Gray shading denotes technologies that are not retained.
IWCS = Interim Waste Containment Structure.
LUC = Land-use control.

Table 3-2. Remedial Alternatives for the IWCS OU

Alternative Type	Alternative ID	Alternative[a]
No Action	1	No Action
Enhanced Containment	2	Enhanced Containment of Subunits A, B, and C
Partial Removal with Off-Site Disposal and Enhanced Containment of Residual Waste	3A	Removal, Treatment, and Off-site Disposal of Subunit A Enhanced Containment of Subunits B and C
	3B	Removal, Treatment, and Off-site Disposal of Subunits A and B Enhanced Containment of Subunit C
Complete Removal	4	Removal, Treatment, and Off-site Disposal of Subunits A, B, and C

[a] All removal alternatives (3A, 3B, and 4) assume treatment of Subunit A waste. Land-use controls are assumed for any alternative where IWCS wastes would remain on-site.
ID = Identifier.
IWCS = Interim Waste Containment Structure.
OU = Operable unit.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

4.1 DESCRIPTION OF THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT APPROACH

The detailed analysis of alternatives assembles information on each remedial alternative so that the rationale for selecting one remedy over another is documented and clear. The analysis is performed by evaluating each alternative against nine criteria that reflect the statutory requirements of CERCLA Section 121 and technical and cost considerations deemed appropriate for consideration in the remedy selection (EPA 1988). Two of the criteria, regulatory acceptance and community acceptance, are addressed later in the process, when the Proposed Plan is developed, and are not discussed in this FS. The remaining seven criteria include two threshold and five balancing criteria.

The two threshold criteria include:

- **Overall Protection of Human Health and the Environment** – This assessment is the final determination that an alternative provides adequate protection of human health and the environment. It draws on the findings from other assessments, especially long-term protection of human health, short-term effectiveness, and compliance with ARARs. It addresses the ability of the alternative to meet the project RAOs. The RAOs for the IWCS are listed in Section 1.6.

- **Compliance with ARARs** – This assessment determines whether the alternative meets the requirements of the laws identified as ARARs. The ARARs for the IWCS are listed in Section 1.5.

The five balancing criteria are the primary criteria used to define and compare alternatives. These include:

- **Long-Term Effectiveness and Permanence** – This assessment evaluates the ability of the alternative to be effective and to protect human health and the environment once the action is complete.

- **Reduction in Toxicity, Mobility, and Volume Through Treatment** – The CERCLA law includes a statutory preference for selecting alternatives that permanently treat wastes to reduce toxicity, mobility, and volume. This analysis assesses whether the alternative meets this preference.

- **Short-Term Effectiveness** – This assessment evaluates how the alternative addresses potential human health and environmental impacts during construction and implementation.

- **Implementability** – This assessment evaluates the technical and administrative implementability of the alternative.

- **Cost** – This assessment evaluates the capital and O&M costs of the alternative.

Table 4-1 lists additional specific factors that are useful in performing each of the assessments.

The assembled alternatives are combinations of standard remedial actions for each of the three subunits. As such, much of the information presented for one alternative also applies to other alternatives (e.g., the cap for Alternative 2 also applies to Alternatives 3A and 3B) and will not be repeated throughout the section. The detailed conceptual designs (including drawings) for the remedial actions are provided in appendices and drawings that are referenced as necessary in this detailed analysis. The reader is referred to Appendices F, G, and H for the full conceptual designs of the actions. Table 4-2 provides a crosswalk of the location of the information for each assembled alternative (minus the No Action alternative).

Table 4-1. Factors Used in the Detailed Analysis of Alternatives

Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost
• Magnitude of residual risk • Adequacy and reliability of controls	• Treatment process used and materials treated • Amount of hazardous materials destroyed or treated • Degree of expected reduction in toxicity, mobility, and volume • Degree to which treatment is irreversible • Type and quantity of residuals remaining after treatment	• Protection of community during remedial actions • Protection of workers during remedial actions • Environmental impacts • Time until remedial action objectives are achieved	• Ability to construct and operate the technology • Reliability of the technology • Ease of undertaking additional remedial actions, if necessary • Ability to monitor effectiveness of remedy • Ability to obtain approvals from other agencies • Coordination with other agencies • Viability of off-site treatment, storage, and disposal services and capacity • Availability of necessary equipment and specialists • Availability of prospective technologies	• Capital costs • O&M costs • Present worth costs

O&M = Operation and maintenance.

Table 4-2. Crosswalk of Actions, Alternatives, and Locations of Detailed Information in Appendices and Drawings

Remedial Action	Subunit	Alternative 2	Alternative 3A	Alternative 3B	Alternative 4	Location of Detailed Conceptual Design
Enhanced Containment	A	X				Appendix G
	B	X	X			
	C	X	X	X		
Removal, Treatment, and Off-Site Disposal	A		X	X	X	Appendix F
Removal and Off-Site Disposal	B			X	X	Appendix H
	C				X	
Civil Drawing Numbers		C-7, C-8, C-9, C-20	C-10, C-11, C-12	C-13, C-14, C-15	C-16, C-17, C-18, C-19	Appendix K

4.2 ANALYSIS OF ALTERNATIVE 1 – NO ACTION

The National Oil and Hazardous Substances Pollution Contingency Plan (40 *CFR* 300.430[e][6]) requires the No Action alternative be evaluated as part of the FS process as a baseline for comparison to the other alternatives being considered. EPA considers this alternative to equate with baseline conditions.

4.2.1 Description of Alternative 1

For this FS, the definition of No Action is adopted from EPA guidance (EPA 1988). Because no remedial activities or long-term maintenance or monitoring would be implemented with the No Action alternative, long-term human health and environmental risks for the site essentially would be the same as those identified in the baseline risk assessment (USACE 2007c), or in the case of the IWCS, the potential risks identified in Appendices B and C.

The No Action alternative, as defined by EPA (EPA 1988):

- Provides no control of exposure to contaminated soil and no reduction in risk to human health posed through groundwater.
- Includes no LUCs to prevent exposure and no long-term management measures. All current and potential future risks would be valid under this alternative.
- Provides no reduction in toxicity, mobility, or volume of contaminated soil through treatment.
- Results in no implementability concerns because no action would be taken.

The capital and O&M costs of Alternative 1 are estimated to be $0 because there would be no action.

Following is the assessment of the No Action alternative for the IWCS.

4.2.2 Comprehensive Environmental Response, Compensation, and Liability Act Criteria

Detailed analysis of Alternative 1 according to CERCLA threshold and balancing criteria is provided in the following sections. Table 4-3 presents the results of the analysis; supporting detail is provided in Sections 4.2.3 and 4.2.4.

Table 4-3. Detailed Analysis of Alternative 1 (No Action)

CERCLA Threshold Criteria		
CERCLA Criterion		**Result of Evaluation**
Overall protection of human health and the environment		Not protective over the long term; Resident Intruder could be exposed to unacceptable risk
Compliance with ARARs		Does not comply with ARARs
CERCLA Balancing Criteria		
CERCLA Criterion	**Evaluation Factor (Table 4-1)**	**Results of Evaluation**
Long-Term Effectiveness and Permanence	Magnitude of residual risk	All residues and waste remain in place resulting in unacceptable risk
	Adequacy and reliability of controls	No LUCs. Current site controls cease
	Summary	Not effective at preventing long-term exposures assuming absence of LUCs. Estimated cancer risk is 4×10^{-1}, three orders of magnitude greater than the acceptable human health risk range. Ecological risk also exceeded
Reduction of Toxicity, Mobility, and Volume Through Treatment	Treatment process used and materials treated	No treatment used
	Amount of hazardous materials destroyed or treated	No materials destroyed
	Degree of expected reduction in toxicity, mobility, and volume	No reduction in toxicity, mobility, or volume
	Degree to which treatment is irreversible	No treatment used
	Type and quantity of residuals remaining after treatment	All ore residues and wastes remain
	Summary	Does not reduce toxicity, mobility, or volume through treatment
Short-Term Effectiveness	Protection of community during remedial actions	No short-term impacts to community
	Protection of workers during remedial actions	No short-term impacts to workers
	Environmental impacts	No short-term impacts to the environment
	Time until remedial action objectives are achieved[a]	Zero years
	Summary	No short-term impacts
Implementability	Ability to construct and operate the technology	No action proposed
	Reliability of the technology	NA
	Ease of undertaking additional remedial actions, if necessary	Additional action could be implemented
	Ability to monitor the effectiveness of the remedy	No monitoring proposed
	Ability to obtain approvals from other agencies	Unlikely
	Viability of off-site treatment, storage, and disposal services and capacity	NA
	Availability of necessary equipment and specialists	NA
	Summary	NA
Cost	Capital costs	Zero cost
	O&M costs (not discounted)	Zero cost
	Present worth O&M costs (discounted)	Zero cost

[a] Estimates to complete the action assume projects receive sufficient annual funding to meet schedules.
ARAR = Applicable or relevant and appropriate requirement.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
LUC = Land-use control.
NA = Not applicable.
O&M = Operation and maintenance.

4.2.3 Threshold Criteria

4.2.3.1 Overall protection of human health and the environment

Ongoing environmental monitoring indicates that there is no current hazard to human health and the environment from the wastes and residues in the IWCS as long as current programs to monitor, maintain the cap, and control access—specifically to control human intrusion—are in place. Under the No Action alternative, these programs are assumed to cease. If access controls are no longer in place and a Resident Intruder scenario becomes viable, the No Action alternative would not be protective of human health and the environment (see Section 4.2.3.1 for a discussion of intruder risks).

4.2.3.2 Compliance with ARARs

As indicated in Section 1.2.8, the IWCS currently meets most of the performance requirements of the ARARs identified in Section 1.5. However, under the No Action alternative, current maintenance activities that help ensure compliance with ARARs would cease, resulting in conditions that could reduce the effectiveness of the cap to a point that releases exceed the performance criteria in the ARARs. As such, this alternative would not comply with identified ARARs.

4.2.4 Balancing Criteria

4.2.4.1 Long-term effectiveness and permanence

Ongoing monitoring of radon in air and gamma radiation demonstrates that the multi-layer cap currently in place is effective at limiting human exposure to radionuclides in the IWCS to levels below risk-based and regulatory-based standards. However, the existing cap layers require maintenance to ensure they remain competent over the long term. Because the design specification for the life of the existing cap is 25 to 50 years, additional actions would be required to maintain the IWCS to provide long-term effectiveness.

Because active site control (monitoring and maintenance) would terminate under the No Action alternative, the assessment of long-term effectiveness for this alternative must also account for additional future land uses. Historical risk assessments and fate and transport modeling efforts for the IWCS have considered future land uses, including (1) future human intrusion into the waste and subsequent direct exposure to the primary radionuclides within the IWCS, and (2) migration of the contaminants to and through groundwater to potential future drinking water users.

The Resident Intruder is a person who might occupy the disposal site after closure and engage in normal activities, such as agriculture, the construction of dwellings, or other pursuits in which the person might be unknowingly exposed to radiation from the waste. The Final Environmental Impact Statement for the IWCS evaluated a Resident Intruder looking only at the risk from radon inhalation (DOE 1986a). Subsequent revisions to this analysis in the Health Effects TM (USACE 2012b) provided an estimate of fatal cancer risks of 0.4, or 4×10^{-1}. This estimate was based on an average Ra-226 concentration in the high-activity IWCS residues of 152,000 pCi/g.

An estimated fatal cancer risk of 4×10^{-1} is three orders of magnitude above the acceptable human health risk range. Thus, the No Action alternative does not meet the requirements for long-term protectiveness and permanence for human health. No Action also would not meet the long-term protectiveness and permanence requirements for the environment.

To support the analysis of the potential for contaminants to leach to groundwater and pose a risk to future groundwater users, a three-dimensional groundwater flow and solute transport model previously developed for the NFSS (USACE 2007b; 2011d) was used to predict the transport of radionuclides from the IWCS. For this analysis, a site-specific NFSS model was applied to quantify rates of solute transport and predicted concentrations of IWCS-derived wastes at vertical and lateral boundaries over time. As required by 10 *CFR* 40, Criterion 5B, the selected point of compliance for the modeling analysis is the top of the Alluvial Sand and Gravel Aquifer at the IWCS boundary. The period of compliance is dictated by 10 *CFR* 40 Criterion 6, which requires the cap to be effective for up to 1,000 years.

The details of the modeling effort are presented in Appendix B. Key results for the Alternative 1, No Action, simulation are as follows:

- At the IWCS boundary coincident with the IWCS cut-off wall in the brown clay till, a U-238 concentration of 0.04 pCi/L is predicted at 200 years. By 1,000 years, this concentration is predicted to increase to 0.92 pCi/L. Both concentrations are well below the total uranium maximum contaminant level and New York State Department of Health drinking water standard of 27 pCi/L (USACE 2012d). Both the brown clay till and gray clay units produce poor water quality, and water from either of these units would have to be treated prior to domestic use.

- At the IWCS boundary in the Alluvial Sand and Gravel Aquifer (the point of compliance), predicted U-238 concentrations are predicted to be zero at 1,000 years.

- Concentrations of thorium-230, Ra-226, and lead-210 are predicted to be negligible or non-detectable at the IWCS boundaries throughout 1,000 years of simulation time.

- For all simulation time periods, the model predicts that radionuclides in the IWCS will not migrate to the NFSS site boundary point of compliance at detectable concentrations.

Vertical migration to the lower groundwater zone is predicted to be at levels below detection limits at the point of compliance; hence, this alternative meets the RAO for preventing the transport of hazardous substances to groundwater.

In summary, the No Action alternative would not be effective over the long term in preventing unacceptable exposures to future human receptors. Because of the absence of LUCs and cap maintenance under this alternative, risk to the Resident Intruder who may be exposed directly to the high-activity residues in Subunit A is unacceptable. The estimated cancer risk to the Resident Intruder exceeds the risk limit by three orders of magnitude.

4.2.4.2 Reduction of toxicity, mobility, and volume through treatment

The No Action alternative provides for no treatment of the wastes within the IWCS and, therefore, there is no reduction in the toxicity, mobility, or volume of the wastes. Natural processes (i.e., radioactive decay) occurring within the IWCS will not degrade the waste to acceptable levels. No waste is destroyed under this alternative, which results in a residue waste stream that presents an unacceptable risk to the Resident Intruder.

4.2.4.3 Short-term effectiveness

Because there are no remedial actions planned under this alternative, there would be no additional short-term risk to the community, workers, or the environment.

4.2.4.4 Implementability

Because no construction, remediation, or long-term maintenance activities are planned under this alternative, there are no engineering implementability considerations.

4.2.4.5 Cost

There are zero capital and long-term operations, maintenance, and monitoring costs associated with the No Action alternative.

4.3 ANALYSIS OF ALTERNATIVE 2 – ENHANCED CONTAINMENT

4.3.1 Description of Alternative 2

The existing IWCS is a containment system that includes horizontal barriers (a multi-layer cap and underlying naturally occurring clay layers) and vertical barriers (clay trench walls and dikes). Alternative 2 proposes an enhanced containment system for all three subunits within the IWCS. Because the technology selected is an enhancement to the existing waste containment method and not a new technology, this alternative is referred to as enhanced containment. This alternative includes various engineered and administrative LUCs. Appendix G presents the detailed conceptual design for this alternative. The design is used to effectively evaluate Alternative 2 against the CERCLA criteria and to develop the FS cost estimate. The conceptual layout for this alternative is presented in Drawings C-7, C-8, C-9, and C-20 within Appendix K.

The primary objectives of the enhanced containment system are protecting human health and the environment by maintaining control of the buried waste, preventing direct contact with potential receptors, and protecting against potential releases throughout the required life of the facility. Therefore, a conceptual design for the enhanced containment system was developed to meet the following criteria (see Appendix G):

- Provide a structurally stable, long-term cap so that no sliding or sloughing of the structure occurs under the most severe conditions; ideally no steeper than 20% slopes.
- Provide a barrier to radiation and radon emanation to prevent potential exposures.
- Resist water infiltration from precipitation to prevent waste saturation and leachate generation by establishing a fully self-sustaining vegetative cover.
- Minimize wind and water erosion and promote evapotranspiration—use embankment and cover slopes to minimize erosion potential and to promote deposition (with conservative factors of safety); ideally no steeper than 20% slopes.
- Prevent cap degradation caused by mechanical forces (i.e., freeze/thaw cycles and flooding).
- Prevent desiccation and cracking of the cap component.
- Prevent human intrusion into the waste.
- Prevent biointrusion into the waste (burrowing animals and plant roots).
- Provide for controlled drainage to prevent head build-up on the barrier component of the cap.

- Resist migration of contaminants in the waste to groundwater.

The results of the Failure Analysis Report (BNI 1994) also were used to identify potential modifications and performance improvements for the enhanced containment conceptual design.

The proposed multi-layered cap would contain the following layers (described from the waste upward) (Figure 4-1 and Appendix K, Drawing C-20):

- Approximately 1 m (3 ft) of compacted, low-permeability clay to resist water infiltration to the underlying waste and to attenuate radon emissions and gamma radiation. The clay layer would serve as the principle barrier to water infiltration, radon emanation, and gamma radiation and exhibits an average permeability of 2.15 x 10^{-8} cm/sec.

- A 60-mil, high-density, polyethylene geomembrane liner that, when used with the clay component as a composite layer, would resist infiltration to a greater extent than both the clay and the geomembrane when used individually.

- A 0.15-m (6-in.) sand drainage layer sloped to direct percolating rainwater away from the geomembrane-clay composite layer and to reduce the head on the geomembrane liner, thereby reducing transmission of water through the liner. The sand would have a minimum permeability of 1 x 10^{-2} cm/sec.

- A 0.46-m (1.5-ft) rip-rap biointrusion layer consisting of R-4 rip-rap (average rock size of 0.2 m [8 in.]) with a maximum rock size of 0.3 m (12 in.) and a gravel choke course to protect against frost action, erosion, root penetration, and damage caused by burrowing animals. Separation geotextile below and above the rip-rap would function as filter layers designed to prevent the fine-grained silt subsoil layer (above) from entering and reducing the biointrusion properties of the rip-rap and choke course and to prevent IWCS surface subsidence features. Likewise, the geotextile would prevent the sand particles from migrating into the overlying rip-rap layer.

- A 0.46-m (1.5-ft) subsurface soil/common fill layer to provide an evapotranspiration and rooting zone for the shallow-rooted turf established on the topsoil layer, to promote growth of the vegetative cover, and to furnish additional resistance to surface water erosion of the underlying layers.

- A 0.15-m (6-in.) topsoil layer to maintain vegetative growth and reduce the potential for erosion.

The enhanced containment system also would include the existing clay dike and cut-off walls that form part of the waste containment system. The dike has a minimum width of 2.4 m (8 ft) and extends approximately 1.5 m (5 ft) above the original grade. The dike rests on the cut-off wall, which has a minimum width of 3.7 m (12 ft) and extends at least 0.49 m (1.6 ft) into the gray clay unit. The gray clay unit serves as the bottom of the containment system. The thickness of the cut-off wall ranges between 3.0 and 6.7 m (10 and 22 ft), varying with changes in the elevation of the top of the gray clay unit (DOE 1986b). The existing dike and cut-off walls surrounding the IWCS function as hydraulic and adsorption barriers to radionuclide migration from the waste containment area.

The enhanced containment cap would measure approximately 160 m wide and 323 m long (525 ft wide and 1,060 ft long) or approximately 5.18 ha (12.8 acre) and extend beyond the existing clay dike. The maximum elevation of the final enhanced cap would be 108 m (353 ft) above mean sea level for a maximum height of 11 m (36 ft). The distance from the buried waste to the existing NFSS property boundary is approximately 61 m (200 ft) and provides a sufficient buffer zone between the buried waste and the property boundary.

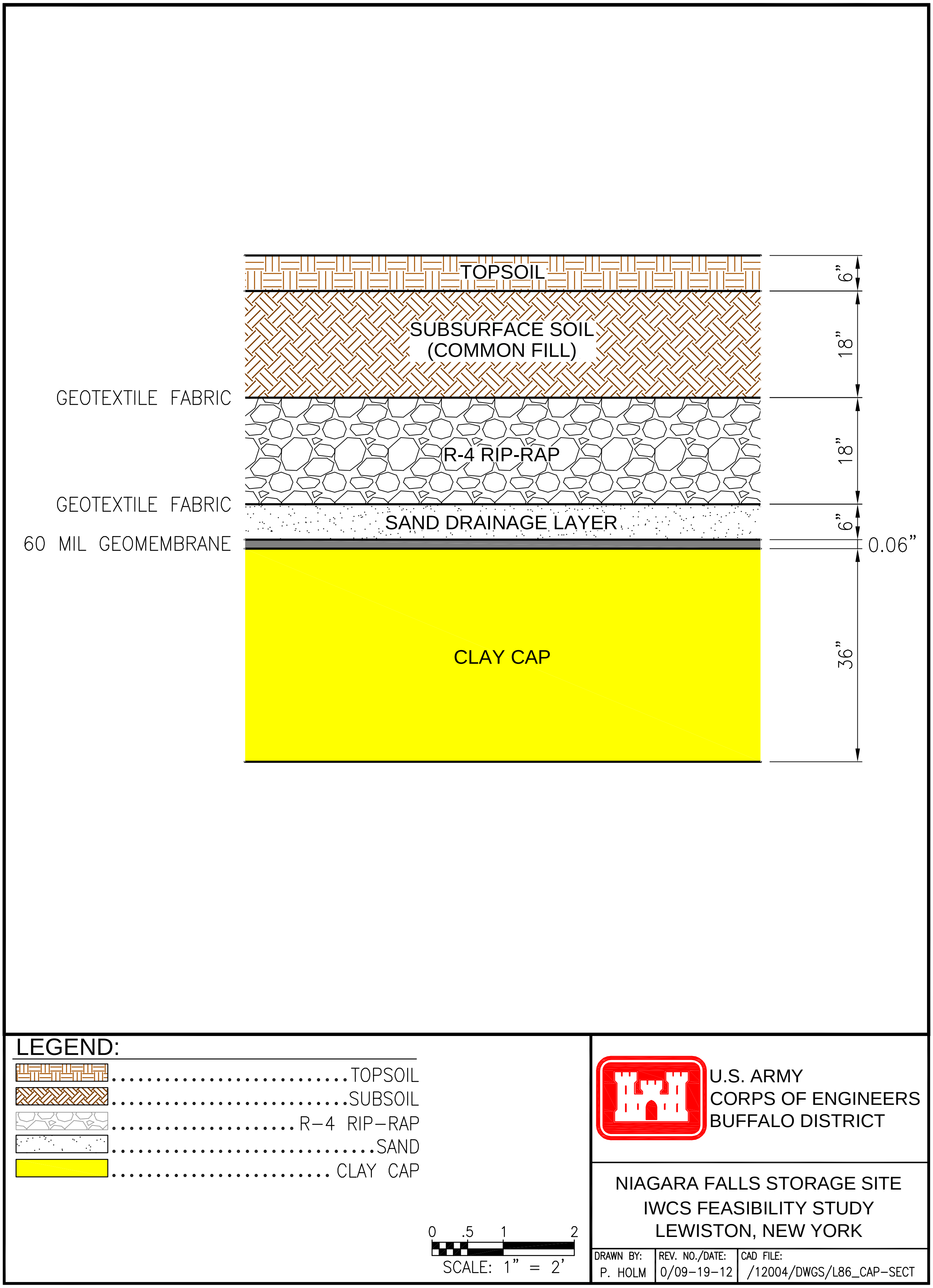

Figure 4-1. Enhanced Cap Cross-Section

Three additional components of the enhanced containment system for the IWCS would include the following:

- Construction of a 1.5-m (5-ft)-high and 248-m (815-ft)-long gabion wall on the east side of the IWCS to prevent encroachment of the enhanced cap into the Central Drainage Ditch.

- Addition of clay to the existing clay layer on the IWCS side slopes to flatten the slopes to 5:1 to increase slope stability during seismic events.

- Installation of R-6 rock rip-rap armor around the perimeter of the enhanced containment system to protect the landfill toe from flooding during a maximum probable flood event.

Maintenance of the enhanced cap would include inspection and grounds keeping of the vegetative cover (i.e., mowing and irrigation), clearing of the engineered surface water drainage channels, and inspection of the cap. The vegetative cover of the cap would be inspected for surface erosion, shrinkage cracks, seeps, animal burrows, and deep-rooted vegetation. Seeded areas would be fertilized and reseeded as necessary to maintain a vigorous, dense, vegetative cover. The cap would be inspected for subsidence, cracks, weathering, subsidence trends, or other integrity issues. Grid surveys would be used to detect surface deformation and to identify areas of vegetation stress as necessary. Additional requirements include inspection and maintenance of the fence around the property, roads and access to sampling locations, and any support facilities. Inspections are assumed to be completed at the time of groundwater sampling each fall and spring (after the last frost). Repairs, including compaction or regrading, would be required if biotic intrusion, settlement, or freeze-thaw effects are observed to have caused damage.

LUCs would be implemented to maintain perpetual, Federal, active control over the site. Long-term surveillance, monitoring, and maintenance of materials within the IWCS would be performed by the Federal Government. Additionally, the Federal Government would provide LUCs to prevent re-exposure of contaminants as necessary. LUCs would be defined in a LUC Plan, developed during the remedial design phase. The LUCs would be maintained until the remaining hazardous substances are at levels allowing for unlimited use and unrestricted exposure. Due to the presence of long-lived radionuclides in the IWCS, the LUCs would need to be maintained to provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Likely LUCs include the following:

- Prevent development and use for residential housing, schools, childcare, facilities, or playgrounds.

- Prevent construction activities involving drilling, borings, digging, or other use of heavy equipment that could disturb vegetation, disrupt grading or drainage patterns, cause erosion, or otherwise compromise the integrity of the landfill cover, or manage these activities such that any damage to the cover is avoided or repaired as necessary.

- Maintain administrative controls (e.g., deed restrictions).

- Perform periodic site inspections and review to verify integrity of the landfill cap.

- Provide for access necessary for continued maintenance, monitoring, inspections, or repair.

The enhanced containment system also would require an environmental monitoring program and a performance review of the continued protectiveness of the area at least once every 5 years. The site also could be designated by passive controls to include, but not be limited to, a marker that is as permanent as practicable. Markers are physical structures (e.g., earthworks and stone monoliths) that are capable of displaying a message for an extended period of time. The marker would serve to identify the site after permanent closure. Additional details are presented in Appendix G.

4.3.2 Comprehensive Environmental Response, Compensation, and Liability Act Criteria

Detailed analysis of Alternative 2 according to CERCLA threshold and balancing criteria is provided in the following sections. Table 4-4 presents the results of the analysis; supporting detail is provided in Sections 4.3.3 and 4.3.4.

4.3.3 Threshold Criteria

4.3.3.1 Overall protection of human health and the environment

Alternative 2 is protective of human health and the environment. In developing the design criteria for Alternative 2, several key design criteria were identified to prevent human exposure to unacceptable risk:

- Provide a structurally stable, long-term cap to prevent sliding or sloughing of the structure under the most severe reasonable conditions, thereby preventing erosion and subsequent receptor exposure.
- Provide a barrier to radiation and radon emanation to prevent potential exposures.
- Resist migration of contaminants in the waste to groundwater.
- Implement LUCs, including physical security measures (e.g., fencing, warning signs, and permanent land markers) and plans for monitoring and maintaining the site under Federal ownership in perpetuity. Perpetual maintenance of the multi-layered cap will ensure that human receptors are not directly exposed to the wastes and that the cap will not degrade to a point that radon levels would increase or leaching could occur.

Based on this, the human intruder identified for the No Action alternative (Alternative 1) is not applicable to Alternative 2 because measures are in place to prevent penetration of the cap. The human receptors identified to assess the overall protection of human health for Alternative 2 are the On-Site Maintenance Worker and the Off-Site Resident. Appendix C discusses the approach and model parameters used to assess the risk to these two receptors.

Two exposure pathways were evaluated for the On-Site Maintenance Worker: inhalation of radon and exposure to gamma radiation. The estimated cancer incidence risk from radon inhalation is 1.0×10^{-6}. The estimated gamma risk is 2.5×10^{-5}. The total estimated risk to the On-Site Maintenance Worker is 2.6×10^{-5} (Table 1-5).

Two exposure pathways were evaluated for the Off-Site Resident: inhalation of radon and exposure to gamma radiation. The estimated cancer incidence risk from radon inhalation is 1.0×10^{-7}. The estimated gamma risk is 3.3×10^{-7}. The total estimated risk to the Off-Site Resident is 4.4×10^{-7}.

The target risk range used in CERCLA decisions is 1×10^{-6} to 1×10^{-4}. The risks to the On-Site Maintenance Worker and the Off-Site Resident are within and below this target, respectively.

A second consideration in overall protection of human health is the ability of the cap to prevent leaching to groundwater above acceptable levels. Results of the modeling show that the enhanced cap would be protective of human health and the environment; the results are further discussed in Appendix B and in Section 4.3.3.1.

Table 4-4. Detailed Analysis of Alternative 2 (Enhanced Containment of Subunits A, B, and C)

CERCLA Threshold Criteria		
CERCLA Criterion		**Result of Evaluation**
Overall protection of human health and the environment		LUCs and cap maintenance are protective; prevents unacceptable exposures to IWCS materials
Compliance with ARARs		Complies with ARARs
CERCLA Balancing Criteria		
CERCLA Criterion	**Evaluation Factor (Table 4-1)**	**Results of Evaluation**
Long-Term Effectiveness and Permanence	Magnitude of residual risk	All residues and waste remain in place under the enhanced cap. Risk to human and ecological receptors is within or below the acceptable risk range
	Adequacy and reliability of controls	Structurally stable design, LUCs, and cap maintenance are in place to prevent exposure over the long term
	Summary	Structurally stable design, LUCs, and cap maintenance are effective at preventing unacceptable exposure to wastes over the long term
Reduction of Toxicity, Mobility, and Volume Through Treatment	Treatment process used and materials treated	No treatment used
	Amount of hazardous materials destroyed or treated	No materials destroyed
	Degree of expected reduction in toxicity, mobility, and volume	No reduction in toxicity, mobility, or volume
	Degree to which treatment is irreversible	No treatment used
	Type and quantity of residuals remaining after treatment	On-site untreated residuals = approximately 278,072 yd^3
	Summary	Does not reduce toxicity, mobility, or volume through treatment
Short-Term Effectiveness	Protection of community during remedial actions	Little to no potential for community exposure; truck traffic increases minimally
	Protection of workers during remedial actions	Low potential for exposure to workers
	Environmental impacts	Controls in place to prevent environmental impacts
	Time until remedial action objectives are achieved[a]	2 years
	Summary	Minimal short-term impacts can be addressed by work controls
Implementability	Ability to construct and operate the technology	Use of proven technologies increases constructability
	Reliability of the technology	Cap technology is reliable through the required performance period (1,000 years); cap maintenance and LUCs required
	Ease of undertaking additional remedial actions, if necessary	Additional action could be implemented
	Ability to monitor the effectiveness of the remedy	Monitoring currently proving effective; monitoring will remain in place under LUCs
	Ability to obtain approvals from other agencies	Would require discussion to obtain buy-in
	Viability of off-site treatment, storage, and disposal services and capacity	NA
	Availability of necessary equipment and specialists	Readily available
	Summary	Implementable
Cost	Capital costs	$23.4M
	O&M costs (not discounted)	$1,450M
	Present worth O&M costs (discounted)	$44.0M

[a] Estimates to complete the action assume projects receive sufficient annual funding to meet schedules.

ARAR = Applicable or relevant and appropriate requirement.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
IWCS = Interim Waste Containment Structure.
LUC = Land-use control.
NA = Not applicable.
O&M = Operation and maintenance.
yd^3 = Cubic yard.

4.3.3.2 Compliance with ARARs

The enhanced containment conceptual design was developed to meet the regulatory requirements of the identified ARARs. Table 4-5 presents the proposed design specifications identified to show compliance with these ARARs. Based on this analysis, the enhanced containment alternative can be implemented to comply with all ARARs.

4.3.4 Balancing Criteria

4.3.4.1 Long-term effectiveness and permanence

Under the enhanced containment alternative, all existing waste will be left in place. Therefore, engineered and administrative controls have been included to prevent human exposure to the waste over the long term and to resist leaching to groundwater.

As indicated in Section 4.3.2.1, the estimated direct-contact risk to the future On-Site Maintenance Worker and Off-Site Resident meets the definition of acceptable risk under CERCLA. Similarly, with the enhanced cap in place, there are no ecological risk concerns (see Section 1.4). Thus, Alternative 2 is effective at preventing long-term unacceptable radon and gamma radiation exposures.

To assess the potential for contamination migration to and through groundwater associated with Alternative 2, modeling was performed as described and detailed in Appendix B. Model results for the analysis of Alternative 2 are summarized below:

- At the IWCS boundary coincident with the IWCS cut-off wall in the brown clay till, no measurable radionuclide concentrations are predicted within the initial 200-year simulation period. At simulation time equal to 1,000 years, the concentration of U-238 is predicted to be 0.42 pCi/L. This is well below the total uranium background level of 16.7 pCi/L (USACE 2007a). Both the brown clay till and gray clay units produce poor water quality, and water from either of these units would have to be treated prior to domestic use.

- At the IWCS boundary point of compliance below the IWCS cut-off wall in the Alluvial Sand and Gravel Aquifer, U-238 concentrations are predicted to be zero at 1,000 years.

- Concentrations of thorium-230, Ra-226, and lead-210 are predicted to be negligible or non-detectable throughout 1,000 years of simulation time.

- For all simulation time periods, the model predicts radionuclides will not migrate to the NFSS site boundary at detectable concentrations.

The results of the enhanced containment alternative model runs indicate that the enhanced IWCS cap would remain protective out to the 1,000-year compliance period required in 10 *CFR* 40.

In summary, Alternative 2, Enhanced Containment, is protective of human health and the environment in the presence of long-term LUCs.

Reliability and permanence of the containment system

The overarching protection standard for the enhanced containment alternative is to "be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years" (10 *CFR* 40, Appendix A, Criterion 6[1], *Design of Earthen Cover*). In addition to this protection standard are

Table 4-5. ARARs Identified for Enhanced Containment for the IWCS FS

Criterion	Description	Design Objective	Design Specification
ARARs			
10 *CFR* Part 40, Appendix A, Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content			
Criterion 5B(1), Groundwater Protection Standards	"Uranium and thorium byproduct materials must be managed to conform to the following secondary ground-water protection standard: Hazardous constituents entering the ground water from a licensed site must not exceed the specified concentration limits in the uppermost aquifer beyond the point of compliance during the compliance period. Hazardous constituents are those constituents identified by the Commission pursuant to paragraph 5B(2) of this criterion. Specified concentration limits are those limits established by the Commission as indicated in paragraph 5B(5) of this criterion. The Commission will also establish the point of compliance and compliance period on a site specific basis through license conditions and orders. "	Establish points of compliance and long-term monitoring and compliance plan. Groundwater model illustrates the IWCS is not leaching contaminants to groundwater	Continue the existing environmental monitoring program. Develop monitoring plan for water infiltration into the cap surface. Design sampling ports that are easily accessible and measurable. Design flow-measuring devices that are easily maintained. Ensure existing monitoring points are either maintained or relocated as appropriate
Criterion 5B(2), Groundwater Protection Standards	"A constituent becomes a hazardous constituent subject to paragraph 5B(5) only when the constituent meets all three of the following tests: (a) The constituent is reasonably expected to be in or derived from the byproduct material in the disposal area; (b) The constituent has been detected in the ground water in the uppermost aquifer; and (c) The constituent is listed in Criterion 13 of this appendix."		
Criterion 5B(3), Groundwater Protection Standards	"Even when constituents meet all three tests in paragraph 5B(2) of this criterion, the Commission may exclude a detected constituent from the set of hazardous constituents on a site specific basis if it finds that the constituent is not capable of posing a substantial present or potential hazard to human health or the environment."		
Criterion 5B(5), Groundwater Protection Standards	"At the point of compliance, the concentration of a hazardous constituent must not exceed— (a) The Commission approved background concentration of that constituent in the ground water; (b) The respective value given in the table in paragraph 5C if the constituent is listed in the table and if the background level of the constituent is below the value listed; or (c) An alternate concentration limit established by the Commission."		
Criterion 5C, Maximum Values for Groundwater Protection	Provides maximum concentrations allowed in groundwater for arsenic; barium; cadmium; chromium; lead; mercury; selenium; silver; endrin; lindane; methoxychlor; toxaphene; 2,4-dichlorophenoxyacetic acid; 2,4,5-trichlorophenoxypropionic acid; radium-226; radium-228; and gross alpha		

Table 4-5. ARARs Identified for Enhanced Containment for the IWCS FS (continued)

Criterion	Description	Design Objective	Design Specification
Criterion 6(1), Closure of Waste Disposal Areas	"In disposing of waste byproduct material, licensees shall place an earthen cover (or approved alternative) over tailings or wastes at the end of milling operations and shall close the waste disposal area in accordance with a design which provides reasonable assurance of control of radiological hazards to (i) be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, and (ii) limit releases of radon-222 from uranium byproduct materials, and radon-220 from thorium byproduct materials, to the atmosphere so as not to exceed an average release rate of 20 picocuries per square meter per second ($pCi/m^2/sec$) to the extent practicable throughout the effective design life determined pursuant to (1)(i) of this Criterion. In computing required tailings cover thicknesses, moisture in soils in excess of amounts found normally in similar soils in similar circumstances may not be considered. Direct gamma exposure from the tailings or wastes should be reduced to background levels. The effects of any thin synthetic layer may not be taken into account in determining the calculated radon exhalation level. If non-soil materials are proposed as cover materials, it must be demonstrated that these materials will not crack or degrade by differential settlement, weathering, or other mechanism, overlong-term intervals"	Minimum clay cap thickness of 5.4 in. required to meet the regulatory criterion (BNI 1986a). Typically, at least four layers: (1) layer directly over waste, (2) interim cover, (3) radon barrier, and (4) erosion barrier/vegetative cover	Cap design includes a 3-ft-thick clay layer and five additional layers with a total thickness of 7 ft. Assess the design life of materials and estimate longevity. Evaluate the current monitoring system. Review the Radon TM (USACE 2012c) for proper controls. Perform necessary cap maintenance throughout the 1,000-year design life

ARAR = Applicable or relevant and appropriate requirement.
CFR = Code of Federal Regulations.
FS = Feasibility study.
ft = Feet.
in. = Inch.
IWCS = Interim Waste Containment Structure.
Radon TM: *Radon Assessment Technical Memorandum for the Niagara Falls Storage Site, Lewiston, New York.*

numerous industry standard practices for design specifications for long-term reliability of the cap (Appendix G). These specifications are designed to minimize cap erosion from rain (including floods) and wind, to specify reliable materials and material properties for the cap, and to emphasize engineered controls over administrative controls. Many of these industry standard practices are designed to address the long-term reliability of the cap. Table 4-6 provides the selected design criteria for the enhanced containment alternative.

Table 4-6. Design Requirements for the IWCS Enhanced Containment System

Description	Cap	Dike and Cut-Off Walls	Bottom
Component construction	Topsoil, rock, and clay	Clay	Gray clay unit
Average clay permeability	2.15×10^{-8} cm/sec	2.15×10^{-8} cm/sec	2.15×10^{-8} cm/sec
Design service life	200 – 1,000 years	200 – 1,000 years	200 – 1,000 years
Safety Factor for Sidewalls Slope Stability			
Static conditions	1.5	1.5	--
Earthquake	1.0	1.0	--
Surface Drainage Slope			
Top surface	2%	--	--
Side slopes	20%	--	--
Surface erosion protection	Shallow-rooted grass	Rip-rap to PMF elevation	--
Frost penetration	48 in.	--	--
Radon barrier required	Yes (20 pCi/m^2/sec)	--	--
Radiation barrier required	Yes (10 mrem/year)	--	--
Intrusion barrier required	Yes	--	--
Clay Adsorption Coefficient[a]			
Natural uranium	5 mL/g	5 mL/g	5 mL/g
Radium-226	500 mL/g	500 mL/g	500 mL/g
Internal cap drainage layer	Yes	--	--
Annual precipitation	30.0 in.	--	--
Average annual deep infiltration rate	0.21 in.	--	--
Floodplain elevation	PMF, 327 ft AMSL	PMF, 327 ft AMSL	--
Groundwater elevation	--	--	319 ft AMSL
Wind speed and direction	80 mph southwest	--	--
Earthquake pseudostatic coefficient	0.15 G	0.15 G	--
Buffer zone	100 ft	--	--
Concentration Guide for Radionuclide Migration (uncontrolled site areas)			
Natural uranium	--	600 pCi/L	600 pCi/L
Radium-226, -228	--	30 pCi/L	30 pCi/L
Migration limits	--	Not to exceed EPA primary drinking water standards in off-site groundwater	

[a] Adsorption coefficients listed are the design parameters in the *Failure Analysis Report for the Niagara Falls Storage Site, Lewiston, New York* (BNI 1994). Adsorption coefficients used in groundwater modeling are provided in Appendix B of this FS Report.

AMSL = Above mean sea level.
cm/sec = Centimeters per second.
EPA = U. S. Environmental Protection Agency.
ft = Feet.
G = Gravities.
in. = Inch.
IWCS = Interim Waste Containment Structure.
mL/g = Milliliters per gram.
mph = Miles per hour.
mrem/year = Millirems per year.
% = Percent.
pCi/L = Picocuries per liter.
pCi/m^2/sec = Picocuries per square meter per second.
PMF = Probable maximum flood.

The following processes represent the most common degradation issues observed for engineered caps designed for low-level radioactive waste (LLRW) (NRC 2010):

- soil pedogenesis (i.e., freeze-thaw, desiccation, and biological influences),
- geomembrane and geotextile service life,

- erosion,
- biotic intrusion and plant succession,
- differential settlement and waste subsidence,
- drainage layer clogging, and
- structural stability.

Appendix G contains a detailed longevity analysis of the enhanced cap, much of which was developed in the Failure Analysis Report (BNI 1994). Key findings of the longevity analysis used to evaluate this issue follow:

- Pedogenic (soil transformation) features could result from long-term freeze/thaw, desiccation cracking, plant roots, worm tubes, and other biological influences that create macro-pores in soil. Several design features have been added to the conceptual design to prevent pedogenic features from forming over the 1,000-year performance period.

- The estimate of geomembrane service life for the enhanced cap is 500 years. After that time, the natural material features would be the key features to resisting infiltration.

- The soil fill and topsoil layers could potentially erode within 600 years; however, erosion is not anticipated to compromise the integrity of the enhanced cap. The rip-rap and clay layers will continue to provide an effective barrier against all forms of radiation, even if the upper layers are completely eroded.

- The addition of larger rock with smaller rock in the rip-rap intrusion layer will not allow animal burrows to stay open as the clean gravel has no cohesion and will cause burrows to collapse readily.

- The rip-rap layer and clay barrier are not a good water source; therefore, it is unlikely that tree roots would penetrate the clay.

Differential settlement is not expected to be problematic for the enhanced cap because the materials have been in place for over 25 years with no settlement to date.

- Historical stability analyses conducted under static and seismic forces indicated that slopes ranging from 20 to 33% with heights of 3.0 to 6.0 m (10 to 20 ft) provide a factor of safety of 2.3 to 3.4, respectively, for short- and long-term analyses. Peak ground accelerations under the maximum probable seismic event were determined to be insufficient to initiate significant slope failure (DOE 1986b). A side slope of 20% was included in the FS concept design.

- LUCs, such as security fences and repairs and maintenance, are included in the alternative to ensure performance standards are met.

The Failure Analysis Report (BNI 1994) looked at most of these issues and concluded the proposed enhanced containment system would withstand maximum probable flood and seismic events and still function as intended. It also found that long-term erosion without maintenance could potentially strip the topsoil and subsoil from the cap, leaving the rip-rap, sand, and clay layers. With these layers left in place, the containment system could continue to provide the necessary armoring, hydraulic barrier, and radiation protection required. The sand and rip-rap layers would serve as a frost break, thereby protecting the clay from frost heave and cracking. Also, to address a woody vegetation succession, the rip-rap barrier could prevent compromise of the clay barrier layer. Pedologic processes could not form in the clay to increase its permeability because frost heave could not occur and roots could not penetrate into the clay. Man-made geomembrane material would not stay viable over the design life of the facility.

In summary, the key features included in the conceptual design to increase the reliability of the enhanced containment alternative are:

- Addition of a 60-mil geomembrane placed between a sand drainage layer and the clay component of the cap. Use of a geomembrane and clay layer reduces the amount of infiltration through the cap up to two orders of magnitude over the current cap configuration. Geomembrane design life is estimated at 500 years, after which the clay component becomes the primary flow barrier for the cap.

- Addition of a new cap configuration that increases stability. Proposed enhancements to the IWCS cap consist of flattening the top slope of the cap to 2% or less and modifying the side slopes by thickening the clay layer, thus resulting in a maximum slope of 5:1. These modifications increase the overall stability of the landfill by providing a stable structure during the maximum probable seismic event throughout the design life of the facility (1,000 years). The proposed enhancements will ensure a structurally stable cap that will remain competent during a maximum probable seismic event and will continue to prevent access to the waste and movement of the waste from the IWCS.

- Addition of rock rip-rap armoring to the base of the IWCS. Proposed enhancements to the IWCS consist of adding R-6 rip-rap to the perimeter of the IWCS up to the maximum probable flood elevation. This feature ensures protection of the IWCS from flood erosion during the required design life of the facility (1,000 years) and will continue to prevent access to the waste and movement of the waste from the IWCS.

- Addition of a rip-rap biotic barrier layer to prevent erosion, animal burrowing, and plant root penetration into the clay component of the cap and wastes in the IWCS.

4.3.4.2 Reduction of toxicity, mobility, and volume through treatment

There is no planned treatment included in this alternative; therefore, there is no reduction in toxicity or volume through treatment. The cap is designed to reduce migration (mobility) of contamination (but not through treatment).

4.3.4.3 Short-term effectiveness

The items covered by the short-term effectiveness criterion include (1) protection of the community and worker, (2) environmental impacts during implementation, and (3) the amount of time required to complete the action. Under the enhanced containment alternative, the current IWCS cap is assumed to remain intact, and the enhanced containment is assumed to incorporate additional layers of material on top of the existing cap. Primarily because Alternative 2 does not require exposing the residues, there are no significant short-term effectiveness issues associated with Alternative 2.

The alternative requires removal of the existing topsoil and subsoil layers and scarifying the existing clay layer, but there is no need to excavate into the existing waste. Radon emanation and flux from the ore residues through the waste and cap layers at the worst-case location (directly above the K-65 residues in Bays A and C) decreases significantly before it gets into the existing clay cap layer; modeling estimates that up to 0.46 m (1.5 ft) of the existing clay cap could be removed without exceeding the radon release limit (20 pCi/m^2/sec) from the excavated surface (USACE 2012c). Because of this, the exposure pathways are managed at current levels, and the potential for risk to workers and the public during remediation is assumed to be minimal. This analysis assumes that elevation and radiation surveys conducted during remediation will help prevent breach of the clay component of the existing cap.

In addition to protection against worker and community exposure to radon during remediation, standard construction protocol is included in this alternative to prevent exposure and migration, including personal protective equipment, Occupational Safety and Health Administration compliance, dust control, erosion and sedimentation control, stormwater management, site security (fencing) and monitoring, air and water monitoring, and wetland protection.

Although there is no waste hauling under the enhanced containment alternative, there will be increased truck traffic in the area due to materials deliveries. Materials coming from off-site include additional clay, sand, rip-rap, crushed stone, and additional topsoil. Approximately 107,990 m^3 (141,247 yd^3) of material (approximately 6,450 truckloads) are anticipated to be required. A traffic control plan will be required to minimize impact to the surrounding community and to coordinate with the heavy amount of daily truck traffic that already occurs at the adjacent Modern Landfill, Inc.

The estimated time required to complete the action is 1.5 construction seasons or approximately 2 years.

4.3.4.4 Implementability

The technologies used to implement this alternative are well proven to be implementable and reliable when constructed to specifications.

This alternative uses standard construction practices, equipment, and materials and controls. Resources, both trained suppliers and materials supplies, are readily available. Clay and rock materials, the largest materials volume, are available either locally or regionally. Because the enhanced containment alternative is planned for the same footprint as the current IWCS, there are no issues related to land availability. Land area is available at the NFSS to support the cap construction, including areas for materials stockpiling and water treatment.

Permits are not required for CERCLA actions completed by the Federal Government, but the remedy will comply with the substantive requirements of the regulations.

The land use resulting from this alternative is consistent with the adjacent Modern Landfill, Inc. and CWM Chemical Services, LLC landfills. If future risk is identified, this alternative would not impede the ability to implement a future action.

4.3.4.5 Cost

The complete breakdown of the estimated cost to implement Alternative 2, Enhanced Containment, is provided in Appendix J.

The estimated capital cost is $23.41M.

The estimated O&M cost is $43.97M, discounted at 3.5% over 1,000 years. The non-discounted O&M cost is $1.45B. The O&M cost assumes $1.1M/year for 1,000 years and scheduled 5-year reviews. Current O&M costs at the site are $1.1M and are used as the basis for this estimate.

The capital cost breakdown is as follows:

- mobilization – $1,408,654;
- monitoring, sampling, testing, and analysis – $95,200;

- site work – $1,814,850;
- surface water collection and control – $356,571;
- solids collection and containment – $7,041,270;
- site restoration – $420,174;
- design and project management – $4,499,235; and
- project contingency – $1,775,707.

The cost also includes a $6M supervision and administration item. The major individual cost components in this estimate are the labor, materials, and equipment related to the large rock components of the enhanced containment, including the rip-rap needed for the landfill toe, the slope stability and the intruder barrier, and the gabion baskets for construction of the 1.5-m-high and 248-m-long (5-ft-high and 815-ft-long) gabion wall on the east side of the IWCS to prevent encroachment of the enhanced cap into the Central Drainage Ditch. These rock components of the system make up approximately 30% of the construction cost. The geomembrane liner and geotextile layer are approximately 6% of the total cost.

4.4 ANALYSIS OF ALTERNATIVE 3A – REMOVAL, TREATMENT, AND OFF-SITE DISPOSAL OF SUBUNIT A AND ENHANCED CONTAINMENT OF SUBUNITS B AND C

4.4.1 Description of Alternative 3A

Alternative 3A is one of two alternatives that include partial removal of the materials in the IWCS followed by enhanced containment of the remaining materials. Alternative 3A includes:

- removal, treatment, and off-site disposal of Subunit A; and
- enhanced containment of Subunits B and C.

The enhanced containment portion of Alternative 3A is similar to the enhanced containment described for Alternative 2 because the entire area of the IWCS will be capped once Subunit A is removed and backfilled. Hence, the alternative description in this section focuses primarily on the removal, treatment, and off-site disposal of the Subunit A materials. The remaining subsections analyze the Subunit A remedial action and the combined impact of the remedial actions for Subunits A, B, and C.

The key components of Alternative 3A remediation include:

- Construction of remediation support infrastructure.

- Construction of a radon control system (RCS) to capture and treat the radon gas generated during all stages of Subunit A remediation.

- Construction of the containment structure over Subunit A, referred to as the Retrieval Facility.

- Removal of a portion of Subunits B and C to obtain access to Subunit A.

- Subunit A waste retrieval and segregation.

- Packaging, shipping, and off-site disposal of lower-activity residues, soil, and other waste materials.

- Construction of the waste stabilization treatment facility, referred to as the Stabilization Facility.

- Transfer, treatment (S/S), packaging, transport, and off-site disposal of the high-activity residues.

- D&D, disposition, and demobilization of Subunit A equipment and facilities from the site.

- Enhanced containment of Subunits B and C. Refer to Section 4.3.1 and Appendix G for descriptions of the enhanced containment of Subunits B and C.

- Implementation of long-term LUCs.

The site layout for this alternative is presented in Drawings C-10, C-11, and C-12 within Appendix K. Schematic diagrams of the Subunit A facilities are provided in Appendix F.

4.4.1.1 Construction of remediation infrastructure

The conceptual design for this alternative includes the following infrastructure support (Appendices G and H; Drawing C-10 within Appendix K).

Upgrade of site controls

Controls necessary for implementing the work will be put in place prior to construction start, including the following:

- health and safety/worker protection,
- erosion and sedimentation,
- stormwater,
- dust, and
- construction water.

Construction of remediation support infrastructure

The conceptual design includes the following infrastructure support required for waste characterization, excavation, loading, and transportation (Appendix H; Drawing C-10 within Appendix K):

- sewer,
- potable water,
- dewatering line,
- power and communications,
- dust control and vehicle wash/decontamination station, and
- roads and culverts.

Construction of materials support facilities

Key materials support facilities are required for the excavation of Subunits B and C materials above Subunit A:

- equipment and materials lay-down areas;
- staging area for clean construction materials;
- vehicle washdown area; and
- additional support area, including construction trailers.

4.4.1.2 RCS

An RCS will be constructed and operated to capture and treat radon gas during the retrieval, treatment, and packaging of K-65 residues. The RCS will be operated during K-65 residue excavation and processing to protect on-site personnel and off-site residents and to implement as low as reasonably achievable principles. The conceptual design of the RCS for Subunit A is based on the successful implementation of the RCS at the Fernald K-65 Project. The Fernald K-65 Project RCS design successfully demonstrated that radon gas originating from K-65 materials can be collected, monitored, and treated (removed to below acceptable levels) prior to discharge via an exhaust stack to the environment.

A work area ventilation system consisting of heating, ventilation, and air conditioning (HVAC) systems will collect high volumes of air from areas where there are low radon concentrations, as in the Retrieval Facility and the work areas of the Stabilization Facility (e.g., the control room and corridors).

The RCS and HVAC systems will be operated in phases as the Subunit A activities progress and will be designed to control radon emissions to the atmosphere and detect and quantify any releases. Redundant systems will be used to mitigate any system upsets.

Ventilation gas will be drawn away from each source and transferred to the RCS building for treatment. Ducting will direct the gases to a header, which will connect to roughing filters for initial particulate daughter removal. The gas stream will then be chilled and dried to enhance the dynamic adsorption capacity of an activated carbon filtration system. Condensed liquids from the gas stream will be transferred to a water storage tank in the Retrieval Facility and used to condition excavated residues before stabilization. Carbon beds will capture the chilled and dried air stream and significantly reduce radon concentrations. The treated gas stream will flow from the carbon adsorption units through high-efficiency particulate air filtration units. The outlet air will be either recycled to the Retrieval Facility or exhausted through a stack if it meets release limits. Carbon steel structures of sufficient thickness to provide shielding will be installed adjacent to the carbon beds to reduce general area dose rates.

4.4.1.3 Removal of Subunits B and C materials to access Subunit A

Prior to retrieval of Subunit A residues and waste, approximately 25,107 m^3 (32,839 yd^3) of Subunit B materials from Buildings 411, 413, and 414 and approximately 4,081 m^3 (5,338 yd^3) of Subunit C soil must be removed (see Appendix G). Table 4-7 shows the breakdown of this volume. The 12,901 m^3 (16,874 yd^3) of contaminated soil removed from Subunit B in this alternative is 39% of the total 32,715 m^3 (42,790 yd^3) of waste stored in Subunit B. A small amount of R-10 residues in Subunit C may be encountered during the excavation required north of Building 411. If this occurs, these residues would be handled and disposed of similar to the L30, F-32, and L-50 wastes, described below. The uncontaminated topsoil, subsurface soil, and clay cap materials will be stockpiled and reused as needed. The contaminated soil from Subunit B will be packaged, shipped, and disposed off-site at an LLRW (or low-level mixed waste [LLMW] if needed) facility as described in Appendix H.

4.4.1.4 Subunit A waste retrieval and segregation

Table 1-2 shows the breakdown of Subunit A materials that will be removed from the IWCS. Subunit A residue and waste retrieval will occur in phases. During Phase 1, lower-activity waste materials (essentially all materials other than the K-65 residues) within Building 411 will be removed using conventional excavation equipment and methods, with engineered and administrative controls as needed to protect equipment operators and other workers. A key control will be the construction of an enclosed

Table 4-7. Subunits B and C Materials Excavated to Access Subunit A for Alternative 3A[a]

Material Description	In-Situ Volume (yd^3)	Bulking Factor (%)	Ex-Situ Volume (yd^3)	Assumed Waste Classification
Subunit B topsoil	1,936	30	2,517	NA
Subunit B subsurface soil	3,130	30	4,069	NA
Subunit B clay cap	10,899	33	14,496	NA
Subunit B contaminated soil	16,874	30	21,936	LLRW/LLMW[b]
Subtotal Subunit B	***32,839***		***43,018***	
Subunit C topsoil	370	30	481	NA
Subunit C subsoil	534	30	694	NA
Subunit C clay cap	2137	33	2,842	NA
Subunit C contaminated soil	2,267	30	2,947	LLRW
Subunit C R-10	30	33	40	11e.(2)
Subtotal Subunit C	***5338***		***7,004***	

[a] From Appendix H, Table H-2.
[b] For estimating purposes, LLMW is assumed to be 10% of the LLRW volume.
LLMW = Low-level mixed waste.
LLRW = Low-level radioactive waste.
NA = Not applicable.
% = Percent.
yd^3 = Cubic yard.

Retrieval Facility over the Building 411 area to prevent any residue releases from entering the atmosphere. The materials to be removed during Phase 1 include portions of the Tower Soil and portions of the L-30/F-32 residues, sand, clay, and debris. Care will be taken to maintain a cover layer over the K-65 residues to minimize radon releases. Radon and particulate emissions will be controlled by the RCS and HVAC systems, thus allowing intermittent personnel access as required.

Phase 2 includes retrieval of the K-65 residues, the commingled portion of the L-30 and F-32 residues, and associated debris that was dropped into the residues during transfer in the late 1980s. This work will use remote technology, including cameras and remotely controlled equipment, because direct radiation and radon levels will be highest when K-65 residues are exposed. During Phase 2, the waste will be moved through a material screen. Screened residues will pass through the rest of the pre-treatment equipment and then be pumped to the equipment in the Stabilization Facility for stabilization and packaging.

Phase 3 includes removal of the L-50 residues in Buildings 413 and 414. The L-50 residues can be safely removed using conventional excavation equipment, and no containment facility would be needed.

Any time after Phase 2 is completed and monitoring confirms that remote operations are no longer necessary, residual materials in Building 411 will be removed. These materials will consist primarily of soil used to build ramps and roadways needed to provide access to the waste being removed during Phase 2, low-activity waste remaining in place underneath the roadways, and debris set aside during Phase 2 that can be removed safely and more efficiently using conventional equipment. Packaging, transport, and disposal of these materials will be managed as described above for the waste not sent to the Stabilization Facility.

4.4.1.5 Handling of lower-activity residues and wastes

As indicated above, the low-activity residues and other wastes within Subunit A will be excavated using conventional excavation equipment. Waste handling equipment will be used to package the materials with minimal treatment (e.g., adding an absorbent).

The oversized material and other excavated waste that does not require treatment will be placed into appropriate containers in a manner needed to meet transport requirements and disposal facility WAC. Debris will be segregated from the soil, size-reduced as needed, and placed into B-25 boxes. Soil-like material will be placed into soft-sided containers (i.e., supersacks). Prior to transport, the waste containers will be inspected for free water. If necessary, absorbent will be added to the container prior to placement on the transport vehicle. The waste containers will be transported via dump trucks and flatbed trailers to a rail transfer facility where they will be loaded into lined and covered gondola railcars and transported to the selected disposal facility.

As with the Fernald K-65 Project, all Subunit A waste streams are assumed to meet the low specific activity definition in 49 *CFR* Part 173.403 and the transport requirements in 49 *CFR* Part 173.427. A list of potential containers acceptable for shipment of these materials was generated and evaluated (see Appendix I). With the exception of the K-65 waste stream, no shielding will be required for the transport of the material to meet the exposure criteria specified in DOT regulations for shipments of radiological materials (49 *CFR* Part 173.441) when shipping by either truck or rail. Both intermodal and gondola containers were found to be acceptable for the lower-activity residues and wastes.

For this FS, all of the Subunit A materials are assumed to be classified as 11e.(2) waste for the purposes of disposal. The lower-activity waste streams within Subunit A would likely be shipped to any of several disposal facilities licensed to accept 11e.(2) waste. For the purposes of this FS, the assumed disposal site is the Energy*Solutions* disposal facility in Clive, Utah. Non-radioactive hazardous and sanitary wastes generated as part of the retrieval and stabilization activities are expected to be transported by truck via local roads to neighboring landfills.

4.4.1.6 Treatment and handling of high-activity residues

Cement stabilization was identified as the likely treatment technology for Subunit A (see Section 2.4.4). Cement stabilization was the method ultimately employed on the Fernald K-65 Project after treatability studies showed it was effective at stabilizing the lead in the residues waste stream and at reducing radon emanation rates. The Fernald K-65 Project cement stabilization mixture formulation, lessons learned, and successes have been used to develop the conceptual design for treatment, packaging, shipment, and disposal of the K-65 residues at the NFSS (see Appendix F).

The stabilization/treatment process involves:

- constructing the Stabilization Facility using designs and lessons from the Fernald K-65 Project,
- receiving and pre-treating K-65 and commingled residues with a vibrating oversize screen and a grinder,
- conveying the material into conditioning tanks,
- generating a slurry of residues and water,
- transferring the slurry to the Stabilization Facility,
- stabilizing the slurry by mixing it with cement and fly ash,
- packaging the stabilized waste in Industrial Package-2-compliant containers, and
- shipping the containers to an approved disposal facility licensed to accept 11e.(2) wastes.

The K-65 residues are located in Bays A and C of the NFSS IWCS. The volume of K-65 residues in the IWCS has been determined to be 3,100 m^3 (4,030 yd^3). The K-65 residues within Bay C are co-located with L-30 residues and minimal F-32 residues. During the retrieval process, the K-65 residues will be blended with commingled portions of the L-30 and F-32 residues and stabilized (see Appendix F). For the purposes of this FS Report, an approximate total volume of 4,610 m^3 (6,030 yd^3) of extracted/retrieved materials is assumed to be mixed with cement, fly ash, and water to form a stabilized waste form. The remainder of the L-30 residues are assumed to be down-blended to meet shipping and WAC requirements for untreated waste.

Appendix I provides details related to the selection of the containers and transportation mode for off-site disposal of the Subunit A residues. The residues and waste can be managed as low specific activity materials for transportation purposes, as evaluated in Appendix I. The low specific activity limits presented in 49 *CFR* 173.403 were used to determine that the stabilized product will be placed into Industrial Package-2-compliant packages and shipped to an approved disposal facility over a period of approximately 2 years. The custom Industrial Package-2 containers, with steel walls less than 0.012 m (0.5 in.) thick, would provide sufficient shielding to meet DOT exposure criteria. This container would be similar to the one used for the treated K-65 residues under the Fernald K-65 Project. Under the current WAC for the disposal facilities that can take 11(e).2 waste, the K-65 residue waste streams would most likely be shipped to Waste Control Specialists (WCS) in Texas. WCS received the K-65 residues from the Fernald K-65 Project. A detailed discussion of the WCS option is presented in Appendix I.

Multiple transportation modes were evaluated for the stabilized residues (Appendix I), with emphasis on potential dose rates for the different container-mode combinations and the availability or ease of obtaining needed transportation infrastructure (e.g., existing rail routes). The transportation approach selected for the conceptual design of the Subunit A remediation is that waste containers will be transported via dump trucks and flatbed trailers to a rail transfer facility where they will be loaded into lined and covered gondola railcars and transported to the selected disposal facility (Appendix I).

4.4.1.7 D&D of Subunit A equipment and facilities

The final step of Subunit A removal is deactivation, demolition, removal, and disposal of the retrieval stabilization equipment and facilities and the stabilization equipment and facilities. The D&D process begins with assessments of the facilities to review process data and to investigate the elements of the building structure, its contents, and appurtenances to plan safety and waste management considerations. These assessments will determine the waste streams (e.g., types, contamination levels, paths for disposal, and disposal and transport options) and will be used to mitigate potential hazards. Typical hazards anticipated include hot work, fall protection, flammable and combustible liquids storage, chemical and radiological hazards, and temperature extremes.

As demolition debris is generated, it will be segregated according to waste types and disposal locations. The waste must meet disposal facility WAC and transportation requirements and may require treatment or size reduction to achieve an acceptable waste form for transportation and disposal. Treatment may include adding absorbents, filling void spaces of containers, decontamination, or applying fixative sprays to contaminated surfaces. Size reduction may require a shredder and shear to ensure the materials do not exceed size restrictions at the disposal facility. Once demolition is complete, the demolition areas will be backfilled and graded as needed to promote positive drainage. Seeding and watering to promote vegetation will finalize the D&D.

4.4.1.8 Enhanced containment of Subunits B and C

Once Subunit A retrieval activities are completed, the areas above Buildings 411, 413, and 414 will be backfilled, and the enhanced cap will be completed over Subunits B and C. The enhanced containment portion of Alternative 3A is virtually the same as the enhanced containment described for Alternative 2 because the entire area of the IWCS will be capped once Subunit A is removed and backfilled (see Appendix G).

4.4.1.9 LUCs

LUCs would be implemented to maintain perpetual, Federal, active control over the site. Long-term surveillance, monitoring, and maintenance of materials within the IWCS would be performed by the Federal Government. Additionally, the Federal Government would provide LUCs to prevent re-exposure of contaminants as necessary. LUCs would be defined in a LUC Plan, developed during the remedial design phase. The LUCs would be maintained until the remaining hazardous substances are at levels allowing for unlimited use and unrestricted exposure. Due to the presence of long-lived radionuclides in the IWCS, the LUCs would need to be maintained to provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Additional discussion on LUCs is presented in Section 4.3.1.

4.4.2 Comprehensive Environmental Response, Compensation, and Liability Act Criteria

Detailed analysis of Alternative 3A according to CERCLA threshold and balancing criteria is provided in the following sections. Table 4-8 presents the results of the analysis; supporting detail is provided in Sections 4.4.3 and 4.4.4.

4.4.3 Threshold Criteria

4.4.3.1 Overall protection of human health and the environment

Alternative 3A is protective of human health and the environment. The risk profile for Alternative 3A is similar to Alternative 2 because all residual waste will be under a cap and LUCs will be in place to prevent direct exposure. However, there are key differences. The majority of the radioactivity related to ore residues in the IWCS (e.g., over 90% of the Ra-226 inventory) would be removed and shipped off-site under Alternative 3A. The residuals remaining under an enhanced cap would include (1) the R-10 ore residues; (2) minor amounts of residual K-65, L-30, F-32, and L-50 residues that may be present due to contamination by contact with residues (including building materials and equipment in the IWCS); and (3) large volumes of low-activity contaminated soil from previous NFSS and vicinity properties soil remediation projects. As such, the risk source term for Alternative 3A is significantly less than the risk source term remaining for Alternative 2.

As indicated in Section 4.3.2.1, estimated cancer risks to the On-Site Maintenance Worker and the Off-Site Resident associated with Alternative 2 are 2.6×10^{-5} and 4.4×10^{-7}, respectively. These values are within or below the acceptable risk range under CERCLA. With the removal of Subunit A, the estimated future risks would be lower.

Table 4-8. Detailed Analysis of Alternative 3A (Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C)

CERCLA Threshold Criteria		
CERCLA Criterion		**Result of Evaluation**
Overall protection of human health and the environment		LUCs and cap maintenance are protective; prevents unacceptable exposures to IWCS materials
Compliance with ARARs		Complies with ARARs
CERCLA Balancing Criteria		
CERCLA Criterion	**Evaluation Factor (Table 4-1)**	**Results of Evaluation**
Long-Term Effectiveness and Permanence	Magnitude of residual risk	Highest-activity waste removed. The residues and wastes in Subunits B and C, including the R-10 pile, remain in place under the enhanced cap. Risk to human and ecological receptors is within or below the acceptable risk range
	Adequacy and reliability of controls	Structurally stable design, LUCs, and cap maintenance are in place to prevent exposure over the long term
	Summary	Structurally stable design, LUCs, and cap maintenance are effective at preventing unacceptable exposure to wastes over the long term
Reduction of Toxicity, Mobility, and Volume Through Treatment	Treatment process used and materials treated	Cement stabilization used to treat approximately 6,030 yd^3 of K-65 and commingled residues
	Amount of hazardous materials destroyed or treated	Approximately 6,030 yd^3 of K-65 and commingled residues treated
	Degree of expected reduction in toxicity, mobility, and volume	Reduction in the mobility and radon release hazard related to the treated K-65 and commingled residues; increased volume of K-65 waste due to addition of stabilizer
	Degree to which treatment is irreversible	High; treated waste form is a cement stabilized solid in a steel container
	Type and quantity of residuals remaining after treatment	Off-site wastes that are not treated (Subunits A and B) = 59,298 yd^3. On-site untreated residuals (Subunits B and C) = 286,746 yd^3
	Summary	Reduces the toxic effect and mobility of the highest-activity material (K-65 and commingled residues). Does not reduce volume. Does not reduce toxicity, mobility, or volume of untreated L-30, L-50, and F-32 residues or Subunits B and C materials
Short-Term Effectiveness	Protection of community during remedial actions	Controls included to ensure no exposure to airborne contaminants during remediation, including an engineered containment facility and RCS. Local truck traffic increases. Rail used to reduce risk during transport to the disposal facility
	Protection of workers during remedial actions	In addition to complying with all radiation worker protection requirements, robotics will be used to retrieve most hazardous residues
	Environmental impacts	Controls in place to prevent environmental impacts
	Time until remedial action objectives are achieved[a]	7.5 years: 2 years design and 5.5 years construction
	Summary	Short-term impacts to workers and community can be controlled through robust work control processes
Implementability	Ability to construct and operate the technology	For Subunit A, remediation is a challenge to construct and operate, but a similar approach was proven at the Fernald K-65 Project. Subunits B and C rely on proven technologies
	Reliability of the technology	Subunit A approach proven reliable at the Fernald K-65 Project. Cap technology is reliable through the life of the geomembrane (approximately 500 years); cap maintenance and LUCs required
	Ease of undertaking additional remedial actions, if necessary	Additional action could be implemented on Subunits B and C
	Ability to monitor the effectiveness of the remedy	Monitoring currently proving effective; monitoring will remain in place
	Ability to obtain approvals from other agencies	Would require discussion to obtain buy-in. Essentially equivalent to Alternative 3B. More likely to be accepted than Alternative 2
	Viability of off-site treatment, storage, and disposal services and capacity	There is only one facility that has accepted K-65 residues in the past
	Availability of necessary equipment and specialists	Specialty capabilities required for Subunit A are available. Readily available for Subunits B and C
	Summary	Implementable with available specialty resources
Cost	Capital costs	$259.6M
	O&M costs (not discounted)	$1,450M
	Present worth O&M costs (discounted)	$43.8M

[a] Estimates to complete the action assume projects receive sufficient annual funding to meet schedules.
ARAR = Applicable or relevant and appropriate requirement.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
IWCS = Interim Waste Containment Structure.
LUC = Land-use control.
O&M = Operation and maintenance.
RCS = Radon control system.
yd^3 = Cubic yard.

4.4.3.2 Compliance with ARARs

Alternative 3A complies with all the requirements of the identified ARARs. Excavation activities were designed to meet relevant and appropriate requirements that apply to excavation activities, as described in Table 4-9. The activities related to the enhanced containment portion of Alternative 3A were designed as discussed in Section 4.3.2.2 and comply with the ARARs identified in Table 4-5.

In addition to the identified requirements, the Fiscal Year 2004 Energy and Water Appropriations Bill, HR 2754 contains the following information that pertains to disposal of the NFSS residues and requires that "ore processing residual materials" at the NFSS be handled as 11e.(2) byproduct materials for the purpose of disposal:

> SEC. 312. Notwithstanding any other provision of law, the material in the concrete silos at the Fernald uranium processing facility currently managed by the 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 shall 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, shall regulate the material as '11e.(2) by-product material' for the purpose of disposition of the material in an NRC-regulated or Agreement State-regulated facility.

This requirement would be met by disposition of materials at an 11e.(2) disposal facility.

4.4.4 Balancing Criteria

4.4.4.1 Long-term effectiveness and permanence

Under Alternative 3A, the Subunit A high-activity residues would be removed and the residual waste left in place would include the miscellaneous wastes in Subunit B and the R-10 residues and soil in Subunit C. These wastes will be under an enhanced cap and, thus, engineered and administrative controls have been included to prevent human and ecological receptor contact with the waste and to resist leaching to groundwater. As with Alternative 2, the potential long-term human health receptors are the On-Site Maintenance Worker and the Off-Site Resident. The risks associated with these receptors have been estimated to be 2.6 x 10-5 and 4.4×10^{-7}, respectively, which are within and below the CERCLA acceptable risk range. Similarly, with the enhanced cap in place, there are no ecological risk concerns, as discussed in Section 1.4. Thus, Alternative 3A is effective at preventing long-term unacceptable radon and gamma radiation exposures.

The results of groundwater modeling performed to predict contaminant migration over time for Alternative 3A are summarized below. Details of the analyses are presented in Appendix B:

- At the IWCS boundary coincident with the IWCS cut-off wall in the brown clay till, no measurable concentrations are predicted within the initial 200-year simulation period. At simulation time equal to 1,000 years, the concentration of U-238 is predicted to be 0.42 pCi/L. This is well below the total uranium background level of 16.7 pCi/L (USACE 2007a). Both the brown clay till and gray clay units produce poor water quality, and water from either of these units would have to be treated prior to domestic use.

Table 4-9. ARARs Identified for Excavation and Off-Site Disposal for the IWCS FS

Criterion	Description	Design Objective	Design Specification
	ARARs		
40 *CFR* Part 61, National Emission Standards for Hazardous Air Pollutants			
40 *CFR* 61.92 – Standards	Emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that might cause any member of the public to receive, in any year, an EDE of 10 mrem/year or greater	Identify points of compliance and monitoring frequency to monitor radiation levels during excavation and disposal activities	Implement construction site controls (e.g., radon, dust, and water) during excavation and disposal implementation
	Monitoring is required at release points having the potential to discharge radionuclides that could cause an EDE in excess of 1% of the standard (0.1 mrem/year) to any member of the public	Define temporary storage controls. Define disposal container requirements	Use designated storage areas. Use containers identified in the transportation assessment (Appendix I)
	No source at a DOE facility shall emit more than 20 pCi/m^2/sec of radon-222 as an average for the entire source during periods of storage and disposal		
10 *CFR* 40, Appendix A: Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for their Source Material Content			
10 *CFR* 40, Criterion 6(6) – Closure of Waste Disposal Areas	"The design requirements in this criterion for longevity and control of radon releases apply to any portion of a licensed and/or disposal site unless such portion contains a concentration of radium in land, averaged over areas of 100 square meters, which, as a result of byproduct material, does not exceed the background level by more than: (i) 5 picocuries per gram (pCi/g) of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over the first 15 centimeters (cm) below the surface, and (ii) 15 pCi/g of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over 15-cm thick layers more than 15 cm below the surface. Byproduct material containing concentrations of radionuclides other than radium in soil, and surface activity on remaining structures, must not result in a total effective dose equivalent (TEDE) exceeding the dose from cleanup of radium contaminated soil to the above standard (benchmark dose), and must be at levels which are as low as is reasonably achievable. If more than one residual radionuclide is present in the same 100-square-meter area, the sum of the ratios for each radionuclide of concentration present to the concentration limit will not exceed "1" (unity). A calculation of the potential peak annual TEDE within 1000 years to the average member of the critical group that would result from applying the radium standard (not including radon) on the site must be submitted for approval."	Define the excavation boundary based on soil screening criteria	Excavation will be conducted until cleanup meets criteria based on the ARAR

ARAR = Applicable or relevant and appropriate requirement.
CFR = Code of Federal Regulations.
DOE = U. S. Department of Energy.
EDE = Effective dose equivalent.
IWCS = Interim Waste Containment Structure.
mrem/year = Millirem per year.
% = Percent.
pCi/m^2/sec = Picocuries per square meter per second.

- At the IWCS boundary point of compliance below the IWCS cut-off wall in the Alluvial Sand and Gravel Aquifer, U-238 concentrations are predicted to be zero at 1,000 years.

- Concentrations of thorium-230, Ra-226, and lead-210 are predicted to be negligible or non-detectable throughout 1,000 years of simulation time.

For all simulation time periods, the model predicts that radionuclides will not migrate to the NFSS site boundary at detectable concentrations.

The results of the Alternative 3A model runs indicate that the alternative would remain protective out to the 1,000-year model period.

In summary, Alternative 3A is effective at preventing unacceptable exposures over the long term by preventing direct contact with the waste and performing surveillance and maintenance to ensure the integrity of the cap to resist leaching to groundwater.

4.4.4.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 3A calls for the removal and treatment of the most radioactive residues in the IWCS—the K-65 residues and commingled residues (a portion of the L-30 and F-32 residues). The remaining Subunit A residues and material will not be treated, other than by size-reduction of debris and adding an absorbent to ensure there is no free liquid in containers to be shipped off-site for disposal. The RCS will capture radon gas and treat it through filtration and absorption in carbon beds. None of the wastes in Subunits B or C will be treated.

The proposed K-65 and commingled residues treatment is cement stabilization. The cement stabilization process used to treat the K-65 residues will be similar to that implemented at the Fernald K-65 Project. Cement stabilization reduces the mobility of contaminants by binding them in a cement mixture.

As part of the Fernald K-65 Project process design, treatability study data were collected and used to optimize stabilization process requirements, including reduction in leachability. The only Resource Conservation and Recovery Act heavy metal that leached at levels of concern from the Fernald Site K-65 residues was lead. The findings revealed that leaching of lead could be minimized to meet requirements by controlling the pH through the addition of the correct amount of Portland cement (see Appendix F). Adding cement at a value of 8 to 12% of the final batch weight of the treated material minimized lead leaching to acceptable levels. Design of the cement stabilization process for the IWCS K-65 residues will incorporate the findings of the previous treatability studies, and process controls will be designed and implemented to ensure the proper design mixture is employed.

The stabilized waste form, combined with sealed containerization, reduces radon emanation to meet regulatory standards, as was shown during the stabilization of the Fernald K-65 Project residues (USACE 2011a).

Use of cement-stabilization technology will increase the volume of material to be disposed at an off-site disposal facility as a result of the additives. The average volumetric increase at the Fernald K-65 Project was approximately 169% (USACE 2011a). Treatment of the NFSS K-65 residues will result in a similar volumetric increase.

The RCS captures radon gas and particulate daughters, thus reducing mobility. Toxicity will be effectively eliminated by retention in the treatment media long enough for radioactive decay from radon into a stable element. The treated air released through a stack will meet ARARs regarding acceptable radon concentrations in air. The RCS will generate spent filters as secondary waste.

Secondary waste will be generated as a result of the operations and D&D of the retrieval and treatment systems. Secondary waste includes personal protective equipment and equipment that cannot be decontaminated. These wastes would be managed in accordance with the waste management plan prepared for the project.

4.4.4.3 Short-term effectiveness

The conceptual designs for all excavation and off-site disposal actions in this FS Report were developed to meet the following criteria to minimize impacts to workers, public, and the environment during remedial implementation:

- Implement worker protection based on risk-based analyses and action level determination.
- Implement health and safety monitoring, sampling, and analyses during excavation and construction support activities, where appropriate.
- Implement site access controls to prevent public and non-protected worker access to restricted areas.
- Implement erosion and sediment controls to protect sensitive environmental features on-site.
- Implement specific construction procedures for waste, dust, radon, and stormwater management and control.
- Comply with regulatory limits for surface water discharge.
- Comply with waste transportation and disposal regulations, procedures, and codes.

The primary issues related to short-term protection of the community, workers, and the environment during Alternative 3A remediation are associated with the Subunit A excavation. The majority of the work in Subunits B and C will not breach the existing clay component of the cap. As with Alternative 2, containment of Subunit C will result in minimal or no short-term issues during remediation. The early excavation of Subunit B materials located above Building 411 could expose some low-level contaminated material; however, the Subunit B contaminant concentrations (assumed to average 16 pCi/g of Ra-226 in soil) and low volume/short duration of the work (3 months) are of less concern than the short-term issues related to Subunit A. Work and process controls, as described below, will further increase short-term protectiveness of the alternative.

The Health Effects TM (USACE 2012b) identified several potential short-term issues that could occur during remediation of Subunit A in the absence of proper controls. The analysis included short-term risk, assuming typical work control processes were in place, and found all potential exposures could be controlled to acceptable levels. A discussion on the types of controls that are included in the designs to address short-term risks follows.

Protection of the community

Exposing the K-65 material during removal could result in releases of radon to the ambient air. Radon exposures would be mitigated by capturing radon inside the Retrieval Facility, the Stabilization Facility, and at all excavation faces. The HVAC systems and RCS would place all remediation areas subject to potential releases of radon under negative pressure. The gases would then be treated prior to release to the environment.

Dust created during construction and D&D would be controlled with standard dust suppression techniques to provide protection to the local community.

Site-wide access controls would prevent trespassers from inadvertently becoming exposed to the contaminants. Through the use of fences and guards, access to the materials by the public would be controlled. Access controls are effective and commonly used.

Potential radiation exposure to the public resulting from the transport of radioactive waste material to the off-site disposal facilities would be below the DOT requirements and far below the target cancer risk range of 10^{-4} to 10^{-6} (Appendix I). In addition, injuries and/or fatalities may occur due to transportation accidents. The estimated number of accidents via intermodal transportation is lower than by truck (Appendix I), which is one reason for the selection of a bimodal truck-rail option for the larger volumes of waste in Subunits A and B.

For the stabilized waste in Subunit A that will be transported to the WCS off-site disposal facility via truck, the estimated potential of accidents related to shipping the stabilized residues to the WCS facility is low (Appendix I). There were no fatalities or injuries associated with residue transport under the Fernald K-65 Project, which involved transport of significantly more containers than are estimated to move the IWCS waste.

In addition to potential accidents, the following security considerations would need to be addressed in the final design (Appendix I):

- Truck:
  - driver background checks and United States citizenship,
  - high frequency of truck shipments (i.e., approximately 40 trucks/day),
  - length of truck shipment duration on unsecured roadways,
  - vulnerability to terrorist action (e.g., hijacking, armed attack, and bombing), and
  - "tracking" of truck shipments.
- Rail bimodal:
  - route infrastructure vulnerabilities (i.e., rail lines, bridges, tunnels, etc.),
  - rail switch yard(s) vulnerabilities,
  - limited flexibility with respect to routing shipments away from population centers,
  - large volume of radioactive waste per individual rail shipment, and
  - all truck concerns from above.

Protection of workers

Both the release of radon and exposure to direct radiation from the residues could create a risk to workers. With appropriate measures of protection (e.g., negative air pressure in containment facilities, personal protective equipment, training, and shielding), the removal and treatment of residues are estimated to result in an excess cancer risk level below the occupational standards. Significant monitoring, remote operations, and shielding would be required to ensure worker protection.

Risks associated with remediation work, such as vehicular accidents, would be addressed through worker health and safety plans.

Short-term environmental impacts

Short-term environmental impacts could be realized during retrieval, construction, and D&D of the treatment system. Construction and excavation activities would disturb the immediate area by causing erosion and generating fugitive dust emissions. Erosion control measures and fugitive dust suppression are commonly used during construction activities and would be sufficient mitigation measures to prevent transport of contaminants to adjacent surface water bodies. Upon completion of site construction activities, the site would be restored.

In addition to the fugitive dust emissions, heavy equipment exhaust is likely to be generated but is not expected to impact air quality.

During operations, radon gas would be controlled with the RCS and HVAC systems under negative pressure to mitigate the possibility of a release.

Waste stabilization operations would generate process wastewater, which would be recycled into the treatment system to minimize waste generation. Any remaining process wastewater that could not be recycled (e.g., decontamination water) would be treated by the on-site water treatment plant.

Time to complete

A sequencing approach has been developed to estimate the time to complete all of the components of Alternative 3A (Figure 4-2).

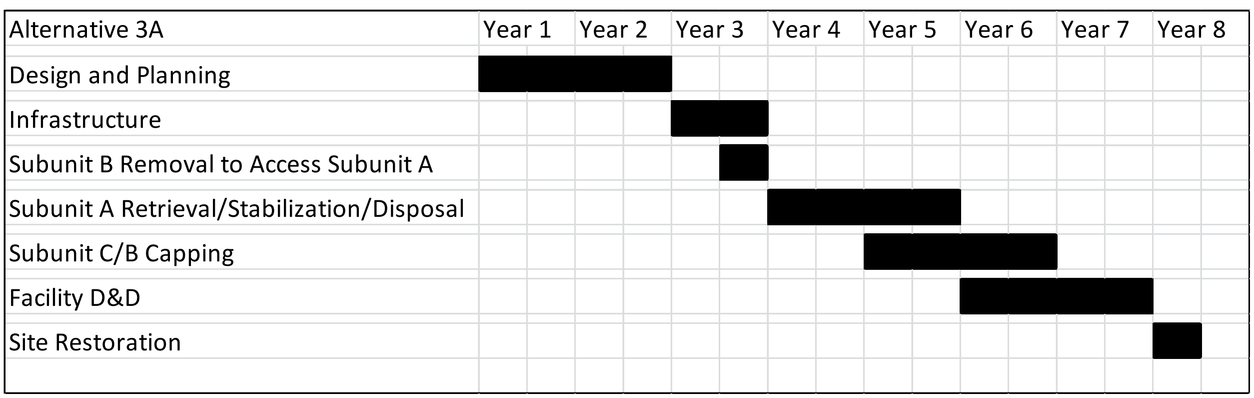

Figure 4-2. Sequencing of Activities for Alternative 3A

The time related to post-construction regulatory documents is not included in this estimate. The estimated durations in Figure 4-2 are based on the productivity assumptions used in the cost estimation presented in Appendix J. The total estimated time to implement Alternative 3A is 7.5 years, including:

- One year for infrastructure development, including support facilities, road upgrades, the Subunit A retrieval facility, and the RCS.
- Two years to complete the retrieval, stabilization, packaging, shipping, and disposal of the residues in Buildings 411, 413, and 414.

- Two years to complete the Subunits B and C cap, starting on the north end of the IWCS.
- Two years to complete D&D of all support facilities.

The conceptual design uses dual systems or backup systems wherever practical to mitigate any delays resulting from technical problems.

4.4.4.4 Implementability

Implementability associated with the enhanced containment portion of Alternative 3A has been previously discussed in Section 4.3.3. As indicated in that discussion, there are no technical implementability concerns.

The discussion below addresses the implementability of the Subunit A portion of Alternative 3A, followed by a summary discussion on the implementability of the full alternative.

The proposed Subunit A removal conceptual design includes demonstrated technologies with commercially available components. Although the technologies are commonly used and readily available, project-specific designs would be required to accommodate specific operations (e.g., remote excavation and container lidding). The Industrial Package-2 containers used for waste disposal would be constructed to meet project-specific technical and regulatory requirements. There are no concerns regarding the availability of equipment or personnel needed to implement Subunit A remedial actions or excavation of a portion of Subunit B. Personnel would receive specialized training and protection related to working in a high-radioactivity and high-radon environment.

For the most part, the Subunit A remediation facilities will use standard building construction materials and methods. Most of the retrieval, packaging, and shipping operations are standard construction-type activities with readily available resources and standard procedures. The Retrieval Facility containment structure has been successfully used at numerous radiological and nuclear materials remediation projects on DOE and Formerly Utilized Sites Remedial Action Program sites. Approximately 25% of Subunit A waste material will require remote operations to prevent unacceptable worker exposures. Remote technology is commonly used in the hazardous waste and nuclear industries, and the skill sets and equipment are readily available.

Even in cases where specialized materials and methods are required for shielding or handling the K-65 materials, experience at the Fernald K-65 Project has proven the approach to be implementable. One exception is that the Fernald K-65 Project used hydraulic mining to remove the residues; whereas, this FS proposes mechanical removal. As a result, there are some unknowns associated with the residue removal portion of the alternative.

One of the most difficult issues to overcome on the Fernald K-65 Project was waste disposal of the stabilized K-65 material because many states would not accept this waste stream into permitted facilities. This issue was resolved by (1) obtaining permission for temporary storage of the stabilized waste at the WCS facility in Texas, and (2) the enactment of legislation attached to the 2004 appropriations bill that clarified that all the Fernald Site K-65 residues (as well as the NFSS residues) would be deemed 11e.(2) for disposal.

Prior to these efforts, disposal of the K-65 residues was an implementability issue for the Fernald K-65 Project remediation. However, because of the precedents set in the Fernald K-65 Project, the implementability risk associated with waste disposal has been greatly reduced, but not eliminated, for the NFSS. There still is only one off-site storage/disposal option for the K-65 wastes – at the WCS facility in

Texas; therefore, implementability relies on this disposal option remaining viable or another option being identified. Discussion with WCS representatives indicated that they will require an additional permit revision to accept the NFSS wastes, but this is not expected to be an issue.

Several facilities have 11e.(2) disposal cells that can accept the lower-activity Subunit A waste. The Subunit B materials above Buildings 411, 414, and 415 will be disposed of at an approved LLRW or LLMW disposal facility.

Transport of the non-stabilized Subunit A waste material to the disposal facilities will use truck trailers and rail that are readily available and commonly used. Truck drivers will be certified under DOT requirements.

In summary, both components of Alternative 3A have been found to be implementable given assumed conditions. The conditions that require ongoing consideration are the use of a new approach to residue retrieval and continued availability of disposal options for the stabilized K-65 residues.

4.4.4.5 Cost

The complete breakdown of the estimated cost to implement Alternative 3A is provided in Appendix J. The estimated capital cost is $259.63M.

The estimated O&M cost is $43.75M, discounted at 3.5% over 1,000 years. The non-discounted O&M cost is $1.45B.

The capital cost breakdown is as follows:

- Mobilization and preparatory work – $1,978,167.

- Subunit A retrieval, treatment, and off-site disposal:

  - program management – $10,573,367;
  - solid collection and containment (retrieval) – $33,434,879;
  - stabilization/fixation/encapsulation – $65,523,180;
  - off-site disposal – $36,572,804;
  - D&D – $14,747,049; and
  - physical treatment (RCS) – $19,365,366.

- Subunits B and C enhanced containment:

  - monitoring, sampling, testing, and analysis – $1,978,167;
  - site work – $3,341, 787;
  - surface water collection and control – $636,653;
  - solids collection and containment – $9,767,380;
  - off-site transport and disposal – $9,934,634;
  - site restoration – $526,004;
  - design and project management – $5,531,445; and
  - project contingency – $34,665,707.

The cost also includes an $11.25M supervision and administration item. Disposal costs vary over time based on market conditions and likely will vary from previously published costs (e.g., in the WDO/Fernald LL TM [USACE 2011a]).

4.5 ANALYSIS OF ALTERNATIVE 3B – REMOVAL, TREATMENT, AND OFF-SITE DISPOSAL OF SUBUNITS A AND B AND ENHANCED CONTAINMENT OF SUBUNIT C

4.5.1 Description of Alternative 3B

Alternative 3B is the second alternative that includes partial removal of the materials in the IWCS followed by enhanced containment of the remaining materials. Alternative 3B includes:

- removal, treatment, and off-site disposal of Subunit A;
- removal and off-site disposal of Subunit B; and
- enhanced containment of Subunit C.

Descriptions and evaluations of the removal of Subunit B wastes above Buildings 411, 413, and 414 and removal, treatment, and off-site disposal of Subunit A residues and wastes are discussed in Sections 4.4.1, 4.4.2, and 4.4.3 and in Appendices F and G. The description and evaluation of enhanced containment for Subunit C are discussed in Sections 4.3.1, 4.3.2, and 4.3.3 and in Appendix G. The shape of the cap over Subunit C is modified from Alternative 2, as discussed below. This section provides additional information and analysis of the new scope in this alternative—removal of all of Subunit B—and discusses the analysis of the combination of the remedial actions for Subunits A, B, and C.

The key components of Alternative 3B remediation include:

- construction of remediation support infrastructure and an RCS,
- removal of a portion of Subunit B to access Subunit A,
- removal of Subunit A,
- removal and off-site disposal of the remainder of Subunit B,
- construction of the enhanced containment system for Subunit C, and
- implementation of long-term LUCs.

The site layout for this alternative is presented in Drawings C-13, C-14, and C-15 within Appendix K.

4.5.1.1 Construction of remediation support infrastructure and RCS

Refer to Alternative 3A, Sections 4.4.1.1 and 4.4.1.2, for a description of this work.

4.5.1.2 Removal, treatment, and off-site disposal of Subunit A

Refer to Alternative 3A, Section 4.4.1, for a description of this work.

4.5.1.3 Removal and off-site disposal of the remainder of Subunit B

In lieu of available analytical data on Subunit B, information gathered from numerous investigations, assessments, and reports was used to estimate waste material characteristics and volumes in Subunit B. Subunit B includes the contaminated building debris; underground piping; equipment debris; contaminated clay dike and cut-off walls; and contaminated soil placed outside Buildings 411, 413, and 414 in the south end of the IWCS. The total in-situ volume of Subunit B waste that will be removed is approximately 48,266 m^3 (63,130 yd^3) (Table 4-10); 39% of this will be removed prior to retrieval of the Subunit A residues. A check of the total waste volume was performed by comparing the documented

Table 4-10. Total of Subunit B Materials Excavated as a Component of Alternative 3B

Material Description	In-Situ Volume (yd^3)	Bulking Factor (%)	Ex-Situ Volume (yd^3)	Assumed Waste Classification
Clean topsoil and subsurface soil	9,400	30	12,220	NA
Clean clay cap	17,500	33	23,275	NA
Clean dike	3,960	33	5,267	NA
Contaminated clay cap	8,750	33	11,638	LLRW
Contaminated dike	2,390	33	3,179	LLRW
Contaminated soil beneath waste	5,640	30	7,332	LLRW
Contaminated soil beneath Buildings 411, 413, and 414	3,340	30	4,342	11e.(2)
Contaminated dike (below IWCS floor)	220	33	293	LLRW
Contaminated soil 1984 – 1985	7,950	30	10,335	LLRW/LLMW[a]
Contaminated soil in Subunit A above buildings	7,950	30	10,335	LLRW/LLMW[a]
Middlesex sands	230	18	271	11e.(2)
Miscellaneous materials	12,130	70	20,621	LLRW
Building 410 rubble and concrete	4,210	40	5,894	LLRW
Buildings 409 and 412 debris	3,500	40	4,900	LLRW
Buildings 411, 413, and 414	4,950	40	6,930	11e.(2)
Building 415	100	40	140	LLRW
Building 434	1,400	40	1,960	11e.(2)
Thaw House Foundation	200	40	280	11e.(2)
K-65 transfer piping	170	50	255	11e.(2)
Subtotal Subunit B clean material	***30,860***	--	***40,762***	--
Subtotal Subunit B contaminated material	***63,130***	--	***88,704***	--
Total Subunit B material	***93,990***	--	***129,466***	--

[a] For estimating purposes, LLMW is assumed to be 10% of the LLRW volume.
IWCS = Interim Waste Containment Structure.
LLMW = Low-level mixed waste.
LLRW = Low-level radioactive waste.
NA = Not applicable.
% = Percent.
yd^3 = Cubic yard.

volume of waste in historical reports and studies against the capacity of the Subunit B portion of the IWCS. The capacity of Subunit B represents the total volume required to fill that portion of the IWCS. The capacity was determined by examining construction records, historic information, and site topographic survey information as input data used to construct a model of the IWCS using EarthVision™ software.

The components involved in the removal and off-site disposal of Subunit B materials include:

- development of remediation infrastructure support,
- construction of materials support facilities,
- excavation and waste containerization,
- transportation and disposal, and
- site preparation for the Subunit C enhanced containment system.

Details of these steps are presented as part of the description of Alternative 4, which covers the excavation approach to all materials within the IWCS (Section 4.6.1), and the discussion in Appendix H, which covers complete removal and off-site disposal of both Subunits B and C.

If any Subunit B material disposed off-site fails the Toxicity Characteristic Leaching Procedure analyses, it will be sent to an LLMW facility for pre-treatment prior to disposal.

4.5.1.4 Enhanced containment of Subunit C

The approach to enhanced containment for Subunit C is provided in Section 4.3.1 and Appendix G. The Alternative 3B cap is a modified version of the full cap developed for Alternatives 2 and 3A because the Alternative 3B cap will cover only the northern portion of the IWCS (Subunit C). The modified dimension of the cap is shown in Drawings C-14 and C-15 within Appendix K. The cap layers and materials as described for Alternative 2 in Section 4.3.1 are the same.

4.5.1.5 LUCs

LUCs would be implemented to maintain perpetual, Federal, active control over the site. Long-term surveillance, monitoring, and maintenance of materials within the IWCS would be performed by the Federal Government. Additionally, the Federal Government would provide LUCs to prevent re-exposure of contaminants as necessary. LUCs would be defined in a LUC Plan, developed during the remedial design phase. The LUCs would be maintained until the remaining hazardous substances are at levels allowing for unlimited use and unrestricted exposure. Due to the presence of long-lived radionuclides in the IWCS, the LUCs would need to be maintained to provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Additional discussion on LUCs is presented in Section 4.3.1.

4.5.2 Comprehensive Environmental Response, Compensation, and Liability Act Criteria

Detailed analysis of Alternative 3B according to CERCLA threshold and balancing criteria is provided in the following sections. Table 4-11 presents the results of the analysis; supporting detail is provided in Sections 4.5.3 and 4.5.4.

4.5.3 Threshold Criterion

4.5.3.1 Overall protection of human health and the environment

Alternative 3B is protective of human health and the environment. The risk profile for Alternative 3B is similar to Alternatives 2 and 3A because all residual waste will be under a cap and LUCs will be in place to prevent direct exposure. As indicated in Section 4.3.2.1, estimated cancer risks to the On-Site Maintenance Worker and the Off-Site Resident associated with Alternative 2 are 2.6×10^{-5} and 4.4×10^{-7}, respectively. These values are within or below the acceptable risk range under CERCLA. With the removal of Subunits A and B wastes, these future risks would be lower.

4.5.3.2 Compliance with ARARs

Alternative 3B is similar to Alternative 3A with the exception that additional Subunit B waste will be removed. The analyses presented in Tables 4-5 and 4-9 show that both the enhanced containment and excavation portions of Alternative 3A meet the requirements of the ARARs. Because Alternative 3B removes even more waste, Alternative 3B also meets the requirements of the ARARs.

Table 4-11. Detailed Analysis of Alternative 3B (Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C)

CERCLA Criterion	Evaluation Factor (Table 4-1)	Results of Evaluation
CERCLA Threshold Criteria		
CERCLA Criterion		**Result of Evaluation**
Overall protection of human health and the environment		LUCs and cap maintenance are protective; prevents unacceptable exposures to IWCS materials
Compliance with ARARs		Complies with ARARs
CERCLA Balancing Criteria		
CERCLA Criterion	**Evaluation Factor (Table 4-1)**	**Results of Evaluation**
Long-Term Effectiveness and Permanence	Magnitude of residual risk	Highest-activity waste removed. All residues and waste in Subunit C, including the R-10 pile, remain in place under the enhanced cap. Risk to human and ecological receptors is within or below the acceptable risk range
	Adequacy and reliability of controls	Structurally stable design, LUCs, and cap maintenance are in place to prevent exposure over the long term
	Summary	Structurally stable design, LUCs, and cap maintenance are effective at preventing unacceptable exposure to wastes over the long term
Reduction of Toxicity, Mobility, and Volume Through Treatment	Treatment process used and materials treated	Cement stabilization used to treat approximately 6,030 yd^3 of K-65 and commingled residues
	Amount of hazardous materials destroyed or treated	Approximately 6,030 yd^3 of K-65 and commingled residues and a minor amount of Subunit B and LLMW treated
	Degree of expected reduction in toxicity, mobility, and volume	Reduction in the mobility and radon release hazard related to the treated K-65 and commingled residues; increased volume of K-65 waste due to addition of stabilizer
	Degree to which treatment is irreversible	High; treated waste form is a cement stabilized solid in a steel container
	Type and quantity of residuals remaining after treatment	Off-site wastes that are not treated (Subunits A and B) = 120,449 yd^3. On-site untreated residuals (Subunit C) =225,595 yd^3
	Summary	Reduces the toxic effect and mobility of the highest-activity material (K-65 and commingled residues). Does not reduce volume. Does not reduce toxicity, mobility, or volume of untreated L-30, L-50, and F-32 residues or Subunits B and C materials
Short-Term Effectiveness	Protection of community during remedial actions	Controls included to ensure no exposure to airborne contaminants during remediation, including an engineered containment facility and RCS. Local truck traffic increases. Rail used to reduce risk during transport to the disposal facility
	Protection of workers during remedial actions	In addition to complying with all radiation worker protection requirements, robotics will be used to retrieve most hazardous residues
	Environmental impacts	Controls in place to prevent environmental impacts
	Time until remedial action objectives are achieved[a]	8 years: 2 years design and 6 years construction
	Summary	Short-term impacts to workers and community can be controlled through robust work control processes
Implementability	Ability to construct and operate the technology	For Subunit A, remediation is a challenge to construct and operate, but a similar approach was proven at the Fernald K-65 Project. Subunit C relies on proven technologies
	Reliability of the technology	Subunit A approach proven reliable at the Fernald K-65 Project. Cap technology is reliable through the life of the geomembrane (approximately 500 years); cap maintenance and LUCs required
	Ease of undertaking additional remedial actions, if necessary	Additional action could be implemented on Subunit C
	Ability to monitor the effectiveness of the remedy	Monitoring currently proving effective; monitoring will remain in place
	Ability to obtain approvals from other agencies	Would require discussion to obtain buy-in. Essentially equivalent to Alternative 3A. More likely to be accepted than Alternative 2
	Viability of off-site treatment, storage, and disposal services and capacity	There is only one facility that has accepted K-65 residues in the past. Several options exist for Subunit B wastes
	Availability of necessary equipment and specialists	Specialty capabilities required for Subunit A are available. Readily available for Subunits B and C
	Summary	Implementable with available specialty resources
Cost	Capital costs	$318.4M
	O&M costs (not discounted)	$1,450M
	Present worth O&M costs (discounted)	$43.8M

[a] Estimates to complete the action assume projects receive sufficient annual funding to meet schedules.
ARAR = Applicable or relevant and appropriate requirement.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
IWCS = Interim Waste Containment Structure.
LLMW = Low-level mixed waste.
LUC = Land-use control.
NA = Not applicable.
O&M = Operation and maintenance.
RCS = Radon control system.
yd^3 = Cubic yard.

4.5.4 Balancing Criteria

4.5.4.1 Long-term effectiveness and permanence

Under Alternative 3B, the Subunit A high-activity residues and the Subunit B wastes are removed and the residual waste left in place includes the R-10 residues and soil in Subunit C. These wastes will be under an enhanced cap and, thus, engineered and administrative controls have been included to prevent human and ecological receptor contact with the waste and to resist leaching to groundwater. As with Alternative 2, the potential long-term human health receptors are the On-Site Maintenance Worker and the Off-Site Resident. The risks associated with these receptors have been estimated to be 2.6×10^{-5} and 4.4×10^{-7}, respectively, which are within and below the CERCLA acceptable risk range. Similarly, with the enhanced cap in place, there are no ecological risk concerns, as discussed in Section 1.4. Because the Alternative 3B source term is significantly less than Alternative 2, the risks associated with Alternative 3B would be significantly lower over the long term. Thus, Alternative 3B is effective at preventing long-term unacceptable radon and gamma radiation exposures.

Separate groundwater model runs were not performed for Alternative 3B. Because model runs for Alternative 3A showed that removal of just Subunit A would be protective of groundwater, removal of both Subunits A and B also would be protective.

4.5.4.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 3B calls for the removal and treatment of the most radioactive residues in the IWCS—the K-65 residues and commingled residues (a portion of the L-30 and F-32 residues). The remaining Subunit A residues and material will not be treated other than by size-reduction of debris and adding an absorbent to ensure there is no free liquid in containers to be shipped off-site for disposal. There is no waste treatment planned for Subunit B waste, with the exception of any waste that does not meet hazardous waste requirements measured by Toxicity Characteristic Leaching Procedure and size reduction. Planned size reduction of debris will not significantly change the volume of material. There is no treatment planned for the Subunit C materials that will remain under the enhanced cap.

The benefits of treating the K-65 and commingled residues are described in Section 4.4.3.2.

4.5.4.3 Short-term effectiveness

The conceptual design components used to minimize impacts to workers, the public, and the environment are described in Section 4.4.3.3. The primary issues related to short-term protection of the community, workers, and the environment during remediation are associated with the Subunit A portion of this alternative. Excavation of Subunit B materials could expose some low-level contaminated materials; however, the contaminant concentrations (average 16 pCi/g of Ra-226 in soil) and low volume/short duration of the work are of much lesser concern. As with Alternative 2, the containment of Subunit C results in little to no short-term issue during remediation.

The Health Effects TM (USACE 2012b) identified several potential short-term issues that could occur during remediation of Subunit A in the absence of proper controls. To mitigate these potential risks to the community, workers, and the environment during remediation, controls have been designed into the Alternative 3B components.

Protection of the community

Radon exposures would be mitigated by capturing radon inside the Retrieval Facility, the Stabilization Facility, and at all excavation faces. The HVAC systems and RCS would place all remediation areas subject to potential releases of radon under negative pressure. The gases would then be treated prior to release to the environment.

Dust created during retrieval, construction, and D&D would be controlled with standard dust suppression techniques to provide protection to the local community.

Site-wide access controls would prevent trespassers from inadvertently becoming exposed to the contaminants. Through the use of fences and guards, access to the materials by the public would be controlled. Access controls are effective and commonly used.

Potential radiation exposure to the public resulting from the transport of radioactive waste material to the off-site disposal facilities would be below the DOT requirements and far below the target cancer risk range of 10^{-4} to 10^{-6} (Appendix I). Injuries and/or fatalities may occur due to transportation accidents. The estimated number of accidents is lower for bimodal transportation than by truck (Appendix I), which is one reason for the selection of a bimodal truck-rail option for the larger volumes of waste in Subunit A and all of Subunit B.

For the stabilized waste in Subunit A that will be transported to WCS via truck, the estimated potential of accidents related to shipping is low (Appendix I). There were no fatalities or injuries associated with transport of the Fernald K-65 residues, which was a significantly greater number of shipments than will be required for the IWCS. However, this does not preclude the possibility for accidents with the IWCS waste stream.

Protection of workers

Both the release of radon and exposure to direct radiation from the residues could create a risk to workers. This risk is greater for the Subunit A work than for Subunit B due to the difference in Ra-226 concentrations between the two components. For Subunit A, with appropriate measures of protection (e.g., negative air pressure in containment facilities, personal protective equipment, training, and shielding), the removal and treatment of residues are estimated to result in an excess cancer risk level below the occupational standards required by worker exposure requirements. Significant monitoring, remote operations, and shielding would be required to maintain worker protection and to identify the need for corrective action. For Subunit B, it is not anticipated that these controls would be necessary. Instead, continuous radiological protection monitoring would be in place to identify if controls need to be implemented. The only portion of Subunit B work anticipated to possibly require supplied air is work conducted in the vicinity of the buildings that housed the residues (Buildings 411, 413, and 414).

Risks associated with remediation work, such as vehicular accidents, would be addressed through worker health and safety plans.

Short-term environmental impacts

Short-term environmental impacts could be realized during excavation, construction, and support facility D&D. Excavation and construction activities would disturb the immediate area by causing erosion and generating fugitive dust emissions. Significant erosion control measures have been designed into the alternative to prevent transport of contaminants to adjacent surface water bodies (see Drawing C-13 within Appendix K). Upon completion of site construction activities, the site would be restored.

In addition to fugitive dust emissions, heavy equipment exhaust is likely to be generated but is not expected to impact air quality. During operations, radon gas would be controlled with the RCS and HVAC systems under negative pressure to mitigate the possibility of a release.

Waste stabilization operations would generate process wastewater, which would be recycled into the treatment system to minimize waste generation. Any remaining process wastewater that could not be recycled (e.g., decontamination water) would be treated by the on-site water treatment plant.

Time to Complete

A sequencing approach has been developed to estimate the time to complete all of the components of Alternative 3B (Figure 4-3).

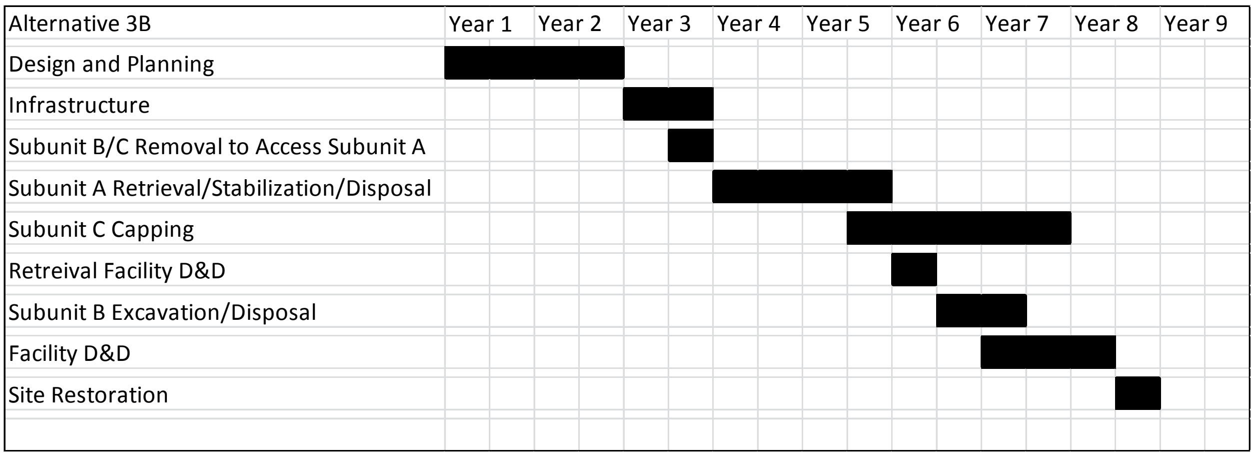

Figure 4-3. Sequencing of Activities for Alternative 3B

The time related to post-construction regulatory documents is not included in this estimate. The estimated durations are based on the productivity assumptions used in the cost estimation presented in Appendix J. The total estimated time to implement Alternative 3B is 8 years. One of the differences between Alternatives 3A and 3B is the extended finish on the Subunit C cap, which cannot be completed until after the Subunit B excavation is complete.

4.5.4.4 Implementability

The implementability of the remedial action proposed for Subunit A is discussed in Section 4.4.3.4.

The Subunit B excavation component is implementable as described for Alternative 3A (Section 4.6.3.4).

The implementability of an enhanced containment option for Subunit C is discussed as part of the evaluation of Alternative 2, Enhanced Containment (Section 4.3.3.4).

In summary, the remedial actions proposed for each subunit are implementable individually and as a consolidated alternative. The items that require ongoing consideration are the continued availability of a disposal option for the stabilized K-65 residues and the uncertainty related to implementing LUCs for a period of 1,000 years for the enhanced containment portion of this alternative to prevent exposure to the R-10 residues.

4.5.4.5 Cost

The complete breakdown of the estimated cost to implement Alternative 3B is provided in Appendix J.

The estimated capital cost is $318.44M.

The estimated O&M cost is $43.75M, discounted at 3.5% over 1,000 years. The non-discounted O&M cost is $1.45B.

The cost breakdown is as follows:

- Mobilization and preparatory work – $2,346,159.

- Subunit A retrieval, treatment, and off-site disposal:

    - program management – $10,573,367;
    - solid collection and containment (retrieval) – $33,434,879;
    - stabilization/fixation/encapsulation – $65,523,180;
    - off-site disposal – $36,572,804;
    - D&D – $14,747,049; and
    - physical treatment (RCS) – $19,365,366.

- Subunits B and C:

    - monitoring, sampling, testing, and analysis – $2,544,166;
    - site work – $4,234,064;
    - surface water collection and control – $1,042,550;
    - solids collection and containment – $14,806,469;
    - chemical treatment – $3,736,744;
    - off-site transport and disposal – $34,399,853;
    - site restoration – $1,322,584;
    - design project management – $12,744,766; and
    - project contingency – $49,043,707.

The cost also includes a $12M supervision and administration line item. Disposal costs vary over time based on market conditions and likely will vary from previously published costs (e.g., in the WDO/Fernald LL TM [USACE 2011a]).

4.6 ANALYSIS OF ALTERNATIVE 4 – REMOVAL; TREATMENT (SUBUNIT A ONLY); AND OFF-SITE DISPOSAL OF SUBUNITS A, B, AND C

4.6.1 Description of Alternative 4

Alternative 4 includes excavation and off-site disposal of all wastes in the IWCS. Alternative 4 includes:

- removal, treatment, and off-site disposal of Subunit A; and
- removal and off-site disposal of Subunits B and C.

The description of the removal, treatment, and off-site disposal of Subunit A is presented under Alternative 3A in Section 4.4.1. The alternative description in this section focuses on the removal and off-site disposal of the entire contents of Subunits B and C. The key components of Alternative 4 remediation include:

- construction of remediation support infrastructure,
- removal of Subunit A,
- removal of Subunits B and C, and
- site restoration and closure.

The site layout for this alternative is presented in Drawings C-16, C-17, C-18, and C-19 within Appendix K.

4.6.1.1 Construction of remediation support infrastructure

Refer to Alternative 3A, Sections 4.4.1.1 and 4.4.1.2, for a description of this work.

4.6.1.2 Removal, treatment, and off-site disposal of Subunit A

Refer to Alternative 3A, Section 4.4.1, for a description of this work.

4.6.1.3 Removal and off-site disposal of Subunits B and C

Alternative 4 includes the removal of all Subunits B and C materials, as listed in Table 4-10 and Table 4-12, respectively. Table 4-12 also shows the assumed waste type of the material used for estimating the cost of off-site disposal.

As indicated in the description of Alternative 3B, the components involved in the removal and off-site disposal of Subunits B and C wastes include:

- pre-excavation characterization and waste profile development,
- excavation and waste containerization, and
- transportation and disposal.

Appendix H provides additional details of these components.

<u>*Characterization and waste profile development*</u>

Additional pre-design characterization will take place to plan for the proper handling and disposal of the wastes. The data quality objective for the characterization effort will be to obtain results necessary to comply with WAC.

Working in conjunction with selected disposal facilities, these results will be used to develop generic waste profiles for each of the waste streams (i.e., 11e.[2], LLRW, and LLMW) so that minimal sampling of stockpiled material will be required to demonstrate that excavated materials fall within the boundaries of the approved profiles.

<u>*Excavation and waste containerization*</u>

The major components of the conceptual design for excavation of Subunits B and C are as follows:

- equipment selection for excavation, handling, and loading of soil-like material and debris;

Table 4-12. Subunit C Materials Excavated for Alternative 4

Material Description	In-Situ Volume (yd^3)[a]	Bulking Factor (%)	Ex-Situ Volume (yd^3)	Assumed Waste Classification
Clean topsoil and subsurface soil	16,750	30	21,775	NA
Clean clay cap	17,743	33	23,598	NA
Clean dike	4,600	33	6,118	NA
Contaminated clay cap	15,200	33	20,216	LLRW
Contaminated dike	2,450	33	3,259	LLRW
Contaminated soil beneath waste	4,842	33	6,440	LLRW
Contaminated dike (below the IWCS floor)	210	33	279	LLRW
Contaminated soil beneath R-10 pile	35,000	33	46,550	11e.(2)
Contaminated soil in pile (soil/fill)	6,800	30	8,840	LLRW
R-10 original ore	9,500	33	12,635	11e.(2)
Contaminated soil in R-10 pile – 1972 remedial action soil	15,000	30	19,500	11e.(2)
1982 remedial action – eroded R-10 placed on R-10 pile	15,700	30	20,410	LLRW/LLMW[a]
1983 remedial action (placed north of Building 411)	54,000	30	70,200	LLRW
Contaminated soil (1984 remedial action)	24,300	30	31,590	LLRW
1991 Miscellaneous soil – north of Building 411	3,200	30	4,160	LLRW
1991 – Miscellaneous debris – north of Building 411	300	50	450	LLRW
Subtotal Subunit C clean material	*39,093*	--	*51,491*	--
Subtotal Subunit C contaminated material	*186,502*	--	*244,529*	--
Total Subunit C Material	*225,595*	--	*296,020*	--

[a] For estimating purposes, LLMW is assumed to be 10% of the LLRW volume.
IWCS = Interim Waste Containment Structure.
LLMW = Low-level mixed waste.
LLRW = Low-level radioactive waste.
NA = Not applicable.
% = Percent.
yd^3 = Cubic yard.

- waste screening and monitoring;
- waste handling, staging, and loading;
- transportation to rail siding and loading into rail cars;
- excavation approach and controls; and
- excavation phasing.

As shown in Table 4-12, most of the waste in Subunit C is soil or soil-like, as opposed to the material in Subunit B, which contains a significant volume of rubble and debris. Therefore, removal of material in Subunit C follows a standard earthmoving scenario where production can be optimized by choosing large equipment where production is relatively high and precision is not necessary. Conversely, debris removal is a much slower, more surgical process due to disposal requirements relative to requirements to cut, size, and process/handle odd-sized objects prior to loading. In addition, waste characterization, screening, and monitoring must be performed to ensure that the waste meets WAC for the chosen disposal facility. 11e.(2) waste will be exempt from Resource Conservation and Recovery Act requirements; however, minimal sampling of the LLRW will be required to confirm its Resource Conservation and Recovery Act status.

Appendix H provides detailed conceptual design components of the excavation activities for Subunits B and C, including excavation and loading equipment requirements, waste containers, materials loading, and transportation approaches. A major assumption in the design and pricing of this alternative is that treatment will not be required based on radioactivity levels.

Excavation of Subunit C will begin at the northeastern corner of the IWCS. Removal of clean soil will commence westward and southward. Initially, clean soil will be removed in an area large enough to efficiently accommodate three loading stations. Temporary erosion and sedimentation diversions will be installed at the up-slope edge of the disturbed area to prevent runoff from entering the excavated area. Excavation will proceed south and westward toward the loading station. Clean soil removed will be stockpiled in the designated areas shown on Drawings C-10, C-13, and C-16 within Appendix K, and impacted material will be loaded directly from the IWCS. Excavation will proceed to the target depth before disturbing more areas and expanding the areal size of the excavation, as long as efficient access is still possible given spatial constraints and equipment routing requirements. Temporary sumps will be constructed in the northwestern corner of each excavation area to remove water from the excavation. In this way, the excavation will always be sloped away from the Central Drainage Ditch to avoid potential release of untreated surface water. In addition, a perimeter diversion dike, discussed in Appendix H, will protect the ditch from impacted surface water. Mud pumps will be used to dewater excavated areas, as needed, and will transfer water from the sumps to the construction water drain line installed along the western boundary of the IWCS (Drawing C-17 within Appendix K) prior to discharging to the dirty water pond and water treatment facility. If wet soil is encountered, it can be mixed with dry material as the excavation proceeds southward or can be transported to a bermed and lined soil-drying area, shown on Drawing C-16 within Appendix K, where it can be manipulated until it meets disposal moisture requirements. Excavation will proceed southward as clean material is used to fill the completed excavated area to the north.

The detailed information presented in Appendix H serves as the basis for the detailed costing for this alternative in Appendix J.

4.6.1.4 Site restoration

The conceptual design for the excavation and disposal alternatives contains demolition and site restoration components that include infrastructure dismantlement, demolition, and restoration; material removal and recycling; and land grading and shaping, removal of the temporary erosion and sediment controls (i.e., earthen diversion dike and sediment basins), and seeding/mulching. Site restoration activities will include backfilling and grading of the staging areas, material lay-down areas, vehicle maintenance and wash-down areas, construction trailer areas, and temporary haul roads and removal of retention basins. Drawing C-18 within Appendix K shows the final disposition of the NFSS after removal of the waste and the re-grading of the IWCS for Alternative 4.

The wastewater treatment building will be dismantled and either reused or recycled. All concrete pads used to support excavation activities will be removed, size-reduced, and disposed. Fencing will be installed to the original configuration after excavation activities. Site re-grading will be conducted at all disturbed areas. A minimum of 0.15 m (6 in.) of topsoil will be installed over disturbed areas. The topsoil will be seeded with a seed mixture of several varieties of sun-tolerant and moisture-tolerant Kentucky Bluegrass, fescues, and perennial ryegrass reseed. The seeded areas will be mulched with clean straw mulch at a minimum of 2 tons/acre, or as specified. Equipment will be decontaminated, disassembled or size-reduced, and disposed. All material and equipment will be decontaminated as practical prior to disposal or reuse. Alternative 4 consists of the excavation and disposal of all of the contents of the IWCS. Clean soil removed from the cap will be used to fill the excavation to grade.

A long-term maintenance, surveillance, and environmental monitoring program will not be required for this alternative because all residual material will be removed, thereby eliminating any potential unacceptable exposure to receptors. The site is assumed to undergo 5 years' worth of post-action monitoring and one 5-year review. After that point, there will be no requirement for long-term monitoring or LUCs related to the IWCS; however, site controls may still be in place for the Balance of Plant OU.

4.6.2 Comprehensive Environmental Response, Compensation, and Liability Act Criteria

Detailed analysis of Alternative 4 according to CERCLA threshold and balancing criteria is provided in the following sections. Table 4-13 presents the results of the analysis; supporting detail is provided in Sections 4.6.3 and 4.6.4.

4.6.3 Threshold Criteria

4.6.3.1 Overall protection of human health and the environment

This alternative is protective of human health and the environment because it removes all the waste in the IWCS consistent with the RAOs. All IWCS waste will be removed to action levels as determined by ARARs, reducing risk to negligible levels. Materials remaining at the site transfer to the Balance of Plant OU.

4.6.3.2 Compliance with ARARs

Alternative 4 complies with all the requirements of the identified ARARs. Excavation alternatives were designed to meet regulatory and technical relevant and appropriate requirements for excavation activities identified in Table 4-9, specifically to remove radium in compliance with the requirements of 10 *CFR* 40, Criterion 6(6).

4.6.4 Balancing Criteria

4.6.4.1 Long-term effectiveness and permanence

Alternative 4 removes all residues and wastes from the IWCS, thereby eliminating all risk at the site. A Multi-Agency Radiation Survey and Site Investigation Manual-based verification program will be implemented to verify compliance with health-based ARARs.

4.6.4.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 4 calls for treatment of the most radioactive residues in the IWCS—the K-65 residues and commingled residues (a portion of the L-30 and F-32 residues). The remaining Subunit A residues and material will not be treated, other than by size-reduction of debris and adding an absorbent to ensure there is no free liquid in containers to be shipped off-site for disposal. There is no waste treatment planned for Subunits B and C waste, with the exception of any waste that does not meet hazardous waste requirements measured by Toxicity Characteristic Leaching Procedure and size reduction. Planned size reduction of debris will not significantly change the volume of material.

The benefits of treating the K-65 and commingled residues are described in Section 4.4.3.2.

Table 4-13. Detailed Analysis of Alternative 4 (Removal, Treatment [Subunit A only], and Off-Site Disposal of Subunits A, B, and C)

CERCLA Threshold Criteria		
CERCLA Criterion		**Result of Evaluation**
Overall protection of human health and the environment		Protective of human health and the environment over the long term; removes all wastes
Compliance with ARARs		Complies with ARARs
CERCLA Balancing Criteria		
CERCLA Criterion	**Evaluation Factor (Table 4-1)**	**Results of Evaluation**
Long-Term Effectiveness and Permanence	Magnitude of residual risk	No residual waste remains in place, negligible residual risk
	Adequacy and reliability of controls	No controls necessary because all residues and wastes are removed
	Summary	Effective at removing all risk over the long term
Reduction of Toxicity, Mobility, and Volume Through Treatment	Treatment process used and materials treated	Cement stabilization used to treat approximately 6,030 yd^3 of K-65 and commingled residues
	Amount of hazardous materials destroyed or treated	Approximately 6,030 yd^3 of K-65 and commingled residues and an estimated 2,000 yd^3 of Subunits B and C LLMW treated
	Degree of expected reduction in toxicity, mobility, and volume	Reduction in the mobility and radon release hazard related to the treated K-65 and commingled residues; increased volume of K-65 waste due to addition of stabilizer
	Degree to which treatment is irreversible	High; treated waste form is a cement stabilized solid in a steel container
	Type and quantity of residuals remaining after treatment	Off-site wastes that are not treated (Subunits A, B and C) = 346,044 yd^3. No on-site untreated residuals
	Summary	Reduces the toxic effect and mobility of the highest-activity material (K-65 and commingled residues). Does not reduce volume. Does not reduce toxicity, mobility, or volume of untreated L-30, L-50, and F-32 residues or Subunits B and C materials
Short-Term Effectiveness	Protection of community during remedial actions	Controls included to ensure no exposure to airborne contaminants during remediation, including an engineered containment facility and RCS. Truck traffic increases. Rail used to reduce risk during transport to the disposal facility
	Protection of workers during remedial actions	In addition to complying with all radiation worker protection requirements, robotics will be used to retrieve most hazardous residues
	Environmental impacts	Controls in place to prevent environmental impacts
	Time until remedial action objectives are achieved[a]	8 years: 2 years design and 6 years construction
	Summary	Short-term impacts to workers and community can be controlled through robust work control processes
Implementability	Ability to construct and operate the technology	For Subunit A, remediation is a challenge to construct and operate, but a similar approach was proven at the Fernald K-65 Project. Subunits B and C rely on proven technologies
	Reliability of the technology	Subunit A approach proven reliable at the Fernald K-65 Project. Subunits B and C incorporate reliable excavation, loading, and transport approaches
	Ease of undertaking additional remedial actions, if necessary	No additional action would be necessary
	Ability to monitor the effectiveness of the remedy	Monitoring not required
	Ability to obtain approvals from other agencies	Likely
	Viability of off-site treatment, storage, and disposal services and capacity	There is only one facility that has accepted K-65 residues in the past. Several options exist for Subunits B and C wastes
	Availability of necessary equipment and specialists	Specialty capabilities required for Subunit A are available. Readily available for Subunits B and C
	Summary	Implementable with available specialty resources
Cost	Capital costs	$490.6M
	O&M costs (not discounted)	Zero cost
	Present worth O&M costs (discounted)	Zero cost

[a] Estimates to complete the action assume projects receive sufficient annual funding to meet schedules.
ARAR = Applicable or relevant and appropriate requirement.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
RCS = Radon control system.
LLMW = Low-level mixed waste.
LUC = Land-use control.
O&M = Operation and maintenance.
yd^3 = Cubic yard.

4.6.4.3 Short-term effectiveness

Multiple short-term impacts have been evaluated for this alternative, focusing on potential short-term exposures during remediation (USACE 2012b), environmental impacts, and short-term impacts related to transportation of the wastes to an off-site facility.

Short-term impacts associated with the Subunit A component are presented in the discussion of Alternative 3A (Section 4.4.3.3). Because of the inherent hazard associated with the Subunit A residues compared to the materials in Subunits B and C, those impacts represent the greatest concern for this alternative. However, excavation of Subunits B and C introduces additional short-term impacts that have been considered in the conceptual design:

- Some of the Subunit B waste types do not have characterization data. These include the building materials for Buildings 411, 413, and 414; the rubble from the original tower (Building 434) that housed the K-65 materials; and materials used to transfer the K-65 residues. These waste streams may pose hazards upon contact. Continuous radiological monitoring has been included in the approach to ensure that both radon and gamma radiation levels are safe for workers as these materials are addressed; if the levels exceed protection standards, work controls will be implemented.

- The current level of contamination throughout the R-10 pile likely varies. The average concentration, as identified in the Final Environmental Impact Statement (DOE 1986a) and the Failure Analysis Report (BNI 1994), is 95 pCi/g. The *Final Report on a Comprehensive Characterization and Hazard Assessment of the DOE-Niagara Falls Storage Site* (Battelle 1981a) indicates that there could be a layer of elevated Ra-226 representative of the original ore residues. If this is encountered, worker protection controls would increase.

To address these concerns, remediation activities will be conducted in accordance with a Radiation Protection Program under the direction of a Radiological Control Technician. Due to the nature of the materials, the key pathway of concern for community and worker protection is the air pathway. Therefore, air controls will be developed and maintained based on characterization data and on analytical and monitoring data generated during execution of the removal action.

At this time, throughout much of the Subunits B and C excavation, workers are assumed to be in Level D personal protection equipment, with two possible exceptions. Workers may need additional protection (supplied air or negative pressure caps) around the materials in Subunit B that have been in contact with the K-65 residues and as the excavation in Subunit C approaches the original R-10 residue layer.

To meet environmental compliance requirements, erosion/sedimentation, stormwater, dust controls, and a dewatering water treatment system have all been included in the conceptual design (Appendix H).

Activities, such as excavation, stockpiling, materials management activities, and Subunit B materials reduction for a large volume of soil and debris, result in a high degree of machinery use. Work controls included in the conceptual design to address the potential impact related to construction risks include continuous worker monitoring and a reduced work productivity rate to accommodate worker safety concerns.

Excavation of Subunits B and C results in a high volume of materials that must be shipped off-site. The selected mode of off-site transportation is bimodal. Wastes will be loaded into trucks at the sites, transported via truck to a rail line, and shipped to the disposal facility via rail (Appendix I).

The estimated time to complete Alternative 4 is 8 years. The time related to post-construction regulatory documents is not included in this estimate. The estimated durations in Figure 4-4 are based on the productivity assumptions used in the cost estimation presented in Appendix J.

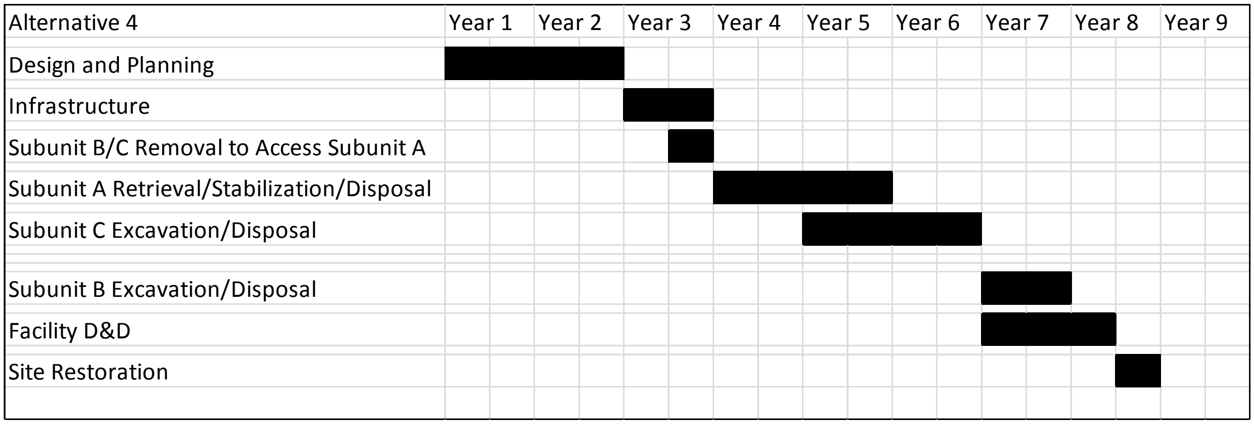

Figure 4-4. Sequencing of Activities for Alternative 4

4.6.4.4 Implementability

A detailed discussion of the implementability evaluation for the Subunit A component of this alternative is provided in the discussion of Alternative 3A (Section 4.4.3.4). Excavation of Subunits B and C does not introduce any new implementability challenges compared to the other remedial alternatives (3A, 3B, and 3C) other than the handling of a larger volume of radioactively contaminated materials.

Subunit B

- Excavation equipment used to excavate Subunit B is similar to the equipment planned for the lower-activity wastes in Subunit A. This equipment is conventional and readily available.
- There is no specialized equipment needed for this alternative.
- A water treatment plant is included in this design to address stormwater collection and treatment.
- Multiple existing disposal facilities are available to disposition each of the waste types (i.e., 11e.[2], LLRW, and LLMW) in Subunit B.

Subunit C

- Excavation equipment used to excavate Subunit C is similar to the equipment planned for the lower-activity wastes in Subunits A and B. This equipment is conventional and readily available.
- There is no specialized equipment needed for this alternative.
- Multiple existing disposal facilities are available to disposition each of the waste types (i.e., 11e.[2], LLRW, and LLMW) in Subunit C.

In summary, all components of Alternative 4 have been proven to be implementable. Removal, treatment, and disposal of Subunit A materials will require some project-specific upgrades to conventional approaches and supplies.

4.6.4.5 Cost

The complete breakdown of the estimated cost to implement Alternative 4 is provided in Appendix J.

The estimated capital cost is $490.6M.

The estimated O&M cost is zero.

The cost breakdown is as follows:

- Mobilization and preparatory work – $2,842,888.

- Subunit A retrieval, treatment, and off-site disposal:

    - program management – $10,573,367;
    - solid collection and containment (retrieval) – $33,434,879;
    - stabilization/fixation/encapsulation – $65,523,180;
    - off-site disposal – $36,572,804;
    - D&D – $14,747,049; and
    - physical treatment (RCS) – $19,365,366.

- Subunits B and C excavation:

    - monitoring, sampling, testing, and analysis – $4,580,989;
    - site work – $6,281,327;
    - surface water collection and control – $1,175,622;
    - solids collection and containment – $30,898,171;
    - chemical treatment – $4,199,464;
    - off-site transport and disposal – $134,372,133;
    - site restoration – $1,753,616; and
    - design and project management – $36,811,413.

- Project contingency – $75,508,026.

Disposal costs vary over time based on market conditions and likely will vary from previously published costs (e.g., in the WDO/Fernald LL TM [USACE 2011a]). The cost also includes a $12M supervision and administration item.

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5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

Table 5-1 consolidates the findings of the detailed analysis of alternatives presented in Chapter 4.0. Table 5-2 presents a semi-quantitative comparative analysis of the five alternatives. To the extent possible, quantitative information from Table 5-1 is used to develop the analysis in Table 5-2.

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternative 1 (No Action) is considered not protective due to the potential termination of active site control and Resident Intruder exposures to the waste. Alternatives 2 (Enhanced Containment of Subunits A, B, and C), 3A (Removal, Treatment, and Off-site Disposal of Subunit A and Enhanced Containment of Subunits B and C), and 3B (Removal, Treatment, and Off-site Disposal of Subunits A and B and Enhanced Containment of Subunit C) are considered protective because long-term exposure and risk will be prevented by maintaining perpetual control of the land and maintaining the integrity of the enhanced containment system. Alternative 4 (Removal, Treatment, and Off-site Disposal of Subunits A, B, and C) is protective because it removes all waste and, thus, eliminates future risk.

5.2 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Alternative 1 is not compliant with ARARs. Because there is no future containment system maintenance included in Alternative 1, the multiple layers of the cap could degrade, resulting in increased levels of radon emanation and possible direct exposure to the residues. Although natural degradation of the cap would not be expected to occur for at least 1,000 years, unintended intrusion could occur prior to that time period.

Alternatives 2, 3A, 3B, and 4 have all been designed to comply with the requirements of 10 *CFR* 40 and 40 *CFR* 61 and, thus, are considered compliant with ARARs.

5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

The rankings of each alternative for long-term effectiveness and permanence mimic the rankings described in Section 5.1 for overall protection of human health and the environment.

5.4 REDUCTION IN TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Rankings applied to this criterion are based on the amount of untreated materials that would remain at the IWCS, as shown on Table 5-1. The highest amount of untreated residuals is associated with Alternative 1 (No Action) and Alternative 2 (Enhanced Containment). These alternatives receive a “low” ranking for this criterion. The least amount of untreated materials remaining on-site is associated with Alternative 4, with zero amount of untreated residual remaining on-site, thus Alternative 4 receives a “high” ranking. Alternatives 3A and 3B receive a “moderate” ranking.

5.5 SHORT-TERM EFFECTIVENESS

With the exception of Alternative 1, No Action, each of the alternatives could result in some level of potential short-term impacts to the community, workers, and the environment during remediation. To address these issues, controls have been included and costed into the alternatives so that, in effect, each of them could receive a “high” ranking. However, rankings have been given based on the relative potential for short-term impacts during remediation. Because these short-term impacts can be controlled, none of the alternatives receive a “low” ranking.

Table 5-1. Summary of Detailed Analysis of Alternatives

CERCLA Evaluation Criterion	Alternative 1 – No Action	Alternative 2 – Enhanced Containment of Subunits A, B, and C	Alternative 3A – Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C	Alternative 3B – Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C	Alternative 4 – Removal, Treatment (Subunit A only), and Off-Site Disposal of Subunits A, B, and C
Threshold Criteria					
Overall protection of human health and the environment	Not protective over the long term; Resident Intruder could be exposed to unacceptable risk	LUCs and cap maintenance are protective; prevents unacceptable exposures to IWCS materials	LUCs and cap maintenance are protective; prevents unacceptable exposures to IWCS materials	LUCs and cap maintenance are protective; prevents unacceptable exposures to IWCS materials	Protective of human health and the environment over the long term; removes all wastes
Compliance with ARARs	Does not comply with ARARs	Complies with ARARs	Complies with ARARs	Complies with ARARs	Complies with ARARs
Balancing Criteria					
Long-Term Effectiveness and Permanence					
Magnitude of residual risk	All residues and waste remain in place resulting in unacceptable risk	All residues and waste remain in place under the enhanced cap. Risk to human and ecological receptors is within or below the acceptable risk range	Highest-activity waste removed. The residues and wastes in Subunits B and C, including the R-10 pile, remain in place under the enhanced cap. Risk to human and ecological receptors is within or below the acceptable risk range	Highest-activity waste removed. All residues and waste in Subunit C, including the R-10 pile, remain in place under the enhanced cap. Risk to human and ecological receptors is within or below the acceptable risk range	No residual waste remains in place, negligible residual risk
Adequacy and reliability of controls	No LUCs. Current site controls cease	Structurally stable design, LUCs, and cap maintenance are in place to prevent exposure over the long term	Structurally stable design, LUCs, and cap maintenance are in place to prevent exposure over the long term	Structurally stable design, LUCs, and cap maintenance are in place to prevent exposure over the long term	No controls necessary because all residues and wastes are removed
Summary	Not effective at preventing long-term exposures in the absence of LUCs. Estimated cancer risk is 4 x 10^{-1}, three orders of magnitude greater than the acceptable human health risk. Ecological risk also is exceeded	Structurally stable design, LUCs, and cap maintenance are effective at preventing unacceptable exposure to wastes over the long term	Structurally stable design, LUCs, and cap maintenance are effective at preventing unacceptable exposure to wastes over the long term	Structurally stable design, LUCs, and cap maintenance are effective at preventing unacceptable exposure to wastes over the long term	Effective at removing all risk over the long term
Reduction of Toxicity, Mobility, and Volume Through Treatment					
Treatment process used and materials treated	No treatment used	No treatment used	Cement stabilization used to treat approximately 6,030 yd^3 of K-65 and commingled residues	Cement stabilization used to treat approximately 6,030 yd^3 of K-65 and commingled residues	Cement stabilization used to treat approximately 6,030 yd^3 of K-65 and commingled residues
Amount of hazardous materials destroyed or treated	No materials destroyed	No materials destroyed	Approximately 6,030 yd^3 of K-65 and commingled residues treated	Approximately 6,030 yd^3 of K-65 and commingled residues and a minor amount of Subunit B and LLMW treated	Approximately 6,030 yd^3 of K-65 and commingled residues and an estimated 2,000 yd^3 of Subunits B and C LLMW treated

Table 5-1. Summary of Detailed Analysis of Alternatives (continued)

CERCLA Evaluation Criterion	Alternative 1 – No Action	Alternative 2 – Enhanced Containment of Subunits A, B, and C	Alternative 3A – Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C	Alternative 3B – Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C	Alternative 4 – Removal, Treatment (Subunit A only), and Off-Site Disposal of Subunits A, B, and C
Degree of expected reduction in toxicity, mobility, and volume	No reduction in toxicity, mobility, or volume	No reduction in toxicity, mobility, or volume	Reduction in the mobility and radon release hazard related to the treated K-65 and commingled residues; increased volume of K-65 waste due to addition of stabilizer	Reduction in the mobility and radon release hazard related to the treated K-65 and commingled residues; increased volume of K-65 waste due to addition of stabilizer	Reduction in the mobility and radon release hazard related to the treated K-65 and commingled residues; increased volume of K-65 waste due to addition of stabilizer
Degree to which treatment is irreversible	No treatment used	No treatment used	High	High	High
Type and quantity of residuals remaining after treatment	All ore residues and wastes remain	On-site untreated residuals = approximately 352,074 yd^3	Off-site wastes that are not treated (Subunits A and B) = 59,298 yd^3. On-site untreated residuals (Subunits B and C) = 286,746 yd^3	Off-site wastes that are not treated (Subunits A and B) = 120,449 yd^3. On-site untreated residuals (Subunit C) = 225,595 yd^3	Off-site wastes that are not treated (Subunits A, B, and C) = 346,044 yd^3 No on-site untreated residuals
Summary	Does not reduce toxicity, mobility, or volume through treatment	Does not reduce toxicity, mobility, or volume through treatment	Reduces the toxic effect and mobility of the highest-activity material (K-65 and commingled residues). Does not reduce volume. Does not reduce toxicity, mobility, or volume of untreated L-30, L-50, and F-32 residues or Subunits B and C materials	Reduces the toxic effect and mobility of the highest-activity material (K-65 and commingled residues). Does not reduce volume. Does not reduce toxicity, mobility, or volume of untreated L-30, L-50, and F-32 residues or Subunits B and C materials	Reduces the toxic effect and mobility of the highest-activity material (K-65 and commingled residues). Does not reduce volume. Does not reduce toxicity, mobility, or volume of untreated L-30, L-50, and F-32 residues or Subunits B and C materials
Short-Term Effectiveness					
Protection of community during remedial actions	No short-term impacts to community	Little to no potential for community exposure; truck traffic increases minimally	Controls included to ensure no exposure to airborne contaminants during remediation, including an engineered containment facility and RCS. Local truck traffic increases but rail used to reduce risk	Controls included to ensure no exposure to airborne contaminants during remediation, including an engineered containment facility and RCS. Local truck traffic increases but rail used to reduce risk	Controls included to ensure no exposure to airborne contaminants during remediation, including an engineered containment facility and RCS. Greatest amount of truck and rail traffic

Table 5-1. Summary of Detailed Analysis of Alternatives (continued)

CERCLA Evaluation Criterion	Alternative 1 – No Action	Alternative 2 – Enhanced Containment of Subunits A, B, and C	Alternative 3A – Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C	Alternative 3B – Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C	Alternative 4 – Removal, Treatment (Subunit A only), and Off-Site Disposal of Subunits A, B, and C
Protection of workers during remedial actions	No short-term impacts to workers	Low potential for exposure to workers	In addition to complying with all radiation worker protection requirements, robotics will be used to retrieve most hazardous residues	In addition to complying with all radiation worker protection requirements, robotics will be used to retrieve most hazardous residues	In addition to complying with all radiation worker protection requirements, robotics will be used to retrieve most hazardous residues
Environmental impacts	No short-term impacts to the environment	Controls in place to prevent environmental impacts	Controls in place to prevent environmental impacts	Controls in place to prevent environmental impacts	Controls in place to prevent environmental impacts
Time until remedial action objectives are achieved[a]	Zero years	2 years	7.5 years: 2 years design and 5.5 years construction	8 years: 2 years design and 6 years construction	8 years: 2 years design and 6 years construction
Summary	No short-term impacts	Minimal short-term impacts can be addressed by work controls	Short-term impacts to workers and community can be controlled through robust work control processes	Short-term impacts to workers and community can be controlled through robust work control processes	Short-term impacts to workers and community can be controlled through robust work control processes
Implementability					
Ability to construct and operate the technology	No action proposed	Proven technologies	For Subunit A, remediation is a challenge to construct and operate, but a similar approach was proven at the Fernald K-65 Project. Subunits B and C rely on proven technologies	For Subunit A, remediation is a challenge to construct and operate, but a similar approach was proven at the Fernald K-65 Project. Subunit C relies on proven technologies	For Subunit A, remediation is a challenge to construct and operate, but a similar approach was proven at the Fernald K-65 Project. Subunits B and C rely on proven technologies
Reliability of the technology	NA	Cap technology is reliable through the life of the geomembrane (approximately 500 years); cap maintenance and LUCs required	Subunit A approach proven reliable at the Fernald K-65 Project. Cap technology is reliable through the life of the geomembrane (approximately 500 years); cap maintenance and LUCs required	Subunit A approach proven reliable at the Fernald K-65 Project. Cap technology is reliable through the life of the geomembrane (approximately 500 years); cap maintenance and LUCs required	Subunit A approach proven reliable at the Fernald K-65 Project. Subunits B and C incorporate reliable excavation, loading, and transport approaches
Ease of undertaking additional remedial actions, if necessary	Additional action could be implemented	Additional action could be implemented	Additional action could be implemented on Subunits B and C	Additional action could be implemented on Subunit C	No additional action would be necessary
Ability to monitor the effectiveness of the remedy	No monitoring proposed	Monitoring currently proving effective; monitoring will remain in place in perpetuity	Monitoring currently proving effective; monitoring will remain in place in perpetuity	Monitoring currently proving effective; monitoring will remain in place in perpetuity	Monitoring not required

Table 5-1. Summary of Detailed Analysis of Alternatives (continued)

CERCLA Evaluation Criterion	Alternative 1 – No Action	Alternative 2 – Enhanced Containment of Subunits A, B, and C	Alternative 3A – Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C	Alternative 3B – Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C	Alternative 4 – Removal, Treatment (Subunit A only), and Off-Site Disposal of Subunits A, B, and C
Ability to obtain approvals from other agencies	Unlikely	Would require discussion to obtain buy-in	Would require discussion to obtain buy-in but is more likely than Alternative 2	Would require discussion to obtain buy-in but is more likely than Alternative 2	Likely
Viability of off-site treatment, storage, and disposal services and capacity	NA	NA	There is only one facility that has accepted K-65 residues in the past	There is only one facility that has accepted K-65 residues in the past. Several options exist for Subunit B wastes	There is only one facility that has accepted K-65 residues in the past. Several options exist for Subunits B and C wastes
Availability of necessary equipment and specialists	NA	Readily available	Specialty capabilities required for Subunit A are available. Readily available for Subunits B and C	Specialty capabilities required for Subunit A are available. Readily available for Subunits B and C	Specialty capabilities required for Subunit A are available. Readily available for Subunits B and C
Summary	NA	Implementable	Implementable with available specialty resources	Implementable with available specialty resources	Implementable with available specialty resources
Cost					
Capital costs	Zero cost	$23.4M	$259.6M	$318.4M	$490.6M
O&M costs (not discounted)	Zero cost	$1,450M	$1,450M	$1,450M	Zero cost
Present worth O&M costs (discounted)	Zero cost	$44.0M	$43.8M	$43.8M	Zero cost

[a] Estimates to complete the action assume projects receive sufficient annual funding to meet schedules.
ARAR = Applicable or relevant and appropriate requirement.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
IWCS = Interim Waste Containment Structure.
LLMW = Low-level mixed waste.
LUC = Land-use control.
NA = Not applicable.
O&M = Operation and maintenance.
RCS = Radon control system.
yd^3 = Cubic yard.

Table 5-2. Comparative Analysis of Alternatives for the IWCS FS

Criterion	Alternative 1 – No Action	Alternative 2 – Enhanced Containment of Subunits A, B, and C	Alternative 3A – Removal, Treatment, and Off-Site Disposal of Subunit A and Enhanced Containment of Subunits B and C	Alternative 3B – Removal, Treatment, and Off-Site Disposal of Subunits A and B and Enhanced Containment of Subunit C	Alternative 4 – Removal, Treatment (Subunit A only), and Off-Site Disposal of Subunits A, B, and C
Overall protection of human health and the environment	No	Yes	Yes	Yes	Yes
Compliance with ARARs	No	Yes	Yes	Yes	Yes
Long-term effectiveness and permanence	Low	Moderate	Moderate	Moderate	High
Reduction of toxicity, mobility, and volume through treatment	Low	Low	Moderate	Moderate	High
Short-term effectiveness	High	High	Moderate	Moderate	Moderate
Implementability	NA	High	Moderate	Moderate	Moderate
Cost (capital)	No cost	$23.4M	$259.6M	$318.4M	$490.6M
Cost (O&M discounted)	No cost	$44.0M	$43.8M	$43.8M	$0

ARAR = Applicable or relevant and appropriate requirement.
FS = Feasibility study.
IWCS = Interim Waste Containment Structure.
NA = Not applicable.

Alternative 1, No Action, poses the lowest probability of potential impacts and receives a “high” ranking. There is a low probability of short-term impact for Alternative 2; therefore, Alternative 2 receives a “high” ranking. Alternatives 3A, 3B, and 4 all receive a “moderate” ranking due to increased construction activity associated with the actions.

5.6 IMPLEMENTABILITY

Each of the identified alternatives has proven to be implementable; therefore, none of them receives a “low” ranking for implementability. There is no action proposed for Alternative 1; therefore, it receives an “NA” for this criterion. The alternative that is the most proven to be implementable is Alternative 2 because it uses standard capping construction practices and readily available resources. Alternative 2 receives a “high” ranking for implementability. Alternatives 3A, 3B, and 4 are rated as “moderate” and are assumed to be equally implementable.

5.7 COST

For the comparative summary of the costs of the alternatives, discounted (present value) costs were reviewed. These values are presented in Table 5-2 for comparison purposes. Discounted costs represent the current worth of a future sum of money given a specified rate of return (the discount rate). The discount rate used for this FS is 3.5%. The discounted value is often referred to as the amount of money that would need to be invested today to cover costs over the life of the project. Table 5-1 presents both the discounted costs and non-discounted costs.

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6.0 SUMMARY

The information presented in the detailed and comparative analyses of alternatives is used in combination with risk-management judgments to aid in identifying the preferred alternative in the Proposed Plan. This chapter summarizes the relative advantages and disadvantages of the five alternatives.

6.1 ALTERNATIVE 1 – NO ACTION

This alternative does not meet the threshold criteria of protection of human health and the environment nor can it show definitive compliance with ARARs over the long term. Because this alternative proposes no action, including no long-term maintenance of the current cap or long-term LUCs, future human receptors could come into contact with the contamination and be exposed to levels that significantly exceed RAOs. Because of this, this alternative cannot be considered a viable alternative for future consideration.

6.2 ALTERNATIVE 2 – ENHANCED CONTAINMENT

There are advantages and disadvantages to Alternative 2 relative to the other alternatives.

The primary advantages include “high” rankings for short-term effectiveness and implementability, along with relatively low cost. This alternative has the fewest short-term impacts related to implementation, including little to no worker and public exposure during remediation, no waste transportation on public roads, and is the shortest alternative to implement at less than 2 years. The construction portion of this alternative is easy to implement, with a large number of successful technologies and successful capping projects to use as precedent. The construction materials are readily accessible. This alternative has the lowest capital construction cost outlay of any alternative, with capital costs 90% less than the next lowest cost alternative. Present value O&M costs for this alternative ($43.97M) are high, but are similar to the costs of all other alternatives, with the exception of Alternative 4, which has zero O&M cost.

The primary disadvantage of this alternative is that it does not achieve the CERCLA criterion for reduction of toxicity, mobility, and volume through treatment. Another disadvantage is the long time period and cost to the government necessary to perform cap maintenance and implement LUCs over 1,000 years.

6.3 ALTERNATIVE 3A – REMOVAL, TREATMENT, AND OFF-SITE DISPOSAL OF SUBUNIT A AND ENHANCED CONTAINMENT OF SUBUNITS B AND C

There are advantages and disadvantages to Alternative 3A relative to the other alternatives.

The primary advantage is that the alternative removes all of the high-activity ore residues in Subunit A, thereby reducing the magnitude of residual radioactivity by several orders. In addition, the alternative achieves the goal of reducing the toxicity (via reduced radon emanation) and mobility of the highest activity waste stream—the K-65 residues—through treatment by cement stabilization. The remaining wastes will be under the enhanced cap with in-perpetuity maintenance and LUCs to prevent exposure.

The primary disadvantage of this alternative is the potential short-term impacts to both the worker and the public related to uncovering the high-activity residues and the need to design significant controls into the alternative to address these concerns. Although a similar remediation effort was successfully implemented at the Fernald K-65 Project, including successful cement stabilization of the residues, there are enough differences at the IWCS to acknowledge that there are implementability unknowns with this alternative.

Another disadvantage is the long time period and cost that the government will have to account for to perform cap maintenance and LUCs.

Although significantly higher than Alternative 2, the capital construction cost of this alternative is near the middle of the range of all alternatives. The O&M costs are the same as the other remedial alternatives, except for the zero O&M cost of Alternative 4.

6.4 ALTERNATIVE 3B – REMOVAL, TREATMENT, AND OFF-SITE DISPOSAL OF SUBUNITS A AND B AND ENHANCED CONTAINMENT OF SUBUNIT C

There are advantages and disadvantages to Alternative 3B relative to the other alternatives.

The primary advantage is that the alternative removes all of the high-activity ore residues in Subunit A plus all the building materials exposed to the residues, thereby reducing the magnitude of residual radioactivity by several orders. In addition, the alternative achieves the goal of reducing the toxicity (via reduced radon emanation) and mobility of the highest activity waste stream—the K-65 residues—through treatment by cement stabilization. This alternative also removes the building structures and other wastes that may have been contaminated by contact with the high-activity residues in Building 411. The remaining wastes will be under the enhanced cap with in-perpetuity maintenance and LUCs to prevent exposure.

The primary disadvantages of this alternative are the potential short-term impacts to both the worker and the public related to uncovering the high-activity residues, the need to design significant controls into the alternative to address these concerns, and the complexity of segregating and size-reducing the Subunit B building materials. Although a similar remediation effort was successfully implemented at the Fernald K-65 Project, including successful cement stabilization of the residues, there are enough differences at the IWCS to acknowledge that there are implementability unknowns with this alternative.

Another disadvantage is the long time period and cost that the government will have to account for to perform cap maintenance and LUCs.

Although significantly higher than Alternative 2, the capital construction cost of this alternative is in the middle of the range of all alternatives. The O&M costs are the same as the other remedial alternatives, except for the zero O&M cost of Alternative 4.

6.5 ALTERNATIVE 4 – REMOVAL; TREATMENT (SUBUNIT A ONLY); AND OFF-SITE DISPOSAL OF SUBUNITS A, B, AND C

There are advantages and disadvantages to Alternative 4 relative to the other alternatives.

The primary advantage is that the alternative addresses all of the CERCLA goals at a “moderate to high” ranking by removing all waste from the site. Because the alternative removes all risk, there will be no operation and monitoring cost for Alternative 4.

The primary disadvantage of this alternative is the high capital cost associated with construction. Capital costs for this alternative are over 20 times higher than Alternative 2 and approximately twice that of Alternatives 3A and 3B. The total cost would require a significant funding commitment from the government.

Other disadvantages include the potential short-term impacts to both the worker and the public related to uncovering the high-activity residues and R-10 residues, as well as the complexity of segregating and size-reducing the Subunit B building materials. These issues result in the need to design significant controls into the alternative to address these concerns. This alternative has the greatest amount of transportation risk due to the large volume of off-site transportation of residues and other materials. Although a similar remediation effort was successfully implemented at the Fernald K-65 Project, including successful cement stabilization of the residues, there are enough differences at the IWCS to acknowledge that there are implementability unknowns with this alternative.

6.6 CONCLUSION

This FS Report does not recommend or select a preferred alternative. The information in this FS, including the detailed and comparative analyses of alternatives, will be used by USACE to identify the preferred remedial alternative in the Proposed Plan. USACE will review state and community input (consistent with CERCLA modifying criteria) to determine if the preferred alternative remains the most appropriate remedial action for the site. USACE will then make the final remedy selection decision, which will be documented in the Record of Decision.

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