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# FEASIBILITY STUDY REPORT FOR OPERABLE UNIT 4 VOLUME 1 OF 4 FINAL FEBRUARY 1994

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# FEASIBILITY STUDY REPORT FOR OPERABLE UNIT 4

**DOE/EIS - 0195D**

**FERNALD ENVIRONMENTAL MANAGEMENT PROJECT**
**FERNALD, OHIO**

**REMEDIAL INVESTIGATION AND FEASIBILITY STUDY**

**VOLUME 1 OF 4**

**FEBRUARY 1994**

**U.S. DEPARTMENT OF ENERGY**
**FERNALD FIELD OFFICE**

**FINAL**

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VOLUME 1 OF 4

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U.S. DEPARTMENT OF ENERGY
FERNALD SITE OFFICE
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# ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS

In this document, units of measure are presented with the metric equivalent first, followed by the measured English unit in parentheses. In cases where the measurement was originally made in metric units, the values were not converted back to English units; in tables, the data are generally in English or metric units only. The following table lists the appropriate equivalents for English and metric units.

| Multiply | By | To Obtain |
|---|---|---|
| English/Metric Equivalents | | |
| acres | 0.4047 | hectares (ha) |
| cubic feet ($ft^3$) | 0.02832 | cubic meters ($m^3$) |
| cubic yards ($yd^3$) | 0.7646 | cubic meters ($m^3$) |
| degrees Fahrenheit (°F) | [(°F)-32]* 0.5555 | degrees Celsius or Centigrade (°C) |
| feet (ft) | 0.3048 | meters (m) |
| gallons (gal) | 3.785 | liters (L) |
| gallons (gal) | 0.003785 | cubic meters ($m^3$) |
| inches (in) | 2.540 | centimeters (cm) |
| miles (mi) | 1.609 | kilometers (km) |
| pounds (lb) | 0.4536 | kilograms (kg) |
| short tons (tons) | 907.2 | kilograms (kg) |
| short tons (tons) | 0.9072 | metric tons (t) |
| square feet ($ft^2$) | 0.09290 | square meters ($m^2$) |
| square yards ($yd^2$) | 0.8361 | square meters ($m^2$) |
| square miles ($mi^2$) | 2.590 | square kilometers ($km^2$) |
| yards (yd) | 0.9144 | meters (m) |
| Metric/English Equivalents | | |

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## ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS

| Multiply | By | To Obtain |
|---|---|---|
| centimeters (cm) | 0.3937 | inches (in) |
| cubic meters ($m^3$) | 35.31 | cubic feet ($ft^3$) |
| cubic meters ($m^3$) | 1.308 | cubic yards ($yd^3$) |
| cubic meters ($m^3$) | 264.2 | gallons (gal) |
| degrees Celsius or Centigrade (°C) | 1.8(°C) +32 | degrees Fahrenheit (°F) |
| hectares (ha) | 2.471 | acres |
| kilograms (kg) | 2.205 | pounds (lb) |
| kilograms (kg) | 0.001102 | short tons (tons) |
| kilometers (km) | 0.6214 | miles (mi) |
| liters (L) | 0.2642 | gallons (gal) |
| meters (m) | 3.281 | feet (ft) |
| meters (m) | 1.094 | yards (yd) |
| metric tons (t) | 1.102 | short tons (tons) |
| square kilometers ($km^2$) | 0.3861 | square miles ($mi^2$) |
| square meters ($m^2$) | 10.76 | square feet ($ft^2$) |
| square meters ($m^2$) | 1.196 | square yards ($yd^2$) |

# ACRONYM LIST

| | |
|---|---|
| Ac | actinium |
| AEA | Atomic Energy Act |
| AEC | Atomic Energy Commission |
| AIRFA | American Indian Religious Freedom Act |
| ALARA | as low as reasonably achievable |
| AMS | air monitoring station |
| ARAR | applicable or relevant and appropriate requirements |
| ASI | Advanced Sciences, Inc. |
| AWWT | advanced wastewater treatment |
| BDAT | best demonstrated available technology |
| BMP | Best Management Practive |
| BNI | Bechtel National, Inc. |
| Bs | bismuth |
| °C | Degrees Celsius or Centigrade |
| CAA | Clean Air Act of 1990 |
| CAMU | Corrective Action Management Unit |
| CEDE | committed effective dose equivalent |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| cfm | cubic feet per minute |
| CFR | Code of Federal Regulations |
| CI | confidence interval |
| Ci | Curies |
| CIS | Characterization Investigation Study |
| cm | centimeter |
| CMSA | Consolidated Metropolitan Statistical Area |
| COC | constituents of concern |
| COE | U.S. Army Corps of Engineers |
| CRARE | Comprehensive Response Action Risk Evaluation |
| CRDL | contract required detection limit |
| CRQL | contract required quantitation limit |
| Cs | cesium |
| CT | central tendency |
| CWA | Clean Water Act |
| D&D | decontamination and decommissioning |

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| | |
|---|---|
| DCF | dose conversion factor |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| DPM | disintegrations per minute |
| DQO | data quality objectives |
| EDE | Effective Dose Equivalent |
| EDTA | ethylenediaminetetraacetic acid |
| EA | Environmental Assessment |
| EE/CA | Engineering Evaluation/Cost Analysis |
| EIS | Environmental Impact Statement |
| EP Tox | Extraction Procedure Toxicity |
| EPA | U.S. Environmental Protection Agency |
| ERDA | U.S. Energy Research and Development Administration |
| ERMC | Environmental Restoration Management Contractor |
| ESA | Endangered Species Act of 1973 |
| ESD | Explanation of Significant Differences |
| °F | degrees Fahrenheit |
| FEMP | Fernald Environmental Management Project |
| FERMCO | Fernald Environmental Restoration Management Company |
| FFA | Federal Facility Agreement |
| FFCA | Federal Facility Compliance Agreement |
| FMPC | Feed Materials Production Center |
| ft | feet (foot) |
| $ft^2$ | square feet |
| $ft^3$ | cubic feet |
| $ft^3$/sec | cubic feet per second |
| FR | Federal Register |
| FRG | Final Remediation Goals |
| FS | feasibility study |
| FS/PP-EIS | Feasibility Study/Proposed Plan-Environmental Impact Statement |
| FUSRAP | Formerly Utilized Sites Remedial Action Program |

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| | |
|---|---|
| gal | gallon |
| $gm/cm^3$ | grams per cubic centimeter |
| GPI | glucose phosphate isomerase |
| gpd | gallons per day |
| gpm | gallons per minute |
| GRA | general response action |
| ha | hectares |
| HELP | Hydrologic Evaluation of Landfill Performance |
| HSL | Hazardous Substance List |
| HEAST | Health Effects Assessment Summary Tables |
| HEPA | high efficiency particulate air |
| HDPE | high density polyethylene |
| HI | hazard index |
| ILCR | incremental lifetime cancer risk |
| in. | inch |
| IRIS | Integrated Risk Information System |
| IRM | Interim Remedial Measures |
| ISA | Initial Screening of Alternatives |
| ISO | International Shipping Organization |
| IT | International Technologies Corporation, Inc. |
| kg | kilogram |
| kg/d | kilograms per day |
| KCl | potassium chloride |
| km | kilometer |
| $km^2$ | square kilometers |
| kPa | kiloPascals |
| $\ell$ | pound |
| L | liter |
| L/day | liters per day |
| L/min | liters per minute |
| L/sec | liters per second |
| LC/DS | leachate collection/detection system |

| | |
|---|---|
| LDR | land disposal restriction |
| LOOW | Lake Ontario Ordnance Works |
| lpm | liters per minute |
| LRA | leading remedial alternative |
| LSA | low specific activity |
| m | meter |
| $m^2$ | square meters |
| $m^3$ | cubic meters |
| mi | mile |
| $mi^2$ | square miles |
| MAC | maximum allowable concentrations |
| MCL | maximum contaminant level |
| MCLG | maximum contaminant level goal |
| MCW | Mallinckrodt Chemical Works |
| Mgal/d | Million gallons per day |
| mg/g | milligrams per gram |
| mg/kg | milligrams per kilogram |
| mg/L | milligrams per liter |
| mrem | millirem |
| $\mu$Ci | micro curie |
| $\mu$Ci/year | micro curies per year |
| $\mu$A | micro Ampere |
| MAP | Mitigation Action Plan |
| $\mu$g/g | micrograms per gram |
| $\mu$g/kg | micrograms per kilogram |
| mg/L | milligrams per liter |
| $\mu$g/L | micrograms per liter |
| MTR | minimum technology requirements |
| MSL | mean sea level |
| MTCLP | Modified Toxicity Characteristic Leaching Procedure |
| mtu | metric tons of uranium |
| NAAQS | National Ambient Air Quality Standards |

| | |
|---|---|
| NAGPRA | Native American Graves Protection and Repatriation Act |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NEPA | National Environmental Policy Act |
| NESHAP | National Emissions Standards for Hazardous Air Pollutants |
| NHPA | National Historic Preservation Act |
| NLO | National Lead Company of Ohio, Inc. |
| NOAA | National Oceanic and Atmospheric Administration |
| NOEL | no observed effect levels |
| NOI | Notice of Intent |
| NOV | Notice of Violation |
| NPDES | National Pollutant Discharge Elimination System |
| NPL | National Priorities List |
| NRC | Nuclear Regulatory Commission |
| NRHP | National Register of Historic Places |
| NTS | Nevada Test Site |
| OAC | Ohio Administrative Code |
| O&M | operation and maintenance |
| ODNR | Ohio Department of Natural Resources |
| OEPA | Ohio Environmental Protection Agency |
| OHPO | Ohio Historic Preservation Office |
| Pa | Pascals |
| Pa | protactinium |
| PAH | polynuclear aromatic hydrocarbons |
| Pb | lead |
| PCB | polychlorinated biphenyl |
| pCi/g | pico Curies per gram |
| pCi/L | pico Curies per liter |
| PCT | product consistency test |
| PEIS | Programmatic Environmental Impact Statement |
| PMCL | proposed maximum contaminant level |
| Po | polonium |
| POTW | publicly owned treatment works |

| | |
|---|---|
| PP | Proposed Plan |
| ppb | parts per billion |
| PRG | preliminary remediation goal |
| PRL | proposed remediation level |
| psi | pounds per square inch |
| Pu | plutonium |
| PVC | polyvinyl chloride |
| QA | quality assurance |
| QAPP | Quality Assurance Project Plan |
| QC | quality control |
| Ra | radium |
| RAO | remedial action objectives |
| RAWPA | Risk Assessment Work Plan Addendum |
| RCRA | Resource Conservation and Recovery Act |
| RD/RA | Remedial Design/Remedial Action |
| rem | Roentgen equivalent man |
| RI | remedial investigation |
| RI/FS | Remedial Investigation/Feasibility Study |
| RMI | Reactive Metals, Incorporated |
| RME | reasonable maximum exposure |
| Rn | radon |
| ROD | Record of Decision |
| RSC | relative source contribution |
| RTS | Radon Treatment System |
| SARA | Superfund Amendment and Reauthorization Act |
| SCS | Soil Conservation Service |
| SDWA | Safe Drinking Water Act |
| SHPO | State Historic Preservation Office |
| SMCL | secondary maximum contaminant level |
| SOWC | Southwestern Ohio Water Company |
| SQL | sample quantitation limit |
| Sr | strontium |

| | |
|---|---|
| SR | State route |
| SWOAPCA | South Western Ohio Air Pollution Control Agency |
| SWCR | Site-Wide Characterization Report |
| t | metric tons |
| tpd | tons per day |
| TBC | to be considered |
| Tc | technetium |
| TC | Toxicity Characteristic |
| TCLP | Toxicity Characteristic Leaching Procedure |
| Th | thorium |
| TIE | Technical Information Exchange |
| TKN | total Kjeldahl nitrogen |
| TOC | total organic carbon |
| TON | total organic nitrogen |
| TOX | total organic halides |
| TSDF | treatment, storage, and disposal facility |
| TSP | Total Suspended Particulate |
| TU | temporary unit |
| U | uranium |
| UCL | upper confidence limit |
| UMTRCA | Uranium Mill Tailings Radiation Control Act of 1978 |
| UP | Union Pacific |
| USC | Unconfined compressive strength |
| USCS | Unified Soil Classification System |
| USDA | U.S. Department of Agriculture |
| USGS | U.S. Geological Survey |
| UTL | upper tolerance limit |
| UV | ultraviolet |
| WMCO | Westinghouse Materials Company of Ohio |
| WEMCO | Westinghouse Environmental Management Company of Ohio |
| WIPP | Waste Isolation Pilot Plant |
| yd | yard |
| $yd^3$ | cubic yards |

# EXECUTIVE SUMMARY

This report documents the Feasibility Study (FS) phase of the Fernald Environmental Management Project (FEMP) Operable Unit 4 Remedial Investigation/Feasibility Study (RI/FS) Program. The FEMP, formerly known as the Feed Materials Production Center (FMPC), is a U.S. Department of Energy (DOE) facility that operated from 1952 to 1989. The facility's primary function was to provide high purity uranium metal products to support United States defense programs. Production operations were suspended in 1989 to focus on environmental restoration and waste management activities at the facility. The RI/FS is being conducted pursuant to the terms of a Consent Agreement between DOE and the U.S. Environmental Protection Agency (EPA) under Sections 120 and 106(a) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. The Ohio Environmental Protection Agency (OEPA) is also participating in the RI/FS process at the FEMP through direct involvement in program review meetings and technical review of project documentation. The objective of the RI/FS process is to gather information to support an informed risk management decision regarding which remedy appears to be the most appropriate action for addressing the environmental concerns identified at the FEMP.

To promote a more structured RI/FS and expeditious cleanup of the FEMP property, complex environmental issues associated with the FEMP were divided into five operable units under the Amended Consent Agreement. The term "operable unit" is used to identify a logical grouping of environmental issues that comprise an incremental step toward comprehensively addressing site problems. Separate RI/FS documentation, including Remedial Investigation (RI) and FS Reports, Proposed Plan (PP), and Record of Decision (ROD), are being developed for each of the five operable units at the FEMP. This report documents the FS phase of the RI/FS process for Operable Unit 4, which consists of the following FEMP facilities and associated environmental media:

- Silos 1 and 2 and their contents (also termed K-65 silos)
- Silo 3 and its contents (also termed cold metal oxide silo)
- Silo 4
- K-65 decant sump tank for Silos 1 and 2, its contents, and associated piping
- A radon treatment system (RTS)
- The portion of a concrete pipe trench within the boundaries of Operable Unit 4, and other concrete structures

- An earthen berm surrounding Silos 1 and 2
- Soils beneath and immediately surrounding Silos 1, 2, 3, and 4
- Perched groundwater in the vicinity of the silos that may be encountered during the implementation of cleanup activities

The primary objectives of the FS phase of the Operable Unit 4 RI/FS are to develop and evaluate an appropriate range of remedial action alternatives for addressing environmental concerns at Operable Unit 4, perform a screening of the alternatives, and complete a detailed analysis of the feasible alternatives. The alternatives evaluated in the FS were developed during the RI. The results of the FS, when combined with input from support agencies (i.e., OEPA) and the general public on the preferred comprehensive alternative and the other remedial alternatives identified in the PP, form the basis for selecting the proposed remedial action. Input from the public and other interested parties will be obtained through receipt of comments on a proposed plan to be issued for public review. The PP for Operable Unit 4, which will be issued to the public in March 1994, provides a summary level description of the action proposed for addressing Operable Unit 4 environmental concerns. Subsequently, consistent with the Amended Consent Agreement, selection of a preferred remedial alternative will be documented in a ROD issued by the EPA following consideration of any comments received from the public and other interested parties.

In October 1990, the EPA approved the Operable Unit 4 Initial Screening of Alternatives (ISA) Report (October 1990) which provided a description of the range of cleanup alternatives being considered for the operable unit. Within the ISA report, the Operable Unit 4 facilities and associated environmental media were grouped into three categories: Silos 1 and 2, Silo 3, and Silo 4. During development of the RI Report, it became apparent that the original waste categories identified in the EPA-approved ISA were defined too broadly to support the necessary detailed evaluation required in the FS Report. The variety of waste media, contaminants, and concentrations encountered within Operable Unit 4, coupled with unique remediation technology requirements, required the use of a "subunit" concept for Operable Unit 4. Designating the following subunits allowed the FS Report for Operable Unit 4 to focus on developing discrete remedial actions that would comprehensively address the entire Operable Unit 4. The subunits employed throughout the FS Report for Operable Unit 4 are as follows:

- Subunit A: Silos 1 and 2 contents, and sludges remaining within the decant sump tank

- Subunit B: Silo 3 contents

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- Subunit C: Silo structures 1, 2, 3, and 4, berms, surface and subsurface soils, RTS, drum handling building pad, K-65 decant sump tank and associated piping, concrete pipe trench, perched groundwater, and any rubble or debris (i.e., demolition of waste processing facilities) generated consequential to the implementation of remedial actions for all Operable Unit 4 subunits.

Consistent with DOE Order 5400.4, the FEMP is integrating the National Environmental Policy Act (NEPA) requirements into the documentation being prepared to support the RI/FS process. However, DOE's CERCLA/NEPA integration policy is not intended to represent a statement on the legal applicability of NEPA to remedial actions under CERCLA.

On May 15, 1990, a Notice of Intent (NOI) was published in the Federal Register (55 FR 20183-20188) and was amended on June 28, 1990 (to extend the comment period). The NOI stated intent, on the part of DOE, to prepare an Environmental Impact Statement (EIS) to evaluate the potential impacts associated with proper cleanup activities at the FEMP. The public, interested organizations, and federal, state, and local agencies were invited to provide oral comments at the two scoping meetings held on June 12-13, 1990, and to submit written comments until the close of the EIS scoping period on June 29, 1990. As a result of the scoping meetings, the EIS Implementation Plan was finalized. The EIS Implementation Plan includes: a description of the proposed actions and remedial alternatives; a list of environmental issues to be considered in the EIS (including those identified during public scoping activities); a list of proposed agency consultations; and the timing relationships between the NEPA compliance process and CERCLA project planning and decision-making.

As identified in the NOI, the FS Report and PP for the lead FEMP Operable Unit, in this case, Operable Unit 4, will be issued as a Feasibility Study/Proposed Plan-Draft Environmental Impact Statement (FS/PP-DEIS). This FS has been written to integrate NEPA requirements at the level of an EIS, in part by summarizing and incorporating by reference other key documents prepared in support of the RI/FS process [RI Report and Site-Wide Characterization Report (SWCR)]. The FS Report for Operable Unit 4 coupled with the PP constitutes the EIS (or FS/PP-DEIS). More specifically, in accordance with the "Implementation Plan for the Remedial Investigation/Feasibility Study - Environmental Impact Statement for Remedial Activities at Fernald Environmental Management Project", the FS and the PP have been supplemented to integrate evaluation of the environmental

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consequences, consistent with NEPA, of implementing the leading remedial alternatives of each of the other FEMP operable units (Appendix I). This discussion of the NEPA impact analysis of the leading remedial alternatives (LRAs) for the five operable units will be updated as appropriate and attached to the CERCLA/NEPA documentation for the remaining operable units.

The RI Report supports the examination of environmental impacts by describing the environment potentially affected by the storage of existing waste within the Operable Unit 4 boundary. The RI Report also assesses the impacts associated with the no-action alternative. The Baseline Risk Assessment included in the RI Report for Operable Unit 4 evaluates the potential threat to human health and the environment if no remedial actions were undertaken for Operable Unit 4. Based on the Baseline Risk Assessment, it was determined that remedial action is warranted for Operable Unit 4 to ensure the continued protection of human health and the environment. Additionally, the SWCR (DOE 1993b) evaluated the site-wide no-action alternative by assessing the cumulative, site-wide environmental impacts associated with existing conditions at the FEMP. The RI Report for Operable Unit 4, Baseline Risk Assessment, and the SWCR are incorporated into the FS/PP-DEIS by reference. They are available in the FEMP Administrative Record located in the Public Environmental Information Center (PEIC), 10845 Hamilton-Cleves Highway, Harrison, Ohio 45030.

This FS develops and evaluates alternatives for the remediation of Operable Unit 4 by utilizing all the information provided by the RI Report. The NEPA impact analysis of each alternative has been integrated into the Detailed Analysis of Alternatives discussion in this FS Report (Section 4.0). In addition, this FS provides the NEPA cumulative impact analyses associated with implementing cleanup actions for each of the five operable units (Appendix I). Pursuant to the requirements of 10 Code of Federal Regulations (CFR) 1022, "Floodplain/Wetland Environmental Review Requirements," a wetlands assessment has been prepared for the leading remedial alternative for Operable Unit 4 and is presented in Appendix J. Consistent with the Amended Consent Agreement (September 1991), Section X.F., this FS also presents the results of the initial site-wide Comprehensive Response Action Risk Evaluation (CRARE) in Appendix K. The CRARE provides an analysis of the total cumulative residual human health risk projected to remain after the proposed remediation of the FEMP is complete.

The PP summarizes essential key information from the RI, FS, and CRARE and identifies the preferred comprehensive alternative for remediation of Operable Unit 4. In addition, the PP also presents a summary of the environmental impacts of the preferred alternative. The PP provides key

information on the public's important role in the remedy-selection decision-making process. The PP facilitates public participation by providing a document for comment, which details the process by which the preferred alternative for remedial action was selected.

The cleanup decisions made for Operable Unit 4, based on the RI, FS, CRARE, PP, and public comments, will be presented in the ROD for remediation of Operable Unit 4. The ROD will include a summary of the Operable Unit 4 FS as well as a summary of the comments received on the final FS/PP-DEIS and the manner in which they were addressed.

Source Description

Operable Unit 4 can be defined as the facilities and environmental media within a 2.3-hectare (ha) (5.8-acre) area located in the southwest corner of the Waste Storage Area on the western portion of the FEMP site (see Figure 1-2).

Silos 1 and 2, known as the K-65 silos, contain residues generated from processing high-grade uranium ores; these residues comprise Subunit A. This processing, which was conducted at both the FEMP and the Mallinckrodt Chemical Works (MCW) in St. Louis, Missouri during the late 1940s and early 1950s, was conducted to extract the uranium from the natural ores. The ores, consisting mainly of pitchblende, were shipped to the United States primarily from the Shinkolobwe Mine in the Belgian Congo (now the country of Zaire). Pursuant to the terms of an agreement between the U.S. Atomic Energy Commission (AEC) and the African Metals Corporation (owner of the mine), rights to the uranium in the ores were sold to the United States. The African Metals Corporation retained ownership of the precious metals in the ore including radium, gold, and silver. The K-65 silos were constructed at the FEMP in 1951 to provide interim storage of the residues, pending return of the material to the African Metals Corporation. For more than 30 years, these materials remained in storage at the FEMP under the terms of the original agreement. In 1984, ownership of the residues was transferred to the United States government.

Silo 1 contains 3280 cubic meters ($m^3$) [4,293 cubic yards ($yd^3$)] of residues and 360 $m^3$ (467 $yd^3$) of bentonite clay. Silo 2 contains 2840 $m^3$ (3,719 $yd^3$) of residues and 310 $m^3$ (411 $yd^3$) of bentonite clay. As part of previous studies and as part of the RI, samples were collected from the residues in the silos. These residues are primarily a silty clay with an average moisture content of approximately 40 percent. Analytical results from the residue samples identified significant activity concentrations of radionuclides within the uranium decay series, thus confirming prior process knowledge. The

residue volumes within the two silos contain in excess of 3700 Curies (Ci) of radium (Ra)-226, 600 Ci of thorium (Th)-230, and 1900 Ci of radioactive lead (Pb)-210. The residues also contain leachable concentrations of other metals, primarily lead.

Silos 1 and 2 are equipped with a decant sump tank, which was first used to collect decant liquids from residue slurried into the silos. The system also collects silo leachate that entered the Silos 1 and 2 underdrain system. The tank is buried beneath the silo berm, at a depth approximately 0.61 meter (m) [2 feet (ft)] below the base of the silos, between Silos 1 and 2, and is connected to the berm surface via a standpipe. In 1990, site personnel noted 1.2 m (4 ft) of liquid in the standpipe. In 1991, and again in February 1993, the liquid contents of the decant sump tank were emptied and sampled. Analytical results of these liquids indicated the constituents and concentrations were consistent with the contents of Silos 1 and 2.

The significant quantities of liquid in the decant sump tank indicate that the system is collecting leachate from the silo underdrain system, as it was designed to do. Excess quantities of liquid in the decant sump tank, which cause liquid to rise into the standpipe, provide a possible mechanism for leachate from the silos to enter perched groundwater.

Structural evaluations completed on Silos 1 and 2 in 1985 identified a significant loss of the load-carrying capability at the center portion of the domes on both structures. A protective barrier was placed over the deteriorated central portions of the silo domes in 1986 to minimize potential environmental impacts in the event of a catastrophic dome collapse. The remaining structures, Silos 3 and 4, which are also beyond their original design life, show signs of deterioration from weathering but have required no reinforcement.

As a natural consequence of the decay of Ra-226 present in the Silos 1 and 2 residues, a radioactive gas, radon (Rn)-222, is formed. Air samples collected in 1987 from the unfilled, upper portion of the Silos 1 and 2 "headspace" showed a maximum concentration of 30,000,000 picoCuries per liter (pCi/L). The average background concentration of Rn-222 in ambient air is approximately 0.5 pCi/L. In late 1991, a layer of bentonite clay slurry was placed over the residues in Silos 1 and 2. This clay layer was installed to reduce the release of radon gas to the atmosphere. Samples collected following emplacement of the bentonite clay showed an 85 percent reduction of Rn-222 present in the headspace of the silos.

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The inventory of radionuclides present in the K-65 residues significantly elevates the direct penetrating radiation field in the vicinity of the silos. Measurements collected from the silo dome surfaces before the bentonite clay layer was installed showed exposure rates in excess of 200 millirem per hour (mrem/hr), or approximately 20,000 times natural background radiation levels. Measurements collected from the surfaces of the domes following bentonite installation showed a greater than 95 percent decrease in the direct radiation fields on the dome surface.

Silo 3 contains 3890 $m^3$ (5,088 $yd^3$) of residues, known as cold metal oxides, which were generated at the FEMP during uranium extraction operations in the 1950s. This process involved the previously mentioned Belgian Congo ores and uranium concentrates received from a variety of uranium mills in the United States and abroad; these residues comprise Subunit B. The residues in Silo 3 are substantially different from those in Silos 1 and 2. First, Silo 3 residues have a low moisture content resulting in a powder-like consistency, while residues in Silos 1 and 2 consist of wet slurry from which excess liquids were decanted. Second, while the radiological constituents in Silo 3 are similar to those in Silos 1 and 2, certain radionuclides, such as radium, are present in much lower concentrations. Thus, Silo 3 exhibits a significantly lower direct radiation field and radon emanation rate than Silos 1 and 2.

Residue samples collected from Silo 3 identified the presence of significant activity and concentrations of the radionuclides within the uranium decay series, confirming prior process knowledge. The predominant constituent identified within Silo 3 was Th-230, a radionuclide produced from the natural radioactive decay of U-238. Approximately 450 Ci of Th-230 are distributed within the Silo 3 residues. Tests performed on samples of the Silo 3 residues indicate that arsenic, chromium, and selenium are leachable from the residues.

Silo 4 is empty and was never used for waste storage; however, rainwater has infiltrated into the silo and has been previously removed by maintenance activities whenever necessary.

Development and Screening of Alternatives

This FS presents information to support the selection of the most appropriate remedial alternative for each of the three Operable Unit 4 subunits. The alternatives for remediation in this FS were developed in accordance with EPA guidance by following a series of logical steps that involved developing, in succession, more specific definitions of potential remedial alternatives. The steps included the following:

- Development of contaminant- and media-specific remedial action objectives (RAOs) and preliminary remediation goals (PRGs)
- Identification of general response actions (GRAs)
- Identification of volumes and/or areas of waste media to be addressed
- Identification and screening of remedial technologies and process options
- Evaluation and screening of process options within each technology
- Assemblage of a wide range of remedial alternatives using the selected process options within each remedial technology
- Evaluation of initial screening to determine which alternatives will be analyzed more fully in the detailed analysis phase of the FS

Detailed/Comparative Analysis of Feasible Alternatives

The detailed analysis of alternatives is performed on those alternatives which are retained through the screening of alternative steps described above. The detailed and comparative analyses consist of the analysis and presentation of the relevant information needed to allow decision makers to select a remedial alternative. The alternatives selected for further evaluation in the detailed analysis of alternatives for each of the three subunits of Operable Unit 4 are listed below.

Subunit A - Silos 1 and 2 Contents

- Alternative 0A - No Action
- Alternative 2A - Removal, Stabilization [by vitrification (Vit) or cementation (Cem)], and On-Property Disposal
- Alternative 3A.1 - Removal, Stabilization [by vitrification (Vit) or cementation Cem)], and Off-Site Disposal at the Nevada Test Site (NTS)

Subunit B - Silo 3 Contents

- Alternative 0B - No Action
- Alternative 2B - Removal, Stabilization [by vitrification (Vit) or cementation (Cem)], and On-Property Disposal
- Alternative 3B.1 - Removal, Stabilization [by vitrification (Vit) or cementation (Cem)], and Off-Site Disposal at NTS
- Alternative 4B - Removal and On-Property disposal

Subunit C - Silos 1, 2, 3, 4 Structures, Soils, and Debris

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, and On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS
- Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at a Permitted Commercial Disposal Site

As discussed earlier, the phased RI/FS process is intended to better focus the site investigation so that only those data necessary to support the RI/FS and the decision-making process are collected. Data requirements often necessitate the need to conduct treatability studies in order to collect data on remedial technologies identified during the alternative development process to provide additional information for evaluating technologies. Data are analyzed and interpreted on the technology's effectiveness, implementability, and/or cost, and anticipated results are compared with actual results. Appendix C provides a summary of the treatability studies conducted in direct support of the Operable Unit 4 RI/FS process. Cement stabilization, chemical extraction, and vitrification were leading treatment technologies for which tests were carried out to determine whether the given technologies could achieve the required cleanup goals for Operable Unit 4. The treatability study results were used in the FS Report for Operable Unit 4 to support the detailed analysis of alternatives and to allow selection of the preferred remedial action in the PP for Operable Unit 4 to be made with reasonable certainty of achieving the response objectives.

For each subunit, the no-action alternative was carried forward into the detailed analysis as a baseline for comparison as required per the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The objectives of the detailed/comparative analysis are: (1) to further define the reasonable alternatives that have been carried forward from the alternative screening phase of the CERCLA process; (2) to individually evaluate each alternative against the evaluation criteria as specified in EPA "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988); and (3) to compare alternatives with each other to assess the relative performance of each alternative with respect to each evaluation criterion.

Nine evaluation criteria have been developed in the EPA guidance documents to address the CERCLA requirements as stated in the NCP. Assessments against two of the criteria relate directly to

evaluation against regulatory requirements and are categorized as threshold criteria. These two criteria are:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)

The following five criteria are grouped together because they represent the primary balancing criteria upon which the detailed analysis is based:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The final two criteria will be evaluated following public and agency comments on the FS/PP-DEIS and will be addressed in the ROD once a final remedial action decision is made. The modifying criteria are as follows:

- State acceptance
- Community acceptance

The results of the comparative analysis distinguish the relative advantages and disadvantages of each alternative so that the leading remedial action for each subunit can be identified in the PP. Ideally, the leading remedial action alternative identified in the PP for Operable Unit 4 will consist of those alternatives, one from each subunit, which performed best when evaluated against the nine criteria.

The discrete leading remedial alternatives for each subunit may be combined into one comprehensive remedial action strategy that will effectively address the complex nature of Operable Unit 4 cleanup activities in the PP. The PP will be issued for public review and comment as part of the integrated FS/PP-DEIS. The final remedy for Operable Unit 4 will be determined after public consideration of the PP and any significant new information that may become available subsequent to submittal of the FS/PP-DEIS. The alternatives selected for implementation will be documented in the Operable Unit 4 ROD.

# 1.0 INTRODUCTION

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This report documents the Feasibility Study (FS) phase of the Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit 4 at the U.S. Department of Energy (DOE) Fernald Environmental Management Project (FEMP). The FEMP is located in southwestern Ohio about 27 kilometers (km) [17 miles (mi)] northwest of the city of Cincinnati, Ohio (Figure 1-1). Formerly known as the Feed Materials Production Center (FMPC), the FEMP operated from 1952 until 1989 providing high purity uranium metal products in support of United States defense programs. Production operations were halted in 1989 to focus available resources on environmental restoration initiatives at the facility. One of these initiatives, the RI/FS, is being conducted pursuant to the terms of an agreement with the U.S. Environmental Protection Agency (EPA) to identify the most plausible cleanup actions to be undertaken at the FEMP to address identified environmental concerns. These concerns have been identified by DOE, EPA, the Ohio Environmental Protection Agency (OEPA), and members of the community living near the facility. These concerns have included: the potential impacts on human health and the environment from past releases of hazardous materials from the FEMP to air, water, and the surrounding soils; continuing releases of hazardous materials from the facility; and the on-property accumulation of a large inventory of uranium process materials and low-level radioactive and hazardous wastes at the site. On the basis of these concerns and an evaluation of existing environmental sampling data, the FEMP was placed on the National Priorities List (NPL) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in November 1989. Inclusion on the NPL reflects the relative importance, placed by the federal government, on ensuring the expedient completion of cleanup actions at the FEMP site.

To promote a more structured and expeditious cleanup of the FEMP site, the facility and environmental issues associated with the site are being managed as five operable units. An operable unit is a term employed under federal environmental regulation to identify a logical grouping of environmental issues at a cleanup site. Separate RI/FS documentation is being issued for each of the five operable units at the FEMP. The five operable units for which RI/FS documents are being compiled are defined as:

- Operable Unit 1: Waste Pit Area. Waste Pits 1 through 6, Clearwell, Burn Pit, berms, liners, and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

- Operable Unit 2: Other Waste Units. Flyash Piles, other South Field disposal areas, Lime Sludge Ponds, Solid Waste Landfill, berms, liners, and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

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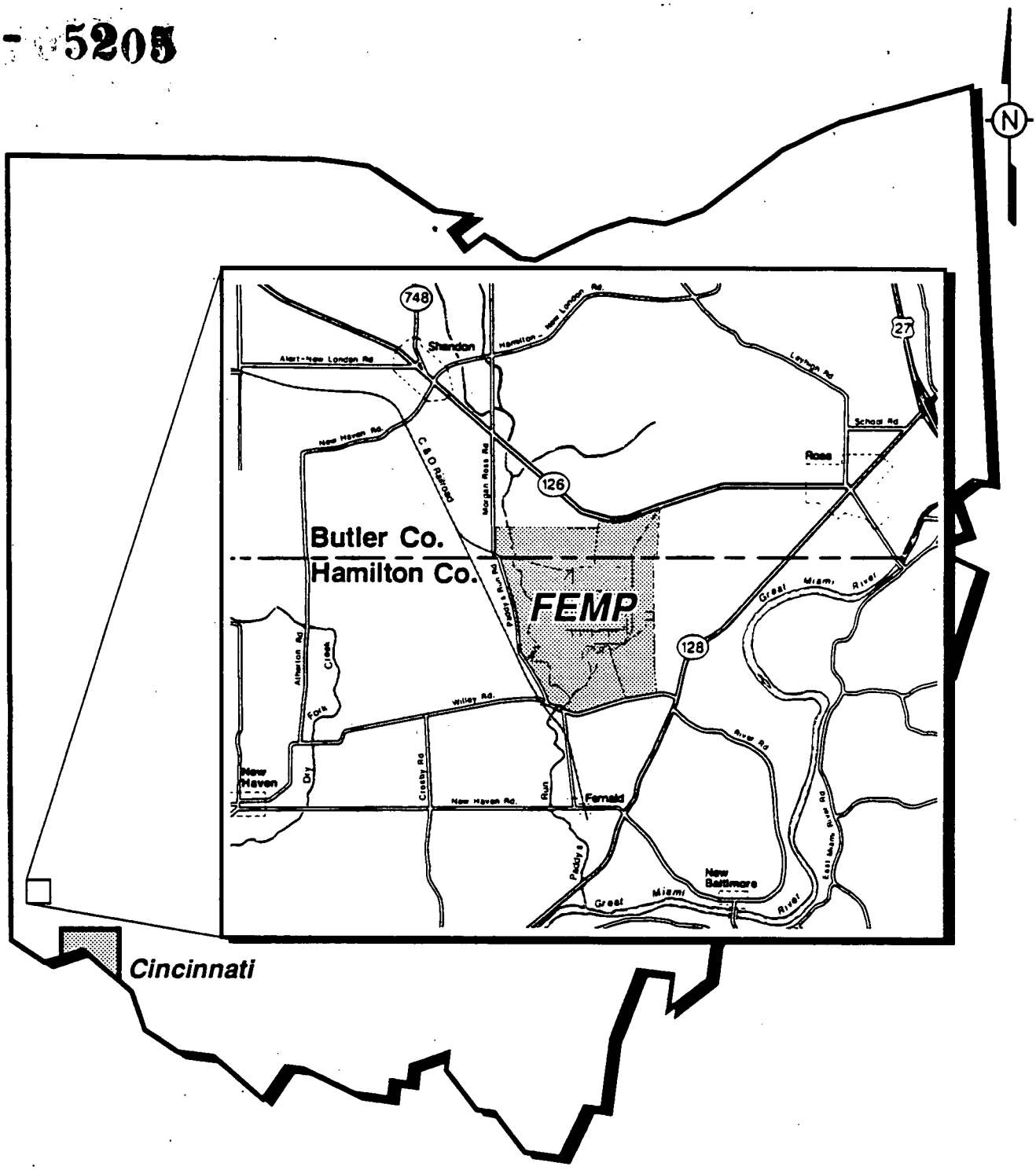


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FIGURE 1-1. FEMP FACILITY LOCATION MAP

- Operable Unit 3: Former Production Area. Former Production Area and production-associated facilities and equipment (includes all above- and below-grade improvements) including, but not limited to, all structures, equipment, utilities, drums, tanks, solid waste, waste, product, thorium, effluent lines, a portion of the K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and coal pile.

- Operable Unit 4: Silos 1 through 4. Silos 1, 2, 3, and 4, berms, decant sump tank system, and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

- Operable Unit 5: Environmental Media. Groundwater, surface water, soil not included in the definitions of Operable Units 1 through 4, sediment, flora, and fauna.

As previously stated, this report documents the FS phase for Operable Unit 4. Operable Unit 4, as depicted in Figure 1-2, consists of the following FEMP facilities and associated environmental media:

- Silos 1 and 2 and their contents (also termed K-65 Silos)
- Silo 3 and its contents (termed cold metal oxide silo)
- Silo 4
- K-65 decant sump tank, its contents, and associated piping
- A radon treatment system (RTS)
- The portion of a concrete pipe trench within the boundaries of Operable Unit 4, and other concrete structures
- An earthen berm surrounding Silos 1 and 2
- Soils beneath and immediately surrounding Silos 1, 2, 3, and 4
- Perched groundwater in the vicinity of the silos that may be encountered during the implementation of cleanup activities

Silos 1 and 2, known as the K-65 Silos, contain residues generated from processing high grade uranium ores. This processing was completed to extract the uranium from the natural ores. These ores, termed pitchblende, were shipped to the United States from a mine in the Belgian Congo (now known as Zaire). The K-65 residues contain high activity concentrations of radionuclides, including radium and thorium. These radionuclides contribute to an elevated direct penetrating radiation field in the vicinity of the silos and to the chronic emission of significant quantities of the radioactive gas, radon, to the atmosphere from the silos. The K-65 residues are classified as byproduct materials, as

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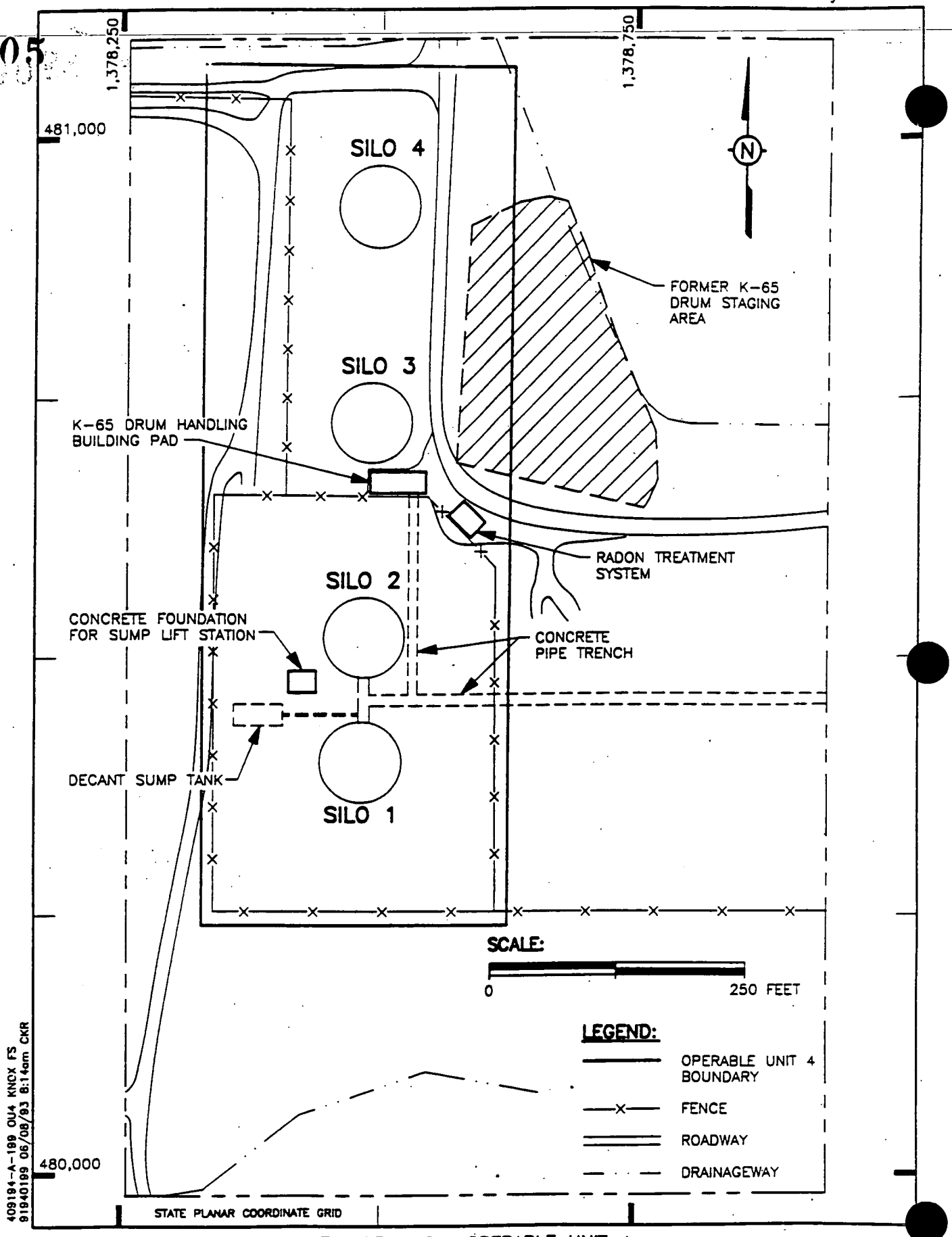


FIGURE 1-2. OPERABLE UNIT 4

defined by Section 11(e)2 of the Atomic Energy Act (AEA), generated consequential to the processing of natural uranium ores.

Silo 3 contains residues, known as cold metal oxides, which were generated at the FEMP site during uranium extraction operations in the 1950s involving the previously mentioned Belgian Congo ores and uranium ore concentrates received from a variety of uranium mills in the United States and abroad. The residues within Silo 3 also contain significant activity concentrations of radionuclides but exhibit a significantly lower direct radiation field and radon emanation rate than the K-65 residues. The residues within Silo 3 are similarly classified as byproduct materials as defined by Section 11(e)2 of the AEA. Silo 4 was never used for waste storage; however, rainwater has infiltrated into the silo and has been previously removed whenever necessary.

The RI/FS for Operable Unit 4 is being conducted in accordance with the Amended Consent Agreement between EPA and DOE. One objective of the RI/FS is to develop a detailed understanding of the nature of the stored residues, their impacts on the surrounding environment, and the threat that the Operable Unit 4 facilities pose to human health and the environment. DOE reported the detailed description of the existing conditions in Operable Unit 4 in the RI Report for Operable Unit 4 issued in November 1993 (DOE 1993b). The purpose of this FS Report for Operable Unit 4 is to evaluate the range of available remedial action alternatives for the permanent disposition of the K-65 residues, cold metal oxides, the silo structures, and associated contaminated environmental media.

For sites undergoing investigations and cleanup under CERCLA, it is DOE policy to integrate the National Environmental Policy Act (NEPA) requirements into the procedural and documentation requirements of the RI/FS process wherever practical. On May 15, 1990, a Notice of Intent (NOI) was published in the *Federal Register* indicating that DOE planned to prepare an integrated FS and Environmental Impact Statement (EIS) consistent with NEPA to evaluate the environmental impacts associated with the implementation of cleanup actions for each of the five FEMP operable units. Consistent with the NOI, this FS Report integrates the elements of an EIS prepared under NEPA. This FS Report is also coupled with the information provided in a proposed plan. This document is the result of this integrated process and is called the Feasibility Study/Proposed Plan-Draft Environmental Impact Statement (FS/PP-DEIS). Additional details on this integration process can be found in Section 1.3.

The DOE issued a second NOI on October 22, 1990 to prepare a Programmatic EIS (PEIS) on DOE's integrated Environmental Restoration and Waste Management Program. The purpose of DOE's proposed integrated Environmental Restoration and Waste Management Program is to provide a broad, systematic approach to addressing cleanup activities and waste management practices at sites nationwide. The remedial actions evaluated and selected in the FEMP site's integrated CERCLA/NEPA documentation will be consistent with the approaches developed in this FS/PP-DEIS.

## 1.1 PURPOSE AND NEED FOR DECISION

Facilities and environmental media at the FEMP site contain radioactive and chemical constituents at levels that exceed certain federal and state standards and guidelines for protecting human health and the environment. DOE maintains custody of the site and restricts access with fences and security forces, precluding a member of the public from being exposed to the more heavily contaminated areas on the site. To support the decision as to whether a given waste site warrants the implementation of cleanup actions, EPA has established a formalized risk assessment process. Under this process, several hypothetical scenarios are examined that could expose members of the public to site contamination. One of these scenarios assumes that site access is not controlled, and a member of the public could be exposed to site contaminants. Results of the risk assessment performed for this hypothetical scenario, which assumes a loss of access controls, indicate that if an individual were to enter the site and establish a residence within the Operable Unit 4 Study Area under existing conditions, that individual could incur adverse health effects.

The ongoing RI/FS site characterization and routine environmental monitoring programs at the FEMP site provide information on the nature and extent of contamination, including information for areas off the FEMP property to which contaminants have migrated or could migrate in the future. The routine environmental monitoring program provides environmental data that can be examined over long periods of time (i.e., months, years, and decades) to provide an early indication of any adverse change in site environmental conditions.

Although human populations are not presently adversely impacted by Operable Unit 4 contaminants due to access and administrative controls (DOE 1993c), the purpose of DOE's environmental restoration program is to preclude the potential for such impacts in the future by implementing long-term cleanup solutions. DOE is addressing long-term management of the FEMP site through the previously identified integrated environmental decision-making process.

## 1.2 PURPOSE AND ORGANIZATION OF REPORT

The purpose of this FS Report is to evaluate the range of available remedial action alternatives for addressing the permanent disposition of the stored residues, their storage structures and support facilities, and existing contaminated environmental media within Operable Unit 4 at the FEMP site. This report has been prepared consistent with the requirements of the Amended Consent Agreement, applicable project documentation, and available EPA guidance. The FS Report has been prepared to provide the necessary information, when coupled with regulatory agency and community input, to support an informed decision regarding the appropriate remedy for Operable Unit 4. The FS Report is organized as follows:

- The remainder of Section 1.0 presents a summary description of the history, environmental setting, and the nature and extent of contamination associated with the FEMP site and Operable Unit 4, emphasizing information from the RI Report for Operable Unit 4. The section further presents a brief discussion of the human health impacts that might occur at the site and Operable Unit 4 in absence of remedial actions, summarizing information from the baseline risk assessment in the RI Report for Operable Unit 4 and the Site-Wide Characterization Report (DOE 1993d).

- Section 2.0 identifies the scope of the proposed remedial actions for Operable Unit 4, the volume of waste and contaminated media being addressed, and the goals and objectives of proposed remedial actions. The section identifies potential technologies and available process options for managing the residues and contaminated media.

- Section 3.0 develops and screens preliminary remedial action alternatives for addressing each waste type and media associated with Operable Unit 4.

- Section 4.0 provides a more detailed description of the remedial action alternatives being considered and performs a detailed analysis of the alternatives employing criteria established by federal regulation. Each detailed analysis has been supplemented to include an impact analysis of the affected environment pursuant to the requirements of NEPA.

- Section 5.0 presents a comparative analysis of the remedial candidates for Operable Unit 4.

Supporting information is contained in Appendices A through K, including more detailed discussions on available process options, costing information, regulatory requirements, and the Comprehensive Response Action Risk Evaluation (CRARE). The CRARE, which is included as Appendix K, presents the results of a risk assessment performed for Operable Unit 4, with the available information from the leading alternatives for the other four FEMP site operable units, to provide an indication of the ability to achieve goals of human health protectiveness from a site-wide perspective.

## 1.3 OVERVIEW OF FEMP SITE ENVIRONMENTAL RESTORATION PROCESS

This section summarizes the major elements of the FEMP environmental restoration process including the RI/FS and removal actions.

### 1.3.1 RI/FS Process

The RI/FS is being conducted in accordance with the requirements of the Amended Consent Agreement between DOE and EPA. The Amended Consent Agreement provides that the RI/FS be performed consistent with CERCLA and other applicable EPA regulations and guidance. The RI/FS documents for Operable Unit 4 have been prepared in accordance with the requirements of CERCLA, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and pertinent EPA guidance. A diagram providing an overview of the RI/FS process as it is being implemented at the FEMP site is presented in Figure 1-3. The RI/FS process comprises the following primary components:

- RI - presents information on the existing conditions at the site, defines the nature and extent of contamination, and performs an assessment of the risks to human health and the environment due to existing environmental conditions.

- FS - develops, screens, and evaluates technologies and alternatives for potential implementation to address identified environmental concerns.

- PP - summarizes the proposed remedial alternative for implementation at a specific operable unit based on information collected and assessed in the RI/FS phase so as to facilitate input from the public and other interested parties in the decision-making process. For Operable Unit 4, the PP has been combined with the FS report, resulting in the integrated FS/PP-EIS document.

- Record of Decision (ROD) - responds to public comments on the PP, documents the selected alternative, and defines final cleanup goals and long-term monitoring requirements.

As previously stated, it is DOE policy to integrate the NEPA requirements into the procedural and documentation requirements of CERCLA wherever practicable. In accordance with this policy, the RI/FS documents prepared to support the Operable Unit 4 decision process include information on the evaluation elements and criteria employed in the development of an EIS under NEPA. This information includes impact analysis on each of the alternatives presented in Section 4.0 and consideration of these impacts in the comparative analysis Section 5.0. Figure 1-3 indicates the RI/FS documents supplemented to address NEPA requirements.

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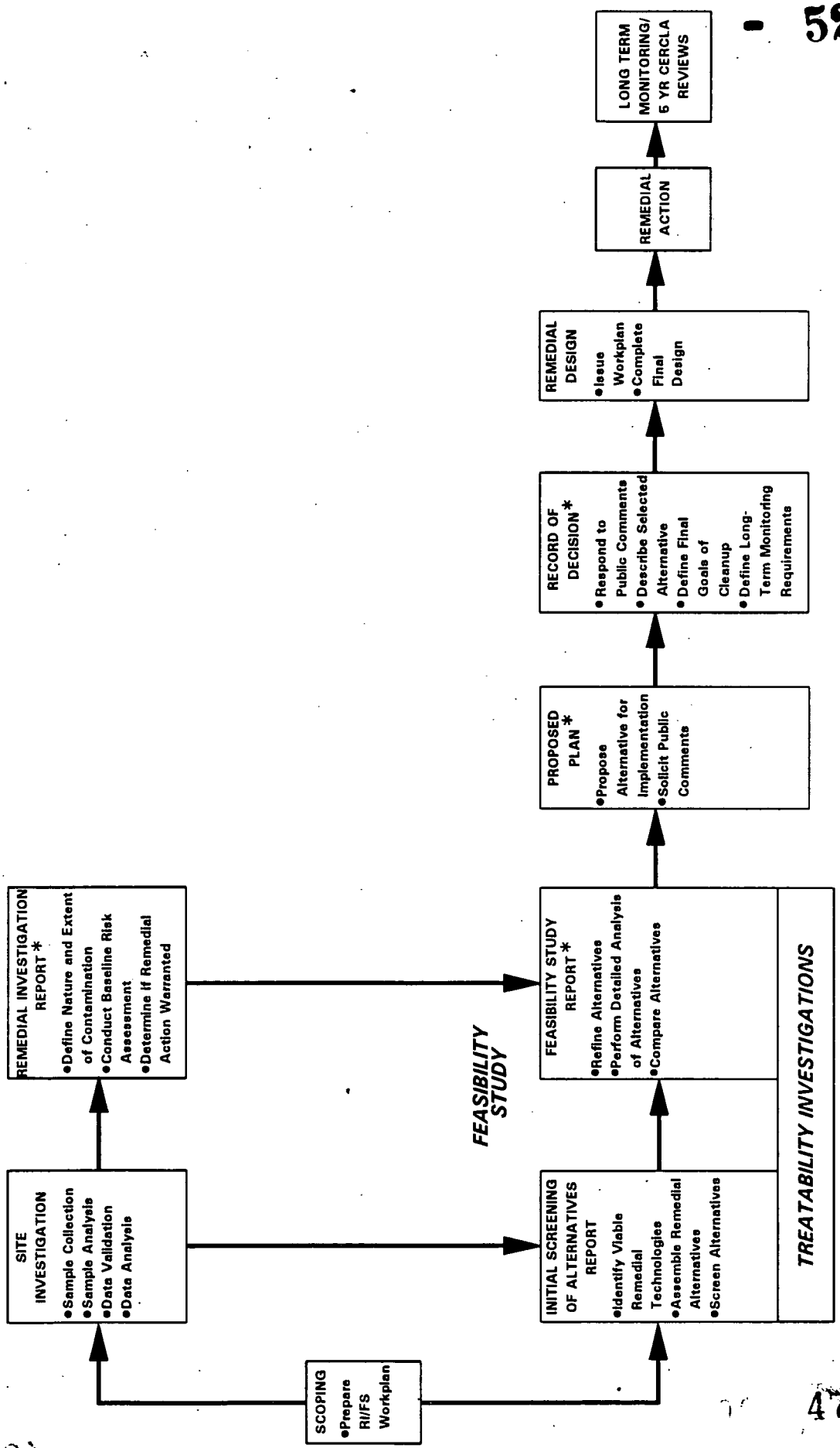


*DOCUMENT INCORPORATING NEPA REQUIREMENTS

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FIGURE 1-3. FEMP ENVIRONMENTAL RESTORATION PROCESS

Separate RI/FS documentation including RI Reports, Initial Screening of Alternatives (ISA) Reports, FS Reports, PPs, and RODs are being issued on varied time schedules for each of the five operable units as established by the Amended Consent Agreement. The lead operable unit (i.e., chronologically, the first operable unit issuing RI/FS documents) for the FEMP site is Operable Unit 4. The integrated CERCLA/NEPA documents for Operable Units 1, 2, 3, and 5 will tier from the lead Operable Unit 4 FS/PP-DEIS.

The RI reports for each operable unit will contain characterization data for the specific operable unit and nearby environmental media and will function as the description of the affected environment for NEPA purposes. The Site-Wide Characterization Report (SWCR), issued in March 1993 (DOE 1993d), includes detailed technical appendices reporting FEMP-wide studies of wetlands, threatened and endangered species, and cultural resources. The SWCR also presents the CERCLA preliminary site-wide baseline risk assessment. The preliminary site-wide baseline risk assessment evaluates the present and future risks posed by the site should no further action be taken; as such, it serves as a mechanism to support the decision, on the part of EPA and DOE as the lead agency, that remedial action is warranted at the FEMP site to protect human health and the environment. Furthermore, it provides input to the NEPA impact analysis of the consequences of implementing no remedial actions. The FS documents prepared for each operable unit will incorporate NEPA requirements in that they will contain the impact analysis of each FEMP alternative for the specific operable unit.

The Operable Unit 4 FS/PP-DEIS functions as the lead CERCLA/NEPA integrated document and addresses the cumulative impacts of the leading remedial alternatives (LRAs) for each operable unit. Specifically, Appendix I of this document contains the NEPA Cumulative Impact Analysis of Leading Remedial Alternatives. Appendix I also contains a list of contributors and a list of agencies contacted pursuant to NEPA requirements. Appendix J contains a Wetlands Assessment pursuant to the requirements of 10 CFR 1022. The CERCLA/NEPA integrated documents prepared subsequent to Operable Unit 4 will be derived from or be fully encompassed by the impact analysis presented in the Operable Unit 4 FS/PP-DEIS. If the LRAs for any of the operable units change, additional NEPA review will be performed and documented as appropriate to evaluate the impacts to human health and the environment. This additional analysis will be presented in the integrated CERCLA/NEPA documents for the remaining operable units where appropriate.

In accordance with both CERCLA and NEPA processes, these documents are made available to the public for comment. Public involvement is an important factor in the decision-making process for site

remediation. Public comments will be considered in the selection of remedy for each operable unit, which will be presented in a ROD. Applying the integrated approach for CERCLA and NEPA, DOE plans to prepare and issue a single ROD to be signed by both DOE and EPA. The contents of the documents prepared for the remedial actions at the FEMP are not intended to represent a statement on the legal applicability of NEPA to remedial actions conducted under CERCLA.

While the operable unit concept provides a management strategy to expedite the cleanup process at a site, the concept does not obviate the statutory requirement to ensure protection of human health and the environment from a site-wide perspective. To ensure site-wide protectiveness, the Amended Consent Agreement provides for a CRARE within each operable unit FS Report and a follow-up Comprehensive Site-Wide Operable Unit.

As identified in Figure 1-4, each FEMP operable unit FS Report incorporates a CRARE. The purpose of this risk evaluation is to provide an indication of the contribution to the residual risk projected to be remaining following completion of remedial activities of the other four FEMP operable units which are not the subject of the particular FS Report. This residual risk contribution is then examined in context with the contribution of residual risk attributable to a representative alternative for the particular operable unit of issue in the FS Report. The intent of this process is to provide decision makers with relevant information of potential cumulative site-wide residual risk across all operable units, as so to provide an indication of the ability of the available alternatives to effectively contribute to the overall goal of site-wide protection of human health and the environment. To accommodate such a process for Operable Unit 4, the LRA for each of the other four FEMP operable units has been employed to estimate the residual risk contribution from these operable units.

The (LRAs) for Operable Units 1, 2, 3, and 5 being employed in this risk evaluation process were previously identified in the SWCR. The LRAs represent the remedial option which, on the basis of available data, is the most likely to be implemented for a particular operable unit. The leading remedial alternatives should in no way be considered a preselection of alternatives for implementation in advance of the formal RI/FS process. The leading remedial candidates have been identified and employed solely to support the progressive evaluation of site-wide protectiveness in the CRARE in each operable unit FS Report.

The residual risk projected to remain following implementation of these leading alternatives has been examined in context with a representative alternative for Operable Unit 4. As the FEMP site

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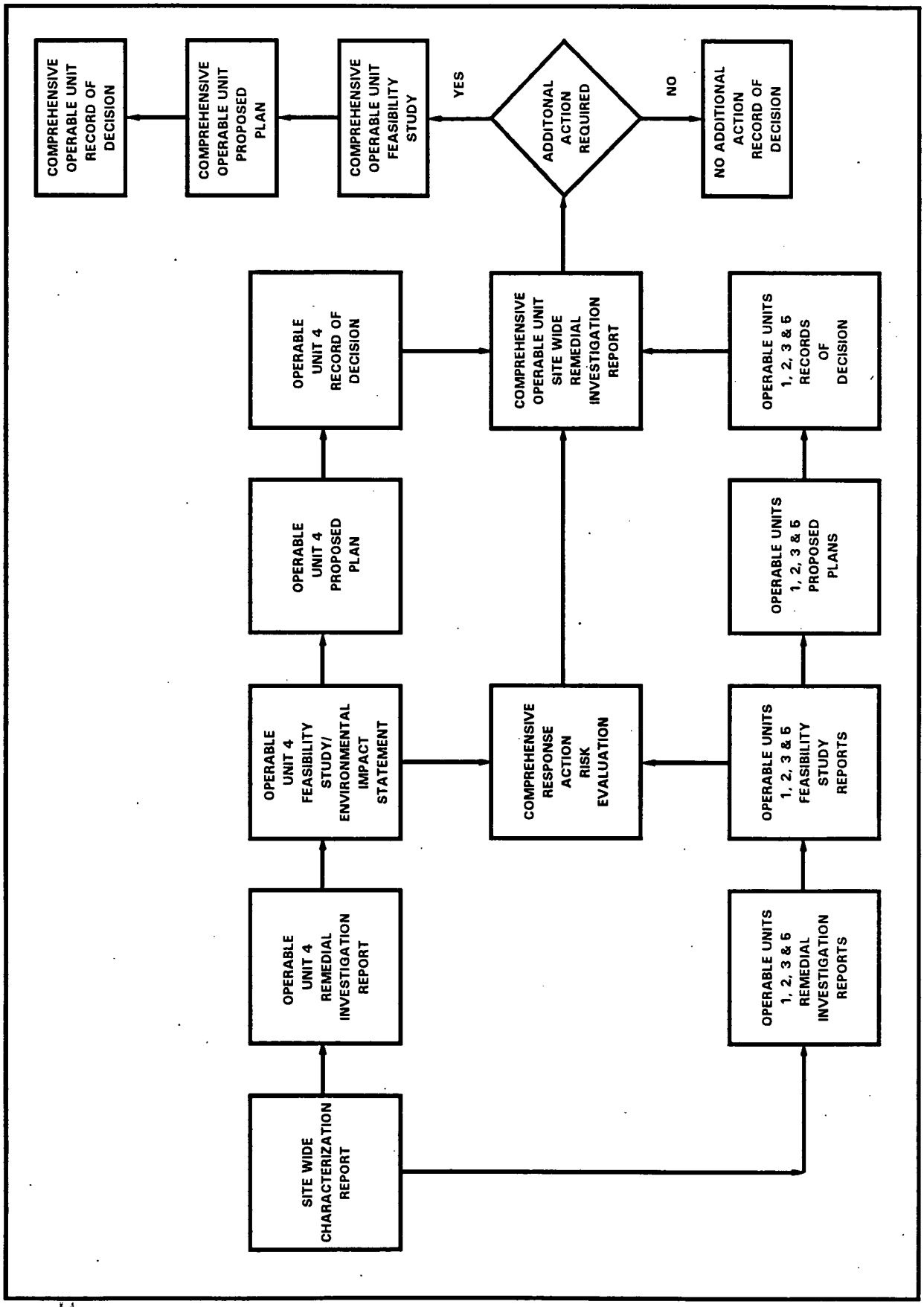


FIGURE 1-4. FEMP OPERABLE UNIT INTEGRATION STRATEGY

proceeds through the RI/FS process for the other operable units, each FS Report CRARE will adopt the leading remedial alternatives or the previously selected alternatives for the other four operable units to provide a progressive analysis of cumulative site-wide residual risks to human health and the environment. The CRARE is provided in Appendix K.

Following issuance of the ROD for the last of the five operable units, the Amended Consent Agreement provides for a Comprehensive Site-Wide Operable Unit. The Comprehensive Site-Wide Operable Unit will involve the completion of a risk assessment to evaluate the residual risk projected to be remaining following the implementation of each of the remedies selected for the five operable units in the RODs. The intent of this risk assessment is to provide a final examination of site-wide residual risks to ensure protection of human health and the environment from a site-wide perspective. If the risk evaluation deems that the residual risks from the five remedies is sufficiently protective, a no-action ROD will be issued for the Comprehensive Site-Wide Operable Unit. Should the risk evaluation deem the projected residual risks for the five selected remedies to not be sufficiently protective, a Comprehensive Site-Wide Operable Unit FS will be conducted. The focus of the FS will be to determine what, if any, supplemental actions must be undertaken by one or more of the five operable units to reduce overall site risks to acceptable levels.

All necessary site investigations have been completed for Operable Unit 4 and the RI Report for Operable Unit 4 was issued in November 1993 (DOE 1993b). The results of the RI Report for Operable Unit 4 are summarized within Sections 1.5.2 and 1.6.3. Remedy selection-based treatability studies have also been completed with the results of these studies summarized in Appendix C.

On October 29, 1990, DOE received approval of the Operable Unit 4 ISA Report. The ISA Report summarizes viable remedial technologies potentially applicable to Operable Unit 4. Viable technologies were assembled into remedial alternatives and screened to remove inappropriate alternatives. The results of the initial screening process and changes since the approved ISA Report are discussed in Section 3.0.

### 1.3.2 Removal Actions

A removal action is a cleanup action undertaken pursuant to CERCLA to address a near term environmental concern at a site, while the typically more lengthy RI/FS process continues to completion. Removal actions typically contribute to the efficient performance of final remedial actions.

Under the terms of the Amended Consent Agreement and in accordance with authorities granted to DOE under Section 106 of CERCLA by Executive Order 12580, the FEMP site is in the process of conducting or has completed 31 removal actions. These removal actions are part of each of the five operable units. Removal actions associated with Operable Unit 4 were previously discussed in Section 1.0 of the RI Report for Operable Unit 4.

## 1.4 BACKGROUND INFORMATION

This section provides a brief summary description and history of the affected sites and Operable Unit 4. The RI Report for Operable Unit 4, Baseline Risk Assessment, and the SWCR are incorporated herein by reference. They are available in the FEMP Administrative Record at the Public Environmental Information Center located at 10845 Hamilton-Cleves Highway, Harrison, Ohio, 45030.

### 1.4.1 Description of Affected Sites

The following provides a description of the sites potentially involved in the Operable Unit 4 Remedial Action. The FEMP will be the primary site where the remedial activities will be conducted. Therefore, the most in-depth discussion has been devoted to the FEMP site. Remedial activities may also involve the Nevada Test Site (NTS) and a representative permitted commercial disposal site. Summary information on the NTS and a brief description of the representative permitted commercial disposal site have been provided in Appendix B.

#### 1.4.1.1 Description of the FEMP Site

The FEMP is a 425-hectare (ha) (1050-acre), government-owned, contractor-operated facility located in southwestern Ohio, about 27 km (17 mi) northwest of downtown Cincinnati, Ohio. The facility is located just north of Fernald, Ohio, a small farming community, and lies on the boundary between Hamilton and Butler counties (Figure 1-1). Of the total site area, 345 ha (850 acres) are in Crosby Township of Hamilton County, and 80 ha (200 acres) are in Morgan and Ross Townships of Butler County.

Production operations at the FEMP site were limited to a fenced, 55-ha (136-acre) tract of land known as the former Production Area, located near the center of the site. Large quantities of liquid and solid wastes were generated by the various operations at the FEMP site. Prior to 1984, solid and slurried wastes from FEMP processes were stored or disposed in the on-site Waste Storage Area. This area, located west of the former Production Area, includes six low-level radioactive waste

storage pits; two earthen-bermed concrete silos containing K-65 residues; one concrete silo containing metal oxides; one unused concrete silo; two Lime Sludge Ponds; a Burn Pit; a Clearwell; and a Solid Waste Landfill. The Production Area is addressed under Operable Unit 3; the Waste Storage Area, shown graphically in Figure 1-5, is addressed under Operable Units 1, 2, and 4. The remaining FEMP site areas consist of forest and pasturelands, a portion of which is leased to nearby dairy farmers to graze livestock.

The following is a brief presentation of the characteristics of the FEMP site and its surrounding environment. Included is a description of the physical, environmental, and demographic settings of the FEMP area. Topics discussed include air quality, climate, topography, seismology, surface water hydrology, geology, groundwater hydrology, soils, land use, population, vegetation, and wildlife. Additional detailed discussion on each of these subjects are available in the RI Report for Operable Unit 4 and the SWCR.

Air Quality

National Ambient Air Quality Standards (NAAQS) are health-protective standards that apply to the six pollutants regulated under the Clean Air Act (CAA) of 1990: inhalable (PM 10) particulates, carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead. Extensive monitoring has been performed by the Southwestern Ohio Air Pollution Control Agency (SWOAPCA) in urban locations where the highest concentrations within its four-county jurisdiction (Hamilton, Butler, Warren, and Clermont) are found. With the exception of ozone, pollutant concentrations at the FEMP site meet the NAAQS. Ozone is a widespread problem requiring regional control and abatement measures mandated by the CAA of 1990. Air quality standards for toxic compounds not regulated under the CAA are defined by individual states. The State of Ohio, acting through the SWOAPCA, has established standards for chemically toxic compounds including ammonia, hydrogen fluoride, and nitric acid, all of which have been released from the FEMP site in small amounts. Estimates of the impacts to air quality resulting from releases from the FEMP site have been developed using air dispersion modeling. The results of this modeling, which are supported by site monitoring results, appear to indicate that concentrations of air contaminants attributable to FEMP site operations have been well within limits set by the State of Ohio in recent years.

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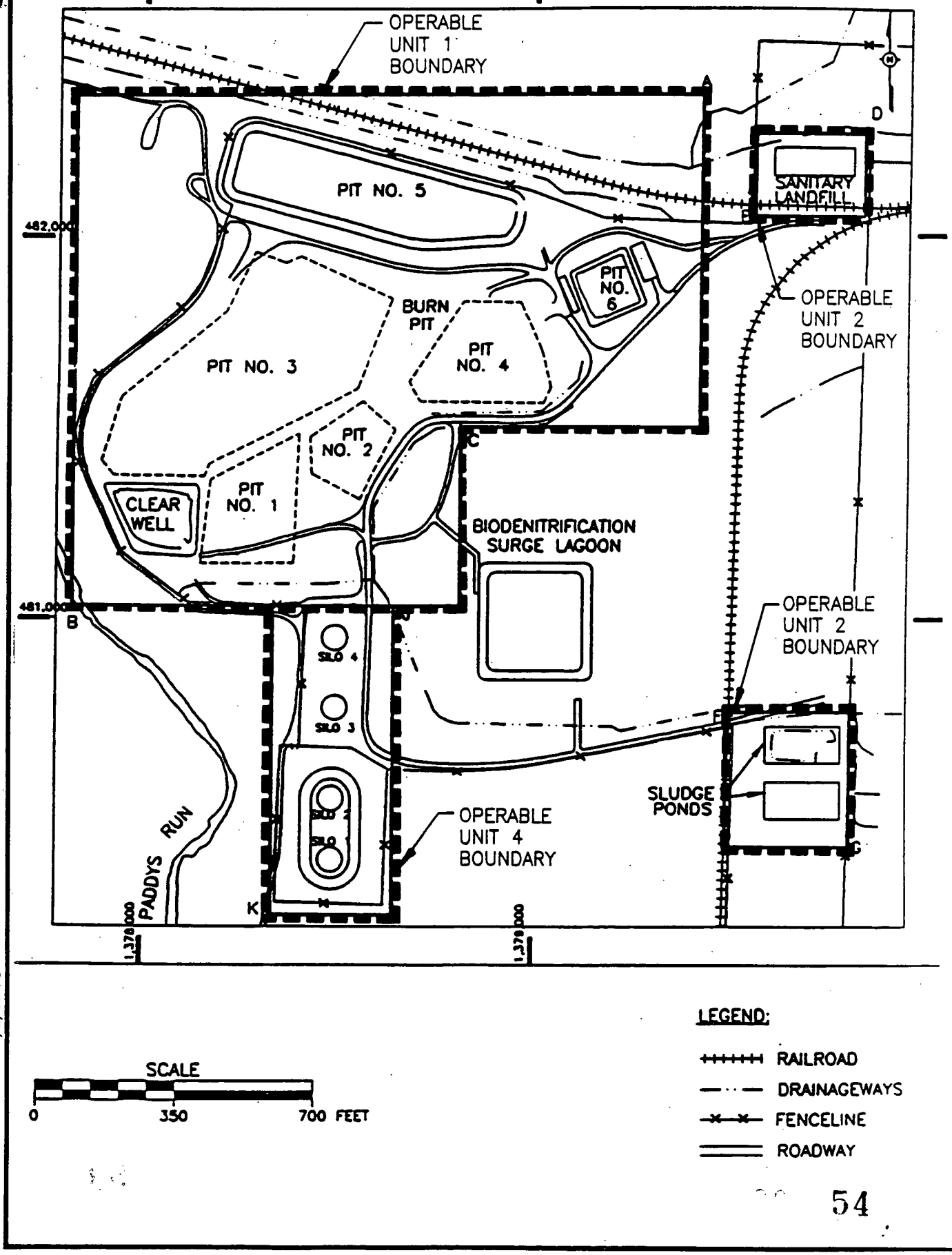


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FIGURE 1-5. WASTE STORAGE AREA

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Meteorology

The FEMP has installed and maintains a site meteorological system providing site-specific data for wind speed and direction, ambient air temperature, lapse rate, dew point, temperature, relative humidity, barometric pressure, and precipitation. The system was used by the National Oceanic and Atmospheric Administration (NOAA) to examine the complexity of the local wind field at the FEMP site.

Prevailing winds are generally from the southwest and west-southwest. Compiled wind rose information from the FEMP meteorological tower for the years 1987 through 1992 is available within the RI Report for Operable Unit 4.

As part of the probabilistic risk assessment performed for the FEMP (DOE 1989), an annual probability was assessed for a tornado occurring per square mile within Ohio. Based on data accumulated from Ohio during the years 1978 through 1990, the probability was calculated to be $1.248 \times 10^{-4}$.

The average annual precipitation for the Cincinnati area for the period of 1960 through 1989 was 103 centimeters (cm) [40.56 inches (in.)] and ranged from 71.1 cm (27.99 in.) in 1963 to 134 cm (52.76 in.) in 1979. The highest precipitation occurs during the spring and early summer. The maximum 24-hour rainfall event of record occurred in March 1964 when 13.2 cm (5.21 in.) fell. Precipitation is typically lowest in late summer and fall.

The average annual snowfall for the 1960 to 1989 period was 59.7 cm (23.5 in.), with the heaviest snowfall usually occurring in January. The maximum monthly snowfall of 80 cm (31.5 in.) occurred in January 1978.

The regional climate is defined as continental, with temperatures ranging from a monthly average of -1.57°C (29.2°F) in January to 24.5°C (75.7°F) in July. The highest temperature recorded from 1960 through 1989 was 39.8°C (103°F) in July 1988, and the lowest was -32°C (-25°F) in January 1977. Average ambient air temperatures measured at the FEMP meteorological station for the years 1987 through 1992 ranged from 10.5°C (50.7°F) to 13.1°C (55.4°F), with the highest annual average daily maximum temperature of 18.5°C (65.1°F) and the lowest annual average daily minimum temperature of 5°C (41°F).

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The average number of days per year with a minimum temperature of 0°C (32°F) or less is 109 days, and the average number of days per year with a maximum temperature of 32°C (90°F) or greater is 20 days. Frost depth ranges from 76.2 to 91.4 cm (30 to 36 in.).

Topography and Surface Water

Maximum elevation along the northern boundary of the FEMP property is a little more than 213 meters (m) [700 feet (ft)] above mean sea level (MSL). The former Production Area and Waste Storage Area rest on a relatively level plain at about 177 m (580 ft) above MSL. The plain slopes from 183 m (600 ft) above MSL along the eastern boundary of the FEMP site to 174 m (570 ft) above MSL at the K-65 Silos, and then drops off toward Paddys Run at an elevation of 168 m (550 ft) above MSL. All drainage, including surface water, on the FEMP site is generally from east to west into Paddys Run, with the exception of the extreme northeast corner, which drains east toward the Great Miami River (Figure 1-6).

Surface waters on and adjacent to the FEMP site are the Storm Sewer Outfall Ditch, Paddys Run, and the Great Miami River. The Storm Sewer Outfall Ditch originates within the FEMP site and flows toward the southwest where it enters Paddys Run, which flows southward along the western boundary of the facility. Paddys Run, in turn, is a tributary of the Great Miami River. The Great Miami River flows generally toward the southwest; however, locally it flows to the east and south of the FEMP site.

Paddys Run originates north of the FEMP site, flows southward along the western boundary of the facility, and enters the Great Miami River approximately 2.4 kilometers (km) [1.5 miles (mi)] south of the southwest corner of the FEMP property. The stream is approximately 14 km (8.8 mi) long and drains an area of approximately 40.9 square kilometers ($km^2$) [15.8 square miles ($mi^2$)]. Due to the highly permeable channel bottom, the stream loses water to the underlying Great Miami Aquifer. In addition, the stream is intermittent and is generally dry during the summer months.

Paddys Run is a steep-sided stream, and its banks erode severely during high flow periods. In 1961 and 1962, the course of the stream was altered to prevent it from eroding into the Operable Unit 1 Study Area [Westinghouse Materials Company of Ohio (WMCO) 1987]. In 1970, a reach of the stream south of the K-65 Silos was straightened to prevent erosion of Paddys Run Road. The stream is ungauged, but typically flows from January through May and ranges from 5.7 to 113 liters/second (L/s) [0.2 to 4.0 cubic feet per second ($ft^3/s$)]. Channel overflow resulting from 25-year, 24-hour and

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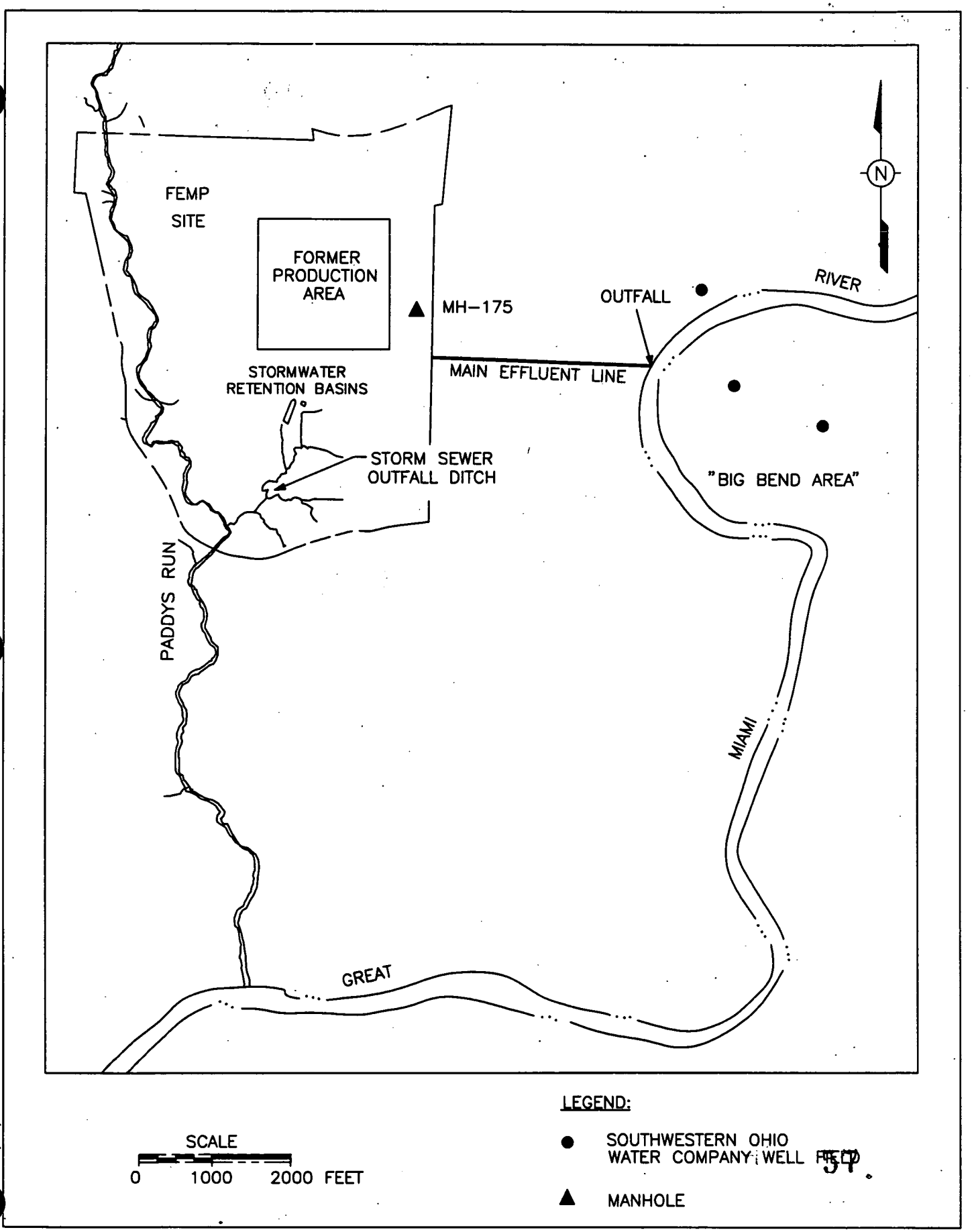



FIGURE 1-6. SURFACE WATER HYDROLOGY

100-year, 24-hour storm events is possible, but peak flows occurring during storm events have not been measured.

The Great Miami River is the main surface water feature in the vicinity of the FEMP site and is the receiving water from a National Pollutant Discharge Elimination System (NPDES)-permitted discharge from the FEMP site. The river flows generally to the southwest and has a drainage area of approximately 8702 $km^2$ (3360 $mi^2$) at the Hamilton gauge, which is located about 16.1 km (10 mi) upstream from the FEMP site discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 900 m (3000 ft). Directly east of the FEMP site and within the site-wide RI/FS Study Area, the river passes through a 180-degree curve known as the Big Bend. A 90-degree bend in the river also occurs near New Baltimore, approximately 3.2 km (2 mi) downstream from the FEMP site discharge outfall.

Soils and Seismology

The Butler County and Hamilton County Soil Surveys [U.S. Department of Agriculture (USDA) 1980, 1982] have 15 specific soil series or types mapped within FEMP site boundaries. The major series are Fincastle and Xenia silt loams, which also cover large areas west of the FEMP. These soils are moderately high in productivity when properly managed. Moisture-supplying capacity is moderate, as is fertility and organic content.

The Fincastle series consists of deep, nearly level, somewhat poorly drained soils on broad flats. Permeability is low and the available water capacity is high. These soils are associated with the former Production Area and the pastures to the east and west of the facility. The Xenia soil series is a deep, nearly level, moderately well-drained soil located on till plains. Permeability is moderately low, available water capacity is high, and the runoff potential is low.

A seismic risk zone of two (on a scale of less-than-one to four), a measurement of earthquake intensity, has been assigned to the region of the FEMP site.

Geology and Groundwater

The following discussion provides a summary of the physiography, geologic history, and hydrogeological setting of the area surrounding the FEMP site.

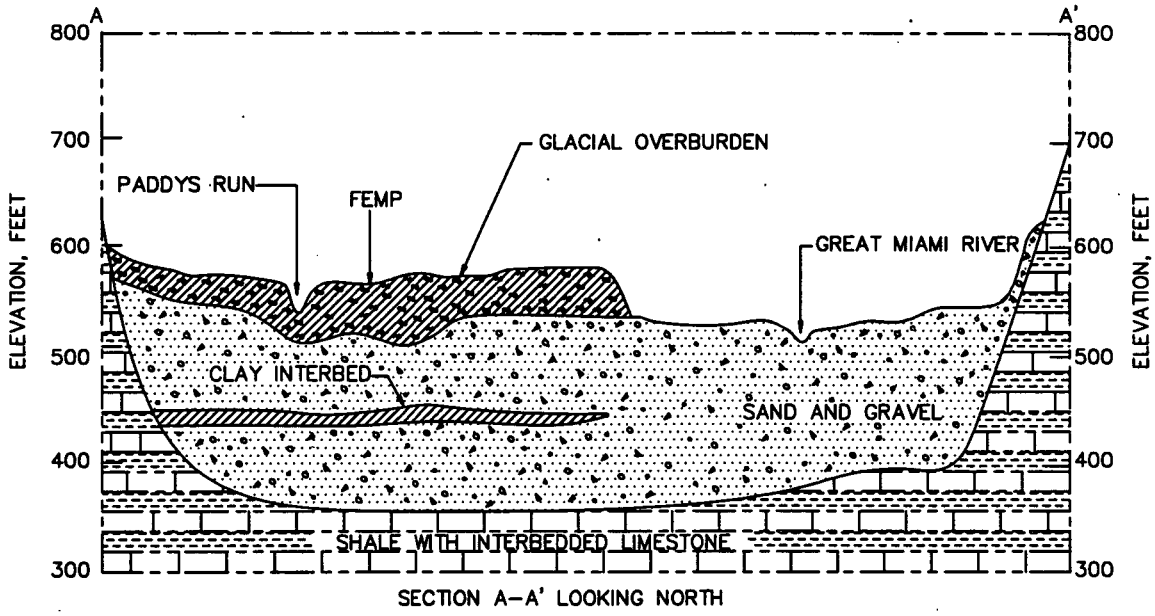
Physiography. The FEMP site lies in the Till Plains section of the Central Lowland physiographic province, characterized by structural and sedimentary basins and domes. The main physiographic features in the area are gently rolling uplands, steep hillsides along the major streams, and the Great Miami River Valley. This valley is a relatively broad, flat-bottomed valley flanked on either side by bluffs that rise to a maximum of 90 m (300 ft) above the general level of the valley floor.

Geologic History. In summary, the FEMP overlies a 3.2- to 5.6-km (2- to 3-mi) wide buried Pleistocene valley known as the New Haven Trough. This valley was formed (eroded) by the ancestral Ohio River during the Pleistocene period and was subsequently filled with glacial outwash materials that were in turn covered by glacial overburden as glaciers advanced across the area. The outwash deposits under the FEMP are a part of the Great Miami Aquifer, which is a widely distributed buried valley aquifer. In addition to surface water, the valley fill aquifer system is the major source of drinking water in the southwestern Ohio area.

Since the last retreat of continental glaciers, the streams in the area have removed much of the glacial overburden and lacustrine strata left by the ice sheets. The Great Miami River has eroded through the glacial overburden and is now in direct contact with the glaciofluvial outwash deposits that comprise the Great Miami Aquifer. Paddys Run is also in contact with these deposits in its lower reaches. The FEMP site is located on a dissected glacial overburden plain left by the Wisconsin Glaciation.

Site-Wide Hydrogeology. The Great Miami Aquifer is the principal aquifer within the FEMP Study Area and has been designated a sole-source aquifer under the provisions of the Safe Drinking Water Act (SDWA). According to the U.S. EPAs groundwater protection strategy, the Great Miami Aquifer is categorized as a Class I aquifer, which potentially affects the cleanup of the aquifer and contaminated soil. The buried valley in which it occurs varies in width from about 0.8 km (0.5 mi) to more than 3.2 km (2 mi), having a U-shaped to box-shaped cross section with a broad, relatively flat bottom, and steep valley walls (Figure 1-7). This valley is filled with extensive deposits of sand and gravel that range in thickness from 36 to 60 m (120 to 200 ft) in the valley to only several feet along the valley walls, along the scattered silt and clay deposits.

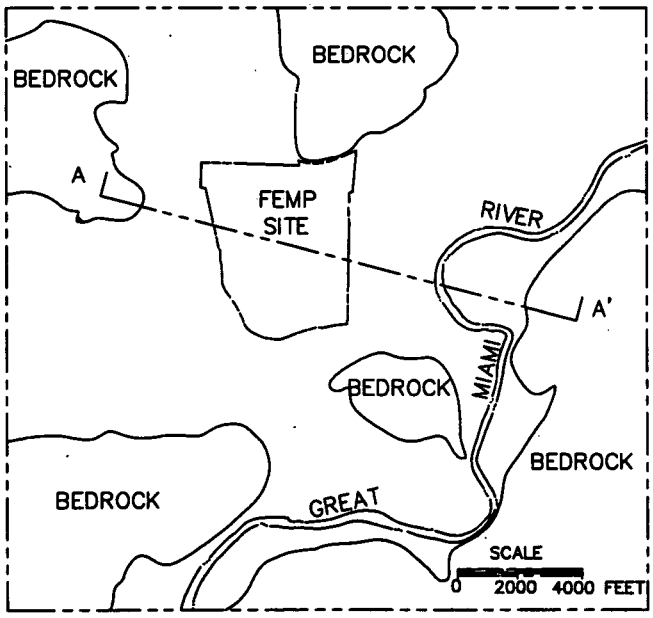
Contained within the sand and gravel that underlies much of the FEMP property is a relatively continuous, low-permeability clay interbed ranging from about 1.5 to 4.5 m (5 to 15 ft) in thickness. The clay interbed occurs at an approximate elevation of 140 m (460 ft), and where present, divides




SECTION A–A' LOOKING NORTH

NOTES:

HORIZONTAL SCALE IS APPROXIMATELY 1" = 2500'




LOCATION OF CROSS SECTION

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FIGURE 1–7. SCHEMATIC CROSS SECTION OF BURIED CHANNEL AQUIFER

the aquifer into upper and lower sand and gravel units, referred to as the Upper Great Miami Aquifer and the Lower Great Miami Aquifer.

Large groundwater supplies occur in the sand and gravel deposits, allowing the aquifer to yield a considerable amount of water. In areas where the aquifer is 45 to 60 m (150 to 200 ft) thick or more and induced stream infiltration is available, water supply wells in the Great Miami Aquifer are the most productive; individual wells can yield 11,355 liters per minute (L/min) [3000 gallons per minute (gpm)] or more in these areas (Spieker 1968). In areas where the aquifer is capped by glacial till, subdivided by the clay interlayer, and induced stream recharge is not available, wells generally yield 379 to 1893 L/min (100 to 500 gpm), though wells of 3785 L/min (1000 gpm) are not uncommon. The bedrock outside the buried valleys has a lower hydraulic conductivity, and bedrock well yields are generally less than 38 L/min (10 gpm) (Spieker 1968).

Hydrogeology of the Glacial Overburden. Overlying the Great Miami Aquifer throughout most of the FEMP property are a series of glacial overburden deposits. The glacial overburden is composed primarily of till, a dense, silty clay that contains discontinuous and isolated lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt. Lacustrine deposits lie upon till as superficial deposits under most of the FEMP site. The lacustrine deposits have at least one, and possibly more, laterally extensive permeable sand/silt strata. The glacial overburden exposed at the surface has relatively low permeability, so most of the precipitation that falls on it is lost to evaporation and surface water runoff. Limited infiltration occurs along the upper weathered portion of the overburden and in isolated areas where more permeable deposits of silt, sand, and gravel are the primary overburden constituents. The thickness of the glacial overburden ranges from 1.5 to 15 m (5 to 50 ft) within the FEMP Study Area, but most commonly averages between 6 and 9 m (20 and 30 ft). Except for some scattered deposits, this overburden does not exist along the floodplain of the Great Miami River to the east and south of the FEMP site. The only on-property areas that lack overburden are certain reaches of Paddys Run and the Storm Sewer Outfall Ditch where this material has been eroded away. These streams are in direct contact with the upper portion of the Great Miami Aquifer along these reaches, allowing surface water leakage directly to the aquifer.

Erratically distributed pockets of silty sand and gravel within the glacial overburden contain zones of perched groundwater. Perched groundwater is separated from the underlying aquifer by the surrounding relatively impermeable clay and silt components of the overburden. These low-permeability units behave as an aquitard that can store groundwater but transmit it slowly downward

from one more porous saturated zone to another. Depth to perched groundwater at the FEMP site ranges from 0.3 to 4.5 m (1 to 15 ft) below the land surface. This measurement can fluctuate seasonally by up to 3 m (10 ft) at a single location, with the highest water levels occurring during the early spring and the lowest during the late fall.

In the K-65 Silos area, sand and gravel outwash deposits of the buried valley are overlain by 1.5 to 3 m (5 to 10 ft) of till that is in turn overlain by 4.5 to 6 m (15 to 20 ft) of lacustrine sediments. The till is an unsorted mixture of clay, silt, sand and pebble to cobble size material with 70 to 80 percent of the material falling in the clay and silt size range. The till contains sparse, thin, and discontinuous lenses of sand and gravel.

The lacustrine strata consists of a 1.5- to 3-m (5- to 10-foot) thick coarse-grain stratum that is overlain by clay and silt. The coarse grain stratum is part of a widespread glacial outwash unit that is found at the base of lacustrine strata throughout the northern half of the filled lacustrine basin. The coarse grain unit was deposited by streams and debris flows that entered the basin from the north. The unit comprises clayey silt, silt, sands with appreciable fine fractions, and clean sands with silty/clayey sand being the dominant lithology. Strata that overlie the outwash unit were deposited by lower energy depositional lacustrine processes. The low-energy lacustrine sediment consists of clay, silty clay, clayey silt, silt and fine sand with silty clay the dominant lithology. A loess cap probably overlies the lacustrine strata; however, it cannot be readily distinguished from the low-energy lacustrine deposits using the U.S. Geological Survey (USGS) soil description/classification methods used during the RI/FS. Elsewhere on the site, where the loess cap can be distinguished, loess is a clayey silt approximately 3 feet thick.

The conceptual model for groundwater flow in the glacial overburden is that the lacustrine strata has good, but slow, hydraulic communication and that the till that underlies the lacustrine strata acts as an aquitard. Groundwater within the approximately 6 m (20 ft) of lacustrine strata is predicted to flow at a lateral rate that is significantly greater than its downward rate. Therefore, groundwater is likely discharging westward to the bank of Paddys Run and southward in the east-west drainageway immediately south of Silo 1.

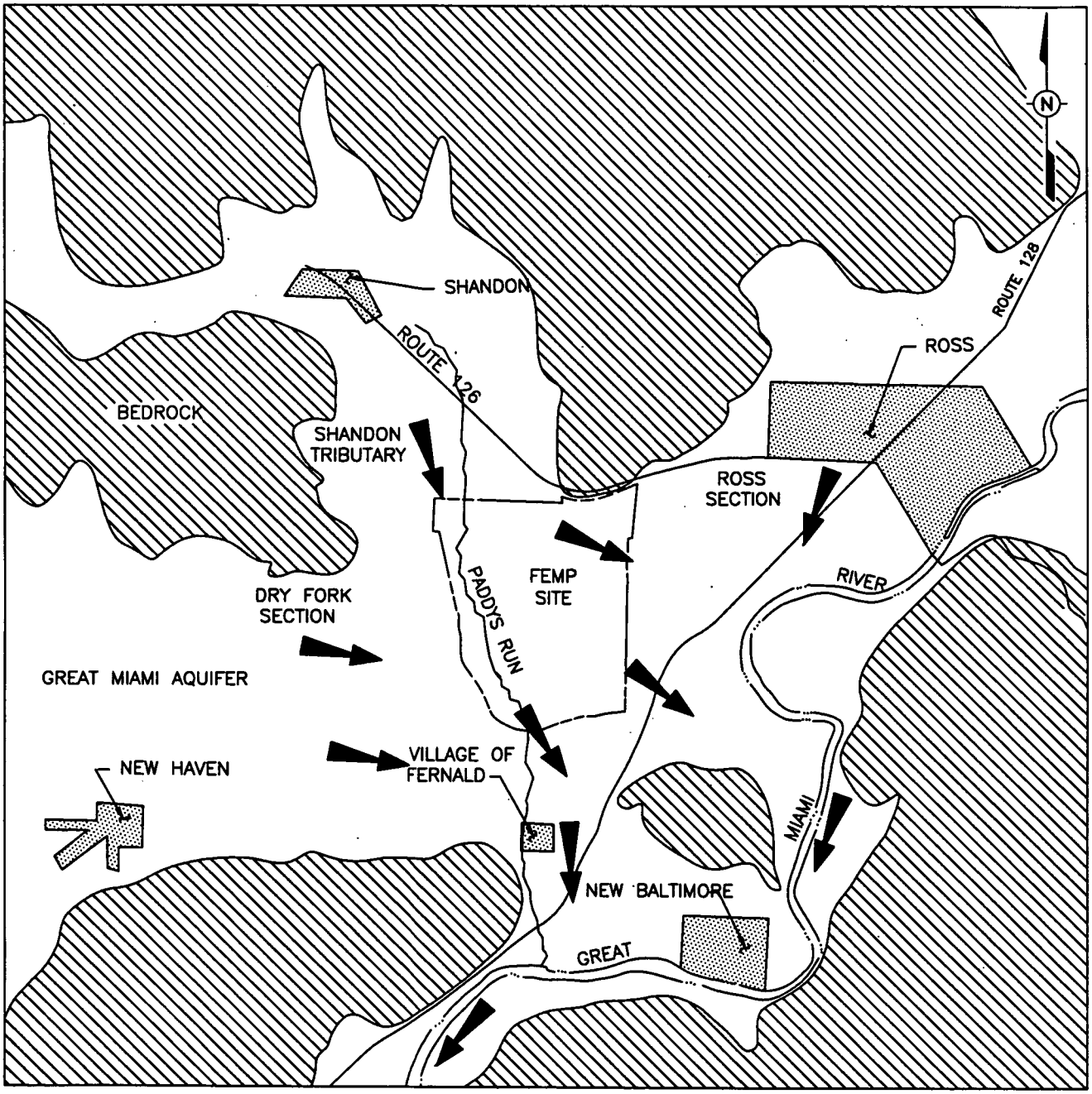
Hydrogeology of the Great Miami Aquifer. The principal sources of aquifer recharge in the FEMP Study Area are direct precipitation and stream infiltration. Infiltration of rainfall and snowmelt is the dominant regional source of groundwater recharge, providing approximately 2,157,450 liters per day

(L/day) per km$^2$ [570,000 gallons per day (gpd) per mi$^2$], or roughly 30.5 cm (12 in.) per year to the water table of the aquifer (Dove 1961). Much of the precipitation that runs off the glacial overburden on the FEMP property enters Paddys Run and the Storm Sewer Outfall Ditch, both of which are subject to leakage directly to the aquifer along portions of their length. These streams are intermittent and provide recharge on a seasonal basis. The pumping of the Southwestern Ohio Water Company (SOWC) supply wells, located at the Big Bend meander of the Great Miami River east of the FEMP site, causes a portion of the surface water to infiltrate through the bed of the river and recharge the aquifer. In areas of the river not influenced by the pumping wells, groundwater flows from the aquifer to the river, except during dry periods when the elevation of the water table is below the bed of the river. Recharge from groundwater occurring in bedrock is limited due to its low permeability. However, erratically distributed joints and cracks allow small amounts of water to seep into the aquifer.

The generalized groundwater flow in the Great Miami Aquifer is shown in Figure 1-8. Groundwater enters the FEMP Study Area from three separate flow systems: the Dry Fork Section of the New Haven Trough to the west, the Shandon Tributary to the north, and the Ross Section of the New Haven Trough to the northeast. Natural gradients cause the groundwater to exit the FEMP Study Area either by flowing east to the Great Miami River, upstream from New Baltimore, or south through the branch of the bedrock channel west of New Baltimore. The Great Miami River is the ultimate receptor of all groundwater in the FEMP Study Area.

Population and Land Use

The Fernald site is located approximately 18 miles northwest of Cincinnati, within Hamilton and Butler Counties in Ohio. The land adjacent to the FEMP is primarily devoted to open land use such as agriculture and recreation. Commercial activity is generally restricted to the village of Venice (Ross), approximately 4.8 km (3 mi) northeast of the facility, and along State Route (SR) 128 between Willey Road and New Haven Road. Residential units are situated immediately north of the FEMP, in Ross, and directly east in a trailer park adjacent to the intersection of Willey Road and SR 128. Other residences located around the site are generally associated with farmsteads. There are no areas within the FEMP site boundaries considered to be prime farmlands under the Farmland Protection Act of 1981 (7 CFR 658). Pine plantations are located to the northeast and southwest of the former Production Area. Because the area had been intensively used for agricultural purposes prior to the establishment of the FEMP site, there is no land on or in the vicinity of the FEMP site where a predevelopment natural environment remains intact. The land closest to the description is the




SCALE
0 2500 5000 FEET

NOTE:
DIRECTION OF GROUNDWATER FLOW BASED ON APRIL 1986 WATER LEVEL CONTOURS AND GROUNDWATER MODELING OUTPUT (3DPART07.OUT)

LEGEND:
GENERALIZED GROUNDWATER FLOW DIRECTION.
BEDROCK OUTSIDE GREAT MIAMI AQUIFER

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FIGURE 1-8. GENERALIZED GROUNDWATER FLOW IN BURIED CHANNEL AQUIFER

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recreated prairie lands on the Miami Whitewater Forest property, located several miles south of the FEMP site.

The Consolidated Metropolitan Statistical Area (CMSA) for the Cincinnati region consists of thirteen counties: Brown, Butler, Clermont, Hamilton, and Warren Counties in Ohio; Boone, Campbell, Gallatin, Grant, Kenton, and Pendleton Counties in Kentucky; and Dearborn and Ohio Counties in Indiana. Population within the thirteen counties was 1.8 million in 1991, and within an 8 km (5 mi) radius of the FEMP site, there were an estimated 22,927 residents in 1990. Population density throughout the CMSA varies from 796 residents/km$^2$ (2062 residents/mi$^2$) in Hamilton County to 17 residents/km$^2$ (44 residents/mi$^2$) in Pendleton County. Excluding the heavenly urbanized area in Hamilton County (Cincinnati), the average population density in the thirteen county region is 108 residents/km$^2$ (278 residents/mi$^2$). Population density within an 8 km (5 mi) radius of the site is 352 residents/km$^2$ (917 residents/mi$^2$). Labor force in the multicounty area was 951,987 with unemployment at approximately 8.7 percent in March 1992. For detailed socioeconomic data, refer to the SWCR (DOE 1993d).

The area surrounding the FEMP site has a large and diverse archaeological and historical resource base. According to records kept by the Miami Purchase Association for Historic Preservation, an unusually high percentage of the existing 19th century buildings in the area are historically important. Within the vicinity of the FEMP site [a 3.2-km (2-mi) radius from the boundary], there are three properties listed in the National Register of Historic Places (NRHP) and a number of additional structures that have been judged eligible for inclusion in the listing. Six major archaeological sites lie within 8 km (5 mi) of the FEMP, and five of these are included in the NRHP.

Ecology

This section describes the regional ecology, ecological communities on the FEMP site, the floodplains and wetlands, and threatened and endangered species at the FEMP site.

Regional Ecology. The FEMP site and surrounding areas lie in a transition zone between two distinct sections of the Eastern Deciduous Forest Province as described by Bailey (1978): the Oak-Hickory and the Beech-Maple. The region is characterized by the presence of a mosaic of these forest types. The Oak-Hickory and Beech-Maple forest sections share many characteristics, including similar fauna and the presence of white oak as a common species. The Beech-Maple section covers northern Ohio, Indiana, and lower Michigan. It is bordered by Oak-Hickory to the southwest, Mixed Mesophytic to

the southeast, and Appalachian oak to the east. Beech-Maple forests are typically dominated by beech trees in the canopy, the uppermost layer of the forest, with sugar maples dominant in the understory, below the canopy. The Oak-Hickory section covers southwest Ohio, western Kentucky and Tennessee, and parts of Indiana, Illinois, Missouri, and Arkansas.

The dominant species are oaks, with an abundance of hickories. The fauna vary little between the two forest sections and include white-tailed deer, gray fox, gray squirrel, white-footed mouse, and short-tailed shrew; the cardinal, woodthrush, summer tanager, red-eyed vireo, and the hooded warbler; the box turtle, common garter snake, and timber rattlesnake (Bailey 1978; Shelford 1963).

Ecological Communities on the FEMP Site. Ecological communities on the FEMP site consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and the "reclaimed flyash pile area." The reclaimed flyash pile area coincides approximately with the South Field and the Inactive Flyash Pile, and it was considered a distinct habitat by Facemire et al. (1990) due to the unique plant and animal species composition. A total of 47 species of trees and shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates inhabit the FEMP site.

Typical grasses found on the FEMP site are red fescue, Kentucky bluegrass, timothy, and red top. Herbs include teasel, red and white clovers, and goldenrod. The dominant tree species in the pine plantations are white and Austrian pine, with Norway spruce occurring occasionally. Common trees in the deciduous woodlands are white ash, American elm, shagbark hickory, and slippery elm. Dominant tree species in the riparian woodlands are eastern cottonwood, hackberry, American elm, and box elder. The reclaimed flyash pile area is dominated by American elm, eastern cottonwood, and black locust.

Mammal species observed on the FEMP site include the white-tailed deer, coyote, red fox, opossum, raccoon, groundhog, eastern cottontail, fox squirrel, and several species of bats. Common small mammals are the white-footed mouse, short-tailed shrew, meadow vole, meadow jumping mouse, and eastern chipmunk.

The most common birds breeding on site include the mourning dove, American robin, blue jay, American crow, American goldfinch, northern bobwhite, and common grackle. Species occurring in

the greatest density are the goldfinch, song sparrow, and robin. Raptor species observed on site are the northern harrier, red-shouldered hawk, Cooper's hawk, red-tailed hawk, and American kestrel. In addition, the eastern screech owl and great horned owl have been observed in the vicinity of the FEMP site.

Amphibians and reptiles that occur on the FEMP site include the American toad, spring peeper, eastern box turtle, and snapping turtle. Several species of snakes also occur on site, including the eastern garter snake, Butler's garter snake, black rat snake, northern water snake, and the queen snake.

Approximately 130 insect families from 15 orders are represented in FEMP site habitats. Leaf hoppers are abundant in all habitats, while less abundant groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

Floodplains and Wetlands. Floodplains within the FEMP property are confined to the north-south corridor containing Paddys Run. Outside the boundaries of the FEMP site, the 100-year floodplain of the Great Miami River extends west of the Big Bend area nearly to the eastern boundary of the facility (Figure 1-9). The 100-year floodplain of the river also extends northward along Paddys Run from the confluence of the two streams to a point about 180 m (600 ft) from the southern boundary of the FEMP site. This area overlaps the South Plume, a body of uranium-contaminated groundwater that is a component of Operable Unit 5.

A site-wide wetland delineation was conducted in February 1993 in accordance with the 1987 Army Corps of Engineers (COE) Wetlands Delineation Manual. The purpose of the delineation was to determine the extent of jurisdictional wetlands and waters of the United States and to avoid or minimize impacts to these resources during future activities at the FEMP site. A jurisdictional determination has been requested from the COE to verify the wetland boundaries and waters of the United States. Preliminary results from the site-wide delineation as shown in Figure 1-10, subject to COE approval, indicate a total of 14.4 ha (35.9 acres) of wetlands that include 10.63 ha (26.58 acres) of palustrine forested wetlands, 2.78 ha (6.95 acres) of drainage ditches/swales, and 0.95 ha (2.37 acres) of isolated emergent and emergent-scrub/shrub wetlands.

The largest of the four palustrine forested wetland areas is located north of the former Production Area. The remaining three areas are located: (1) along the east bank of Paddys Run near the northern

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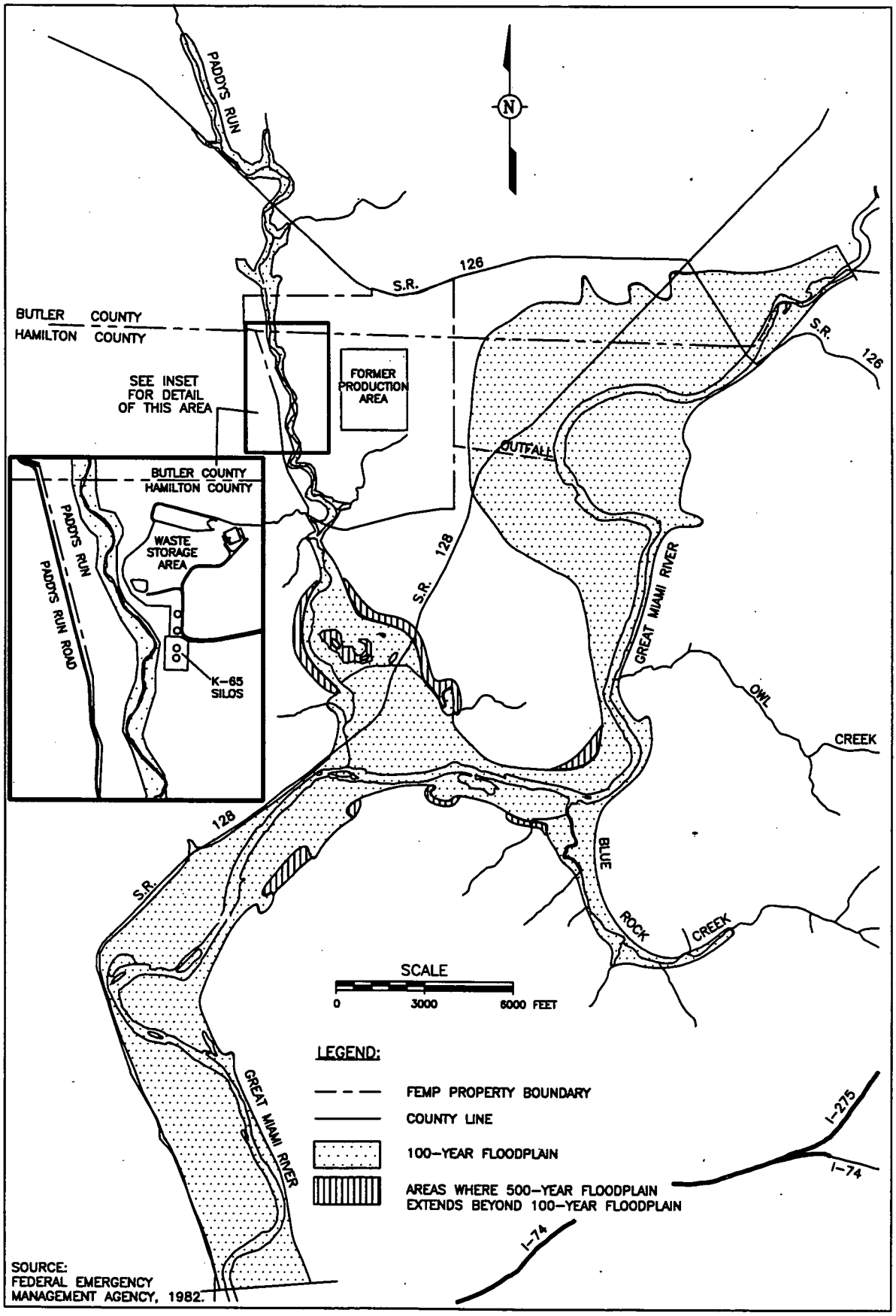


FIGURE 1-9. GREAT MIAMI RIVER AND PADDYS RUN 100-YEAR AND 500-YEAR FLOODPLAIN



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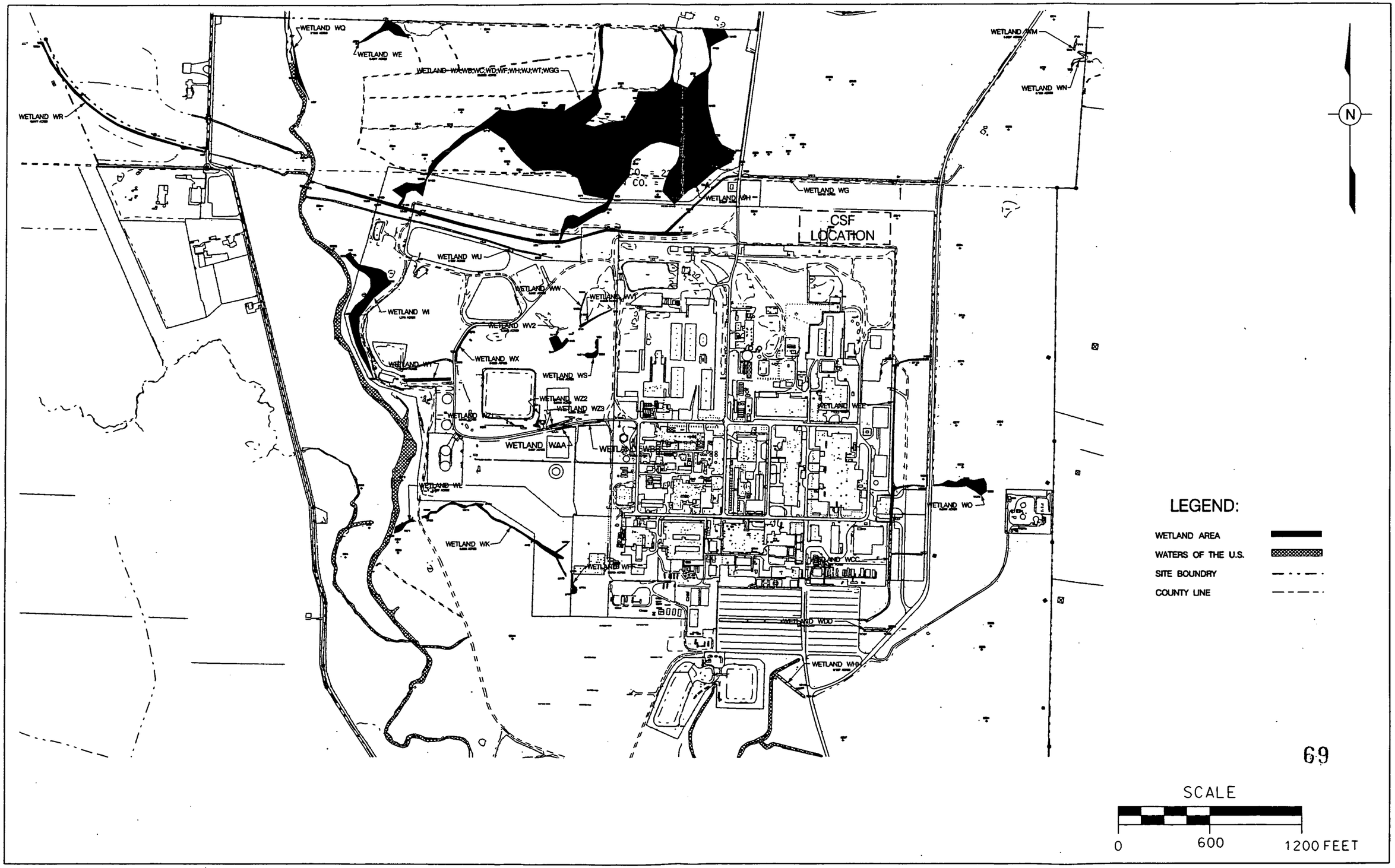


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WETLANDS/RES NO.2227-11x17-FIG1-10.DGN-CRU#4
FERMCO/ENGCAD/REVISON.#0-1/28/94

FIGURE 1-10 APPROXIMATE BOUNDARIES OF JURISDICTIONAL WETLANDS AT FEMP.

site border, (2) on the northeast corner of the site, and (3) southwest of the K-65 Silos. Drainage ditches and swales are located in four sections throughout the site: (1) north of the former Production Area traversing west into Paddys Run, (2) drainage of the Waste Pit Area, (3) drainage of the area south of the K-65 Silos, and (4) adjacent to the east boundary of the former Production Area, draining higher elevations of the site to the east.

Two of the four isolated scrub/shrub and/or emergent wetlands are located in the northern part of the site: one near the eastern corner and the other just east of Paddys Run, near the western corner of the site. The remaining two are located in the vicinity of the Waste Pit Area, one to the east and one to the west.

On-property waters of the United States are confined to Paddys Run and its unnamed tributary and total approximately 3.6 ha (8.9 acres).

Threatened and Endangered Species. Potential remedial actions at the FEMP site must comply with the substantive requirements of the Endangered Species Act (ESA) of 1973. To comply with Section 7(a)(2) of the ESA of 1973, as amended, requiring federal agencies "...in consultation with and with the assistance of..." the Secretaries of the Interior and Commerce, to ensure that their actions are "...not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of the critical habitat of such species...", Miami University performed an Ecological Characterization Study of the FEMP in 1986 and 1987. The following discussion concerning threatened and endangered species with potential habitats in the vicinity of the FEMP were drawn from that study as well as from supplemental investigations conducted as part of the RI Report for Operable Unit 4.

Sloans Crayfish (Orconectes sloanii). The Sloan's crayfish is a state listed threatened species reported in Paddys Run by Facemire et al (1990).. One individual of this genus, not identified to species, was recorded in Paddys Run during RI/FS sampling (DOE 1992b). Preliminary data from follow-up surveys conducted in the fall of 1993 found individuals present in sections of Paddys Run in the northern part of the site and south of the site (St John 1993).

Indiana Bat (*Myotis sodalis*). The Indiana bat is listed as both a federally and state endangered species and occurs in Butler and Hamilton Counties. Surveys were conducted at the FEMP to determine the distribution and presence of the Indiana bat and to identify potential habitat on the

FEMP and in the immediate vicinity. The Indiana bat has not been identified at the FEMP, but during the summer of 1988, a population was identified approximately 4.8 km (3.0 mi) northeast of the FEMP on Banklick Creek, a tributary of the Great Miami River (Facemire et al. 1990). Potential habitat for the Indiana bat occurs in portions of the riparian woodland associated with Paddys Run. Studies are continuing to determine the presence of the Indiana bat. If habitat or individuals are found, appropriate mitigative measures will be taken.

Cave Salamander (*Eurycea lucifuga*). The cave salamander, a state listed endangered species, has not been identified at the FEMP site. During the summer of 1988, a population was identified 1.6 km (1.0 mi) northeast of the FEMP at the Ross Trails Girl Scout Camp. Potential habitat occurs along Paddys Run (Facemire et al. 1990). Preliminary data from a survey in the fall of 1993 has identified moderate habitat in an abandoned well in the northeastern part of the site. In addition, only marginal habitat was identified in other parts of the site (e.g., ravine in north wood lot).

Others. The northern waterthrush (*Seiurus noveborgcensis*), a state listed endangered species, was reported as a spring migrant along Paddys Run during the Spring of 1987 by Facemire et al (1990).. The northern harrier (*Circus cyaneus*), a state listed endangered species, and the red-shouldered hawk (*Buteo lineatus*), a state listed threatened species, were observed flying over the FEMP by Facemire et al (1990). on two separate occasions. Neither species has been reported to nest at the FEMP site. Slender finger-grass (*Digitaria filiformis*) and mountain bindweed (*Polygonum cilinode*) are state listed endangered species recorded in low densities along Paddys Run and in the northern pine planation by Facemire et al.. The dark-eyed junco (*Junco hyemalis*), a state listed endangered species, was observed throughout the FEMP during the winter of 1986 and 1987 by Facemire et al (1990).. Running buffalo clover (*Trifolium stoloniferum*), a state and federally listed endangered species, has not been identified at the FEMP. A population was identified less than 8.0 km (5.0 mi) southwest of the FEMP at Miami Whitewater Forest. Potential habitat exists in introduced grassland areas, and riparian and deciduous woodlands on the FEMP site.. Spring coralroot (Corallorhiza wisteriana), a state-listed threatened species, has not been found at the FEMP. However, populations have also been surveyed at Miami Whitewater Forest. Potential habitat exists on FEMP property in the northern forested wetlands. The cobblestone tiger beetle (*Cicendela Margipennis*), which is under review by the U.S. Fish and Wildlife Service for possible consideration as a threatened or endangered species, was found on a gravel bar in the Great Miami River 3.2 km (2.0 mi) southwest of the bridge at New Baltimore, Ohio.

1.4.1.2 Description of Operable Unit 4

Operable Unit 4 is a geographic area located on the western side of the FEMP, south of the Operable Unit 1 Study Area (Figure 1-5). The geographic area constituting Operable Unit 4 is bounded by the following Ohio State Plane Coordinates: North 481033, East 1378642, and North 480222, East 1378329. Operable Unit 4 comprises 2.3 ha (5.8 acres). Within the boundary of the operable unit is a series of FEMP facilities previously defined in Section 1.0. The following is a summary description of each of these facilities.

Silos 1, 2, 3, and 4 and the Decant Sump Tank

The waste storage silos were constructed to provide storage for the residues resulting from the processing of pitchblende ores and uranium ore concentrates to extract their uranium content. The silos are large concrete storage structures that were built in 1951 and 1952. Each of the four domed silos is 24.38 m (80 ft) in diameter, 10.97 m (36 ft) high to the center of the silo dome, and 8.15 m (26.75 ft) tall to the top of the vertical side walls.

The side walls are 20-cm (8-in.) thick concrete wrapped with steel post-tensioning wires. The silo sides are covered with a 1.9-cm (0.75-in.) thick layer of gunite (a cement based plaster used to protect the post-tensioning wires). The domed roofs are made of reinforced concrete and taper from 20-cm (8-in.) thick at the silo walls to 10-cm (4-in.) thick at the dome's center. The floors of Silos 1, 2, 3, and 4 consist of 10 cm (4 in.) of reinforced concrete. Residues were originally transferred to Silos 1 and 2 by pumping the residues in the form of a slurry. The residues eventually settled and formed two layers consisting of settled solids covered by the slurry liquid. To remove the layer of clear liquid following settling, Silos 1 and 2 were equipped with a series of decant ports. Silos 3 and 4 were also equipped with decant ports; however, the structures were not designed to accommodate slurried residues. These ports were arranged in two vertical lines located on diametrically opposed sides of each silo. There were 25 ports in each line, totaling 50 ports per silo. The bottom port on each silo is 30 cm (12 in.) from the silo bottom. The remaining 49 ports are located at 15-cm (6-in.) intervals.

At the time of filling, each decant port for Silos 1 and 2 was valved into a single pipe that led to a 34,065 liter (L) [9000-gallon (gal.)] carbon steel decant sump tank. The decant sump tank was located between Silos 1 and 2 at a level below the base of the silos to allow for gravity drainage. At the base of Silos 1 and 2, at the original ground surface, skirt drains were used to contain any seepage through the walls of the silos or leakage from the decant ports. These skirt drains directed 72

any collected water through a concrete pipe trench to an in-ground concrete-lined sump at the K-65 Drum Handling Building, formerly located between Silos 2 and 3.

Beneath the floor of Silos 1 and 2 is an underdrain system which consists of a 5-cm (2-in.) slotted pipe in a 20-cm (8-in.) gravel layer. The gravel layer is underlain by a 5-cm (2-in.) thick layer of asphaltic concrete followed by a 43-cm (17-in.) thick layer of compacted clay. The underdrain system is connected to the decant sump tank to collect any potential leakage through the base of the silos.

Large areas of spalling occurred on the exterior surface coating of Silos 1 and 2, particularly Silo 2, leaving post-tensioning wires corroded and exposed to weathering. The exterior surfaces were patched with a 1.9-cm (0.75-in.) thick coat of cement mortar and a waterproof membrane that was applied in 1964.

In January 1986, two load-spreading dome covers, 9.1 m (30 ft) in diameter, were installed to span a deteriorated portion of the concrete domes of Silos 1 and 2. The covers are self-supporting and sit on a rolled plate-steel skirt. The covers are composed of structural steel members that support 1.9-cm (0.75-in) thick plywood sheeting, which is covered with a weatherproof membrane. The dome cover increases the stresses in the existing concrete, but all stresses are outside the deteriorated area and within acceptable limits. The dome covers were installed so that containment of the silos' contents would be maintained in the event of a center-silo dome collapse (Shanks and Vogel 1988). The dome covers were not designed to be airtight, and therefore do not contain the movement of gases such as radon.

In 1987, a layer of rigid polyurethane foam insulation was applied to the exterior of the Silos 1 and 2 domed surfaces. The purpose of this layer was to control the release of radon from the silos by limiting "breathing" created by pressure differentials between the silos' interior and the outside atmosphere. The application of the foam was successful in limiting the release of radon due to "breathing"; however, it did not completely eliminate radon emanation.

Silo 1 contains 3280 cubic meters ($m^3$) [4293 cubic yards ($yd^3$)] of waste residues and 360 $m^3$ (467 $yd^3$) of bentonite clay. Silo 2 contains 2840 $m^3$ (3,719 $yd^3$) of waste residues and 310 $m^3$ (411 $yd^3$) of bentonite clay. Silo 3 contains 3890 $m^3$ (5088 $yd^3$) of waste materials. Silo 4 is empty and has never been used for material storage.

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Radon Treatment System

An existing RTS was constructed in 1987 within Operable Unit 4 to support planned interim remedial measure (IRMs), including placement of the dome covers and waterproofing of the domes, for the K-65 Silos. The RTS is approximately 6.5 $m^2$ [70 square ft ($ft^2$)] of pre-engineered aluminum clad building that contains two calcium drier canisters, eight charcoal adsorption canisters, and two fan units, with a 0.8-m (32-in.) thick concrete block wall surrounding the frame of the structure. Also associated with the RTS are multiple lengths of 30-cm (12-in.) diameter polyvinyl chloride (PVC) pipe, a 15-cm (6-in.) diameter flexible hose, and miscellaneous fittings and valves.

Concrete Pipe Trench and Miscellaneous Structures

A concrete trench that contained the piping used to transfer residues to Silos 2 and 3 runs 530 m (1750 ft) from the FEMP refinery (Plant 2/3) to the silo storage area. A portion of the concrete trench, as shown in Figure 1-2, resides within the geographical boundaries of Operable Unit 4. The trench is 0.75 m (2.5 ft) wide by 0.9 m (3 ft) deep with a 0.5-cm (3/16-in.) thick steel plate cover. The piping within the pipe trench was removed prior to placement of the earthen embankment.

Additionally, within the Operable Unit 4 boundary are two concrete structures associated with former K-65 Silos operational facilities. A structure called the K-65 Drum Handling Building was located between Silos 2 and 3 until it was demolished in 1983. While the above-grade structure was demolished and removed, the concrete slab on grade remains within the boundary of Operable Unit 4.

Also associated with the operation of the K-65 Silos was a concrete lift station used to house the pump for the transfer of decant liquids from the decant sump tank to a hold tank in the K-65 Drum Handling Building (Figure 1-2). The concrete foundation associated with the structure remains within the Operable Unit 4 boundary.

K-65 Silo Berms

In 1964, following the patching of the exterior of Silos 1 and 2, an earthen embankment was built surrounding the top of the walls of Silos 1 and 2 to provide relief from tensile stress that had developed within the walls. The embankment was also constructed to provide weather protection, reduce radon emissions, and increase shielding from penetrating radiation. The embankment was originally constructed on a slope of 1.5:1, but was subsequently modified to 3:1 in 1983 to reduce soil erosion and facilitate grass cutting.

Prior to berming the silos in 1964, the decant sump system was disconnected from the decant sump tank, but the underdrain system remained intact. The decant sump system collected any leakage into the underdrain system. Access was provided to this decant sump tank by placing a 0.8-m (30-in.) diameter corrugated metal pipe from the tank to above the surface of the soil embankment. This pipe extended upward 10 m (33 ft). The earthen berm was placed around this pipe as the berm was built around the silos.

The soils comprising the earthen berm constructed in 1964 were surface soils and underlying clays removed from an area directly south of the concrete trench and north of a small drainage ditch running parallel to the trench. The soils comprising the earthen berm constructed in 1983 originated from two on-site areas: 1) from the location of the Biodenitrification Surge Lagoon and 2) from a borrow area west of Pit 5. No surveys were performed by site personnel to determine the potential presence of radiological contamination of these soils before excavation and placement in the berms.

### 1.4.2 Site History

The primary mission of the FEMP site during its 37 years of operation was the processing of "feed" materials to produce high-purity uranium metal, thus the derivation of the site's original title, the Feed Materials Production Center. These high-purity uranium metal products were then shipped to other DOE facilities for use in the nation's ongoing weapons program. A graphic depiction of the FEMP's integration with other DOE facilities is presented in Figure 1-11.

The Atomic Energy Commission (AEC), predecessor to the U.S. Energy Research and Development Administration (ERDA) and now known as the DOE, established the FMPC in conformance with AEC orders in the early 1950s. In 1951, National Lead Company of Ohio, (NLO) Inc., entered into a contract with the AEC as the Operations and Management Contractor for the facility. This contractual relationship lasted, first with the AEC and finally with DOE, until January 1, 1986. Westinghouse Materials Company of Ohio (WMCO), a wholly-owned subsidiary of Westinghouse Electric Corporation, then assumed management responsibilities for the site operations and facilities. In 1991, Westinghouse renamed this subsidiary the Westinghouse Environmental Management Company of Ohio (WEMCO). On December 1, 1992, the Fernald Environmental Restoration Management Corporation (FERMCO) assumed responsibility for the site as the first Environmental Restoration Management Contractor (ERMC) for DOE.

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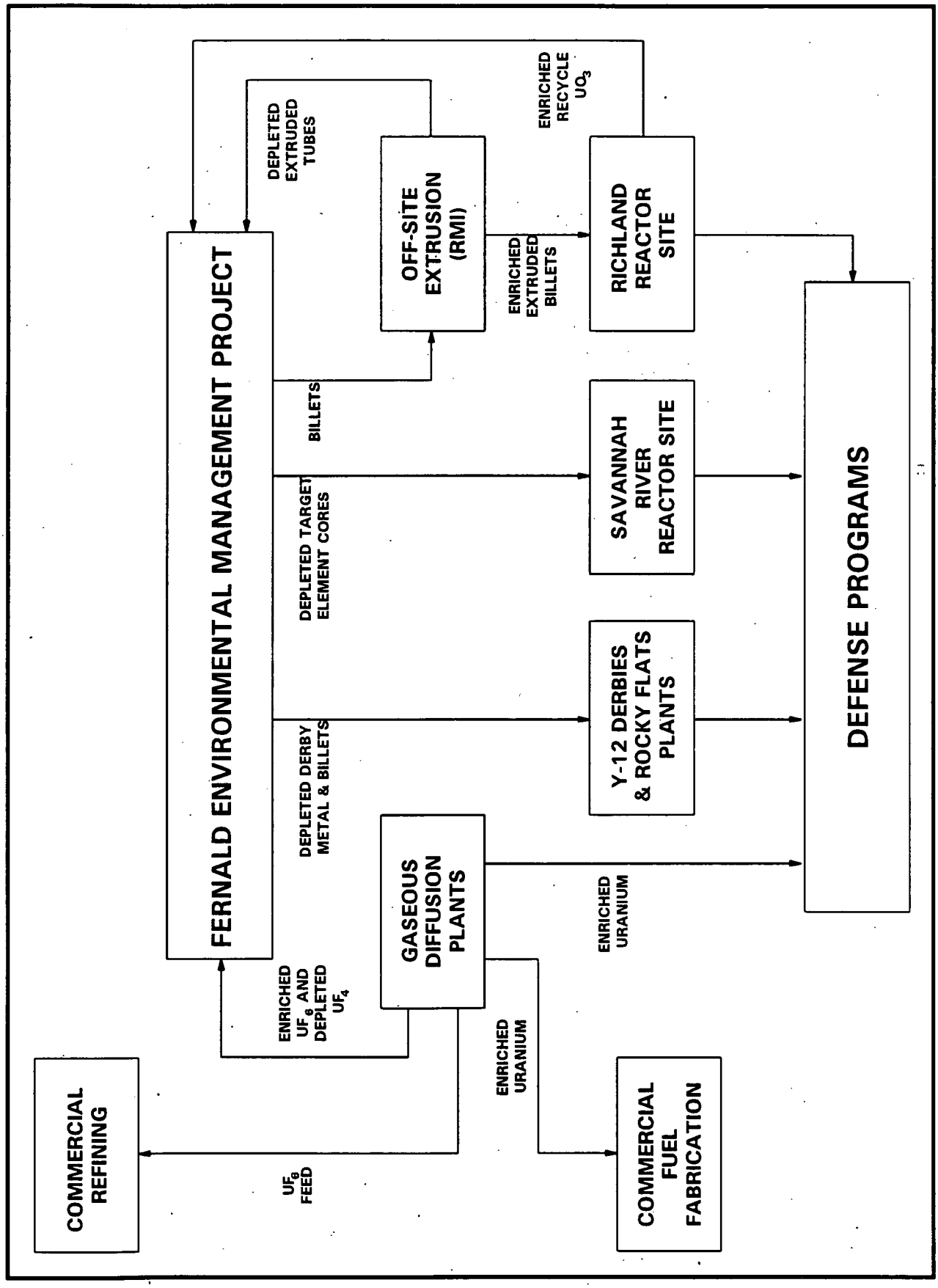


FIGURE 1-11 FEMP INTEGRATION WITH OTHER DOE FACILITIES



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The FEMP began operations in 1951 upon completion of the Pilot Plant as the site's first operational facility. Production peaked in 1960 at approximately 12,000 metric tons of uranium (mtu) (13,228 tons) per year. A product decline began in 1964 and reached a low in 1975 of about 1230 mtu (1356 tons). During the 1970s, consideration was given to closing the FEMP. Thus, capital improvements and staffing were minimized. The staffing level, which peaked at 2891 personnel in 1956, slowly declined to 662 personnel in 1972 and then to 538 personnel in 1979. In 1981, the FEMP began planning to accommodate increased production requirements. Production levels significantly increased and there was a rapid staff buildup for several years. The renewed need for uranium metal resulted in the implementation of a major facilities restoration program. Then, production ceased in the summer of 1989 and plant resources were focused on environmental cleanup activities. In June 1991, the site was officially closed as a federal production facility. To indicate its evolution to a new mission, the site was renamed from the Feed Materials Production Center to the Fernald Environmental Management Project.

On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by DOE and EPA detailing actions to be taken by DOE to assess environmental impacts associated with the FEMP site. The FFCA was entered into pursuant to Executive Order 12088 [43 *Federal Register (FR)* 47707] to ensure compliance with existing environmental statutes and implementing regulations such as the CAA, Resource Conservation and Recovery Act (RCRA), and CERCLA. In particular, the FFCA was intended to ensure that environmental impacts associated with past and present activities at the FEMP site would be thoroughly and adequately investigated so that appropriate remedial response actions could be formulated, evaluated, and implemented. As required by the FFCA, a RI/FS was initiated at the FEMP site in July 1986, pursuant to CERCLA.

In November 1989, the FEMP site was placed on the NPL for investigation and remediation under CERCLA. This placement, in addition to progressive findings in the RI/FS program, resulted in the amendment of the existing agreement between DOE and EPA. The 1986 FFCA was amended by a Consent Agreement under Section 120 and 106(a) of CERCLA providing for the implementation of the operable unit concept for the FEMP RI/FS and revising the milestone commitments for the RI/FS program without modifying the underlying objectives in the FFCA. The Consent Agreement was signed on April 9, 1990, and became effective on June 29, 1990, following a period of public comment. In September 1991, certain terms of the 1990 Consent Agreement, including the provisions relating to schedules for completion of the RI/FS for each operable unit, were amended.

### 1.4.3 Operable Unit 4 History

#### 1.4.3.1 History of Silo 1

Silo 1 was constructed in 1952, as one of the first facilities at the FEMP site, with the intent to store drummed residues in inventory at other United States facilities. The residues stored in Silo 1 were generated at the Mallinckrodt Chemical Works (MCW) in St. Louis, Missouri, as a result of processing to extract uranium from pitchblende ores. The pitchblende ores processed at MCW came from one mine, the Shinkolobwe Mine in the Belgian Congo. These ores contained relatively high concentrations of uranium oxides ($U_3O_8$) in the range of 40 to 50 percent (Litz 1974). The Shinkolobwe Mine, owned by the African Metals Corporation, began operation in 1921 for the purpose of obtaining radium. The mine was re-opened in 1943 for its uranium. Based on the high value of radium at the time, the agreement reached between the AEC and the African Metals Corporation stipulated that the African Metals Corporation would retain ownership of the radium within any processing residues. That is, after the United States had processed the pitchblende ore to extract uranium, the residue would be returned to the African Metals Corporation. The K-65 Silos were constructed at the FEMP site to provide interim storage of the residues, pending the return of the materials to the country of origin. For more than 30 years, these materials remained in storage at the FEMP site, under the terms of the original agreement, awaiting transfer. In 1984, ownership of the K-65 residues was transferred to DOE.

Initially, the residues from the MCW refining operations were sent back to the African Metals Corporation. Beginning in April 1949, the residues were no longer returned to the African Metals Corporation following processing but were stored at MCW for future disposition. As production continued, storage became a problem. As a result, the drummed K-65 residues were sent from MCW to Lake Ontario Ordnance Works (LOOW) near Niagara Falls, New York, for storage. Some of the drums sent to LOOW were emptied into a concrete tower at that site. Approximately 6000 drums were shipped from LOOW to the FEMP site for storage. Beginning in 1951, continuing production at MCW resulted in approximately 25,000 drums being sent directly from St. Louis to the FEMP site.

Approximately 24,000 of the 31,000 drums of pitchblende ore processing residues received at the FEMP site from MCW and LOOW were transferred to Silo 1 for storage. The remaining 7000 drums of K-65 residues were transferred to Silo 2. As the drums were received by railroad car at the FEMP, the drums were temporarily staged in an area to the east of Silos 3 and 4. The drummed

material was transferred to Silo 1 from July 1952 until November 1953 through the use of a specially constructed K-65 Drum Handling Building.

Within the K-65 Drum Handling Building, the drummed residue was transferred to a hold tank and slurried with the addition of water. The slurry was then pumped into Silo 1 where it was allowed to settle into two layers. The slurry liquor, which consisted of either water or a metal nitrate solution, formed the top layer over a lower level of settled, wet solids. This layer of clear liquor was decanted from the silos through decant ports and collected in a decant sump tank. From here, the decanted liquid was periodically pumped back to the K-65 Drum Handling Building where it passed through a pressure filter and was stored in a filtrate storage tank. The filtered liquid was then used for slurry preparation in the K-65 Drum Handling Building. Excess liquids were transported to Plant 8 at the FEMP site for treatment, then to the general sump for final treatment before discharge to the Great Miami River. The K-65 Drum Handling Building was demolished in 1983 to allow for the renovation of the earthen berm surrounding Silos 1 and 2.

1.4.3.2 History of Silo 2

While Silo 1 was completely filled by the residues from MCW and LOOW, Silo 2 was filled with a mixture of MCW K-65 material and FEMP-generated K-65 material. As previously stated, 7000 drums of K-65 residues transferred from MCW and LOOW to the FEMP were emptied into Silo 2. The transfer of the drummed residues received from off site into Silo 2 occurred between late 1953 and January 1956. The generating process and the methodology to transfer the MCW/LOOW materials to Silo 2 is similar to those used in Silo 1 as discussed in the previous section.

The FEMP generated K-65 material resulted from the processing of pitchblende ores shipped directly from the Shinkolobwe Mine and a small quantity of Australian ores from two mines, the Rum Jungle Mine and the Radium Hill Mine. The processing completed at the FEMP was performed to extract the uranium values from these very rich pitchblende ores. Processing of these ores was conducted at the FEMP from May 1954 until February 1959. Belgian Congo ores were processed at the FEMP from May 1954 until August 1958. Australian ores were processed at the FEMP from May 1957 until March 1958. The last K-65 slurry was added to Silo 2 in January 1959. The Australian ore residues constitute less than 180,000 kilograms (kg) (200 tons) of the estimated 4.4 million kg (4900 tons) in Silo 2. The term K-65 was used to describe both the Belgian Congo and the Australian ores processed at the FEMP.

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Following completion of K-65 processing operations at the FEMP, approximately 150 drums of radium-contaminated material, consisting of soils from the MCW/LOOW drum staging area, cleanup materials, and excess K-65 samples were placed into Silo 2 in June 1960. In 1979, in response to concerns on the part of the FEMP Operating Contractor, NLO, relative to the chronic radon emissions from the silos, all vents, manways, and other penetrations through the domes of Silos 1 and 2 were sealed. No materials (with the exceptions of decant liquid and RI/FS samples) have been removed from Silos 1 or 2 since final filling.

1.4.3.3 History of Silos 3 and 4

Silos 3 and 4 were constructed in 1952 for storing metal oxides generated through the operation of the FEMP refinery. Silo 3 received metal oxides generated consequentially from all FEMP refinery operations from May 1954 until late 1957. During this period, the FEMP refinery processed the previously mentioned pitchblende ores and uranium ore concentrates received from a number of foreign and domestic uranium mills. Raffinates from the refinery extraction process were passed through a pre-coated rotary vacuum filter to separate the solid phase from the aqueous phase. In the case of pitchblende ore processing, the filter cake was transferred to Silo 2 to store the radium; the filtrate from the vacuum filter was subjected to further waste processing and eventually was transferred to Silo 3.

The filtrate waste streams from the extraction process were transferred to a series of agitating hold tanks in the former FEMP refinery area. These surge tanks fed a set of evaporators where approximately 90 percent of the liquids were evaporated and the remaining concentrates were withdrawn for further processing. Evaporator temperatures ranged from 90°C (200°F) to 120°C (250°F). The concentrates from the evaporator were transferred to one of two processing operations depending on the time period in which they were transferred. From plant start-up through the mid-1950s, the concentrates were transferred to a spray calciner. The spray calciner operated at a temperature of 510°C (950°F) to remove the remaining liquids and convert the metal nitrates present in the concentrates into oxides.

Due to operational difficulties experienced with the spray calciners, a second process was installed to complete the drying of the concentrates. In this process, the concentrates from the evaporators were transferred to a drum dryer where the materials were spread in a rotating dryer. In the dryer, liquids were removed from the concentrates by centrifugal force. The drum-dried concentrates were then transferred to a rotary calciner to remove the remaining liquids and complete conversion of the metal

nitrates into oxides. The concentrates were retained in the furnace zone at 650°C to 820°C (1200°F to 1500°F) for approximately 10 minutes. The finely powered, dried metal oxides were transferred to a surge hopper from where the materials were pneumatically conveyed through a pipeline to Silo 3. A dust collector, which was used to control discharges to the atmosphere resulting from the discharge of the powdered material into Silo 3, was located at the top of the silo. Silo 3 was filled to its present level using this rotary calcining system. No materials (except samples) have been removed from Silo 3 since filling in 1957.

Following a programmatic decision in early 1957 to utilize raffinate surface impoundments, the spray calcining and rotary calcining systems were eventually abandoned. As a result of this decision, Silo 4 was never employed for the storage of cold metal oxides or other site materials and remains empty. Inspections completed on Silo 4 during the Operable Unit 4 RI-related site investigations confirmed that no waste materials were present within the silo.

1.4.3.4 History of the Radon Treatment System

The RTS was installed in November 1987 to reduce the radon inventory within the headspace of Silos 1 and 2 prior to the application of a polyurethane foam to the exposed surfaces of their domes. The RTS was originally designed to withdraw the radon gas from the headspace of each silo separately. The RTS operated as a closed, re-circulating system so that the radon component of the gas flow from the silo was directed continuously across charcoal beds. The basic operation of the RTS involved the removal of the radon-laden air from the silo headspace, transport to the treatment building, removal of moisture via two calcium sulfate canisters, adsorption of the radon on the charcoal beds and return of the dry air to the silo. The RTS was utilized on numerous occasions following the initial run to support the foam installations. The RTS was used extensively during RI sampling efforts, which are described in Section 2.0 of the RI Report for Operable Unit 4.

In March 1990, a cracked PVC pipe tee in the RTS piping system was discovered and attributed to degradation brought on by ultraviolet (UV) radiation and thermal stresses. In response to this finding, the RTS was upgraded in July 1991. The upgrades included new piping, a new fan, and the installation of remote controlled butterfly valves. The RTS was last used in November 1991 to support the K-65 Silos Removal Action. The RTS remains intact within the Operable Unit 4 Study Area.

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## 1.5 NATURE AND EXTENT OF CONTAMINATION

This section summarizes the nature and extent of contamination both on a site-wide basis and for Operable Unit 4. The site-wide summary is presented in this section to frame Operable Unit 4 within the entire FEMP, consistent with the role of this FS Report for Operable Unit 4 to include the CRARE, which was described in Section 1.3.

### 1.5.1 Site-Wide Summary

DOE submitted the final FEMP SWCR to EPA in March 1993. It is incorporated herein by reference and is available in the Administrative Record. The SWCR compiles all FEMP site data available as of December 1, 1991. The major purpose of the SWCR is to support the preparation of the individual operable unit RI and FS Reports by: describing the regional environment of the FEMP; providing the site-wide information necessary for FS cumulative response action risk evaluations; and providing a number of detailed technical appendices on ecological studies, population estimates, and modeling efforts supporting the RI/FS. Data required for describing the sources, and nature and extent of contamination related to specific operable units were still being collected when preparation of the SWCR began. Accordingly, data interpretation in the SWCR is limited. Comprehensive data usability assessments and interpretations are provided in the respective operable unit RI/FS reports.

The site characterization work performed to determine the nature and extent of contamination at the FEMP has generated thousands of data points. Additional data continue to be collected through an ongoing environmental monitoring program and remaining RI/FS characterization activities. The results of six primary data collection programs were compiled by the SWCR as summarized below:

- DOE Litigation Study
- Characterization Investigation Study (CIS)
- RCRA Groundwater Compliance Monitoring
- DOE Sampling and Analysis
- Annual Environmental Monitoring Program
- RI/FS Characterization Studies

These data collection programs encompass solid and liquid waste, structures and equipment, and all environmental media including air, surface water and groundwater, soils, and flora and fauna. Table 1-1 presents a general overview of the results of these investigations by environmental medium and source area. The discussion below briefly highlights major observations as reported in the SWCR Volume 2, Part I, Section 4.0, Data Summary. Readers are referred to the SWCR for full details.

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TABLE 1-1

SUMMARY OF NATURE AND EXTENT OF CONTAMINATION AT THE FEMP

| Source Area/Environmental Medium | Description |
|---|---|
| **A. ENVIRONMENTAL MEDIA** | |
| **Air Quality** | |
| Site-wide air quality. | Emissions of radionuclides site wide have been substantially reduced from the time of active production. Radon emissions decreased significantly with the placement of bentonite over the contents of Silos 1 and 2 during November 1991.<br><br>**Key Contaminants:**<br>**Particulate-borne uranium and radon** |
| **Surface Water/Sediments** | |
| Great Miami River, Paddys Run, on-property surface drainages. | Data indicate that the FEMP has only a slight effect on uranium concentrations in the Great Miami River, with no effect on sediment. On-property concentrations of uranium in Paddys Run surface waters and sediment trend higher than downstream off-property locations. Radionuclide levels in various on-property drainageways including the storm sewer outfall ditch have decreased since the construction of the storm water retention basins in 1986.<br><br>**Key Contaminants:**<br>**Uranium** |
| **Groundwater** | |
| Perched groundwater zones and Great Miami Aquifer. | Perched groundwater zones on the FEMP are contaminated by a variety of constituents originating from major sources including the former Production Area, Solid Waste Landfill and South Field, waste pits, and Silos 1 and 2. Data for samples collected from the Great Miami Aquifer generally show lower concentrations of contaminants than the perched water. The majority of off-property wells sampled had total uranium concentrations less than 2 picoCuries/liter (pCi/L).<br><br>**Key Contaminants:**<br>**Uranium** |

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**TABLE 1-1**
**(Continued)**

| Source Area/Environmental Medium | Description |
|---|---|
| **Surface Soils** | |
| On-property soils outside the boundary of specific operable units and off-property soils. | Annual sampling of surface soil indicates that uranium concentrations decrease with distance from the center of the FEMP. The highest concentrations of uranium were consistently measured in samples in the vicinity of the former incinerator at the Sewage Treatment Plant.<br><br>**Key Contaminants:**<br>**Uranium** |
| **Subsurface Soils** | |
| On-property subsurface soils contiguous with source areas. | Consistent with past waste management and disposal practices (i.e., waste pits, K-65 Silos) on-property subsurface soils adjacent to source areas are contaminated with radionuclides and organic/inorganic constituents. The ranges of concentrations and vertical distributions of constituents in subsurface soil samples verify process knowledge regarding waste disposal practices.<br><br>**Key Contaminants:**<br>**Radium, Uranium** |
| **Biological Receptors** | |
| Macroinvertebrates and fish in Paddys Run and the Great Miami River; grass/forage; produce; milk; and mammals. | Various ecological survey contaminant uptake studies have been performed over the years. Although isotopic uranium has been detected in a variety of biological samples (both flora and fauna), no significantly elevated concentrations have been detected. Generally, concentrations declined since FEMP production shut down and with increasing distance from the site.<br><br>**Key Contaminants:**<br>**Uranium** |

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**TABLE 1-1**
**(Continued)**

| Source Area/Environmental Medium | Description |
|---|---|
| **B. SOURCE AREAS** | |
| **OU1**<br>Waste Pits 1 through 6, Clearwell and Burn Pit, and associated contaminated soils within the operable unit boundary. | The six waste pits previously received large quantities of solid and slurried wastes from FEMP processes. The Clearwell received process water, settleable solids, and storm water runoff from Waste Pit 5. The Burn Pit was used to burn laboratory chemicals and waste oils.<br><br>**Key Contaminants:**<br>**Uranium, thorium, radium, and technetium** |
| **OU2**<br>Solid Waste Landfill, Lime Sludge Ponds, Active and Inactive Flyash Piles and the South Field, and associated contaminated soils within the operable unit boundary. | The Solid Waste Landfill reportedly contains cafeteria wastes, rubbish, and wastes from nonprocess areas. The Lime Sludge Ponds received spent lime sludges and boiler plant blowdown. The Flyash Piles received flyash from the FEMP coal-fired boiler plant and were periodically sprayed with waste oils for dust control. The South Field reportedly received construction rubble containing low levels of radioactive materials.<br><br>**Key Contaminants:**<br>**Uranium, thorium, radium, and cadmium** |
| **OU3**<br>Former Production Area, all above and below ground production associated facilities and equipment. | The former Production Area occupies about 55 ha (136 acres) and encompasses structures, utilities, drums, tanks, solid wastes, product (e.g., uranium metal, and thorium), effluent lines, wastewater treatment and fire training facilities, scrap metal piles, feedstock, and the coal pile.<br><br>**Key Contaminants:**<br>**Uranium, thorium, lead, asbestos, and trichlorethylene** |
| **OU4**<br>Silos 1 through 4, earthen berms, decant sump, and associated contaminated areas within the operable unit boundary. | Earthen bermed concrete Silos 1 and 2 contain K-65 residues that are high-specific activity, radium-bearing residues resulting from the pitchblende refining process. Concrete Silo 3 contains metal oxides. Concrete Silo 4 is unused. The decant sump tank contains liquids collected from Silos 1 and 2 via an underdrain system.<br><br>**Key Contaminants:**<br>**Radium, thorium, lead, radon, and arsenic** |

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1.5.1.1 Air Quality

Air quality monitoring at the FEMP has focused on uranium (U)-238 as a measure of the impact of production operations and waste handling activities, and radon as a measure of the impact of continued storage of the contents of Silos 1 and 2 in Operable Unit 4.

Annual U-238 emissions, as determined by a combination of point-source and nonpoint-source monitoring and modeling, declined from a total of 35,400 microCuries per year ($\mu$Ci/year) in 1988 (the last full year of production at the FEMP site) to 9890 $\mu$Ci/year in 1989 and 1080 $\mu$Ci/year in 1990. Corresponding reductions in concentrations of airborne uranium occurred at the 16 air monitoring sites in and around the FEMP site.

Compared to data collected in October 1991, on-property radon concentrations decreased by 90 percent: off-property concentrations, which were already near background, decreased by 50 percent after the placement of bentonite in Silos 1 and 2 in November 1991.

1.5.1.2 Surface Water and Sediment

The major surface water features of concern at the FEMP site are the Great Miami River, the receiving body for the NPDES permitted discharge, Paddys Run, a small stream traversing the western border of the property, and the Storm Sewer Outfall Ditch, a major tributary to Paddys Run. Data collection has focused on monitoring total uranium concentrations in the surface water and sediments, supplemented by sampling and analysis for other parameters during the RI/FS. Uranium concentrations in surface water samples collected downstream from the Great Miami River FEMP effluent discharge are typically 1 to 2 picoCuries/liter (pCi/L) higher than the usual concentration of 1 pCi/L in upstream samples. Samples collected from river sediments are typically 1 picoCurie/gram (pCi/g) both above and below the effluent discharge. The concentrations of inorganic chemical constituents show no upstream/downstream variability with respect to the effluent discharge.

Surface water samples collected from an on-property location in Paddys Run have averaged 76 pCi/L total uranium. Concentrations measured from off-property sampling locations averaged less than 7 pCi/L total uranium. Uranium concentrations in Paddys Run sediment adjacent to the confluence with the storm sewer outfall ditch have been reported at up to 62 pCi/g, but average less than 2 pCi/g. In addition, environmental monitoring data from 1988 to 1990 show no variability for upstream/downstream samples collected relative to the confluence of Paddys Run with the Great Miami River.

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The storm sewer outfall ditch is normally dry, but uranium concentrations in runoff from various drainages to Paddys Run have been recorded as high as several milligrams per liter (mg/L). Environmental monitoring data indicate that radionuclide levels in Paddys Run and the storm sewer outfall ditch sediment have decreased since the construction of the storm water retention basins in 1986. Recent sampling of the storm sewer outfall ditch sediment found a maximum of about 17 pCi/g total uranium.

1.5.1.3 Groundwater

The major focus of groundwater investigations at the FEMP has been on radionuclide contamination of the regional Great Miami Aquifer. Related studies have been conducted on the extensive zones of perched groundwater on and adjacent to the FEMP site.

Both radiological and nonradiological constituents have been detected in perched and regional aquifer groundwater. The highest concentrations of uranium in perched groundwater and the regional aquifer were found in the former Production Area. Total uranium concentrations greater than 1 mg/L in the former Production Area were observed in perched groundwater beneath Plant 2/3, Plant 6, and Plant 8 areas. The highest average total uranium concentrations in the former Production Area are 568 mg/L in perched groundwater and 0.071 mg/L in the regional aquifer. Concentrations of uranium in the perched groundwater are generally higher than those shown in the regional aquifer groundwater. Other radiological constituents that have been recurrently detected in the perched groundwater at the FEMP site, primarily in the vicinity of the former Production Area, include radium (Ra)-226, Ra-228, strontium (Sr)-90, technetium (Tc)-99, thorium (Th)-228, Th-230, and Th-232.

Above background concentrations of a number of inorganic constituents were found in perched groundwater and the regional aquifer, with concentrations generally lower in the latter. General chemical constituents with statistically elevated concentrations in the regional aquifer groundwater beneath the Waste Storage Area and the former Production Area were similar to those found in the perched groundwater in these areas.

A variety of volatile and semivolatile organic compounds were detected in perched groundwater and aquifer groundwater from the vicinity of the Waste Storage Area, the former Production Area, and the South Field. Various volatile and semivolatile organic compounds were also detected in perched groundwater in the vicinity of the sewage treatment plant and fire training area and in the regional aquifer near and south of the local industries south of the FEMP property.

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1.5.1.4 Surface Soils

Annual sampling and analysis of surface soil by the FEMP environmental monitoring program indicates that uranium concentrations decrease with distance from the center of the FEMP. In 1990, total uranium concentrations reported for samples collected at on-property locations 0.1 km (0.06 mi) and 1.1 km (0.7 mi) from the FEMP center were 41 pCi/g and 15 pCi/g, respectively. Off-property concentrations ranged from 1.1 to 7.2 pCi/g total uranium at distances from 40 to 1.3 km (25 to 0.8 mi) from the FEMP center. Sampling and analysis of surface soils conducted to characterize the Waste Storage Area and the former Production Area reported higher concentrations of uranium, as well as other radioisotopes including Ra-226, Th-228, Th-230, and Th-232. The highest concentrations of uranium occurred adjacent to the former incinerator near the sewage treatment plant, with total uranium values ranging up to 23,000 milligrams per kilogram (mg/kg). Elevated thorium and radium concentrations (up to 7901 pCi/g Th-228 and up to 2950 pCi/g Ra-226) were found in samples collected from the former Production Area.

Inorganic and organic constituents were also detected in surface soil samples collected for the RI/FS. Inorganic constituents found include aluminum, arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, iron, magnesium, nickel, vanadium, and zinc. Forty-seven volatile and semivolatile organics were detected, with polychorinated biphenyls (PCBs), benzo(a)pyrene, and methylene chloride found in all RI/FS samples for which those constituents were analyzed. The highest concentrations of inorganics and organics were found in the former Production Area.

1.5.1.5 Subsurface Soils

Sampling and analysis of subsurface soils has focused on contamination sources including the Waste Storage Area, the flyash piles and South Field, the Solid Waste Landfill soils, beneath Silos 1 and 2, and the former Production Area. Uranium and thorium isotopes were consistently detected in subsurface samples collected from the waste pits. RI/FS samples from the Pit 1 berm had mean concentrations of 349 pCi/g U-234, 894 pCi/g U-238, and 3811 pCi/g Th-230. U-238 was the most abundant radionuclide detected in CIS samples from the Solid Waste Landfill, with a maximum concentration of 338 pCi/g and an average of 11.3 pCi/g. Radionuclides detected in CIS samples from the flyash piles and South Field include isotopes of uranium, thorium, radium, and lead (Pb)-210. Uranium isotopes, Th-230, and Ra-228 were the most abundant radionuclides detected in RI/FS samples from borings in structures in the former Production Area. Concentrations of U-238, Th-230, and Ra-228 ranged up to 19,100 pCi/g, 127 pCi/g, and 170 pCi/g, respectively.

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Inorganic constituents were detected in subsurface soil samples collected from the Waste Pit Area. For example, concentration ranges of aluminum (4730 to 24,061 mg/kg), calcium (22,190 to 156,000 mg/kg), iron (2750 to 20,250 mg/kg), and magnesium (12,184 to 30,700 mg/kg) were detected in samples collected throughout the waste pits and the Clearwell. Average ranges of arsenic (102 to 530 mg/kg), lead (232 to 158 mg/kg), sodium (2800 to 5417 mg/kg), and vanadium (870 to 2700 mg/kg) were among the higher concentration inorganic constituents detected in Waste Pits 3 and 5, respectively. Aluminum, calcium, iron, and magnesium were found in concentrations exceeding 7000 mg/kg in samples collected from the flyash piles and the South Field. Antimony, arsenic, lead, molybdenum, selenium, and silver exceeded background levels in both flyash areas. Aluminum, calcium, iron, and magnesium had the highest concentrations among inorganics in samples collected from the Solid Waste Landfill. Aluminum, calcium, iron, and magnesium were the most abundant inorganic constituents in former Production Area subsurface soil.

A variety of organic compounds were detected in subsurface soil samples collected in the Waste Pit Area, including PCBs, phenanthrene, fluoranthene, and pyrene. Aroclor-1254 was detected at 2.3 mg/kg in the Burn Pit. Semivolatile organics were detected in higher levels [up to 2700 micrograms per kilogram ($\mu$g/kg)] in the Active Flyash Pile than in the Inactive Flyash Pile (up to 310 $\mu$g/kg). A variety of organic compounds, including semivolatiles, volatiles, and PCBs were detected in subsurface soil samples collected from the former Production Area.

1.5.1.6 Ecological Assessments

A number of investigations have been conducted to support site-specific ecological assessments at the FEMP. These studies fall into three general categories: characterizations of habitats and species compositions, analyses of organisms for uptake of FEMP contaminants, and toxicity tests of FEMP effluent, soils, and sediments.

The major ecological characterization study at the FEMP was conducted by researchers from Miami University under contract to WEMCO. They described five major habitats at the FEMP: introduced grasslands, pine plantations, deciduous woodlands, a riparian zone along Paddys Run, and an area coincident with the Inactive Flyash Pile and South Field. This study and several follow-up studies also examined possible stress effects on one species of bird and one species of amphibians occupying these habitats. The studies did not establish a correlation between observed effects and contamination from the FEMP.

Benthic macroinvertebrate communities in the Great Miami River and Paddys Run were surveyed five times over a two year period to examine potential effects of the FEMP on aquatic communities. The results of the Great Miami River surveys suggest that the FEMP effluent has minimal impact on the macroinvertebrate community. While some environmental stress on these communities were observed in Paddys Run, they may be attributable to the stressful physical environment of the stream. Observed concentrations of radionuclides and chemicals in Paddys Run are not consistent with those reported in the literature to be toxic to aquatic organisms.

Over the years, various samples of grass and forage, produce, milk, fish, vegetation, and mammal tissue have been collected at and adjacent to the FEMP site. Although concentrations of isotopic uranium were detected in some grass and vegetation samples at values as high as to 35 pCi/g, these concentrations declined both with increasing distance from the center of the site and with the shutdown of plant operations. Uranium was detected at 18 pCi/g in one of eight mammal samples and was sporadically detected at low levels in fish and macroinvertebrate samples collected from the Great Miami River and Paddys Run.

Acute and chronic aquatic toxicity tests were conducted on the FEMP effluent five times over a two-year period following standard EPA protocols. Acute toxicity was never observed. Chronic toxicity was observed in three of five algal growth tests and in one of three dephnid tests. No correlation was observed between effluent toxicity and uranium or other effluent variables. The concentrations causing toxicity were at least eight times the maximum concentrations of effluent, which would be observed in the Great Miami River under worst-case conditions. Aqueous extracts of soils and sediment from the FEMP were tested for acute toxicity to aquatic organisms. No acute toxicity was observed.

### 1.5.2 Operable Unit 4 Summary

This section summarizes the nature of contamination at the source and the nature and extent of contamination within the receptor media in the Operable Unit 4 Study Area. Potential sources include Silos 1 and 2, the decant sump tank, the RTS, Silo 3 and Silo 4. Receptor media within the Operable Unit 4 Study Area include surface soil, berm soil, subsurface soil, perched groundwater, Great Miami Aquifer groundwater, surface water, sediment, air, and direct radiation. Full detail is provided in Section 4.0 of the RI Report for Operable Unit 4. Additional data tables not included in this section are available in Appendix A.

1.5.2.1 Contaminant Source Data

This section summarizes characterization data regarding the nature of contaminants, or sources, within the physical structures contained in Operable Unit 4. Sources considered in this section include Silos 1 and 2, the decant sump tank, the RTS, Silo 3, and Silo 4.

Silos 1 and 2

Silos 1 and 2 sample analyses confirmed prior process knowledge and provided additional data regarding the distribution of constituents within the silos and their specific concentrations. They also identified the presence of previously unknown organic constituents. Table 1-2 presents a summary of radionuclide analyses of the Silos 1 and 2 residues. Table 1-3 presents an inventory of the radiological constituents in Silos 1 and 2.

Silos 1 and 2 contain 6120 $m^3$ (8012 $yd^3$) of K-65 residues and 670 $m^3$ (878 $yd^3$) of bentonite clay for total content of 6790 $m^3$ (8890 $yd^3$). The materials are primarily a silty clay with an average moisture content of 40 percent. In excess of 70 Curies (Ci) of Ac-227, 3700 Ci of Ra-226, 600 Ci of Th-230, 2400 Ci of Po-210, and 1900 Ci of Pb-210 are present within the residue volumes of the two silos. Furthermore, it is estimated that the silos contain 27 metric tons (30 tons) of uranium. Radiological contaminants show a well-defined distribution pattern in the silos. Analytical results confirm homogeneity in the horizontal direction and heterogeneity in the vertical direction. These results are consistent with the waste materials having been slurried into Silos 1 and 2 in 15-cm (6-in.) lifts. Concentrations of Ra-226, Th-230, Pb-210, and uranium generally increase in concentration with depth. This observation is consistent with the knowledge that higher assay ores were processed earlier in the project. The 1990/1991 sampling event that provided analytical results from samples obtained near the bottom of Silos 1 and 2 allowed engineers to establish an upper bound on the waste contents of the silos.

Significant inorganics include nearly 120 metric tons (130 tons) of barium, 830 metric tons (915 tons) of lead, 210 metric tons (230 tons) of calcium, and 190 metric tons (210 tons) of iron. The silos also contain elevated concentrations of Aroclor-1248, Aroclor-1254, and Aroclor-1260 (PCBs) and tributyl phosphate (a solvent for uranium extraction). Toxicity Characteristic Leaching Procedure (TCLP) results show that lead (approximately 500 ppm) exceeds RCRA limits of 5.0 ppm. However, based on the generation process of the residues stored in the silos, they are classified as byproduct material as defined in Section 11(e)2 of the AEA and, therefore, are excluded from regulation under RCRA.

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TABLE 1-2

SUMMARY OF RADIONUCLIDE ANALYSES FOR SILOS 1 AND 2 RESIDUES

| Analyte [a] | Frequency of Detection[b] | Rejected | Arithmetic Mean[c] (pCi/g)[d] | Upper 95% CI on Mean[c] (pCi/g) | Range of Detects[c] (pCi/g) |
|---|---|---|---|---|---|
| **SILO 1** | | | | | |
| Actinium-227 | 13/20 | 0 | 5960 | 7670 | 4320-17390 |
| Lead-210 | 20/20 | 0 | 165000 | 202000 | 48980-381400 |
| Polonium-210 | 13/13 | 0 | 242000 | 281000 | 144000-434000 |
| Radium-226 | 20/20 | 0 | 391000 | 477000 | 89280-890700 |
| Thorium-228 | 2/20 | 0 | 422 | 2280 | 835-2280 |
| Thorium-230 | 24/24 | 0 | 60000 | 68900 | 10569-105372 |
| Thorium-232 | 8/20 | 0 | 424 | 1110 | 661-1106 |
| Uranium-234 | 21/21 | 0 | 800 | 932 | 326-1548 |
| Uranium-235/236 | 14/20 | 0 | 38 | 54 | 19.1-105 |
| Uranium-238 | 20/20 | 0 | 642 | 693 | 387-920 |
| **SILO 2** | | | | | |
| Actinium-227 | 11/14 | 0 | 5100 | 6640 | 2905-10450 |
| Lead-210 | 14/14 | 0 | 145000 | 190000 | 58160-399200 |
| Polonium-210 | 8/8 | 0 | 139000 | 231000 | 55300-241000 |
| Protactinium-231 | 1/14 | 0 | 2350 | 4040 | 4041-4041 |
| Radium-226 | 14/14 | 0 | 195000 | 263000 | 657-481000 |
| Thorium-228 | 5/14 | 0 | 645 | 7360 | 411-7360 |
| Thorium-230 | 15/15 | 0 | 48400 | 76200 | 8365-132800 |
| Thorium-232 | 3/14 | 0 | 402 | 985 | 851-985 |
| Uranium-234 | 13/13 | 0 | 961 | 1160 | 121-1465 |
| Uranium-235/236 | 11/13 | 0 | 73 | 94 | 35.6-172 |
| Uranium-238 | 14/14 | 0 | 912 | 1120 | 46-1925 |

[a]Sample numbers used in this data set include: (Silo 1) 99728, 99743, 99870, 99885, 99909, 99930, 99939, 99948, 99966, 99975, 100004, 100025, 100039, 100108 through 100114; and (Silo 2) 99359, 99710, 99774, 99802, 99811, 99831, 99846, 99861, and 100115 through 100120.
[b]Rejected data not included in total number of samples.
[c]Values qualified with an R are excluded. The mean and upper 95% confidence interval (CI) on mean have been rounded to show three significant figures. The mean is calculated using one-half the SQL for nondetects.
[d]Values expressed in picoCuries per gram (pCi/g).

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TABLE 1-3

SUMMARY OF THE INVENTORY OF RADIOLOGICAL CONSTITUENTS IN SILOS 1 AND 2

| | Silo 1[a] | | Silo 2[b] | |
|---|---|---|---|---|
| Analyte | Mean Inventory[c] (Ci) | UCL Inventory[c] (Ci) | Mean Inventory[c] (Ci) | UCL Inventory[c] (Ci) |
| Actinium-227 | 40 | 52 | 30 | 39 |
| Lead-210 | 1110 | 1360 | 844 | 1110 |
| Polonium-210 | 1630 | 1890 | 809 | 1340 |
| Protactinium-231 | ND[e] | ND[e] | 14 | 24 |
| Radium-226 | 2630 | 3210 | 1140 | 1530 |
| Thorium-228 | 2.8 | 15.3 | 3.8 | 43 |
| Thorium-230 | 403 | 463 | 282 | 444 |
| Thorium-232 | 2.9 | 7.5 | 2.3 | 5.7 |
| Uranium-234 | 5.4 | 6.3 | 5.6 | 6.8 |
| Uranium-235/236 | 0.26 | 0.36 | 0.43 | 0.55 |
| Uranium-238 | 4.3 | 4.7 | 5.3 | 6.5 |
| Total Uranium[d] | 12.9 | 14.1 | 15.9 | 19.5 |

[a]Based on a volume of 3280 $m^3$ and a dry mass density of 2.050 grams per cubic centimeters ($gm/cm^3$).
[b]Based on a volume of 2840 $m^3$ and a dry mass density of 2.050 $gm/cm^3$.
[c]Values for mean and Upper Confidence Limit (UCL) taken from Table 4-2 of the RI Report for Operable Unit 4.
[d]Total uranium mass in metric tons. Calculated from the isotopic distribution of uranium.
[e]ND-Analyte was not detected.

Decant Sump Tank

Samples taken during the 1991 removal action which removed about 8000 gallons of water from the decant sump tank, revealed elevated concentrations of Pb-210 (8660 pCi/L), Po-210 (7080 pCi/L), Ra-226 (1380 pCi/L), and U-238 (23,200 pCi/L). Analytical results also revealed the presence of above background concentrations of Sr-90 and Tc-99. With the exception of these latter two constituents, radiological contaminants present in the decant sump tank are consistent with the relative concentrations of contaminants found in Silos 1 and 2. This result confirms that the decant sump tank is continuing to collect leachate from the underdrains in Silos 1 and 2, as it was designed to do. Sr-90 and Tc-99 are byproducts of nuclear fission and are not present in Silos 1 and 2. Their presence in the decant sump tank indicates existence of some surface water infiltration into the decant sump tank or anomalous analytical results.

One sludge sample was taken during the 1991 removal action. Results from that sample showed measurable levels of Ac-227 (5783 pCi/g), Pb-210 (123,200 pCi/g), Ra-226 (128,500 pCi/g), and Th-230 (52,130 pCi/g). The ratio of these concentrations are consistent with measured values for the residues in Silos 1 and 2.

Metals found in the decant sump tank liquid samples included aluminum, antimony, arsenic, chromium, copper, lead, molybdenum, selenium, silver, vanadium, and zinc. These data are consistent with Extraction Procedure Toxicity (EP Tox) test results and TCLP analyses performed on materials in Silos 1 and 2.

Eighteen organic compounds were detected in the decant sump tank liquids at concentrations near the detection limits. With the exception of toluene, all volatile compounds detected were at or below the contract required quantitation limit (CRQL) or were common laboratory contaminants.

Radon Treatment System

The RTS was sampled during a removal site evaluation in January 1992. The predominant contaminants present are approximately 9.5 Ci of Pb-210 and progeny [polonium (Po)-210 and bismuth (Bs)-210] in secular equilibrium. The contaminants are located in the radon system calcium sulfate drier canisters, the charcoal canisters and, to a lesser extent, the system piping.

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Periodic surveys for direct radiation and removable fixed radioactive contamination reveal that only isolated contamination is present in accessible portions of the RTS. Only one accessible location yielded a measurement that was above the DOE guidelines for unrestricted release.

Silo 3

Silo 3 contains 3890 $m^3$ (5088 $yd^3$) of residues. During the 1989 sampling and analysis of Silo 3 contents, 12 radionuclides were identified including actinium (Ac)-227, Pb-210, protactinium (Pa)-231, and isotopes of radium, thorium, and uranium. Thorium-230 had the highest activity concentration, ranging from 21,010 to 71,650 pCi/g. These sample results are consistent with process knowledge. Present within the silo waste is approximately 450 Ci of Th-230, 26 Ci of Ra-226, and nearly 40 metric tons (44 tons) of uranium. Table 1-4 provides a summary of radionuclide concentrations in Silo 3 residues. Table 1-5 presents an inventory of Silo 3 radiological constituents.

Of the 23 inorganic constituents detected, those which represent the highest relative hazard include arsenic at 1950 mg/kg and vanadium at 1820 mg/kg. EP Tox results from sampling in 1989 indicate that the Silo 3 residues leach arsenic (mean 9.481 mg/L), chromium (mean 5.05 mg/L), and selenium (mean 2.65 mg/L) at levels exceeding RCRA limits of 5.0 mg/L, 5.0 mg/L, and 1.0 mg/L respectively. However, based on the generation process of the residues, they are classified as byproduct material as defined in Section 11(e)2 of the AEA and, therefore, are excluded from regulation under RCRA.

The 1989 Silo 3 volatile organic data and a portion of the semivolatile data were rejected during data validation. Additional sampling was deemed unwarranted based on process knowledge and the organic sample results from Silos 1 and 2. Only two organics, kerosene and tributyl phosphate, were used in the extraction process. Silo 3 materials were generated as part of the same process which produced the materials in Silos 1 and 2. Before transfer to Silo 3, however, waste residues were first dried and then calcined. The calciners operated in a temperature range from 510°C to 820°C (950°F to 1500°F). This process would have combusted or volatilized organics present in the metal oxides prior to their transfer to Silo 3. This hypothesis is confirmed by the absence of PCBs/Aroclors in Silo 3 samples in spite of their presence in Silos 1 and 2 residues.

Silo 4

As related in the Silo 4 history discussion, due to a programmatic decision in early 1957 to utilize raffinate surface impoundments, the spray calcining and rotary calcining systems were eventually

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## TABLE 1-4

## RADIONUCLIDE CONCENTRATIONS IN SILO 3 RESIDUES

| Analyte [a] | Frequency of Detection[b] | Rejected | Arithmetic Mean[c] (pCi/g)[d] | Upper 95% CI on Mean[c] (pCi/g) | Range of Detection[c] (pCi/g) |
|---|---|---|---|---|---|
| **SILO 3** | | | | | |
| Actinium-227 | 9/9 | 2 | 618 | 925 | 234-1363 |
| Lead-210 | 11/11 | 0 | 2620 | 3480 | 454-6427 |
| Protactinium-231 | 9/11 | 0 | 487 | 627 | 266-931 |
| Radium-224 | 11/11 | 0 | 290 | 367 | 64-453 |
| Radium-226 | 11/11 | 0 | 2970 | 3870 | 467-6435 |
| Radium-228 | 9/11 | 0 | 297 | 406 | 82-559 |
| Thorium-228 | 7/11 | 0 | 590 | 747 | 459-996 |
| Thorium-230 | 11/11 | 0 | 51200 | 60200 | 21010-71650 |
| Thorium-232 | 8/11 | 0 | 656 | 842 | 411-1451 |
| Uranium-234 | 11/11 | 0 | 1480 | 1730 | 348-1935 |
| Uranium-235/236 | 10/11 | 0 | 93.6 | 117 | 42-158 |
| Uranium-238 | 11/11 | 0 | 1500 | 1780 | 320-2043 |

[a] Sample numbers used in this data set include: 100097 through 100107.
[b] Rejected data not included in total number of samples
[c] Values qualified with an R are excluded. The mean and upper 95% confidence interval (CI) on mean have been rounded to show three significant figures. The mean is calculated using one-half the SQL for nondetects.
[d] Values expressed in picoCuries per gram (pCi/g)

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## TABLE 1-5

## INVENTORY OF SILO 3 RADIOLOGICAL CONSTITUENTS

| Analyte | Silo 3[a] Mean Inventory[b] (Ci) | Silo 3[a] UCL Inventory[b] (Ci) |
|---|---|---|
| Actinium-227 | 5.4 | 8.2 |
| Protactinium-231 | 4.3 | 5.5 |
| Lead-210 | 23.2 | 30.8 |
| Radium-224 | 2.6 | 3.2 |
| Radium-226 | 26.3 | 34.2 |
| Radium-228 | 2.6 | 3.6 |
| Thorium-228 | 5.2 | 6.6 |
| Thorium-230 | 453 | 532 |
| Thorium-232 | 5.8 | 7.4 |
| Uranium-234 | 13.1 | 15.3 |
| Uranium-235/236 | 0.83 | 1.04 |
| Uranium-238 | 13.3 | 15.7 |
| Total Uranium[c] | 39.9 | 47.2 |

[a]Based on a volume of 3900 $m^3$ and a dry mass density of 2.267 $gm/cm^3$.
[b]Values for mean and UCL concentrations from Table 4-19 of the RI Report for Operable Unit 4.
[c]Total uranium mass in metric tons. Calculated from isotopic distribution of uranium

abandoned. As a result of this decision, Silo 4 was never employed for the storage of cold metal oxides or any other residues and remains empty. Inspections completed on Silo 4 during the RI-related site investigations confirmed that no waste materials were present within the silo. Production and waste disposal records also show that Silo 4 was never used for production, waste storage, or waste disposal activities. Site records indicate that infiltrated rainwater has been periodically removed from Silo 4 and treated through the FEMP wastewater treatment system.

Water samples collected in 1989 contained 121 micrograms per liter ($\mu$g/L) of uranium. Hazardous Substance List (HSL) metal results were consistent with water in contact with cement. Water samples collected in May 1991 revealed an average uranium concentration of 0.3 $\mu$g/L. Thorium results were reported as below the lower limit of detection, 0.4 $\mu$g/L. HSL inorganics were again consistent with water in contact with cement.

1.5.2.2 Nature and Extent of Contamination of Environmental Media

This section summarizes characterization data regarding the nature and extent of contamination in environmental media within Operable Unit 4. Environmental media considered include surface soil, berm soil, subsurface soil, perched groundwater, Great Miami Aquifer groundwater, air, and direct radiation.

Surface Soil

Radiological analytical data from the CIS focused on the upper 0 to 5.1 cm (0 to 2 in.) of soils. Radionuclide concentrations for U-238 ranged from 2.6 to 37.4 pCi/g with a mean of 9.04 pCi/g. Concentrations of Ra-226 ranged from less than 0.5 pCi/g to 35.8 pCi/g with a mean of 5.54 pCi/g. In addition, two samples that were analyzed in an off-site laboratory yielded Th-230 concentrations of 14.0 and 295 pCi/g.

Results from the RI showed that U-238 concentrations ranged from 2.4 to 20.8 pCi/g with a mean of 8.3 pCi/g. Radium-226 concentrations ranged from 0.6 to 2.3 pCi/g with a mean of 1.24 pCi/g. Thorium-230 results ranged from 1.4 to 4.8 pCi/g with a mean of 3.1 pCi/g.

The Waste Pit Area Runoff Control Removal Action included 10 surface soil samples for inorganic constituents, 9 samples for HSL pesticides, and 8 samples for HSL volatile and semivolatile organics in the Operable Unit 4 Study Area. Of the inorganic constituents, antimony, beryllium, chromium, copper, magnesium, nickel, silver, and sodium were consistently above background. For organic

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analyses, the only detected volatile compounds consisted of common laboratory contaminants. With the exception of one sample containing elevated concentrations of semivolatiles (including benzo(a)pyrene), all semivolatile compounds were at or only slightly above the CRQL.

In general, the results of the studies are consistent with one another and show that surface soils across Operable Unit 4 are contaminated with U-238 and, to a lesser extent, Ra-226 and Th-230. Concentrations decrease rapidly with depth, to background below 15.2 cm (6 in.). The results of these samples show no direct link between surface soil contamination and the silo contents. Instead, the data show uniform distribution of low-level radiological surface contamination throughout the Operable Unit 4 Study Area consistent with air deposition of contaminants from the Waste Pit Area and/or the former Production Area.

Berm Soil

With the exception of two sampling locations, berm sample results revealed only background concentrations for all constituents. The first location was at a depth of 1.5 m (5 ft) in the boring near the northeast manway of Silo 1. This sample revealed radionuclide concentrations of 3.38 pCi/g for U-238, 4.01 pCi/g for Th-230, 4.02 pCi/g for Po-210, and 3.67 pCi/g for Ra-226. The sample is considered to be more consistent with general surface soil than berm soil. The second sample was collected at a depth of 9.1 m (30 ft) from the boring located near the northwest manway of Silo 1. The sample yielded radionuclide concentrations of 24.7 pCi/g for U-238, 51.2 pCi/g for Th-230, 876 pCi/g for Ra-226, and 417 pCi/g for Pb-210. At this depth, the borehole had penetrated the native soil that was present prior to installation of the berm. Thus, this contamination could be the result of spillage during silo filling operations, leakage of the silo to surface soils prior to berm installation, or leakage of the silo underdrains to near subsurface soils immediately adjacent to the silos.

TCLP analysis showed that concentrations of the toxicity characteristics were well below the Maximum Allowable Concentrations (MAC) limits in all except one of the samples analyzed. This sample, collected at a depth of 16 ft from Boring No. 1620, was significantly different from other sample results and showed concentrations of cadmium at 11.4 mg/L, chromium at 81.8 mg/L, and silver at 112 mg/L. Several samples were analyzed for various constituents from this interval. A split sample from the same location analyzed for HSL metals, however, detected cadmium (5.4 mg/kg), chromium (16.6 mg/kg), and silver (8.2 mg/kg) at concentrations comparable to the values for Borings Nos. 1621, 1622, and 1623 (cadmium - 4.3, 7.5, 4.3; chromium - 18.7, 20.8, 17.5; and silver - 7.5, 19.2, 5.8). The radiological analysis for the 1-ft interval just above this interval

displayed no elevated concentrations. The other TCLP analytical results for the metals from this boring are consistent with the results from Borings Nos. 1621, 1622, and 1623. The TCLP data from the sample collected at the 16-ft depth from Boring No. 1620, therefore, should not be used in characterizing the berm soil.

Subsurface Soil

Radiological analyses on soil from the slant borings yielded Pb-210, Po-210, Ra-226, Th-230, U-234, and U-238 at concentrations significantly above background. Concentration ranges are Pb-210 (0.46 to 101 pCi/g), Po-210 (0.938 to 86.5 pCi/g), Ra-226 (0.61 to 206 pCi/g), Th-230 (0.80 to 53.7 pCi/g), U-234 (0.8 to 35.9 pCi/g), and U-238 (0.76 to 53.4 pCi/g). In general, elevated concentrations of radiological contaminants were found near the interface of the berm soil with the pre-existing surface soil and near the base of the silos at their perimeter. The data suggest potential spillage on pre-existing surface soils and potential leakage of the silo underdrains to the subsurface soils in the immediate vicinity of Silos 1 and 2.

Metals analyses were performed on 13 samples from the slant borings. Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, cyanide, iron, lead, molybdenum, nickel, selenium, silver, sodium, thallium, and zinc were detected at concentrations above background or represent elements for which no background is available.

Only seven volatile and three semivolatile organic compounds were detected in the slant borings. Of 13 samples, organics were detected in very low concentrations in no more than four samples. Most are common laboratory contaminants.

As part of the RI, radiological analyses were performed on 12 subsurface soil samples collected from two borings within Operable Unit 4 and eight borings immediately adjacent to Operable Unit 4. Furthermore, 16 subsurface soil samples were collected from six borings located in trenches to the west of Silos 1 and 3.

In general, subsurface soil contained concentrations of uranium and progeny at levels less than 4.0 pCi/g. The data indicate that soil contamination in Operable Unit 4, outside of the areas immediately adjacent to and under Silos 1 and 2, is limited primarily to the surface. There appears to be no contamination from the surface through the vadose zone except in samples collected from

trenches located west of the silos. Above background uranium concentrations at depths up to 4.6 m (15 ft) below the surface indicate that this area may be contaminated with construction debris.

Perched Groundwater

Perched groundwater data consist of RI samples collected from the slant borings under Silos 1 and 2, RI and FEMP Environmental Monitoring Program samples collected from five shallow wells located in or near the Operable Unit 4 Study Area, and samples collected for the "Additional Characterization of Vadose and Perched Water in the K-65 Area."

The data show that perched groundwater contamination whose constituents are consistent with those of silo leachate is present in a well defined area directly beneath and to the west of Silos 1 and 2. Perched groundwater contamination, containing U-238 contamination in the range of 1.1 to 1313 pCi/L, is migrating to the west toward Paddys Run from the areas beneath Silos 1 and 2. Data indicates the perched water is not seeping into Paddys Run or the Great Miami Aquifer. Contaminant concentration in the perched water is much less than that in the perched water from the former Production Area, which is currently subject to a removal action. In fact, the concentration of contaminants in the Operable Unit 4 perched water is below the action levels for former Production Area perched water. Data from the "Additional Characterization" program completed after submittal of the RI report for Operable Unit 4 confirm previous findings (See Tables A.3-19 through A.3-22 in Appendix A). Additionally, new perched water data indicates the presence of constituents consistent with those found in the decant sump tank. Elevated levels of radium indicate that the decant sump tank and/or associated piping are leaking.

Great Miami Aquifer Groundwater

Groundwater data from the Great Miami Aquifer consist of samples from three 2000-series wells and two 3000-series wells. Great Miami Aquifer groundwater in the vicinity of Operable Unit 4 flows to the east. 2000-series wells, both upgradient and downgradient of Operable Unit 4, show similar uranium concentrations in the range of less than 1 $\mu$g/L to 40 $\mu$g/L. 3000-series wells, both upgradient and downgradient of Operable Unit 4, show comparable uranium concentrations in the range of less than 1 to 15 $\mu$g/L. The data show no direct link between contamination in the Great Miami Aquifer and the contents of Operable Unit 4 silos.

Air

Air data consist of FEMP Environmental Monitoring Program quarterly radon monitoring results obtained during the period 1989 through 1992. Monitoring results were obtained from 24 sampling stations along the FEMP site perimeter, four sampling stations within the FEMP site proper, 13 sampling stations along the fence surrounding Silos 1 and 2, and eight sampling stations located along the perimeters of the Silos 1 and 2 domes. These data not only demonstrate the effectiveness of the K-65 Silos Removal Action conducted in November 1991, they also define the nature and extent of air contamination from radon emanating from Silos 1 and 2.

Fenceline monitoring for radon performed under the FEMP Environmental Monitoring Program shows small variations from year to year. For example, FEMP site boundary fenceline monitoring stations recorded annual average concentration for 1990 ranging from 0.4 to 1.5 pCi/L as compared to 0.5 to 1.0 pCi/L in 1989. These concentrations are, however, in the background range.

In November 1991, the FEMP site completed the K-65 Silos Removal Action. This removal action consisted of installing a layer of bentonite clay over the residues stored in Silos 1 and 2. While the action resulted in a significant reduction in direct radiation at the FEMP site fenceline, changes in radon concentrations at the fenceline were not discernable and remained at background levels. In the vicinity of Operable Unit 4, however, radon concentrations immediately outside Silos 1 and 2 were reduced by as much as a factor of 20.

Direct Radiation

Direct radiation data consist of quarterly direct radiation exposure data measured at 12 points along the FEMP site perimeter and at two points within the FEMP perimeter, northeast of the former Production Area. A comparison of the average quarterly direct radiation data for 1990 with those data from 1992, which represent the one-year periods before and after the K-65 Silos Removal Action, show a substantial reduction in direct radiation along the FEMP site fenceline.

Natural background radiation measurements for the areas surrounding the FEMP ranged from 6.1 to 6.9 millirem (mrem)/hour during 1990. During 1990, the FEMP site perimeter monitoring station, which exhibited the highest average radiation exposure rate (12.6 mrem/hour) was located 335 m (1100 ft) directly west of Operable Unit 4. The 1992 monitoring data for this location, after the removal action, yielded a dose rate of 5.2 mrem/hour. Thus, along the FEMP site perimeter, direct

radiation from Operable Unit 4 is no longer discernable above background. This condition equates to no additional risks posed to a member of the general public at the fenceline.

The data presented herein have been reviewed and found adequate to meet the objectives established in Section 2.0 to determine the nature and extent of contamination within Operable Unit 4. That is, source terms are sufficiently defined and the extent of contaminant migration sufficiently characterized to support identification and evaluation of remedial action alternatives that may be deemed necessary to address migration of contamination originating from Operable Unit 4.

## 1.6 SUMMARY OF SITE RISKS

The chemical and radiological constituents present within the stored waste inventories and environmental media on the FEMP site and within the Operable Unit 4 Study Area present certain risks to human and environmental receptors. The type and degree of this risk has been estimated for existing, or baseline, conditions using EPA risk assessment methodology.

A baseline risk assessment estimates the risks that could occur in and around the FEMP site in the event no further cleanup actions are taken. These risks are evaluated for the situation as it presently exists and for how it could exist up to 1000 years in the future.

The baseline risk assessment is completed for three land use scenarios. The Current Land Use with Access Controls scenario examines potential risks to human health under existing land use conditions as a DOE industrial type facility with security forces and fences to limit access to the facility. The Current Land Use Without Access Controls scenario estimates potential risks attributable to site contaminants if the FEMP site was to remain an industrial facility, but with the access controls being discontinued. Lastly, a Future Land Use scenario is examined. Under this scenario, the FEMP site is assumed to be transferred to an agricultural farming land use where a family farm is hypothetically placed within the boundary of the FEMP site. These land use scenarios are examined to provide a bounding of the potential risks attributable to the site. Under all of these land use scenarios, assumptions are made to account for the potential impacts due to the expected deterioration of manmade waste containment structures presently in use at the site.

Baseline risks at the FEMP have been evaluated for both the site as a whole and on an operable unit basis. The following is a brief summary of the results of these risk assessments.

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### 1.6.1 Preliminary Site-Wide Baseline Risk Assessment

A preliminary site-wide baseline risk assessment was prepared for the FEMP and included as part of the SWCR. The objective of this baseline risk assessment was to present the site-wide risks for the current and potential future land use scenarios under existing conditions, i.e., assuming no further remedial response actions are implemented. The risk assessment characterizes the current and potential future threat to human health and the environment that may be posed by all hazardous constituents and all viable exposure pathways from the FEMP site. The preliminary site-wide baseline risk assessment was based on all data pertaining to the FEMP site, which were available as of December 1, 1991. The preliminary site-wide risk assessment includes an assessment of the ecological impacts of the FEMP and is supplemented by a NEPA analysis of the environmental consequences of the no-action alternative.

To support the risk assessment, available data were compiled and evaluated to characterize the site and to select the constituents of concern (COC). The results of the compilation and statistical evaluation of the data is embodied within the SWCR and will not be repeated here. On the basis of the compiled data and summary statistics, the risks associated with the viable pathways for exposure of the site contaminants to human and environmental receptors were characterized employing the methodology identified in the Risk Assessment Work Plan Addendum (DOE 1992).

For Current Land Use with Access Controls conditions, the highest calculated risk to human receptors due to the presence of radiological constituents at the FEMP site exceeded an Incremental Lifetime Cancer Risk (ILCR) of $1 \times 10^{-4}$ for a farmer hypothetically located off the FEMP site and using groundwater for consumption and irrigation. Risks were similar under the same land use scenario to a hypothetical trespassing child. CERCLA generally regards an ILCR from a waste site in the range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ to be acceptable and the ILCR of $1 \times 10^{-6}$ as a point of departure (i.e., the waste site is unavailable for unrestricted use). The highest ILCR for chemical constituents under the Current Land Use with Access Controls scenarios was calculated to approximate $1 \times 10^{-3}$ for the same off-property farmer.

Hazard indices (HI) were calculated to provide an indication of the risks due to presence of noncarcinogenic constituents of concern. An HI of less than one for exposures to a given receptor from all constituents of concern is generally regarded as acceptable. The calculated HI for the hypothetical off-property farmer under the Current Land Use with Access Controls scenarios exceeded 1500, primarily due to the intake of cadmium.

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For the Current Land Use Without Access Control scenario, the highest calculated ILCR for radiological constituents approached $1x10^{-2}$ for external radiation exposures to the hypothetical trespassing child and exceeded $1x10^{-4}$ for the off-property farmer using groundwater for consumption and irrigation. For chemical carcinogens, the highest calculated ILCR associated with this land use scenario approached $1x10^{-4}$ for the hypothetical trespassing child. An HI of 1.7 (primarily due to the presence of arsenic) was calculated for this same trespassing child.

For the Future Land Use scenario (which assumes the site is transferred to a family farm and no further clean up takes place), the highest calculated ILCR for radiological constituents exceeded 1 x $10^{-1}$ to the hypothetical on-property farmer. Similarly, the calculated ILCR to the on-property farmer due to the presence of nonradiological carcinogenic constituents approaches $1x10^{-1}$. The HI for the on-property farmer exceeded 2400, primarily due to the presence of arsenic.

As part of the preliminary site-wide baseline risk assessment, an evaluation was completed to estimate the risks due to the presence of naturally occurring or background constituents. Such risks were calculated for the hypothetical on-property farmer. The aggregate ILCR due to the presence of the naturally occurring concentrations of radiological constituents (i.e., uranium and thorium decay products) was calculated to approach $1x10^{-3}$. The highest calculated risk from a single radionuclide and pathway to this receptor was about $1x10^{-3}$ and was due to the inhalation of ambient concentrations of radon (Rn)-222 in air. Background concentrations of naturally occurring noncarcinogenic metals yielded HI which exceeded 0.2 to this same receptor for nine of these elements: arsenic (0.3), mercury (4.2), molybdenum (0.4), silver (1.2), thallium (6), and zinc (3).

### 1.6.2 Site-Wide Baseline Ecological Risk Assessment

The purpose of the ecological risk assessment, which was completed as a companion to the preliminary site-wide baseline risk assessment in the SWCR, was to estimate the potential and future baseline risks of FEMP contaminants to ecological receptors.

The EPA and DOE have agreed in the Amended Consent Agreement (September 1991) that the Site-Wide Ecological Risk Assessment will be performed as part of the RI for Operable Unit 5. The Site-Wide Ecological Risk Assessment in the RI for Operable Unit 5 will quantify and assess the possible risks from current concentrations of site contaminants to ecological receptors inhabiting on-site and off-site areas not presently targeted for remediation based on human-health concerns. More

discussion on the Risk Assessment and Ecological Risk issues specific to Operable Unit 4 can be found in the Operable Unit 4 Proposed Plan.

The ecological receptors potentially exposed to FEMP contaminants include all organisms, exclusive of humans and domestic animals. The ecological risk assessment focused on a group of indicator species selected to represent a variety of exposure pathways and trophic positions. Terrestrial vegetation was represented by a generic plant species. Terrestrial wildlife species to be evaluated were selected based on species abundance on the FEMP site, trophic level position, and habitat requirements. The species evaluated were the white-tailed deer (*Odocoileus virginianus*), white-footed mouse (*Peromyscus leucopus*), racoon (*Procyon lotor*), red fox (*Vulpes fulva*), muskrat (*Ondatra zibethica*), American robin (*Turdus migratorius*), and red-tailed hawk (*Buesto jamaicensis*).

The assessment examined risks to terrestrial organisms associated with contaminants in two environmental media -- surface soils, summarized for the entire site, and surface water in Paddys Run from the northern boundary of the FEMP site to the confluence with the storm sewer outfall ditch. Risks to aquatic organisms were evaluated for exposure to contaminants in Paddys Run, the Great Miami River, and in runoff into the storm sewer outfall ditch. All nonradioactive and radioactive constituents of greatest human health risk were considered to be of concern for the ecological risk assessment. Estimated ecological risks associated with exposure to FEMP site COCs are primarily due to nonradioactive inorganic chemicals in soils, rather than to organic chemicals or radionuclides. This is true for both terrestrial and aquatic organisms and for plants as well as wildlife. In particular, estimated intakes of arsenic, cobalt, lead, and silver from FEMP soils were all higher than the estimated No Observed Effect Levels (NOELs) for at least six of the seven indicator species selected for this assessment. The relative hazards to individual species varied, but the white-footed mouse consistently had the highest indices of these chemicals. This can be attributed to the assumed intake by the mouse of insects (using earthworms as surrogates), which in turn were assumed to assimilate chemicals from soil with a transfer coefficient of 1.0.

Estimated hazards to terrestrial organisms of exposure to COCs in FEMP surface waters were relatively low, with HIs greater than one only for arsenic, lead, molybdenum, and silver. These chemicals presented hazards of two, five, four and three to species, respectively, and the highest HI estimated was for lead intake by the mouse.

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Estimated doses to terrestrial organisms at the FEMP site, originating from soil uptake by plants and earthworms, were below levels expected to cause detectable effects. However, as with inorganic chemicals, this conclusion is sensitive to assumptions about muscle-to-muscle transfer of radionuclides. If perfect transfer or biomagnification of uranium occurs (i.e., transfer factor equals 1.0), it could expose terrestrial wildlife at the FEMP to potentially harmful radiation levels. However, if more realistic muscle-to-muscle transfer coefficient were assumed (i.e., 0.1), the estimated radiation doses would fall below the range likely to result in harmful effects. Radiation doses due to water intake were insignificant.

Exposure to radiological contaminants does not appear to pose a significant risk to aquatic organisms at the measured concentrations in the surface waters and sediments impacted by the FEMP site. However, modeled concentrations of radionuclides in runoff from the FEMP site into surface water would cause estimated exposures to exceed the upper limit of 1 rad/day. A chronic dose rate of 1 rad/day or $3.65 \times 10^{-5}$ mrad/year or less to the maximally exposed member of a population of aquatic organisms would ensure that there were no deleterious effects from radiation on the population. The most affected organisms would be aquatic plants, receiving a total dose from internal and external exposure of about 140 rad/day. The total dose to fish is minimally over the limit, at 1.6 rad/day, and the total dose to benthic macroinvertebrates is about 14 rad/day. The maximum concentrations calculated in the storm sewer outfall ditch were used in source runoff calculations. Doses to aquatic organisms in the storm sewer outfall ditch may exceed the limit of 1 rad/day. Doses in Paddys Run and the Great Miami River would be lower than that indicated in the storm sewer outfall ditch and would be well below 1 rad/day. The measured concentrations of cadmium in Paddys Run and the Great Miami River, copper in the Great Miami River, mercury in Paddys Run, the Great Miami River, and the storm sewer outfall ditch, and silver in Paddys Run water exceeded chronic toxicity criteria for the protection of freshwater organisms.

Field studies on the impact of the FEMP site on terrestrial and aquatic communities do not indicate any effects consistent with contaminant impacts except for above-background levels of arsenic and mercury recorded in RI/FS plant samples. In addition, although potential impacts at the individual level were predicted for wildlife species, detrimental or adverse impacts have not been observed in the field. This suggests that the potential exposures predicted by modeling may not occur in the field or that the resulting potential effects as a result of exposures may not occur. A comparison of the concentrations of inorganic chemical concentrations in FEMP soils to regional background values indicate the mean FEMP concentrations may be similar to the upper 95 percent confidence levels of

background values. This indication suggests that ecological risks estimated using background values of inorganics would be comparable to those estimated for the FEMP site, and emphasizes the conservative nature of the method used.

In summary, although radionuclides are the most ubiquitous contaminants at the FEMP, estimated ecological risks to both terrestrial and aquatic organisms are primarily associated with nonradioactive inorganic chemicals. Although estimated risks are substantial in some instances, they are based on soil inorganic chemical concentrations comparable to background levels, and deleterious effects have not been observed in the field. This suggests that current FEMP site-specific ecological risks are low. However, remedial actions are appropriate to address contaminants which have potential to cause harm in the future.

### 1.6.3 Operable Unit 4 Baseline Risk Assessment

This section summarizes the results of the Operable Unit 4 baseline risk assessment as presented in the RI Report for Operable Unit 4.

The baseline risk assessment is a process that estimates the human health risk associated with exposure to the chemical sources in Operable Unit 4 under the no-action alternative. The process quantifies the health risks to hypothetical receptors due to exposure from chemical sources in Operable Unit 4. The process analyzes the health consequences that could occur under different scenarios if no remedial actions are taken to address these identified environmental concerns. The baseline risk is the fundamental measure used to make comparisons against any changes that occur when various remedial alternatives are proposed to reduce the exposure levels of these chemicals. A health risk is calculated under each of the proposed remedies, and the resulting values are compared with the baseline value to identify where the reduction in human health risk is greatest. The process thereby provides a measure of the relative effectiveness of the different proposed remedial alternatives and their ability to reduce the risk to human health.

Baseline risks were calculated under two source-term scenarios to evaluate potential exposures to hypothetical receptors under the three land use scenarios previously described in Section 1.6. The "current source term" scenario evaluates potential exposure to current sources within Operable Unit 4, including surface and berm soil, airborne contaminants, and surface water. The "future source term" scenario evaluates additional sources that could result in the event that the Silo 3 structure collapsed and Silos 1 and 2 domes failed. Sources under the future source term scenario include contaminated

groundwater and sediment, in addition to Silo 3 residues within the soil, air, and surface water. Under the current land use without access control and the future land use scenarios, risks are calculated for both the current source-term scenario and the future source-term scenario. Under the current land use with access control scenario, the future source-term scenario does not exist; if the site remains under the institutional control of DOE, the silos will be maintained to assure they will not fail. Thus, under the current land use with access control scenario, risk was calculated only for the current source-term scenario.

In summary, the five land use/source-term scenario combinations evaluated under the baseline risk assessment included:

| Land Use Scenario | Source-Term Scenario |
|---|---|
| 1. Current Land Use Without Access Control | Current Source Term |
| 2. Current Land Use Without Access Control | Future Source Term |
| 3. Current Land Use with Access Control | Current Source Term |
| 4. Future Land Use | Current Source Term |
| 5. Future Land Use | Future Source Term |

Under the Current Land Use Without Access Controls scenarios in which the FEMP site is assumed to have been turned over to an industrial concern other than the DOE, potential receptors evaluated included an off-property farmer, a trespassing child, an on-property worker (groundskeeper), and an off-property user of surface water from the Great Miami River.

Under the Current Land Use with Access Controls scenarios where the site is assumed to remain under federal ownership and access restrictions continued, the potential receptors considered included an off-property farmer, a trespassing child, and an off-property user of surface water from the Great Miami River.

For the Future Land Use scenario where access controls are assumed to be absent, hypothetical receptors evaluated included a Reasonable Maximum Exposure (RME) resident farmer, a central tendency (CT) resident farmer, a resident child, an off-property farmer, and an off-property user of surface water from the Great Miami River.

The RME resident farmer considered under this scenario represents the maximum potential exposure to chemical and radiological constituents that a hypothetical on-property farmer could reasonably be expected to receive through viable pathways. The CT resident farmer is similar to the RME resident

farmer except that risk assessment parameter values employed to calculate risks to this hypothetical receptor are adjusted to more closely reflect what an average person would normally receive from site contaminants through the same pathways.

The risk characterization results from the Operable Unit 4 risk assessment are presented in Tables 1-6 and 1-7. The tables summarize maximum radiological and chemical risks, as well as cumulative risk for each receptor by exposure scenario. Table 1-6 provides ILCR estimates for these exposure scenarios for both the current and future source-terms. The largest reported radiological risk values are from the silo and sediment environmental media. Table 1-7 provides the HIs for noncarcinogenic constituents for each receptor by exposure scenario.

Of the scenarios evaluated, the current land use with access controls/current source-term scenario most closely approximates current conditions at the FEMP site. However, conservative assumptions were made in the evaluation of this scenario, consistent with those made for other scenarios, to ensure that the calculated baseline risk represents an upper bound. ILCR and HI results for this scenario are numerically the same as the results for the current land use scenario without access controls assuming the current source term; the presence or absence of access controls does not change the numerical values of exposure parameter values for receptors.

Under this scenario, the dominant radiological risk ($5.0 \times 10^{-3}$) is to the trespassing child from Ra-226 plus progeny in soil and external radiation from the intact silos. The dominant chemical risk ($4.0 \times 10^{-5}$) is to the off-property resident farmer due to ingestion of Indeno(1,2,3-cd)pyrene through meat and milk exposure routes, which is transported via the air pathway. The total calculated risk under this scenario is $5.0 \times 10^{-3}$.

The highest HI is 1.0 to the trespassing child, due primarily to antimony, chromium, and uranium in soil.

Of the remaining scenarios, the future land use/future source-term scenario represents the most conservative scenario considered under the baseline risk assessment. Within this scenario, a family is assumed to have established a residence within the Operable Unit 4 boundaries. Additionally, the domes of Silos 1 and 2 are assumed to have failed and Silo 3 is assumed to have suffered total structural failure, spreading its contents to the surface soil of Operable Unit 4. The dominant radiological risk under this scenario approaches unity (1). The highest risk is to the RME

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# TABLE 1-6

## INCREMENTAL LIFETIME CANCER RISK SUMMARY ALL SOURCES/ALL PATHWAYS

| Land Use/ Source Term Scenario | Type of Risk | Trespassing Child | Groundskeeper | Off-Property Resident Farmer | Off-Property User of Surface Water | CT On-Property Resident Farmer | RME On-Property Resident Farmer | On-Property Resident Child |
|---|---|---|---|---|---|---|---|---|
| Current Land Use without Access Control/Current Source Term Scenario | Radiological Risk | $5.0 \times 10^{-3}$ | $1.0 \times 10^{-4}$ | $1.0 \times 10^{-8}$ | $1.0 \times 10^{-7}$ | NA[a] | NA | NA |
| | Chemical Risk | $1.0 \times 10^{-5}$ | $2.0 \times 10^{-5}$ | $4.0 \times 10^{-5}$ | $1.0 \times 10^{-7}$ | NA | NA | NA |
| | Total Risk | $5.0 \times 10^{-3}$ | $1.0 \times 10^{-4}$ | $4.0 \times 10^{-5}$ | $3.0 \times 10^{-7}$ | NA | NA | NA |
| Current Land Use without Access Control/Future Source Term Scenario | Radiological Risk | $9.0 \times 10^{-3}$ | $2.0 \times 10^{-2}$ | $1.0 \times 10^{-5}$ | $1.0 \times 10^{-6}$ | NA | NA | NA |
| | Chemical Risk | $7.0 \times 10^{-4}$ | $5.0 \times 10^{-4}$ | $1.0 \times 10^{-4}$ | $7.0 \times 10^{-7}$ | NA | NA | NA |
| | Total Risk | $1.0 \times 10^{-2}$ | $2.0 \times 10^{-2}$ | $1.0 \times 10^{-4}$ | $2.0 \times 10^{-6}$ | NA | NA | NA |
| Current Land Use with Access Control/Current Source Term Scenario | Radiological Risk | $5.0 \times 10^{-3}$ | NA | $1.0 \times 10^{-8}$ | $1.0 \times 10^{-7}$ | NA | NA | NA |
| | Chemical Risk | $1.0 \times 10^{-5}$ | NA | $4.0 \times 10^{-5}$ | $1.0 \times 10^{-7}$ | NA | NA | NA |
| | Total Risk | $5.0 \times 10^{-3}$ | NA | $4.0 \times 10^{-5}$ | $3.0 \times 10^{-7}$ | NA | NA | NA |
| Future Land Use/Current Source Term Scenario | Radiological Risk | NA | NA | $1.0 \times 10^{-8}$ | $1.0 \times 10^{-7}$ | $4.0 \times 10^{-4}$ | $4.0 \times 10^{-3}$ | $9.0 \times 10^{-3}$ |
| | Chemical Risk | NA | NA | $4.0 \times 10^{-5}$ | $1.0 \times 10^{-7}$ | $5.0 \times 10^{-3}$ | $7.0 \times 10^{-2}$ | $5.0 \times 10^{-2}$ |
| | Total Risk | NA | NA | $4.0 \times 10^{-5}$ | $3.0 \times 10^{-7}$ | $5.0 \times 10^{-3}$ | $7.0 \times 10^{-2}$ | $6.0 \times 10^{-2}$ |
| Future Land Use/ Future Source Term Scenario | Radiological Risk | NA | NA | $1.0 \times 10^{-5}$ | $1.0 \times 10^{-6}$ | $1.0 \times 10^{-1}$ | $1.0 \times 10^{0}$ | $1.0 \times 10^{-1}$ |
| | Chemical Risk | NA | NA | $1.0 \times 10^{-4}$ | $7.0 \times 10^{-7}$ | $1.0 \times 10^{-2}$ | $2.0 \times 10^{-1}$ | $8.0 \times 10^{-2}$ |
| | Total Risk | NA | NA | $1.0 \times 10^{-4}$ | $2.0 \times 10^{-6}$ | $1.0 \times 10^{-1}$ | $>1.0$ | $2.0 \times 10^{-1}$ |

[a]NA signifies not applicable.



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## TABLE 1-7

## HAZARD INDEX SUMMARY ALL SOURCES/ALL PATHWAYS

| Land Use/ Source Term Scenario | Type of Risk | Trespassing Child | Groundskeeper | Off-Property Resident Farmer | Off-Property User of Surface Water | CT On-Property Resident Farmer | RME On-Property Resident Farmer | On-Property Resident Child |
|---|---|---|---|---|---|---|---|---|
| Current Land Use without Access Control/Current Source Term Scenario | Chemical Hazard Index | 1.0 | 0.1 | 0.05 | 0.0004 | NA* | NA | NA |
| Current Land Use without Access Control/Future Source Term Scenario | Chemical Hazard Index | 60.0 | 20.0 | 5.0 | 0.002 | NA | NA | NA |
| Current Land Use with Access Control/Current Source Term Scenario | Chemical Hazard Index | 1.0 | NA | 0.05 | 0.0004 | NA | NA | NA |
| Future Land Use/Current Source Term Scenario | Chemical Hazard Index | NA | NA | 0.05 | 0.0004 | 6.0 | 10.0 | 70.0 |
| Future Land Use/Future Source Term Scenario | Chemical Hazard Index | NA | NA | 5.0 | 0.002 | 200 | 400 | 2000 |

*NA signifies not applicable.





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on-property resident farmer and is due to external radiation exposure to concentrations of Ra-226 and Th-228 in soils. The dominant chemical risk ($2.0 \times 10^{-1}$) is also to the RME on-property resident farmer and is due primarily to ingestion of arsenic and indeno (1,2,3-cd) pyrene through the meat and milk ingestion exposure routes. The total risk to the RME on-property resident farmer exceeds unity and is due primarily to the radiological risk associated with external exposure from Ra-226 and Th-228 in soil. The highest HI (2000) under this scenario is to the on-property resident child and is due primarily to ingestion of soil and foodstuffs along with dermal contact with soil materials containing arsenic.

# 2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

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## 2.1 INTRODUCTION

Identification, screening, and evaluation of potentially applicable technologies and process options are key steps in the FS process. The primary objective of this phase of the FS is to develop an appropriate range of remedial technologies and process options that will be developed into preliminary remedial alternatives. The criteria for identifying potentially applicable technologies are provided in EPA guidance (EPA 1988b) and in the NCP (EPA 1990). There is strong statutory preference for remedies that will result in a permanent solution; a significant decrease in toxicity, mobility, or volume; and provide long-term protection as identified in Section 121 of CERCLA, as amended. The primary requirements for the final remedy are that it be both protective of human health and the environment and comply with applicable or relevant and appropriate regulatory requirements.

This section discusses the development and screening of the technologies and process options used to assemble the remedial action alternatives for Operable Unit 4. The technology screening process consists of a series of analytical steps that involve making successively more specific definitions of potential remedial activities. The steps include the following:

- Identification of volumes or areas of media
- Development of Remedial Action Objectives (RAOs)
- Identification of general response actions
- Identification and screening of remedial technologies and process options
- Evaluation and selection of process options

Figure 2-1 illustrates the general flow of the FS process and relates the process elements to the relevant section of this FS Report for Operable Unit 4.

The information in Section 2.0 is presented in a format consistent with EPA RI/FS guidance (EPA 1988b). In brief, Section 2.2 presents the development of RAOs for the media of concern in Operable Unit 4, including an estimate of the volume and area of contamination. Also addressed in Section 2.2 are preliminary remediation goals (PRGs) by media or cleanup criteria, where appropriate. Section 2.3 identifies components of Operable Unit 4 areas as subunits. Section 2.4 identifies the general response actions (GRAs) that could meet the RAOs identified in Section 2.2. Section 2.5 identifies the full range of potentially applicable technologies and associated process options and screens them based upon technical feasibility. Technologies and process options which

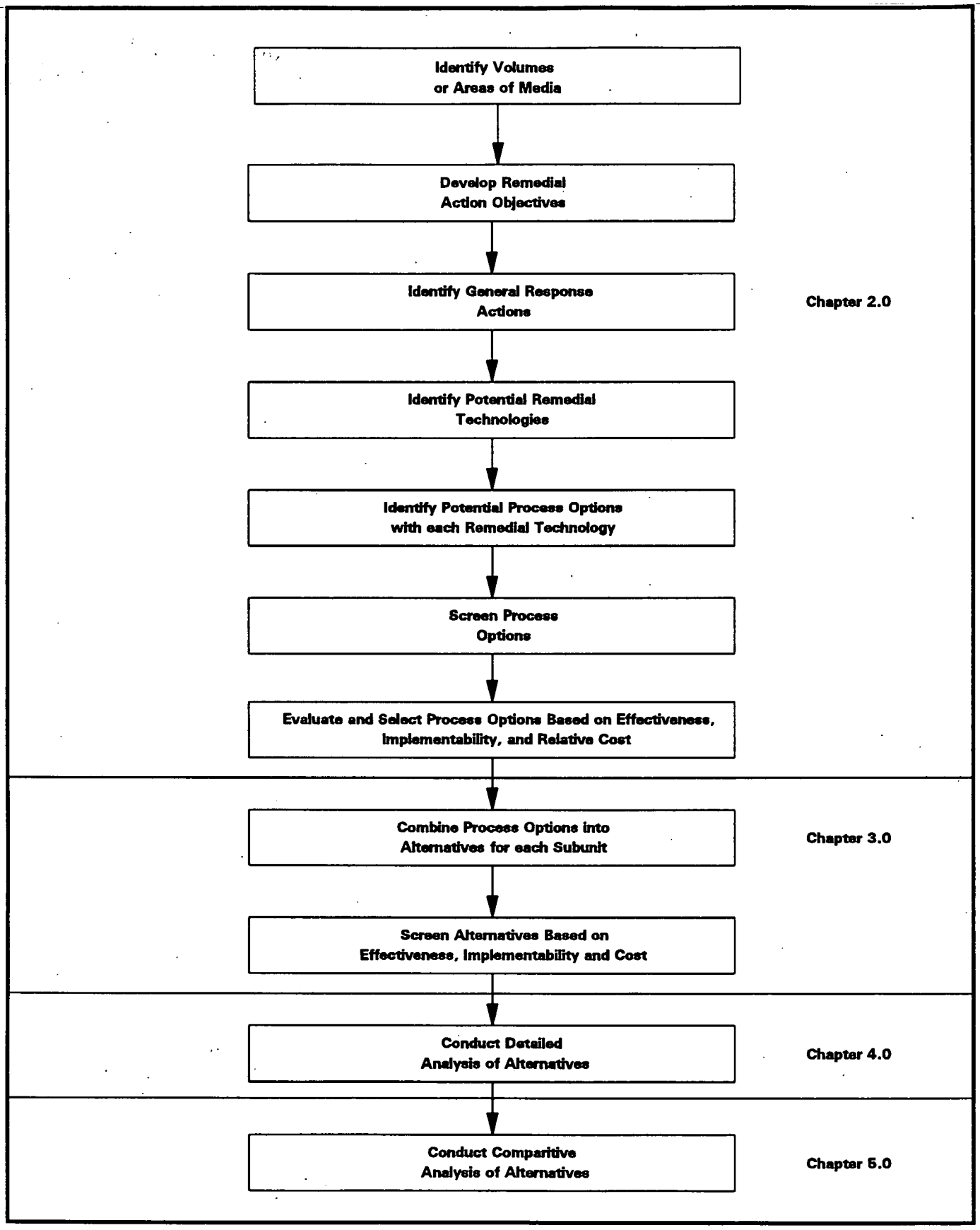


**FIGURE 2-1**
**ELEMENTS OF THE FS PROCESS**

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pass the initial screening are evaluated in Section 2.6 against the criteria of effectiveness, implementability, and cost to select representative options for alternatives.

## 2.2 REMEDIAL ACTION OBJECTIVES

RAOs are site-specific, qualitative goals that define the objective of taking remedial actions. RAOs specify:

- The constituents of concern
- Exposure route(s) and receptor(s)
- An acceptable contaminant level or range of levels for each exposure route (i.e., a PRG)

Because RAOs for protecting environmental receptors typically seek to preserve or restore a resource (e.g., groundwater and surface soil), they are expressed in terms of the medium of interest and target cleanup levels whenever possible (EPA 1988b).

Potential risks associated with exposures due to Operable Unit 4 contamination were assessed in considerable detail in the RI Report for Operable Unit 4 (DOE 1993c) to identify those media that should be addressed to achieve RAOs. From this assessment, contaminated media contained in Operable Unit 4 were identified:

- Waste material including K-65 residues, also known as "hot raffinates," contained in Silos 1 and 2 and the decant sump tank; and metal oxides, also known as "cold metal oxide," contained in Silo 3

- Structural material and equipment including concrete and metal structural materials used in the construction of Silos 1, 2, and 3, and contaminated equipment including the decant sump tank, process piping, process piping trench material, and existing RTS equipment

- Soil within the Operable Unit 4 boundaries including surface soil around the silos, subsurface soil beneath the silos and around pipe trenches, and berm soil around Silos 1 and 2

- Residual water including water contained in the decant sump tank, any water contained in Silo 4, and perched groundwater that may be encountered during potential remedial actions within the Operable Unit 4 boundaries

With the exception of perched water encountered during potential remedial actions, surface water and groundwater are not addressed as source media within this FS Report for Operable Unit 4. With regard to surface water, there are no surface water impoundments within Operable Unit 4. Thus,

surface water runoff during a rain event is not a source, but acts only as a transport mechanism for surface soil contamination. Potential remediation of groundwater contamination for the entire FEMP site is being addressed as part of Operable Unit 5. Thus, within this FS Report, groundwater is considered as an environmental receptor medium but not as a source term for which remedial actions are addressed. A preliminary volume estimate for materials considered for remediation under Operable Unit 4 is presented in Table 2-1. It should be noted that process knowledge clearly indicates that Silo 4 has never been used at the FEMP to store product or waste materials. On this basis, none of the estimated 510 $m^3$ (670 $yd^3$) of construction materials comprising Silo 4 are considered a source of contamination. However, because no free-release criteria have been established for concrete, Silo 4 concrete would be managed in a manner consistent with concrete from Silos 1, 2, and 3.

To address the above three requirements, the development of RAOs is presented in three parts. First, the constituents of concern, by media, are identified. Second, allowable exposures in terms of the medium of interest are identified, and PRGs are established for environmental media. Third, these data are used to develop RAOs.

### 2.2.1 Constituents of Concern

Not all constituents identified during the Operable Unit 4 RI pose significant health risks. The Baseline Risk Assessment evaluated constituents and exposure pathways to ascertain their potential present and future impacts on human health. Methods for establishing COCs are defined in Appendix D of the RI Report for Operable Unit 4. In general, constituents that resulted in risks to a receptor of greater than $10^{-6}$ or which yielded a HI greater than 0.2 were designated as COCs.

Radiological COCs, by media, are shown in Table 2-2. Chemical COCs, by media, are shown in Table 2-3.

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## TABLE 2-1

## MATERIAL VOLUME ESTIMATES
## OPERABLE UNIT 4

| Media | Volume | | |
|---|---|---|---|
| **Waste Material** | Waste Residue | Bentonite Clay | Total Waste |
| Silo 1 contents[a] | 4,293 $yd^3$ | 467 $yd^3$ | 4,760 $yd^3$ (3,640 $m^3$) |
| Silo 2 contents[a] | 3,719 $yd^3$ | 411 $yd^3$ | 4,130 $yd^3$ (3,150 $m^3$) |
| Silo 3 contents[b] | 5,088 $yd^3$ | | 5,088 $yd^3$ (3,890 $m^3$) |
| Decant sump tank sludge[b] | | | 1,000 gallons (3,785 L) |
| **Structural Material and Equipment[c]** | | | |
| Silo 1, 2, and 3 structures | | | 2,000 $yd^3$ (1,530 $m^3$) |
| Silo 4 structure | | | 670 $yd^3$ (510 $m^3$) |
| Decant sump tank, process piping, process piping trenches, radon treatment system | | | 370 $yd^3$ (280 $m^3$) |
| Drum handling building pad, sump lift station concrete | | | 30 $yd^3$ (20 $m^3$) |
| **Soil** | | | |
| Berm soil[d] | | | 10,540 $yd^3$ (8,060 $m^3$) |
| Surface soil[e] | | | 4,440 $yd^3$ (3,400 $m^3$) |
| Subsoil[f] | | | 14,650 $yd^3$ (11,200 $m^3$) |
| **Residual Water** | | | |
| Decant sump tank water[g] | | | 8000 gallons (30,280 L) |
| Residual water (Silo 4)[h] | | | 13,000 gallons (49,210 L) |
| Water encountered during remedial actions | | | Unknown |

[a]Volume estimate based on silo surface mapping results
[b]Volume estimate based on visual observations during sampling operations
[c]Volume estimate based on available construction drawings.
[d]Volume estimate based on quantity of soils comprising berms
[e]Volume estimate based on soil depth of 6 inches across entire OU4 area
[f]Volume estimate based on soil depth of 5 feet extending beneath Silos 1 and 2 to toe of berm, includes 5 foot soil depth beneath decant sump tank
[g]Assumes refilling of decant sump tank by infiltrating liquid after the most recent pumping of the decant sump tank as a maintenance action (January 1993).
[h]Volume assumed to collect based on historical in-leakage of rainwater through silo dome.

## TABLE 2-2

## RADIOLOGICAL CONSTITUENTS OF CONCERN
## OPERABLE UNIT 4

| | Silos 1 & 2 | Silo 3 | Structure/ Equipment[a] | Soil | Residual Water[b] |
|---|---|---|---|---|---|
| Actinium-227 | X | X | X | NA | X |
| Lead-210 | X | X | X | X | X |
| Polonium-210 | X | c | X | X | X |
| Protactinium-231 | X | X | X | NA | X |
| Radium-224 | d | X | X | e | X |
| Radium-226 | X | X | X | X | X |
| Radium-228 | d | X | X | X | X |
| Strontium-90 | NA | NA | NA | X | X |
| Technetium-99 | NA | NA | NA | X | X |
| Thorium-228 | X | X | X | X | X |
| Thorium-230 | X | X | X | X | X |
| Thorium-232 | X | X | X | X | X |
| Uranium-234 | X | X | X | X | X |
| Uranium-235/236 | X | X | X | NA | X |
| Uranium-238 | X | X | X | X | X |

[a]No samples were collected from structures/equipment; however, it is assumed that constituents present in silos have permeated into the concrete structure.
[b]Constituents are primarily based on results of decant sump tank sampling. In addition, constituents detected in silos are assumed to be present in residual water.
[c]This radionuclide is not listed as a constituents of concern in the RI Baseline Risk Assessment; however, the risk contribution is included in the risk calculations for Pb-210 plus progeny.
[d]Ra-224 is not listed as a constituents of concern in the RI Baseline Risk Assessment; however, the risk contribution is included in the risk calculations for Th-228 plus progeny. Ra-224 and Ra-228 sample analytical results for the silos are reported as non-detections.
[e]Constituent detected once, and UTL test suggests that data are less than background while histogram comparison suggests concentration exceeds background. Also, given the fact that parents of this constituent are not constituents of concern, this constituent is assumed to be an anomaly.

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## TABLE 2-3

## CHEMICAL CONSTITUENTS OF CONCERN
## OPERABLE UNIT 4

| Chemical | Silos 1 & 2 | Silo 3 | Structure/ Equipment[a] | Soil | Residual Water[b] |
|---|---|---|---|---|---|
| **Inorganics** | | | | | |
| Antimony | X | NA | X | X | X |
| Arsenic | X | X | X | X | X |
| Barium | X | X | X | X | X |
| Beryllium | X | X | X | X | X |
| Boron | X | NA | X | NA | X |
| Cadmium | X | X | X | X | X |
| Chromium | X | X | X | X | X |
| Cobalt | X | X | X | NA | X |
| Copper | X | X | X | X | X |
| Cyanide | X | NA | X | X | X |
| Lead | X | X | X | NA | X |
| Manganese | NA | X | X | NA | X |
| Mercury | X | X | X | NA | X |
| Molybdenum | X | NA | X | X | X |
| Nickel | X | X | X | X | X |
| Selenium | X | X | X | NA | X |
| Silver | X | X | X | X | X |
| Thallium | X | X | X | X | X |
| Uranium | X[c] | X[c] | X | X[c] | X |
| Vanadium | X | X | X | X | X |
| Zinc | X | X | X | X | X |
| **Organics** | | | | | |
| 2-Butanone | X | NA | X | X | X |
| 2-Hexanone | X | NA | X | NA | X |
| 2-Nitrophenol | NA | X | X | NA | X |
| 4-Methyl-2-pentanone | X | NA | X | NA | X |

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**TABLE 2-3**
**(Continued)**

| Chemical | Silos 1 & 2 | Silo 3 | Structure/ Equipment[a] | Soil | Residual Water[b] |
|---|---|---|---|---|---|
| **Organics (Continued)** | | | | | |
| 4-Nitrophenol | NA | X | X | NA | X |
| Acenaphthylene | NA | NA | NA | X | X |
| Acetone | X | NA | X | X | X |
| Aldrin | X | NA | X | NA | X |
| Anthracene | NA | NA | NA | X | X |
| Aroclor-1248 | X | NA | X | NA | X |
| Aroclor-1254 | X | NA | X | X | X |
| Aroclor-1260 | X | NA | X | NA | X |
| Benzo(a)anthracene | NA | NA | NA | X | X |
| Benzo(a)pyrene | NA | NA | NA | X | X |
| Benzo(b)fluoranthene | NA | NA | NA | X | X |
| Benzo(g,h,i)perylene | NA | NA | NA | X | X |
| Benzoic acid | X | NA | X | X | X |
| Bis(2-ethylhexyl)phthalate | X | NA | X | X | X |
| Carbon tetrachloride | X | NA | X | NA | X |
| Chrysene | NA | NA | NA | X | X |
| 4,4'-DDE | X | NA | X | NA | X |
| 4,4'-DDT | X | NA | X | NA | X |
| Di-n-butyl phthalate | X | NA | X | X | X |
| Di-n-octyl phthalate | X | NA | X | NA | X |
| Dibenzo(a,h)anthracene | NA | NA | NA | X | X |
| Dieldrin | X | NA | X | NA | X |
| Diethyl phthalate | X | NA | X | NA | X |
| Dimethyl phthalate | X | NA | X | NA | X |
| Endosulfan I | X | NA | X | NA | X |
| Endosulfan II | X | NA | X | NA | X |
| Endrin | X | NA | X | NA | X |

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TABLE 2-3
(Continued)

| Chemical | Silos 1 & 2 | Silo 3 | Structure/ Equipment[a] | Soil | Residual Water[b] |
|---|---|---|---|---|---|
| **Organics (Continued)** | | | | | |
| Fluoranthene | X | NA | X | X | X |
| Heptachlor epoxide | X | NA | X | NA | X |
| Indeno(1,2,3-cd)pyrene | NA | NA | NA | X | X |
| Methylene chloride | X | NA | X | X | X |
| N-nitroso-di-n-propylamine | X | NA | X | NA | X |
| Phenanthrene | NA | NA | NA | X | X |
| Phenol | X | NA | X | X | X |
| Pyrene | X | NA | X | X | X |
| Tetrachloroethene | X | NA | X | NA | X |
| Toluene | X | NA | X | X | X |
| Tributyl phosphate | X | NA | X | NA | X |
| Xylenes (total) | X | NA | X | X | X |

[a]No samples collected from structures/equipment; however, it is assumed that constituents present in silos have permeated into the concrete structure.
[b]Constituents are primarily based on results of decant sump tank sampling. In addition, constituents detected in silos and soils are assumed to be present in residual water.
[c]Analysis for uranium by inductively coupled argon plasma was not performed; analysis by radiological methods was performed.

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### 2.2.2 Preliminary Remediation Goals

In the early stages of the RI/FS, as stated in the SWCR (DOE 1993d), PRGs are used as action levels to determine if constituents in the environment need to be further addressed. PRGs are not action levels for remedial actions. PRGs are chemical-specific, medium-specific concentration limits necessary to address all contaminants and all pathways found to be of concern during the Baseline Risk Assessment process. PRGs are based on the following:

- For chemical toxicants, an HI = 0.2
- For chemical and radiation carcinogens, an (ILCR) = $10^{-6}$
- For radionuclides, dose limit applicable or relevant and appropriate requirements (ARARs) and to be considered (TBCs) requirements
- Pertinent ARARs

PRGs must comply with ARARs and be protective of human health and the environment. However, ARARs do not exist for all COCs. Moreover, some ARAR-based PRGs are less stringent than PRGs based on a $10^{-6}$ to $10^{-4}$ risk range and, therefore, do not necessarily meet the "protectiveness of human health" objective. Therefore, both ARAR-based and risk-based PRGs have been developed for the FEMP site. Other ARAR-based PRGs are more stringent than PRGs based on $10^{-6}$ to $10^{-4}$.

Certain media associated with Operable Unit 4, such as groundwater, are outside the scope of remedial actions being considered under this FS. PRGs are presented for groundwater, however, because groundwater serves as an environmental receptor and a pathway for uptake of constituents of potential concern by man. PRGs are not presented for waste material contained in the silos because this material is heavily contaminated and would never be suitable for release. Table 2-4 summarizes the media addressed within this section and provides the rationale for development of PRGs, or cleanup criteria, for those media.

The rationale for using risk information and other technical evaluations in the decision making process for Operable Unit 4 is presented in Attachment II of Appendix D (Risk Assessment) of this FS. This Attachment describes the decision making process in four steps as described below:

- Step I identifies existing and previously approved documents [SWCR and Risk Assessment Work Plan Addendum (RAWPA)] that provide an information base to support the path forward for decision making.

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TABLE 2-4

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## DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS
## OPERABLE UNIT 4

| Medium | Source of Preliminary Remediation Goals | Comments |
|---|---|---|
| Waste Material | Preliminary remediation goals are not relevant for waste material such as that contained in Silos 1, 2, and 3 because this material is heavily contaminated and would not be considered releasable. Residual material remaining after the potential removal of silo contained wastes will be addressed as part of structural materials and soil. | Exposure mitigation measures (e.g., containment, treatment, removal, and disposal) will be considered as part of this FS. |
| Structural Material and Equipment | Radiological release criteria were previously developed for structural building material and equipment with surface contamination (NRC). These criteria were adopted from guidelines established by the U.S. Nuclear Regulatory Commission (NRC) guidance and incorporated into DOE Order 5400.5. These criteria are listed in Table 2-5. Therefore, no new radiological release criteria (or preliminary remediation goals) for structural material and equipment will be developed as part of this FS. | Radiological release criteria have not been established by the DOE or the NRC for material with volumetric contamination, such as concrete. |
| Soil | Regulatory-based chemical and radiological cleanup criteria are not available for most constituents of concern in soil. FEMP site soil cleanup criteria will be developed as part of Operable Unit 5, which includes remediation of site-wide soils. Soil PRGs developed as part of this FS will be subject to modification on the basis of additional information developed through Operable Unit 5. | No comments. |
| Residual Water | Regulatory-based cleanup criteria are not available for all constituents of concern existing in residual liquids or that may be transported from Operable Unit 4 sources. Residual liquids will be directed through existing plant wastewater treatment systems. Discharges will be consistent with existing NPDES permit requirements and commitments defined under the South Groundwater Contamination Plume Removal Action. PRGs were therefore not derived for residual water within Operable Unit 4. | No comments. |

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TABLE 2-4
(Continued)

| Medium | Source of Preliminary Remediation Goals | Comments |
|---|---|---|
| Groundwater | Regulatory-based chemical and radiological cleanup criteria are not available for all contaminants of concern in groundwater. Final FEMP site groundwater cleanup criteria will be developed as part of Operable Unit 5 which includes remediation of site-wide groundwater. The chemical and radiological PRGs in this FS represent the concentration of a particular constituent of concern in groundwater presenting a specific ILCR or HI. These concentrations could occur in groundwater as a result of migration from residuals within Operable Unit 4 or stabilized source materials. These PRGs are established to provide a relative performance measure for groundwater protection that a given alternative must attain to be protective of human health and the environment. | Decisions regarding remediation of groundwater will be addressed by DOE as a part of FEMP site Operable Unit 5. Separation of final groundwater cleanup decisions from those considered under Operable Unit 4 allow further characterization of groundwater and consideration of remedial action for site groundwater as a whole. |

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## TABLE 2-5

## SURFACE CONTAMINATION LIMITS[a]

| NUCLIDE | FIXED PLUS REMOVABLE | | REMOVABLE[b,e] |
|---|---|---|---|
| | AVERAGE[b,c] | MAXIMUM[b,d] | |
| U-nat, U-235, U-238, and associated decay products, alpha emitters. | 5,000 dpm/100 $cm^2$ | 15,000 dpm/100 $cm^2$ | 1,000 dpm/100 $cm^2$ |
| Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129 | 100 dpm/100 $cm^2$ | 300 dpm/100 $cm^2$ | 20 dpm/100 $cm^2$ |
| Th-nat, Th-231, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133 | 1,000 dpm/100 $cm^2$ | 3,000 dpm/100 $cm^2$ | 200 dpm/100 $cm^2$ |
| Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. | 5,000 dpm/100 $cm^2$ | 15,000 dpm/100 $cm^2$ | 1,000 dpm/100 $cm^2$ |

[a] Where surface contamination by both alpha and beta-gamma emitting nuclides exists, the limits established for alpha and beta-gamma emitting nuclides should apply independently.

[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Measurements of average contaminant should not be averaged over more than one square meter. For objects of less surface area, the average should be derived for each object.

[d] The maximum contamination level applies to an area of not more than 100 $cm^2$.

[e] The amount of removable radioactive material per 100 $cm^2$ of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

- Step II reviews the data developed in the Operable Unit 4 Baseline Risk Assessment and identifies important information carried forward, such as: sensitive receptors, exposure pathways, COCs, and summary risks.

- Step III integrates the information developed from the FS Report for Operable Unit 4 and Response Action CRARE with the conclusions associated with the site-wide risks and the fact that contaminant sources have been removed under the proposed FS remedial action alternatives. The FS Report for Operable Unit 4 was developed to determine the alternatives that would satisfy remedial goals and to reduce site-wide risk contributions.

- Step IV describes the process used for developing remedial goals and includes the process used in developing Operable Unit 4 PRGs and Proposed Remediation Levels (PRLs).

The following discussion presents how ARARs, TBCs, risk ranges, and hazard quotient indices for radiological and chemical constituents in surface soil and groundwater are used in developing the PRGs, using the rationale presented in Attachment DII.

2.2.2.1 Risk-Based PRG Development

Potential health effects resulting from exposures to radioactive and chemical contaminants are divided into two categories: carcinogenic and noncarcinogenic. For carcinogens, EPA has identified, in the NCP, a target range for incremental risks of $10^{-6}$ to $10^{-4}$, or 1 in 1,000,000 to 1 in 10,000, to limit the possibility that an individual will develop cancer due to exposures to residual contaminants at an NPL site [40 Code of Federal Regulations (CFR) 300]. As part of cleanup at NPL sites, EPA strives to manage possible incremental cancer risks within the target range with $10^{-6}$ generally serving as the point of departure. For sites where the total estimated ILCR for each receptor is less than $10^{-4}$ and the HI is less than 1.0, action may not be warranted. However, the total incremental risk should be less than $10^{-4}$ after remediation.

Although the upper end of the target range is generally used to make risk management decisions to determine whether or not remedial actions are necessary or warranted, EPA does not consider $10^{-4}$ a discrete limit. That is, risks above that level may be considered acceptable based on site-specific conditions; risks below $10^{-4}$ may not be acceptable (EPA 1991). In addition, factors other than the results of the site-specific risk assessment are used to make the final risk management decision including conservative assumptions applied to estimate risks from possible exposures at the site and other health-based guidance available for certain constituents.

These considerations were incorporated into the development of PRGs for Operable Unit 4. The following general principles for carcinogenic and noncarcinogenic constituents were applied to identify general risk-based objectives for remedial actions:

- Exposures to radionuclides should be reduced to levels as low as reasonably achievable (ALARA) as limited by the natural presence of radionuclides in the soil and groundwater and/or result in a ILCR of less than $10^{-6}$ to $10^{-4}$.
- Exposures to carcinogenic chemicals should not result in an ILCR of more than $10^{-6}$ to $10^{-4}$ as limited by the natural presence of chemicals in soil and groundwater.
- Exposures to noncarcinogenic constituents should not result in significant adverse health effects, indicated by a HI greater than 1.0, as limited by the natural presence of chemicals in the soil and groundwater.
- Exposures of biota should be limited to levels that are not associated with significant adverse ecological effects as limited by the natural presence of radionuclides and chemicals in the soil and groundwater.

The methods and assumptions used to estimate carcinogenic and noncarcinogenic effects from exposures to site constituents are described in the RI Report for Operable Unit 4 (DOE 1993c) and are also described in Appendix D of this FS. The discussions presented in the remainder of this section are based on those detailed analyses.

In developing risk-based PRGs, target risk levels are established for carcinogens, and target hazard quotients and target HIs (the sum of the target hazard quotients) are established for noncarcinogens. Once established, these target risk levels are used in calculating the PRGs. Toxicity data used to develop PRGs are cancer slope factors and reference doses from the Integrated Risk Information System (IRIS) database (EPA 1992b) and Health Effects Assessment Summary Tables (HEAST) (EPA 1992a).

One goal of the NCP is to manage total, site-wide risks such that the sum of all risks does not exceed $10^{-4}$. The default target risk of $10^{-6}$ is suggested by EPA (1991) as the point of departure. In keeping with the NCP, PRGs were calculated for $10^{-4}$, $10^{-5}$ and $10^{-6}$ risk levels, using $10^{-6}$ as the target risk to ensure that cumulative site-wide risk does not exceed $10^{-4}$.

EPA indicates that the cumulative site HI should be less that 1.0. However, no EPA guidance is available on apportioning the allowable level among the range of constituents in various environmental media. The most relevant guidance is provided by the Office of Drinking Water which, in calculating

maximum contaminant level goals (MCLGs), uses a relative source contribution (RSC) factor to account for other sources of exposure (EPA 1989a). Because it is not known what additional sources are contributing to total exposure, this default RSC of 0.20, as stated in the Risk Assessment Work Plan Addendum, was used to develop chemical-/media-specific PRGs to ensure that the total HI does not exceed 1.0.

Following completion of the Baseline Risk Assessment, the land use scenarios, receptor scenarios, exposure parameters, and COCs employed to derive PRGs were reviewed to determine whether refinements were required. A complete presentation of this review, including a detailed discussion of land use and receptors, is found in Appendix D, Attachment DII. As a result of this review, the PRGs originally appearing in the SWCR have been revised to more appropriately reflect Operable Unit 4 conditions. The risk-based PRGs presented in Part III of the SWCR were typically based upon the consideration of a single exposure pathway for each media for the identified receptors. For example, for the groundwater media, an ingestion pathway was examined assuming consumption of 2 liters of water per day for 52 years. An exception to this single pathway framework was the development of PRGs for the recreational user (now designated as the expanded trespasser) as defined in the SWCR. For the expanded trespasser, the SWCR report considered ingestion and external exposure for the development of PRGs for the soil media. Subsequent to the SWCR, the Baseline Risk Assessment for Operable Unit 4 provided a more comprehensive quantitative examination of the viable pathways of exposure to each of the receptors considered.

While the RI Report/Baseline Risk Assessment presented risk information, for a range of receptors under current and future land use scenarios, these land use assumptions and receptors were refined to provide managers with the range of necessary information to support informed decisions in establishing proposed remediation levels. In accordance with the Risk Assessment Work Plan Addendum (DOE 1992) and to ensure consistency with EPA's guidance "Part B, Development of Risk-Based PRGs," the Baseline Risk Assessment for Operable Unit 4 evaluated a future land use scenario, which included the loss of federal ownership of the FEMP and the establishment of a family farm on the site. This land use scenario was evaluated to understand the potential worst-case exposures to site contaminants. This future land use scenario is completely described in the RI Report for Operable Unit 4 (DOE 1993c). In addition to the future land use scenario examined in the RI Report, it is conceivable as part of any future land use of the FEMP that the federal government could retain ownership of the property to preclude further development of the property including the establishment of residential or farming units. This future land use scenario, termed Future Land Use

With Continued Federal Ownership where the land use is a government reserve, does not assume any form of perpetual maintenance or active access restrictions to the site following the completion of remedial actions and attainment of site-wide remedial goals. It is assumed that the site will be fenced, and no trespassing and no hunting signs will be posted. This retention of ownership would support the application of some form of institutional control. The relationship between the land use scenarios presented in the Baseline Risk Assessment and those presented in this FS are described in Appendix D, Attachment DII.

For purposes of providing additional information for use in decision making, PRGs were developed for both the future land use with and without the assumption of continued federal ownership. To establish the PRGs for the future land use without continued ownership scenario, an on-property resident farmer was adopted as the receptor. For PRG development, the on-property resident farmer was assumed to be exposed to COCs in the soil via the inhalation of dusts, consumption of farm products contaminated by dust deposition, oral ingestion of soil, dermal contact, and external radiation pathways associated with the soils. Additionally, the on-property resident farmer was assumed to be exposed to COCs in groundwater through ingestion. The equations and parameters used to calculate these PRGs are presented in the revised Risk Assessment Work Plan Addendum.

For the purposes of establishing PRGs for the Future Land Use With Continued Federal Ownership scenario, an on-property receptor was employed assuming a trespassing type exposure scenario which includes both adult and youth age groups. The exposure parameters established for this receptor, the expanded trespasser, are OU4 specific and will be re-evaluated and fully developed on a sitewide basis within the scope of the Operable Unit 5 Feasibility Study.

The expanded trespassing receptor considered for PRG development for the future land use with continued federal ownership is an individual who visits the property during childhood then visits during adulthood, perhaps for roaming, hiking, bird watching, or similar type activities. Due to the size of the site, fencing, and signs indicating No Trespassing and No Hunting, it is assumed that hunting is not a likely activity. The expanded trespasser is assumed to be exposed to soil contaminants via the oral ingestion, dermal contact, inhalation of dusts, and external radiation pathways. Groundwater PRGs were not developed for the expanded trespasser since there were no viable pathways of exposure.

The evaluation of a fully developed trespasser scenario was abandoned in favor of a truncated scenario, which considered only exposure to a youth, 7-18 years of age, and an adult, 18-50 years of age, as it was determined that the expansion of the trespass scenario, either by age or by time spent on OU4 would result in the development of a PRG which was not technically or economically feasible. It should thus be realized that this scenario describes an activity pattern and total exposure which may not be protective of human health under all circumstances. The PRGs established for this limited expanded trespasser scenario would be protective of human health for the off-property farmer (all pathways).

For the 5.8 acres comprising OU4, however, the current expanded trespasser exposure assumptions are conservative. While it may be reasonable to assume that an expanded trespasser would spend at least 210 hours per year on the 1050 acre FEMP site, it is unlikely that the same receptor would expend the same duration in the boundaries of Operable Unit 4.

Further reduction of PRGs for the OU4 expanded trespasser would provide no practical benefit. That is, in the case of OU4 the most pervasive contaminant of concern for subsurface soils within the OU4 boundary is Ra-226. Ra-226 concentrations were detected as high as 876 pCi/g in subsurface soils. The proposed remediation level (PRL) for Ra-226 (based on the current expanded trespasser) is 2 pCi/g (background concentration of Ra-226 is 1.45 pCi/g). In no case was U-238 detected in subsurface soil above 54 pCi/g as compared to the proposed remediation level for U-238 being 60 pCi/g. To achieve compliance with the PRL for Ra-226 (2 pCi/g) it will be necessary to excavate and treat/dispose of approximately 30,000 $yd^3$ of contaminated soil within the OU4 boundary.

In summary, the PRL for Ra-226 will drive the remediation of OU4 soils and in doing so, residual soils contaminated with Uranium will be at levels approaching background for those isotopes.

Finally, PRGs were developed for soil for an off-property farmer. Exposure pathways from soil to this receptor were considered identical for both the Future Land Use With and Without Continued Federal Ownership scenarios. The off-property farmer is assumed to be exposed to soils within the Operable Unit 4 area through the inhalation of re-suspended dust containing COCs and the consumption of farm products (i.e., milk, meat, and vegetables) contaminated by dust deposition.

ARAR/TBC PRG Development

Chemical-specific ARARs were also examined to identify PRGs for Operable Unit 4 COCs. These ARARs included non-zero MCLGs and Maximum Contaminant Levels (MCLs) for drinking water. Other selected considerations, including available guidance and health advisories, were examined to identify PRGs, termed TBC-based PRGs. TBC guidance examined included DOE orders, ecological benchmark criteria, and drinking water health advisories.

2.2.2.2 As Low As Reasonably Achievable

In addition to establishing PRGs that comply with ARARs and are protective of human health and the environment, DOE plans to apply the principles of ALARA during remedial actions at the FEMP site. The goal of DOE's ALARA process is to reduce exposures and the risk associated with residual contamination to levels that are "as low as reasonably achievable" considering technical, economic, and social constraints as appropriate. In applying the ALARA process at the FEMP site, the two factors used in developing PRGs (ARAR-based environmental standards and protectiveness of human health and the environment) are combined with technical and economic considerations in order to identify the levels of risk reduction that might reasonably be achieved.

The ALARA process includes both planning and field components. The discussions presented in this section are consistent with the planning component of ALARA, in which PRGs are estimated for residual contamination based on hypothetical exposures. This initial analysis will be used to support implementation of ALARA in the field, where additional contamination might be removed below those levels determined in the planning phase when reasonably achievable, based on specific field conditions.

As specified previously, ALARA is site specific. The application of ALARA at another site with different contaminants and exposure scenarios would invariably produce different results.

2.2.2.3 Preliminary Remediation Goals for Soils

The PRGs for soils were calculated using the equations and parameters for all exposure pathways as detailed in the revised Risk Assessment Work Plan Addendum for all receptors. For PRG development, a target risk for both chemical and radiological carcinogenic effects of $10^{-4}$, $10^{-5}$, and $10^{-6}$ were employed to derive PRGs for each of the receptors. A target value (HI) of 0.2 was employed for non-carcinogenic effects.

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To support the derivation of PRGs, it is assumed that dust from soils is inhaled by the receptor and deposited on the crops and forage. The on- and off-property resident farmers are assumed to then consume the crops, eat meat from cows grazing on the forage, and drink milk from cows grazing on the forage. Dust resuspension and transport modeling was performed for the RI Report for Operable Unit 4 to examine exposure point concentrations both on property and off property as a result of baseline conditions within Operable Unit 4. These modeling results were used to calculate resuspension factors and ultimately soil concentration based PRGs. Since the RI and Baseline Risk Assessment modeled the particulate releases as Total Suspended Particulate (TSP) and assumed a 50 percent vegetation ground cover, the values were modified by factors of 2 [TSP to Particulate Matter less than 10 microns in diameter ($PM_{10}$)] and 3.33 to convert to $PM_{10}$ values and 85 percent vegetative cover.

The off-property farmer is assumed to inhale the dust particulate and consume the farm produce contaminated by particulate deposition from Operable Unit 4 for a lifetime of 70 years.

The on-property resident farmer is assumed to build and farm on the residual soils within Operable Unit 4. The resident farmer is exposed to COCs in soils by incidental ingestion, dermal contact, consumption of meat, milk, and produce, and direct radiation. The meat, milk, and produce will accumulate COCs via the direct uptake by roots from the soils and by deposition of particulates on the plant surfaces.

The expanded trespasser is assumed to be exposed to Operable Unit 4 soil via incidental ingestion, dermal exposure, inhalation of particulates, and external radiation. The expanded trespasser is assumed to be present within Operable Unit 4 as an adult and a child/youth for 40 days and 110 days, respectively, each year for a period of one and two hours per day, respectively. The breathing rate is assumed to be 20 $m^3$/day for all age groups, and the ingestion rate is assumed to be 100 mg soil per day.

The PRGs for the PAH compounds were calculated using the Toxic Equivalence Factor (TEF) approach as detailed in the Operable Unit 4 Baseline Risk Assessment. In this approach, the Slope Factor for benzo(a)pyrene was multiplied by the individual TEF for each PAH. This was done for the oral and inhalation pathways where slope factors were available. The PRG calculation did not include a quantitative evaluation of the dermal pathway of exposure because guidance from USEPA suggests that it is inappropriate to derive dermal slope factors from oral slope factors for carcinogenic

PAHs because these compounds are potent contact carcinogens, and the endpoint, skin cancer, is different for the dermal pathway. Thus extrapolation of a dermal slope factor from the oral slope factor may not be protective. The risk from dermal exposure to carcinogenic PAHs (and also the impact of this pathway on the PRG calculation) can be considered to be at least as great, if not greater, than the risk from oral exposure to the compounds.

Tables 2-6, 2-7, and 2-8 present the PRGs for soil for the on-property resident farmer, expanded trespasser, and off-property farmer, respectively. It should be noted that PRGs for soils were only derived for those carcinogenic COCs exhibiting an ILCR greater than $10^{-6}$ to the on-property resident farmer under a current source term scenario, as defined in Table D.II-17 of the RI Report for Operable Unit 4. As previously discussed, risk-based PRGs have been derived for receptors under two land use scenarios, future land use with and without continued federal ownership. For the derivation of these risk-based PRGs, the progeny isotopes of radionuclides present at the FEMP site have been included within the results of the PRG calculation for the parent isotope. For example, U-238 is a radionuclide of concern at the FEMP site. If the presence of its two immediate short-lived progeny is neglected, the risk-based PRG for a residential farmer exposed to U-238 in soil is approximately 25 pCi/g. Including its two short-lived progeny, U-238 yields a PRG of 0.55 pCi/g (Table 2-6). In another example, Ra-226 without progeny would have a PRG of about 0.15 pCi/g for the same scenario. Including its short-lived progeny, Ra-226 reduces the PRG in soil to 0.004 pCi/g (Table 2-6). The PRGs presented in Table 2-6 consider contributions of radioactive progeny to be an integral part of the total risk from the parent nuclide.

Values representing $10^{-6}$ risk-based PRGs under the future land use without continued federal ownership residential farmer scenario differ from the ARARs-based PRG for Ra-226 by several orders of magnitude. Moreover, the $10^{-6}$ risk-based PRGs for U-238 and Ra-226 are 2.6 and 36 times less than background, respectively. Therefore, the PRGs for Ra-226 and U-238 are indistinguishable from either the respective ARAR or background concentrations.

EPA has promulgated standards for Ra-226 and Ra-228 in soil at uranium and thorium mill tailings sites (40 CFR § 192 Subpart B). In brief, these radionuclides are not to exceed background concentrations by more than 5 pCi/g in the top 15 cm (6 in.) of soil or 15 pCi/g in each 15 cm (6 in.) layer beneath the surface, averaged over an area of 100 $m^2$ (1100 $ft^2$). Because the FEMP is on the NPL and subject to Superfund remediation standards and goals, use of these mill tailings standards would not be applicable because they are not risk-based and not considered protective. Use of these

# TABLE 2-6

## PRELIMINARY REMEDIATION GOALS - SOILS
## FUTURE LAND USE WITHOUT CONTINUED FEDERAL OWNERSHIP

| | ON-PROPERTY RESIDENT FARMER | | | | | | |
|---|---|---|---|---|---|---|---|
| | Incremental Above Background Concentrations | | | | | | |
| | HI=0.2 RfD based PRG | $10^{-4}$ risk based PRG | $10^{-5}$ risk based PRG | $10^{-6}$ risk based PRG | | ARAR/ TBC | Background 95th Percentile |
| **Radionuclides (pCi/g)** | | | | | | | |
| Pb-210 + 2 progeny | | 9.10 | 0.91 | 0.091 | | | 1.33 |
| Ra-226 + 5 progeny[b] | | 0.40 | 0.04 | 0.004 | | 5[a] | 1.45 |
| RA-228 + 1 progeny | | 0.82 | 0.08 | 0.0082 | | | 1.19 |
| Sr-90 + 1 progeny | | 1.70 | 0.17 | 0.017 | | | ND |
| Tc-99 | | 1.80 | 0.18 | 0.018 | | | ND |
| Th-228 | | 0.43 | 0.04 | 0.0043 | | | 1.43 |
| U-238 + 2 progeny[b] | | 55.00 | 5.50 | 0.55 | | | 1.22 |
| **Inorganics (mg/kg)** | | | | | | | |
| Antimony | 2.4 | | | | | | 7.7 |
| Arsenic | 5.7 | 5.50 | 0.55 | 0.055 | | | 8.45 |
| Barium | 650 | | | | | | 91.3 |
| Cadmium | 0.99 | | | | | | 0.82 |
| Chromium (III) | 6600 | | | | | | 15.5 |
| Copper[c] | | | | | | | 14.1 |
| Molybdenum | 5.4 | | | | | | 2.6 |
| Nickel | 66 | | | | | | 20.9 |
| Silver | 0.55 | | | | | | 2.6 |
| Thallium | 0.37 | | | | | | 0.58 |
| Vanadium | 200 | | | | | | 30.4 |
| Zinc | 5.4 | | | | | | 62.2 |

**TABLE 2-6**
**(Continued)**

| | ON-PROPERTY RESIDENT FARMER | | | | | | |
|---|---|---|---|---|---|---|---|
| | Incremental Above Background Concentrations | | | | | | |
| | HI=0.2 RfD based PRG | $10^{-4}$ risk based PRG | $10^{-5}$ risk based PRG | $10^{-6}$ risk based PRG | | ARAR/ TBC | Background 95th Percentile |
| **Organics (mg/kg)** | | | | | | | |
| 2-Butanone | 15 | | | | | | |
| Benzo(a)anthracene | | 2.0 | 0.2 | 0.02 | | | |
| Benzo(a)pyrene | | 0.19 | 0.019 | 0.0019 | | | |
| Benzo(b)fluoranthene | | 0.063 | 0.063 | 0.0063 | | | |
| Benzo(g,h,i)perylene | | | | | | | |
| Chrysene | | 65 | 6.5 | 0.65 | | | |
| Dibenzo(a,h)anthracene | | 0.17 | 0.017 | 0.0017 | | | |
| Fluoranthene | 64 | | | | | | |
| Indeno(1,2,3-cd)pyrene | | 0.032 | 0.0032 | 0.00032 | | | |
| Methylene chloride | 0.68 | 6.3 | 0.63 | 0.063 | | | |
| Phenanthrene[c] | | | | | | | |
| Toluene | 110 | | | | | | |

[a]First 15 cm depth (40 CFR 192).
[b]The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will drive the choice of the PRG used in design of remedial alternatives.
[c]No toxicity data available to develop a PRG.

# TABLE 2-7

## PRELIMINARY REMEDIATION GOALS - SOILS
## FUTURE LAND USE WITH CONTINUED FEDERAL OWNERSHIP

| | Expanded Trespasser | | | | | | |
|---|---|---|---|---|---|---|---|
| | Incremental Above Background Concentrations | | | | | | |
| | HI=0.2 RfD based PRG | $10^{-4}$ risk based PRG | $10^{-5}$ risk based PRG | $10^{-6}$ risk based PRG | | ARAR/ TBC | Background 95th Percentile |
| **Radionuclides (pCi/g)** | | | | | | | |
| Pb-210 + 2 progeny | | 7,700 | 770 | 77 | | | 1.33 |
| Ra-226 + 5 progeny[b] | | 37 | 4 | 0.37 | | 5[a] | 1.45 |
| RA-228 + 1 progeny | | 77 | 8 | 0.77 | | | 1.19 |
| Sr-90 + 1 progeny | | 142,000 | 14,200 | 1420 | | | ND |
| Tc-99 | | 3,870,000 | 387,000 | 38,700 | | | ND |
| Th-228 | | 40 | 4 | 0.4 | | | 1.43 |
| U-238 + 2 progeny[b] | | 5,900 | 590 | 59 | | | 1.22 |
| **Inorganics (mg/kg)** | | | | | | | |
| Antimony | 31 | | | | | | 7.7 |
| Arsenic | 510 | 2,300 | 230 | 23 | | | 8.45 |
| Barium | c | | | | | | 91.3 |
| Cadmium | 260 | | | | | | 0.82 |
| Chromium (III) | c | | | | | | 15.5 |
| Copper[d] | | | | | | | 14.1 |
| Molybdenum | 930 | | | | | | 2.6 |
| Nickel | 8700 | | | | | | 20.9 |
| Silver | 130 | | | | | | 2.6 |
| Thallium | 31 | | | | | | 0.58 |
| Vanadium | 1700 | | | | | | 30.4 |
| Zinc | c | | | | | | 62.2 |

TABLE 2-7
(Continued)

| | Expanded Trespasser | | | | | | |
|---|---|---|---|---|---|---|---|
| | Incremental Above Background Concentrations | | | | | | |
| | HI=0.2 RfD based PRG | $10^{-4}$ risk based PRG | $10^{-5}$ risk based PRG | $10^{-6}$ risk based PRG | | ARAR/ TBC | Background 95th Percentile |
| **Organics (mg/kg)** | | | | | | | |
| 2-Butanone | c | | | | | | |
| Benzo(a)anthracene | | 6,100 | 610 | 61 | | | |
| Benzo(a)pyrene | | 880 | 88 | 8.8 | | | |
| Benzo(b)fluoranthene | | 7,200 | 720 | 72 | | | |
| Benzo(g,h,i)perylene | | | | | | | |
| Chrysene | | c | c | 2000 | | | |
| Dibenzo(a,h)anthracene | | 7,900 | 790 | 79 | | | |
| Fluoranthene | 300 | | | | | | |
| Indeno(1,2,3-cd)pyrene | | 3,200 | 320 | 32 | | | |
| Methylene chloride | c | c | c | 8500 | | | |
| Phenanthrene[d] | | | | | | | |
| Toluene | c | | | | | | |

[a]First 15 cm depth (40 CFR 192).
[b]The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will drive the choice of the PRG used in design of remedial alternatives.
[c]PRG is greater than 10,000 mg/kg. The calculated dose-based PRG has been divided by 100 to account for the fact that the 100 mrem limit is for all exposures, while the PRG is for a single exposure pathway and radionuclide. Exposure pathways and parameters are the same as those used for risk-based recreational PRGs.
[d]No toxicity data available to develop a PRG.
ND = Not detected.

## TABLE 2-8

## PRELIMINARY REMEDIATION GOALS - SOILS
## FUTURE LAND USE WITH CONTINUED FEDERAL OWNERSHIP

| | OFF-PROPERTY RESIDENT FARMER | | | | | | |
|---|---|---|---|---|---|---|---|
| | Incremental Above Background Concentrations | | | | | | |
| | HI=0.2 RfD based PRG | $10^{-4}$ risk based PRG | $10^{-5}$ risk based PRG | $10^{-6}$ risk based PRG | | ARAR/TBC | Background 95th Percentile |
| **Radionuclides (pCi/g)** | | | | | | | |
| Pb-210 + 2 progeny | | 620,000 | 62,000 | 6200 | | | 1.33 |
| Ra-226 + 5 progeny[b] | | 1,300,000 | 130,000 | 13000 | | 5[a] | 1.45 |
| RA-228 + 1 progeny | | 3,900,000 | 390,000 | 39000 | | | 1.19 |
| Sr-90 + 1 progeny | | 5,300,000 | 530,000 | 53000 | | | ND |
| Tc-99 | | 76,000,000 | 7,600,000 | 760000 | | | ND |
| Th-228 | | 73,000 | 7,300 | 730 | | | 1.43 |
| U-238 + 2 progeny[b] | | 110,000 | 11,000 | 1100 | | | 1.22 |
| **Inorganics (mg/kg)** | | | | | | | |
| Antimony | 1120 | | | | | | 7.7 |
| Arsenic | c | c | c | 2940 | | | 8.45 |
| Barium | c | | | | | | 91.3 |
| Cadmium | c | | | | | | 0.82 |
| Chromium (III) | c | | | | | | 15.5 |
| Copper[d] | | | | | | | 14.1 |
| Molybdenum | c | | | | | | 2.6 |
| Nickel | c | | | | | | 20.9 |
| Silver | c | | | | | | 2.6 |
| Thallium | c | | | | | | 0.58 |
| Vanadium | c | | | | | | 30.4 |
| Zinc | c | | | | | | 62.2 |

**TABLE 2-8**
**(Continued)**

| | OFF-PROPERTY RESIDENT FARMER | | | | | | |
|---|---|---|---|---|---|---|---|
| | Incremental Above Background Concentrations | | | | | | |
| | HI=0.2 RfD based PRG | $10^{-4}$ risk based PRG | $10^{-5}$ risk based PRG | $10^{-6}$ risk based PRG | | ARAR/TBC | Background 95th Percentile |
| **Organics (mg/kg)** | | | | | | | |
| 2-Butanone | c | | | | | | |
| Benzo(a)anthracene | | c | c | 4000 | | | |
| Benzo(a)pyrene | | c | 3,000 | 300 | | | |
| Benzo(b)fluoranthene | | c | 7,400 | 740 | | | |
| Benzo(g,h,i)perylene | | | | | | | |
| Chrysene | | c | c | c | | | |
| Di-benzo(a,h)anthracene | | c | 2,750 | 275 | | | |
| Fluoranthene | c | | | | | | |
| Indeno(1,2,3-cd)pyrene | | 2,800 | 280 | 28 | | | |
| Methylene chloride | c | c | c | c | | | |
| Phenanthrene[d] | | | 0 | | | | |
| Toluene | c | | | | | | |

[a]First 15 cm depth (40 CFR 192).
[b]The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will drive the choice of the PRG used in design of remedial alternatives.
[c]PRG is greater than 10,000 mg/kg.
[d]No toxicity data available to develop a PRG.

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standards would result in an unacceptable increase risk over background conditions. However, the requirements are considered relevant and appropriate because the waste material at the site is similar to mill tailings.

EPA has identified standards for airborne emissions of radionuclides other than Rn-222, which limit exposures such that a member of the public will not exceed an effective dose equivalent of 10 mrem/year (40 CFR § 61 Subpart H). EPA has also identified annual dose limits of 25 mrem/year whole body, 75 mrem/year to the thyroid, and 25 mrem/year to any other organ for exposures associated with management of uranium and thorium by-product material.

As a general standard for radiological exposures, DOE requires compliance with all federal requirements for limiting doses from specific exposure modes. DOE Order 5400.5 also establishes requirements for nonspecific radiological exposures from DOE facilities. This order requires that the committed effective dose equivalent to a member of the public not exceed 100 mrem/year above background from all nonoccupational exposure routes and that these exposures be reduced to ALARA levels. With this order, DOE defines the ALARA process for reducing residual exposures and risks to levels as low as reasonably achievable below applicable standards considering technical, economic, and social constraints as appropriate. This DOE Order is comparable to the requirements of 10 CFR §20 for the exposure of the public to radioactive materials.

These radiological dose standards and requirements are considered as applicable, relevant and appropriate, or TBCs to remediation efforts at the FEMP site. Current dose estimates for the site perimeter are within the specified limits. Applying ALARA to reduce residual concentrations of specific radionuclides would result in a similar reduction in the resulting radiological exposures and associated risk. The greatest reduction is associated with decreasing residual levels of Ra-226 because this radionuclide and its progeny account for the greatest portion of the total risk estimate within Operable Unit 4, from both external gamma irradiation and inhalation of radon.

EPA has identified two different guidelines for establishing a residual level for lead in soil in a residential setting. These guidelines are considered TBCs. The first is an interim guidance that considers the natural presence of lead in soil and recommends a cleanup level of 500 to 1000 mg/kg, as determined by site-specific conditions (EPA 1992b). The second is draft guidance in the form of an uptake/biokinetic model that can be applied to site-specific data to estimate lead levels in blood for

children, the most sensitive population. A blood lead level of 10 $\mu$g/l or less is EPA's preferred level. This model yields a health-based level of 450 mg/kg for lead in surface soil.

A standard for cleanup of soil following a spill of material containing more than 50 mg/kg PCBs is identified in the Toxic Substances Control Act. The standard indicates that soil in areas of unrestricted access at which a spill occurs can be decontaminated to 10 mg/kg by weight by excavating at least 25 cm (10 in.) of soil and backfilling with material containing less than 1 mg/kg PCBs. Because PCB contamination in soil would have resulted from spills of material that occurred long before the effective date of these standards, they do not specifically apply; however, they are considered relevant and appropriate.

A literature search was conducted to identify any ecological benchmark criteria for use as guidelines for establishing PRGs for soils. No relevant criteria could be identified for the Operable Unit 4 COCs.

2.2.2.4 Preliminary Remediation Goals for Groundwater

Table 2-9 presents the PRGs for groundwater. For groundwater, the PRGs for the future land use with continued federal ownership (expanded trespasser) are the same as those for the future land use without continued federal ownership (RME on-property resident farmer). The only difference is the source of groundwater. Under the RME resident farmer scenario, it is assumed that an individual takes up residence on the FEMP site and installs a domestic drinking water well at that location. Under the expanded trespasser scenario, there are no individuals establishing residences on the FEMP site. Consistent with this assumption, there will be no domestic drinking water wells on the FEMP site. Thus, the groundwater PRGs established under the expanded trespasser scenario must be met at the FEMP site boundary, while PRGs under the RME on-property resident farmer scenario would need to be met for groundwater directly beneath the FEMP site.

The risk-based PRGs for groundwater were calculated using the equations and parameters presented in the revised Risk Assessment Work Plan Addendum. The parameters are also presented in Appendix D.

For organics, most PRGs based on the $10^{-6}$ risk level are well below the CRQLs established by EPA. To date, these CRQLs have been used for the site characterization study at the FEMP site. MCLs for many of the organic carcinogens appear to be equivalent to a $10^{-4}$ risk level (e.g., for PCBs,

**TABLE 2-9**
**PRELIMINARY REMEDIATION GOALS - GROUNDWATER**
**RME FARMER - ALL SCENARIOS**

| Chemical | Risk-Based PRGs, Above Background | | | | ARAR/TBC-Based PRGs | | |
|---|---|---|---|---|---|---|---|
| | | | | | Federal Standards | | State Standards |
| | HI=0.20 RfD-Based PRG[a] | $10^{-4}$ Risk-Based PRG[b] | $10^{-5}$ Risk-Based PRG[b] | $10^{-6}$ Risk-Based PRG[b] | Source[c] | Concentration[d] | Groundwater[e] |
| **Radionuclides (pCi/L)** | | | | | | | |
| Pb-210 + 2 progeny | | 2.6 | 0.26 | 0.026 | 4 mrem dose | 1 | |
| Ra-226 + 5 progeny | | 14 | 1.4 | 0.14 | PMCL[f] | 20 | 5 |
| Ra-228 + 1 progeny | | 17 | 1.7 | 0.17 | PMCL[f] | 20 | 5 |
| Rn-222 | | | | | PMCL[f] | 300 | |
| Sr-90 | | 37 | 3.7 | 0.37 | 4 mrem dose | 8 | |
| Tc-99 | | 830 | 83 | 8.3 | | | |
| Th-228 + 7 progeny | | 32 | 3.2 | 0.32 | 4 mrem dose | 14 | |
| U-238 + 2 progeny | | 62 | 6.2 | 0.62 | | | |
| **Inorganics (mg/L)** | | | | | | | |
| Antimony | 0.003 | | | | MCLG[g] | 0.006 | |
| Arsenic | 0.0013 | $2x10^{-3}$ | $2x10^{-4}$ | $2x10^{-5}$ | MCL | 0.05 | 0.05 |
| Barium | 0.28 | | | | MCLG | 2.0 | 1.0 |
| Cadmium | 0.0013 | | | | MCLG | 0.005 | 0.001 |
| Chromium VI | 0.024 | | | | MCLG | 0.1 | 0.05 |
| Chromium III | 4.4 | | | | | | |
| Copper[h] | | | | | MCL[i] | 1.3 | 1.0 |
| Lead[h] | | | | | MCL[i] | 0.015 | 0.05 |
| Molybdenum | 0.019 | | | | | | |
| Nickel | 0.053 | | | | MCLG | 0.1 | |
| Silver | 0.00025 | | | | MCL | 0.05 | 0.05 |
| Thallium | 0.00025 | | | | MCLG | 0.0005 | |
| Uranium | 0.02 | | | | PMCL | 0.02 | |
| Vanadium | 0.039 | | | | | | |
| Zinc | 0.0046 | | | | | | |

TABLE 2-9
(Continued)

| Chemical | Risk-Based PRGs, Above Background | | | | ARAR/TBC-Based PRGs | | |
|---|---|---|---|---|---|---|---|
| | | | | | Federal Standards | | State Standards |
| | HI=0.20 RfD-Based PRG[a] | $10^{-4}$ Risk-Based PRG[b] | $10^{-5}$ Risk-Based PRG[b] | $10^{-6}$ Risk-Based PRG[b] | Source[c] | Concentration[d] | Groundwater[e] |
| **Organics (mg/L)** | | | | | | | |
| 2-Butanone | 3.7 | | | | | | |
| Benzo(a)anthracene | | $2.4 \times 10^{-3}$ | $2.4 \times 10^{-4}$ | $2.4 \times 10^{-5}$ | | | |
| Benzo(a)pyrene | | $2.8 \times 10^{-4}$ | $2.8 \times 10^{-5}$ | $2.8 \times 10^{-6}$ | MCL | 0.0002 | |
| Benzo(b)fluoranthene | | $1.2 \times 10^{-3}$ | $1.2 \times 10^{-4}$ | $1.2 \times 10^{-5}$ | | | |
| Benzo(g,h,i)perylene | | | | | | | |
| Bis(2-ethylhexyl)phthalate | | | | | MCL | 0.006 | |
| Fluoranthene | 0.017 | | | | | | |
| Methylene chloride[j] | 0.38 | 0.41 | 0.041 | 0.0041 | PMCL | 0.005 | |
| Phenanthrene | | | | | | | |
| Toluene | 0.92 | | | | MCL | 1.0 | |

[a]PRG developed using equation and parameters for drinking water ingestion and chemical-specific RfDs from Health Effect Assessment Summary Tables (HEAST) (EPA 1992b) and the Integrated Risk Information System (IRIS) (EPA 1992a).
[b]PRG developed using equations and parameters for drinking water ingestion and chemical-specific SFs from HEAST and IRIS values represent cleanup goal above background since $10^{-6}$ represents an incremental lifetime cancer risk goal.
[c]ARAR-based PRGs are developed from several sources. The primary source is promulgated or proposed Maximum Contaminant Levels (MCLs) developed under the Safe Drinking Water Act; 40 CFR § 141, 142. If no MCL exists that strictly applies to the individual radionuclide, a PRG is developed using the 4 mrem dose limit that strictly applies to man-made beta and gamma emitters.
[d]Concentration in pCi/L for radionuclides and mg/L for chemicals corresponding to MCL or proposed MCL (PMCL) values.
[e]Based on OAC 3745-81-16; for many radionuclides, values are based on an average dose of beta particle and photon (e.g., gamma) of 4 mrem/yr.
[f]PRG based on interpretation to 4 mrem/yr dose limit for beta and gamma emitters may be applicable to alpha emitters. PRG developed using Committed Effective Dose Equivalents (CEDE) to 4 mrem/yr of intake at a rate of 730 L/yr, using Dose Conversion Factors (DCFs) from EPA (1988b).
[g]Proposed MCLs from "Federal Register," Vol. 55, No. 138, p. 33050.
[h]No toxicity data available to develop a PRG.
[i]This standard is technically an action level rather than a true MCL or MCLG. The lead action level is more stringent than the MCL at 0.05 mg/L; the copper action level is enforceable. This reference is found in 40 § 141.80 (56 FR 26549).
[j]Methylene chloride also commonly referred to as Dichloromethane.

benzo(a)pyrene, chlordane, and vinyl chloride). For noncarcinogens, the MCLs appear to be close to risk-based values.

EPA has promulgated standards for Ra-226 and Ra-228 in groundwater through various regulations, all with the same basic requirements. The regulations include 40 CFR § 141.15, 40 CFR § 257.3-4, and 40 CFR § 264.94. Similar State of Ohio regulations include Ohio Administrative Code (OAC) 3745-81-15, OAC 3745-27-10(D), and OAC 3745-54-94. In brief, the regulations specify that the combined concentration of Ra-226 and Ra-228 in groundwater used as a drinking water source is not to exceed 5 pCi/L. In addition, the gross alpha particle activity (including Ra-226 but excluding radon and uranium) is not to exceed 15 pCi/L.

EPA has proposed standards for uranium and Rn-222 and revised standards for Ra-226 and Ra-228 in drinking water. Under these proposed regulations, the concentration of uranium in drinking water is not to exceed 0.02 mg/L or 30 pCi/L, Rn-222 is not to exceed 300 pCi/L, and the combined concentration of Ra-226/228 are not to exceed 20 pCi/L.

As a general standard for radiological exposures, the DOE requires compliance with all federal requirements for limiting doses from specific exposure modes. DOE Order 5400.5 also establishes standards for nonspecific radiological exposures. These standards require that the Effective Dose Equivalent (EDE) to a member of the public not exceed 100 mrem/year above background from all nonoccupational exposure routes and that these exposures be reduced to ALARA levels.

The Safe Drinking Water Act, 40 CFR § 141, establishes MCLs and MCLGs for specific inorganic and organic chemicals to protect drinking water quality. MCLs are the maximum permissible levels of a contaminant in water that is delivered to a free flowing outlet of the ultimate user of a public water system. The MCLs are not directly applicable because no public water system, as defined in 40 CFR § 141, is involved. The MCLs are relevant and appropriate, however, to protect the underlying aquifer, which may be used as a drinking water source, from contaminants that may leach or migrate from waste materials contained in Operable Unit 4.

The State of Ohio also provides MCLs in OAC 3745-81-11. The state MCLs are more stringent than the federal MCLs for barium, chromium, silver, selenium, endrin, and 2, 4, 5-TP silvex.

EPA provides additional MCLs in RCRA, Subtitles D and C, 40 CFR § 257 and 264, respectively. These MCLs are also contained in State of Ohio regulations, OAC-3745-27. The regulations require that a facility must comply with the requirements specified in the facility permit (i.e., the MCLs) for the uppermost aquifer underlying the waste management area beyond the point of compliance, which is a vertical surface located at the hydraulically downgradient limit of the waste management area. These MCLs are not directly applicable because Operable Unit 4 is not designated as a RCRA waste management area. The MCLs are relevant and appropriate, however, because Operable Unit 4 contains RCRA constituents and because silo leachate may migrate into the underlying aquifer, potentially contaminating drinking water systems.

The Safe Drinking Water Act also establishes MCLGs for specific inorganic and organic chemicals. MCLGs are nonenforceable drinking water health goals intended to represent a contaminant concentration that presents "no known or anticipated adverse effects on the health of persons" while allowing for an adequate margin of safety. The MCLG is more stringent than the MCL for thallium. Similar to the MCLs, the MCLGs are considered to be relevant and appropriate. CERCLA Section 121(d)(2)(A) requires on-property remedies to attain MCLGs where relevant and appropriate under the circumstances of the release. If a MCLG is equal to zero, EPA believes it is not appropriate for setting cleanup levels, and the corresponding MCL will be the relevant and appropriate requirement.

Beyond the MCLGs, the Safe Drinking Water act establishes secondary MCLs in 40 CFR § 143. Secondary MCLs are also contained in Ohio regulations, OAC 3745-82-02. Secondary MCLs are nonenforceable goals for drinking water established for contaminants whose presence in excessive quantities may discourage the use of a public water supply due to poor qualities such as taste, color, odor, and corrosivity. The secondary MCLs are a TBC in evaluating potential remedial actions.

A summary of the MCLs, MCLGs, and secondary MCLs previously discussed is presented in Table 2-10.

### 2.2.3 Proposed Remediation Levels (PRLs)

As stated previously, Operable Unit 5 contains the majority of site-wide soils to be addressed for remediation. The volume of contaminated soils to be generated from the remediation of Operable Unit 4 is estimated to be less than one percent of the contaminated soil that will be generated from the remediation of the whole site. Operable Unit 5 is currently evaluating the technologies and alternatives potentially applicable to the remediation of soils. Preliminary information indicates that

## TABLE 2-10

## SUMMARY OF MCLs, MCLGs, AND SECONDARY MCLs

| Constituents | 40 CFR § 141.62 SDWA MCL (mg/L) | OAC 3745-81-11 MCL (mg/L) | 40 CFR § 257.3-4 and 264.94 Subparts C and D OAC-3745-27-10 MCL (mg/L) | 40 CFR § 141.50 and 141.51 SDWA-NPDWS MCLG (mg/L) | 40 CFR § 143 OAC 3745-82-02 SMCL (mg/L) |
|---|---|---|---|---|---|
| Antimony | 0.006 | | | 0.006 | |
| Arsenic | 0.05[a] | 0.05 | 0.05 | | |
| Barium | 2.0 | 2.0 | 1.0 | 2.0 | |
| Beryllium | 0.004 | | | 0.004 | |
| Cadmium | 0.005 | 0.01 | 0.01 | 0.005 | |
| Chloride | | | | | 250 |
| Chromium | 0.1 | 0.1 | 0.05 | 0.1 | |
| Copper | | | | 1.3[b] | 1.0 |
| Cyanide | 0.2 | | | 0.2 | |
| Fluoride | 4.0 | 4.0 | 4.0 | 4.0 | 2.0 |
| Iron | | | | | 0.3 |
| Lead | 0.015[b] | 0.05 | 0.05 | 0.0 | |
| Manganese | | | | | 0.05 |
| Mercury | 0.002 | 0.002 | 0.002 | 0.002 | |
| Nickel | 0.1 | | | 0.1 | |
| Nitrate | 10.0 | 10.0 | 10.0 | 10.0 | |
| Radium-226/228 | 20 pCi/L[c] | 5 pCi/L[d] | | | |
| Radon-222 | 300 pCi/L[c] | | | | |
| Selenium | 0.05 | 0.05 | 0.01 | 0.05 | |
| Silver | | 0.05 | 0.05 | | 0.1 |
| Strontium-90 | 8 pCi/L | 8 pCi/L | | | |
| Thallium | 0.002 | | | 0.0005 | |
| Uranium | 0.02[c] | | | | |
| Zinc | | | | | 5.0 |

**TABLE 2-10**
**(Continued)**

| Constituents | 40 CFR § 141.62 SDWA MCL (mg/L) | OAC 3745-81-11 MCL (mg/L) | 40 CFR § 257.3-4 and 264.94 Subparts C and D OAC-3745-27-10 MCL (mg/L) | 40 CFR § 141.50 and 141.51 SDWA-NPDWS MCLG (mg/L) | 40 CFR § 143 OAC 3745-82-02 SMCL (mg/L) |
|---|---|---|---|---|---|
| 2,4-D | 0.07 | 0.1 | 0.1 | 0.07 | |
| 2,4,5 - TP Silvex | 0.05 | 0.01 | 0.01 | 0.05 | |
| Benzo(a)pyrene | 0.0002 | | | 0 | |
| Bis(2-ethylhexyl)phthalate | 0.006 | | | 0 | |
| Carbon tetrachloride | 0.005 | 0.005 | 0.005 | 0 | |
| Endrin | 0.002 | 0.0002 | 0.0002 | 0.002 | |
| Heptachlor epoxide | 0.0002 | | | 0 | |
| Lindane | 0.0002 | 0.004 | 0.004 | 0.0002 | |
| Methoxychlor | 0.04 | 0.1 | 0.1 | 0.04 | |
| Methylene Chloride | 0.005 | | | 0 | |
| Polychlorinated biphenyls | 0.0005 | | | | |
| Tetrachloroethene | 0.003 | | | 0 | |
| Toluene | 1.0 | | | 1.0 | |
| Toxaphene | 0.003 | 0.005 | 0.005 | 0 | |
| Trihalomethanes | 0.10[e] | 0.10 | | | |
| Xylenes | 10.0 | | | 10.0 | |

[a]The MCL for arsenic, contained in 40 CFR § 141.11, is the only inorganic MCL not superseded by 40 CFR § 141.62.
[b]The MCL for lead and MCLG for copper are action levels found in 40 CFR § 141.80(c).
[c]Proposed MCL.
[d]The state MCL for radium-226/228 is found in OAC 3745-81-15.
[e]The MCL for total trihalomethanes, contained in 40 CFR § 141.12, is the only organic MCL not superseded by 40 CFR § 141.61.

to reduce U-238 and its two progeny to essentially background concentrations, necessary to reduce the risk to the on-site farmer to an ICLR of $10^{-6}$, is not feasible. Soil washing technology is limited to significantly higher concentrations. Volumes of soils to be managed increase 15 fold to more than 2,000,000 cubic yards over the volume that would need to be managed to protect the "expanded trespasser" and "off-site farmer". Therefore, the proposed final remediation levels for Operable Unit 4 reflect a future land use consistent with the SWCR and the CRARE.

Further, additional input from the Fernald Citizens Task Force and the public is essential before making final recommendations on land use from a site-wide perspective. To allow for Operable Unit 5, Task Force, and public input, the Operable Unit 5 FS and ROD will revisit the Operable Unit 4 soil remediation levels and modify them downward if found to be necessary or feasible.

As previously defined, PRGs are developed from the risk-based PRGs for three receptors and the ARAR/TBC-based PRGs. PRLs are actual soil concentrations and could be considered as the PRG (incremental risk) concentrations plus background. In addition, cost benefit analysis and technology considerations can be used to modify a PRG to develop a PRL. Soil PRLs will be the only PRLs developed for Operable Unit 4. Groundwater final remediation levels will be developed as part of Operable Unit 5 and will be presented in the Operable Unit 5 ROD. In addition, Operable Unit 5 will also develop final remedial levels for Operable Unit 5 soils. If Operable Unit 5 final remedial levels are less than the PRLs developed for Operable Unit 4, then the Operable Unit 5 final remedial levels will be adopted for Operable Unit 4.

The three receptors presented in Tables 2-6, 2-7, and 2-8 represent the two future land use scenarios. The expanded trespasser and the off-property resident farmer are the receptors for the government reserve land use (future land use, continued federal ownership). The off-property resident farmer and the on-property resident farmer are the receptors for the farming land use (future land use without continued federal ownership).

2.2.3.1 Basis of Proposed Remediation Levels

The PRGs for soils presented in Tables 2-6, 2-7, and 2-8 indicate that the on-property resident farmer is the critical receptor for soil contamination. This is consistent with the Baseline Risk Assessment results, which indicate that the highest risks are associated with the on-property resident farmer, followed by the trespassing child and the off-property resident farmer, in descending order. Accordingly, the PRGs range in magnitude from the off-property resident farmer, to the expanded

trespasser, to the on-property resident farmer. To compare these two groups of receptors, the risks associated with the trespassing child exposures will be less than those of the expanded trespasser. Therefore, the expanded trespasser is a more conservative receptor than the trespassing child.

Table 2-11 lists the PRGs for the two key constituents U-238 plus two progeny, Pb-210 plus one progeny and Ra-226 plus five progeny for multiple receptors. These three constituents are shown because uranium is the key constituent driving site-wide clean-up with radium and lead being the drivers for soil clean-up of Operable Unit 4. The PRG values are shown in a tiered presentation, lower to higher. Receptors that are not applicable after remediation are listed as N/A.

Values representing $10^{-6}$ risk-based proposed PRGs under the future land use without farmer scenario differ from the ARARs-based PRG for Ra-226 by several orders of magnitude. Moreover, the $10^{-6}$ risk-based proposed PRGs for U-238 and Ra-226 are 3 and 36 times less than background, respectively.

For organics, most PRGs for soils based on the $10^{-6}$ risk level are well below the CRQLs established by EPA. In fact, the $10^{-6}$ risk-based PRG for the on-property farmer is less than background levels for arsenic. To date, the CRQLs have been used for the site characterization study at the FEMP site. MCLs for many of the organic carcinogens appear to be equivalent to a $10^{-4}$ risk level (e.g., for PCBs, benzo(a)pyrene, chlordane, and vinyl chloride). For noncarcinogens, the MCLs appear to be close to risk-based values. This is not surprising because the method used to develop MCLs is the same method used to develop the risk-based values.

Since PRGs are incremental above background concentrations, this implies that background concentrations would be a determining factor in the development of proposed PRLs. However, the current information concerning soil washing strongly suggests that background concentrations are not achievable for uranium isotopes. Treatability data for the other radionuclides and the heavy metals is not available, but information from other Superfund sites suggest that background concentrations will not be achievable for these contaminants. Since it is likely that PRGs for the on-property resident farmer are not achievable, the future land use scenario as a government reserve with the expanded trespasser was adopted as the most likely land use scenario to develop proposed PRLs.

Table 2-12 indicates which of the receptors are protected that is risks for ILCR below $10^{-6}$ if the PRG for the expanded trespasser is achieved.

## TABLE 2-11

## COMPARISON OF PRGS BASED ON A $10^{-6}$ RISK

| | Evaluation of Receptor | | | | |
|---|---|---|---|---|---|
| | Baseline Risk Assessment | FS Risk Assessment | Pb-210 + 2 progeny (pCi/g) | Ra-226 + 5 progeny (pCi/g) | U-238 + 2 progeny (pCi/g) |
| Miami River Water User | Yes | No | N/A | N/A | N/A |
| Off-property Farmer | Yes | Yes | 6200 | 13000 | 1100 |
| Trespassing Child | Yes | Yes | 97 | 14 | 920 |
| Groundskeeper | Yes | No | ND | ND | ND |
| Expanded Trespasser | No | Yes | 77 | 0.37 | 59 |
| CT On-property Farmer | Yes | Yes | ND | ND | ND |
| On-property Farmer | Yes | Yes | 0.91 | 0.004 | 0.55 |
| Background* | | | 1.3 | 1.5 | 1.2 |
| Surface Soil* | | | 4.5 | 88 | 37 |
| Subsurface Soil* | | | 10 | 206 | 53 |

N/A Not Applicable - Baseline risk less than $10^{-6}$
ND Not Determined - Vertical postion indicates relative risk levels
* Upper 95th percentile value from the OU4 RI

# TABLE 2-12
# PROPOSED REMEDIATION LEVELS IN SOILS

| Constituent of Concern | Expanded Trespasser HI = 0.2 PRG mg/kg | Expanded Trespasser $10^{-6}$ ILCR PRG mg/kg | Background (95th percentile) mg/kg | ARAR Target | Max. Detected Soil Concentration, mg/kg | | Proposed Remediation Levels mg/kg | HI to Receptors from Proposed Remediation Levels | | Risk to Receptors from Proposed Remediation Level | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Surface | Sub surface | | Expanded Trespasser | On-Property Farmer | Expanded Trespasser[a] | On-Property Farmer[b] |
| **Radionuclides (pCi/g)** | | | | | | | | | | | |
| Pb-210 +2 progeny | N/A | 77 | 1.33 | NA | 4.5 | 101 | 78[c] | N/A | N/A | $1x10^{-6}$ | $2.0x10^{-3}$ |
| Ra-226 +5 progeny | N/A | 0.37 | 1.45 | 5 (top 6 inch soil) 15 (below 6 inch) | 88 | 206 | 2[c] | N/A | N/A | $1.0x10^{-6}$ | $3.8x10^{-4}$ |
| Ra-228 +1 progeny | N/A | 0.77 | 1.19 | NA | 0.48 | 1.24 | 2[c] | N/A | N/A | $2.0x10^{-6}$ | $2.4x10^{-4}$ |
| Sr-90 +1 progeny | N/A | 1420 | ND | NA | 1.8 | 0.8 | NR | N/A | N/A | $<1x10^{-6}$ | $6.3x10^{-5}$ |
| Tc-99 | N/A | 38700 | ND | NA | 3.6 | 3.6 | NR | N/A | N/A | $<1x10^{-6}$ | $2.2x10^{-4}$ |
| Th-228 | N/A | 0.4 | 1.43 | NA | 2.9 | 1.3 | 2[c] | N/A | N/A | $2x10^{-6}$ | $4.7x10^{-4}$ |
| U-238 +2 progeny | N/A | 59 | 1.22 | NA | 37 | 53 | 60 | N/A | N/A | $1x10^{-6}$ | $2.1x10^{-4}$ |
| **Chemical (mg/kg)** | | | | | | | | | | | |
| Antimony | 31 | N/A | 7.7 | NA | 32 | 32 | NR | 0.2 | 6.1 | N/A | N/A |
| Arsenic | 510 | 23 | 8.45 | NA | 10 | 12 | NR | N/A | N/A | $<1x10^{-6}$ | $1.3x10^{-3}$ |
| Barium | >10000 | N/A | 91.3 | NA | 112 | 142 | NR | <.1 | 0.10 | N/A | N/A |
| Cadmium | 26 | N/A | 0.82 | NA | 6 | 7 | NR | <.1 | 2.8 | N/A | N/A |
| Chromium(III) | NA | N/A | 15.5 | NA | 23 | 25 | NR | <.1 | 0.19 | N/A | N/A |
| Molybdenum | 930 | N/A | 2.6 | NA | 25 | 30 | NR | <.1 | 1.6 | N/A | N/A |
| Nickel | 8300 | N/A | 20.9 | NA | 39 | 39 | NR | <.1 | 0.28 | N/A | N/A |





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**TABLE 2-12**
**(Continued)**

| Constituent of Concern | Expanded Trespasser HI = 0.2 PRG mg/kg | Expanded Trespasser $10^{-6}$ ILCR PRG mg/kg | Background (95th percentile) mg/kg | ARAR Target | Max. Detected Soil Concentration, mg/kg | | Proposed Remediation Levels mg/kg | HI to Receptors from Proposed Remediation Levels | | Risk to Receptors from Proposed Remediation Level | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Surface | Sub surface | | Expanded Trespasser | On-Property Farmer | Expanded Trespasser[a] | On-Property Farmer[b] |
| Silver | 130 | N/A | 2.6 | NA | 10 | 18 | NR | <.1 | 7.0 | N/A | N/A |
| Thallium | 31 | N/A | 0.58 | NA | 0.5 | 0.5 | NR | <.1 | 0.33 | N/A | N/A |
| Vanadium | 1700 | N/A | 30.4 | NA | 28 | 33 | NR | <.1 | 0.57 | N/A | N/A |
| Zinc | >10000 | N/A | 62.2 | NA | 65 | 67 | NR | <.1 | 2.77 | N/A | N/ |
| Benzo(a)anthracene | NA | 61 | ND | NA | 4.7 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $2.4x10^{-4}$ |
| Benzo(a)pyrene | NA | 8.8 | ND | NA | 5.2 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $2.7x10^{-3}$ |
| Benzo(b)fluoranthene | NA | 72 | ND | NA | 9.7 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $1.5x10^{-3}$ |
| Chrysene | NA | 2000 | ND | NA | 3.5 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $1.5x10^{-5}$ |
| Dibenzo(a,h)anthracene | NA | 7.9 | ND | NA | 0.9 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $5.3x10^{-4}$ |
| Indeno(1,2,3-cd)pyrene | NA | 32 | ND | NA | 4.2 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $1.3x10^{-2}$ |

[a]Includes the direct radiation, soil ingestion, and inhalation pathways.
[b]Includes all pathways including the indirect pathways due to food crops.
[c]Sum of background and PRG.
NA = Not Available.
N/A = Not Applicable.
ND = Not Detected.
NR = No Remediation Required.

An additional consideration which supports continued federal ownership is OAC 3734.02, which specifies that hazardous and solid waste disposal facilities must include a protective covenant to restrict mining, drilling, and residential uses. The site boundaries would likely be relocated to release as much uncontaminated land as possible while adequately enclosing the disposal cells and waste areas. As a government reserve (future land use with continued federal ownership), the reduced area would remain government owned with no land development, and no continued maintenance would be performed.

The following rationale was employed to identify the proposed soil action level. The results of applying this rationale to the Operable Unit 4 soil COCs are summarized in Table 2-12.

It is anticipated that to attain the referenced proposed remediation levels, a minimum 15 cm (6 in.) of soils will be removed from the entire Operable Unit 4 area. Deeper excavations may also be required to remove identified "hot spots." Following excavation, the excavation areas will be backfilled with clean soils and seeded. The following steps were followed in developing PRLs for Operable Unit 4:

Step 1. The soil concentration representing the PRG for the $10^{-6}$ risk level for the expanded trespasser from Table 2-7 was adopted as the proposed preliminary soil remediation level.

Step 2. Pertinent ARARs were identified for the individual COC. If the ARAR concentration level for the COC was less than the value identified above, the ARAR level was adopted.

Step 3. In the event the proposed soil remediation level from the first two steps was less than the 95 percentile of the background soil data set, the proposed soil action level was considered indistinguishable from background. That is, any soil concentrations at or below background concentrations would be considered acceptable as a conclusion for remedial actions.

Step 4. The proposed soil remediation level was compared to the 95th percentile of the observed surface and subsurface soil concentrations, which includes the maximum detected values as reported in the RI Report for Operable Unit 4, including nonvalidated data sets such as Characterization Investigation Study on-site gamma spectrometry analysis. The

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frequency of detection of the COCs in the soils was also considered in this evaluation. If the PRL was greater than the maximum observed concentrations or it was infrequently detected, consideration was given to eliminating the need to propose remediation levels for those COCs.

The risk or HI to the expanded trespasser and the on-property resident farmer was then calculated for the proposed FRGs to demonstrate effectiveness for the expanded trespasser and to demonstrate the relationship to the on-property farmer.

2.2.3.2 Presentation of Proposed Remediation Levels

Table 2-12 presents the radionuclide and chemical PRLs for soil. All HIs were less than .01, so carcinogenic risks will drive these proposed levels. The radionuclides Sr-90 and Tc-99 were present at concentrations below the surface and subsurface soil background concentrations; hence, no remediation is required for these COCs. The PRL for Ra-226 is at background, and the PRLs for Ra-228 and Th-228 are approximately twice background. The last two columns of Table 2-12 present the potential risk to the expanded trespasser for the government reserve land use. The risk calculations were performed using the equations presented in the Baseline Risk Assessment for the on-property RME resident farmer. The expanded trespasser risks were calculated by ratioing the on-property RME resident farmer and expanded trespasser PRGs in Tables 2-6 and 2-7. These on-property risk calculations encompass all pathways of exposure as presented in the RI, that is, exposure through incidental ingestion, direct radiation, inhalation of dust, vegetable consumption, meat consumption, and dairy consumption. It should be noted that the trespassing child receptor would have a potential risk below that of the expanded trespasser, based on the decreased frequency of exposure. The Baseline Risk Assessment reported a radiological ILCR for the trespassing child from the unremediated soils and berms (current source term) to be $1x10^{-5}$. The comparison of current source term to surface soils is not exact since the current source term includes both the surface soils and berm material. The total radiological ILCR from the Baseline Risk Assessment to the on-property RME resident farmer using the current source term was $2x10^{-3}$. If unrestricted use of Operable Unit 4 occurs allowing agricultural use, then the on-property RME resident farmer would have a potential combined risk greater than $2x10^{-3}$, with Pb-210 being the major contributor.

The PRGs for the expanded trespasser were all above the existing surface and subsurface soil concentrations for a chemical COCs. The arsenic ILCR for the trespassing child (current source term) from the Baseline Risk Assessment was $2.7x10^{-7}$, which can be compared to the $1x10^{-6}$ ILCR for the

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expanded trespasser. The ILCR for the on-property REM resident farmer for arsenic (current source term, soils and berm) was $3x10^{-4}$. The total ILCR for the on-property RME resident farmer was $8x10^{-2}$, which can be compared to the $1.4x10^{-3}$ total polynuclear aromatic hydrocarbon (PAH) ILCR from the PRLs. It should be noted that the typical detection limit for PAH compounds is 0.33 mg/kg; therefore, the PAH PRLs are at the detection limits.

### 2.2.4 Development of Remedial Action Objectives

EPA guidance requires that RAOs be developed in the initial phase of the FS and used as the framework for developing the detailed remedial alternatives. RAOs are presented in Table 2-13 for each of the material type and environmental media within Operable Unit 4.

#### 2.2.4.1 Waste Material

Waste material includes K-65 residues, also known as "hot raffinates," contained in Silos 1 and 2 and the decant sump tank; and the cold metal oxides contained in Silo 3.

RAOs for the waste material include:

- Prevent direct contact with or ingestion of waste material.
- Prevent release or migration of waste material that would result in soil concentrations in excess of the PRLs identified in Section 2.2.3.2 and Table 2-12.
- Prevent release or migration of waste material that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.
- Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.
- Prevent exposures to waste material that may cause an individual to exceed annual dose limits of 25 mrem/year whole body, 75 mrem/year to the thyroid, or 25 mrem/year to any other organ.
- Prevent exposures to waste material that may cause an individual to exceed a 100 mrem/year effective dose equivalent, above background, from all exposure routes.

#### 2.2.4.2 Structural Material and Equipment

Structural material and equipment includes concrete and metal used in the construction of Silos 1, 2, 3 and 4 and contaminated equipment including the decant sump tank, K-65 Drum Handling Building pad, process piping, pipe trench material, and the existing RTS equipment. Approximate material volumes to be addressed include: 2040 $m^3$ (2670 yd) of concrete from Silos 1, 2, 3 and 4; 280 $m^3$

## TABLE 2-13

## REMEDIAL ACTION OBJECTIVES FOR OPERABLE UNIT 4

| Environmental Media | Remedial Action Objectives |
|---|---|
| Waste Material | <u>For Human Health:</u><br><br>Prevent direct contact with or ingestion of waste material.<br><br>Prevent release or migration of waste material which would result in soil concentrations in excess of the PRLs identified in Section 2.2.3.2 and Table 2-12.<br><br>Prevent release or migration of waste material which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.<br><br>Prevent exposures to waste material which may cause an individual to exceed annual dose limits of 25 mrem/yr whole body, 75 mrem/yr to the thyroid, or 25 mrem/yr to any other organ.<br><br>Prevent exposures to waste material which may cause an individual to exceed a 100 mrem/yr effective dose equivalent, above background, from all exposure routes.<br><br><u>For Environmental Protection:</u><br><br>Prevent release or migration of waste material which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements. |

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TABLE 2-13
(Continued)

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| Environmental Media | Remedial Action Objectives |
|---|---|
| Structural Material and Equipment | For Human Health:<br><br>Prevent direct contact with or release from the site of equipment with surface contamination in excess of the free release limits listed in Table 2-5.<br><br>Prevent leaching or migration of surface contamination which would result in soil concentrations in excess of the PRLs identified in Section 2.2.3.2 and Tables 2-12.<br><br>Prevent leaching or migration of surface contamination which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.<br><br>For Environmental Protection:<br><br>Prevent leaching or migration of surface contamination which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements. |

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**TABLE 2-13**
**(Continued)**

| Environmental Media | Remedial Action Objectives |
|---|---|
| Soil | For Human Health:<br><br>Prevent direct contact with, inhalation of, or ingestion of soil having constituent concentrations in excess of the PRLs identified in Section 2.2.3.2 and Tables 2-12.<br><br>Prevent release or migration of soil constituents which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.<br><br>Prevent exposures to soil materials which may cause an individual to exceed annual dose limits of 25 mrem/yr whole body, 75 mrem/yr to the thyroid, or 25 mrem/yr to any other organ.<br><br>Prevent exposures to soil materials which may cause an individual to exceed a 100 mrem/yr effective dose equivalent, above background, from all exposure routes.<br><br>For Environmental Protection:<br><br>Prevent release or migration of soil constituents which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements. |
| Residual Water | For Human Health:<br><br>Prevent direct contact with or ingestion of residual water having constituent concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of residual water which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.<br><br>For Environmental Protection:<br><br>Prevent release or migration of residual water which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.<br><br>Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements. |

(370 $yd^3$) of contaminated concrete and metal from the decant sump tank, process piping, pipe trenches, and the RTS; and 20 $m^3$ (30 $yd^3$) of contaminated concrete from the K-65 Drum Handling Building pad and the sump lift station. Based on past efforts at the FEMP, decontamination of concrete is not readily performed. Due to its porous nature relative to metal and lack of established clean levels for free release, it is assumed for the purpose of this report that all concrete generated from remedial actions within Operable Unit 4 is contaminated.

Concrete material will be treated like contaminated soil; therefore, RAOs for concrete are addressed under the RAOs for soil. RAOs for metal structural material and pipe include:

- Prevent direct contact with or release from the site of equipment with surface contamination in excess of the free release limits listed in Table 2-5.
- Prevent leaching or migration of surface contamination that would result in soil concentrations in excess of the PRLs identified in Section 2.2.3.2 and Table 2-12.
- Prevent leaching or migration of surface contamination that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.
- Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.

2.2.4.3 Soil

Soil within the Operable Unit 4 boundaries includes surface soil around the silos, subsurface soil beneath the silos and around pipe trenches, and berm soil around Silos 1 and 2. Approximate material volumes to be addressed include 3400 $m^3$ (4440 $yd^3$) of potentially contaminated surface soil, 8060 $m^3$ (10,540 $yd^3$) of potentially contaminated berm soil, and 11,200 $m^3$ (14,650 $yd^3$) of potentially contaminated subsurface soil.

RAOs include:

- Prevent direct contact with, inhalation of, or ingestion of soil having constituent concentrations in excess of the PRGs identified in Section 2.2.3.2 and Table 2-12.
- Prevent release or migration of soil constituents that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.
- Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.
- Prevent exposures to soil materials that may cause an individual to exceed annual dose limits of 25 mrem/year whole body, 75 mrem/year to the thyroid, or 25 mrem/year to any other organ.

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- Prevent exposures to soil materials that may cause an individual to exceed a 100 mrem/year effective dose equivalent, above background, from all exposure routes.

2.2.4.4 Residual Water

Residual water includes water contained in the decant sump tank, water contained in Silo 4, and perched groundwater that may be encountered during potential remedial actions within the Operable Unit 4 boundaries. Approximate material volumes to be addressed include 30,280 L (8000 gallons) of contaminated water in the decant sump tanks, 49,210 L (13,000 gallons) of residual water in Silo 4, and an unknown quantity of perched groundwater that may be encountered during potential remedial actions. The volume estimate for the decant sump tank assumes that the tank has refilled with leachate from Silos 1 and 2 following the January 1993 maintenance action. The volume of liquid assumed to collect in Silo 4 is based on historical infiltration of rainwater through the silo dome.

RAOs for residual water include:

- Prevent direct contact with or ingestion of residual water having constituent concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.
- Prevent release or migration of residual water that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-9.
- Prevent release or migration of waste material that would result in surface water and sediment concentrations in excess of state discharge requirements.

## 2.3 SUBUNIT DESIGNATIONS

Defining areas or volumes of media should include a consideration of not only acceptable exposure levels and potential exposure routes, but also site conditions and the nature and extent of contamination. For areas with discrete hot spots or areas of more concentrated contamination, it may be more useful to define areas and volumes for remediation based on the site-specific relationship of volume or area to contaminant level (EPA 1988b). In accordance with this approach, components of areas and volumes of media identified for Operable Unit 4 were assembled into groupings designated as subunits.

The areas and volumes of media identified within Operable Unit 4 were assembled into a total of three subunits and were designated as Subunits A, B, and C. These subunits are defined as follows:

- Subunit A - Includes the contents of Silos 1 and 2 and the sludge in the decant sump tank

- Subunit B - Includes the contents of Silo 3

- Subunit C - Includes the structures of Silos 1, 2, 3, and 4, the K-65 Drum Handling Building pad, sump lift station concrete, the berms surrounding Silos 1 and 2, the existing RTS on Silos 1 and 2, the surface soil within the Operable Unit 4 Study Area, the contaminated soils beneath Silos 1, 2, 3, and 4 (if any), the underground decant sump tank and related piping, decant sump tank water, any standing water within Silo 4, the underground process piping and concrete trenches containing the piping, and any rubble or debris (i.e., D&D of waste processing facilities) generated consequential to the implementation of remedial actions for all Operable Unit 4 subunits

These subunits will be utilized in the remainder of the FS Report to support the assembly, detailed evaluation, and comparative analysis of the remedial action alternatives.

## 2.4 GENERAL RESPONSE ACTIONS

GRAs describe actions that could satisfy the RAOs. GRAs include no action, institutional actions, containment, removal, treatment, and disposal. Individually, these GRAs do not have to meet the remedial action objectives. The objectives will be met when the actions are combined into alternatives. The following GRAs were considered for Operable Unit 4.

- No Action - The no-action alternative is retained throughout the FS process as required by the NCP [40 CFR § 300.430(e)(6)]. The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken. In the no-action alternative, the materials are considered to be left "as is", without the implementation of any institutional action or containment, removal, treatment, or other mitigating actions. The no-action alternative does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and the no-action does not provide for access control actions taken to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

- Institutional Action - Institutional action applies various access controls and/or deed restrictions to reduce or eliminate direct exposure pathways. The volume, mobility, and toxicity of the contaminants is not reduced through the singular application of institutional actions.

- Containment - Another method of reducing the risk to the public and the environment is through waste containment, which reduces the contaminants' mobility. To reduce mobility, the contaminated media must be isolated from the primary transport mechanisms such as wind, erosion, surface water, groundwater, biological means, and mechanical means. Contaminated media may be isolated by installing surface and subsurface barriers that either block or divert any transport media from the contaminants.

- Removal - Technologies under the removal response action category are used to move waste or contaminated media from its present location to be treated and/or to be disposed elsewhere. Removal process options are combined with treatment and/or disposal process options to develop alternatives. Silo demolition process options are included in this response action.

- Treatment - Treatment response action includes both in situ and ex situ treatment process options. These process options are designed to reduce the toxicity, volume, or mobility of the contaminants present. Ex situ treatment process options are used with removal and disposal process options to develop alternatives.

- Disposal - Disposal response action includes waste transportation, on-property disposal, and off-site disposal. The disposal process options are used in concert with removal options and possibly treatment options to develop alternatives. Disposal technologies provide for the final deposition of the material.

## 2.5 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

Viable remedial action alternatives for Operable Unit 4 are developed by identifying remedial technologies, and viable process options within these technologies, that may be applied to the various contaminated media at the site. These media, which include soil, sludge, surface water, groundwater, perched water, structural material, and process residues, have been segmented into the three previously identified subunits. The identification and screening of technologies and process options have been conducted in context with these subunits.

The technologies considered in selecting remedial action alternatives for these subunits include those identified in 40 CFR § 300. Additional technologies were considered based on experience and information gained through remedial action planning and implementation at similar sites. In this section, the range of available technology types and process options were screened for applicability to the site in accordance with EPA guidance (EPA 1988b). Following the technology screening process,

the following section presents an evaluation of the remaining process options to select representative process options to support the assembly of remedial action alternatives in Section 3.0.

### 2.5.1 Criteria for Identifying and Screening Technologies

Based on available information, media-specific remedial technologies and process options were identified for each of the GRAs. The technologies and associated process options were compiled using information available in various EPA documents as well as other references. Each process option was screened for technical implementability. When no viable process option was left from a technology family, the technology was also screened. The screening process reduces the variety of possible process options for a given technology family to a smaller and more manageable number of options that were considered appropriate for the various media. In this step, both technologies and process options could be eliminated based on technical implementability criteria. Information, including site description and contaminant characterization and concentrations, was used to eliminate various technologies and process options that would not apply or could not be effectively implemented at the site.

Figure 2-2 summarizes the GRAs, remedial technologies, and associated process options considered for Operable Unit 4 wastes and media. Figure 2-2 further summarizes the applicability of the various process options to the Operable Unit 4 subunits and presents the results of the initial screening process. The following is a brief summary of the identification and screening of technologies and process options.

### 2.5.2 No-Action General Response Action

The no-action response does not provide additional remediation, maintenance, or security activities at the site to further minimize risk to public health and the environment. The no-action GRA is retained as a baseline for comparison to other remediation alternatives as required by the NCP. This GRA is applicable to all subunits.

### 2.5.3 Institutional Action General Response Action

Institutional actions are applicable to all of the subunits and will include monitoring and access controls.

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SUBUNIT APPLICABILITY A | B | C | SCREENING COMMENTS |
|---|---|---|---|---|---|---|---|
| No Action | None | Not Applicable | No Action | X | X | X | Required for consideration by NCP |
| Institutional Action | Monitoring | Groundwater Monitoring | Installation of wells for monitoring groundwater | X | X | X | Potentially applicable |
| | | Leachate Monitoring | Monitoring of leachate collection/detection system | X | X | X | Potentially applicable |
| | | Radon Monitoring | Installation of radon monitoring devices | X | X | X | Potentially applicable |
| | | Surface Water/Sediment Monitoring | Collection/analysis of surface water/sediment samples | X | X | X | Potentially applicable |
| | Access Control | Physical Barriers | Fencing, security, limited road access, etc. | X | X | X | Potentially applicable |
| | | Administrative Controls | Restricted access only, posted signs, etc. | X | X | X | Potentially applicable |
| Containment | Subsurface Flow Control | Subsurface Drains | Gravity driven collection system | X | X | X | Potentially applicable |
| | | Slurry Walls | A soil/bentonite grout wall emplacement | X | X | X | Potentially applicable |
| | | Pumping Wells | Extraction/injection of water into ground | X | X | X | Potentially applicable |
| | | Sheet Pilings | Steel/concrete forms joined and driven into ground | X | X | X | Potentially applicable |
| | | Grout Curtains | Close-spaced grout injections isolate area | X | X | X | Potentially applicable |
| | Capping | Concrete-Based Cap | Concrete slab poured over area of concern | X | X | X | Potentially applicable |
| | | Asphalt-Based Cap | Asphalt poured over area of concern | X | X | X | Potentially applicable |
| | | Soil/Clay-Based Cap | Compacted soil or clay cover over area of concern | X | X | X | Potentially applicable |
| | | Chemical Sealant Cap | Chemical stabilizers mixed with surface soils | X | X | X | Potentially applicable |
| | | Multimedia Cap | Cap formed with various layers | X | X | X | Potentially applicable |
| | | Void Space Grout | Fill dome void space with grout | X | X | - | Not feasible for empty silos |
| | Run-On/Runoff Control | Sedimentation Basin/ Sediment Trap | Temporary storage of runoff to allow settling/Traps to intercept soil particles in runoff | X | X | X | Potentially applicable |
| | | Diversion/Collection | Surface water routing controls | X | X | X | Potentially applicable |
| | | Grading | Topography modification for route control | X | X | X | Potentially applicable |
| | | Revegetation | Vegetative cover provides surface stability | X | X | X | Potentially applicable |
| | Silo Renovation | Silo Rehabilitation | Apply gunite, paint, concrete, etc. to silo | - | - | - | Silos will be removed if residues are removed |

"X" indicates process option to be retained for evaluation
"-" indicates process option not applicable for that subunit
Process option not retained for any subunit.

**FIGURE 2-2**

**INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SUBUNIT APPLICABILITY A | B | C | SCREENING COMMENTS |
|---|---|---|---|---|---|---|---|
| Removal | Mechanical Removal | Loader/Dozer | Tractor- or wheel-mounted excavation vehicles | - | - | X | Not applicable due to material consistency and silo strength limitations |
| | | Crane w/Clamshell System | Tractor-, wheel-, or skid-mounted hoisting system | X | - | X | Not feasible due to material consistency |
| | | Conveyor System | Belt-type conveyor system excavates material | - | - | X | Not feasible due to material consistency, accessibility, and silo strength limitations |
| | | Backhoe | Tractor- or wheel-mounted excavation vehicles | - | - | X | Not feasible due to material accessibility, and silo strength limitations |
| | | Dragline System | Excavating tool pulled across material | - | - | X | Not feasible due to material consistency |
| | Hydraulic Removal | Slurry Pump w/ Jetting Ring | Dislodges and hydraulically removes material | X | X | X | Potentially applicable |
| | Pneumatic Removal | Pneuma/Dozer Dredging | In situ sludge pumping system | - | - | - | Not applicable because of material consistency |
| | | Airlift Dredging | Expanding air pulls material behind it | - | - | - | Not applicable, requires depths > 20-30 ft |
| | | Vacuum w/Cutterhead | Negative pressure displacement system | X | X | - | Not applicable due to material incompatability |
| | Silo Demolition | Controlled Blasting | Use of explosive agents to demolish structure | - | - | X | Only applicable to silo structures |
| | | Impact Hammer | Percussion tools to break apart silo | - | - | X | Only applicable to silo structures |
| | | Flame Cutting | Ignition of iron and aluminum oxides to cut structure/rebar | - | - | X | Only applicable to silo structures |
| | | Thermite Reaction Lance | High-temperature flame cutting device to cut silo | - | - | X | Only applicable to silo structures |
| | | Gas Torch | Torch used to cut structure/rebar | - | - | X | Only applicable to silo structures |
| | | Hydraulic Splitter | High pressure water used to cut structure | - | - | X | Only applicable to silo structures |
| | | Non-explosive Demolition Compounds | Expanding agents fracture structure | - | - | X | Only applicable to silo structures |
| | | Circular Diamond or Carbide Saws | Diamond tipped or carbide saws to cut structural rebar | - | - | X | Only applicable to silo structures |
| | | Diamond Rope Saw | Diamond-tipped rope saw to cut concrete/rebar | - | - | X | Only applicable to silo structures |
| | | Diamond Chain Saw | Diamond-tipped chain saw to cut concrete/rebar | - | - | X | Only applicable to silo structures |
| | | Abrasive Water Jet | Stream of abrasives to cut silo using a high-velocity water jet | - | - | X | Only applicable to silo structures |
| | | Core Stitch Drilling | Drilling closely spaced holes resulting in failure of structure when force is applied | - | - | X | Only applicable to silo structures |
| | | Wrecking Ball | Crane-mounted weight used to collapse structure | - | - | X | Only applicable to silo structures |
| Treatment | In Situ Treatment | Shallow-soil mixing | Chemical-, and/or fly ash-based stabilization | - | - | X | Silo strength limitations |
| | | Insitu Vitrification | High voltage crystallization/glassification of solids | X | X | X | Potentially applicable |
| | | Surcharging | Compaction of material by addition of soil cover | - | - | - | Limited waste compaction expected |
| | | Soil Aeration | Inject air and collect volatiles | - | - | - | Not applicable to inorganics |
| | | Steam Stripping | Inject steam to drive off volatiles | - | - | - | Not applicable to inorganics |

"X" indicates process option to be retained for evaluation
"-" indicates process option not applicable for that subunit
Process option not retained for any subunit.

Figure 2-2
(Continued)

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | Subunit Applicability A | B | C | SCREENING COMMENTS |
|---|---|---|---|---|---|---|---|
| Treatment | Waste Stabilization | Asphalt-Based Stabilization | Asphalt mixed with soil and solidified | X | X | X | Potentially applicable |
| | | Cement-Based Stabilization | Cement mixed with soil and solidified | X | X | X | Potentially applicable |
| | | Thermoplastic Encapsulation | Polymers mixed with soil and solidified | X | X | X | Potentially applicable |
| | | Vitrification | High voltage crystallization/glassification of solids | X | X | X | Potentially applicable |
| | | Lime/Flyash Stabilization | Lime and fly ash mixed with soil | X | X | X | Potentially applicable |
| | Physical Treatment | Air Stripping | Volatile mass transfer process | - | - | - | Not applicable for inorganic materials |
| | | Solid/Liquid Separation | Separation of solids and liquids | X | - | X | Not applicable due to dry powdery matrix |
| | | Oil/Water Separation | Gravity differential separates free oil and water | - | - | - | Not applicable, no free oil phase |
| | | Polymerization | Combines monomers to form polymers | - | - | - | Not applicable, few polymerizable materials |
| | | FEMP AWWT | Treatment at FEMP Advanced Wastewater Treatment System | X | X | X | Potentially applicable |
| | | Soil Aeration | Air injectors remove volatile organics | - | - | - | Not applicable for inorganic materials |
| | | Steam Stripping | Steam injection removes volatile organics | - | - | - | Not applicable for inorganic materials |
| | Chemical Treatment | Chemical Dechlorination | Reduces the amount of chlorinated compounds | - | - | - | Not applicable, few chlorinated compounds |
| | | Oxidation/Ozonation/Photolysis | Organics destroyed by chemical oxidants | - | - | - | Not applicable for radionuclides |
| | | Hydrolysis | Decomposition of compounds using water | - | - | - | Not applicable, material fully hydrolized |
| | | Chemical Extraction | Impurities removed through solubility/affinity | X | X | X | Potentially applicable |
| | | Reduction | Reduction of the ionic state of a compound | - | - | - | Not applicable, few reducible materials |
| | Thermal Treatment | Drying/Calcination | Removes water and decomposes carbonates | X | - | - | Silo 3 already calcined, does not treat radionuclides |
| | | Incineration | Destroys hazardous organics and reduces volume | - | - | - | Not applicable for inorganic materials, radionuclides |
| | | Thermal Desorption | Heating of a solid to drive off volatile organics | - | - | - | Not applicable for inorganic materials, radionuclides |

"X" indicates process option to be retained for evaluation
"–" indicates process option not applicable for that subunit
▨ Process option not retained for any subunit.

Figure 2-2
(Continued)



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| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SUBUNIT APPLICABILITY A | B | C | SCREENING COMMENTS |
|---|---|---|---|---|---|---|---|
| Treatment | Biological Treatment | Biodenitrification | Nitrates/nitrites reduced to molecular nitrogen | - | - | - | Not applicable due to lack of nitrates/nitrites |
| | | Biological Detoxification | Microbial action degrades organics | - | - | - | Not applicable for radionuclides |
| | | Land Farming | Microorganisms cultured in soil | - | - | - | Not applicable for radionuclides |
| | Decontamination and Decommissioning | Vacuum Scabbling | Pneumatically-driven piston, equipped with spikes used to chip away concrete and vacuumed up. | - | - | X | Only applicable to contaminated silo structures |
| | | Pressure Washing | High pressure washer used to clean surface | - | - | X | Only applicable to contaminated silo structures |
| | | Vacuum Grit-Blasting | Stream of abrasives propelled against surface to chip away concrete and vacuumed up | - | - | X | Only applicable to contaminated silo structures |
| | | Acid Washing with Oxidizing Agents | Application of acid to dissolve concrete | - | - | X | Only applicable to contaminated silo structures |
| | | Strippable Coatings | Application of material that cures to a thin solid coating and trapping contaminants in a polymer mix that may be stripped and disposed. | - | - | X | Only applicable to contaminated silo structures |
| Disposal | Waste Transportation | Rail Transport | Railroad transportation along available routes | X | X | X | Potentially applicable |
| | | Truck Transport | Truck transportation along available routes | X | X | X | Potentially applicable |
| | On-Property Disposal | Engineered Disposal Facility | Engineered facility, capped when filled | X | X | X | Potentially applicable |
| | | Above-Grade Vault | Above-ground disposal facility | X | X | X | Potentially applicable |
| | | Lined/Unlined Pits/Trenches | Simple non-structural disposal units | - | - | - | Unacceptable for permanent disposal |
| | Off-Site Disposal | Nevada Test Site | Licensed government facility | X | X | X | Potentially applicable |
| | | Permitted Commercial Disposal Site | Licensed commercial facility | - | - | X | Not applicable, cannot meet waste acceptance criteria |
| | | New Facility Adjacent to FEMP | Engineered facility to be constructed | X | X | X | Potentially applicable |
| | | New Facility w/in 300 Miles of FEMP | Engineered facility to be constructed | X | X | X | Potentially applicable |
| | | Deep Geological Repository | Deep mined disposal facility | - | - | - | Not applicable, facility does not exist which accepts OU4 material |

"X" indicates process option to be retained for evaluation
"–" indicates process option not applicable for that subunit
Process option not retained for any subunit.

**Figure 2-2**
**(Continued)**

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2.5.3.1 Monitoring Technology

Monitoring would be conducted during the implementation of any selected remedial action alternative to assess short-term impacts to workers and the public. Additionally, sampling and/or monitoring would be employed following completion of remedial actions to demonstrate attainment of remedial action objectives and, as necessary, assess the continued performance of on-property waste disposal systems. Groundwater would be monitored through the sampling and analysis of existing and new well installations. In addition, disposal vault performance would be monitored through the existing and new leachate collection/detection systems (LC/DS), and the air would be monitored for radon emissions. Furthermore, surface water and sediment runoff would be monitored as needed. The following discussion presents the monitoring process options considered.

Groundwater Monitoring

Groundwater would be checked through existing and/or new monitoring wells to detect and monitor contaminant migration. Groundwater monitoring is applicable to Subunits A, B, and C and has been retained for evaluation.

Leachate Monitoring

Leachate would be monitored through existing systems such as the decant sump tank or a newly installed collection system. Leachate monitoring is applicable to Subunits A, B, and C and has been retained for evaluation.

Radon Monitoring

The air may be monitored for radon emissions near wastes containing significant quantities of radium. Subunit A and potentially, Subunits B and C, may require periodic monitoring of radon. Consequently, radon monitoring has been retained for further evaluation for Subunits A, B, and C.

Surface Water/Sediment Monitoring

Surface water and sediment monitoring is useful for determining the extent of surface contaminant migration due to runoff and emitted re-suspended contaminants. Accordingly, surface water/sediment monitoring has been retained for further evaluation for Subunits A, B, and C.

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2.5.3.2 Access Control Technology

Access controls would be implemented to regulate access to the site and any contaminated media. The process options for access control technologies consider the potential implementation of active and passive controls. Active controls can consist of physical barriers such as fences, gates, and security forces, while passive controls include administrative controls such as ownership, access permits, and deed restrictions. The following discussion presents the access control process options.

Physical Barriers

Physical barriers limit the potential for inadvertent public or worker exposure to on-property contamination by restricting entry. Public access to the FEMP site is controlled by security forces and fencing. In addition, workers are restricted from contaminated areas within the Operable Unit 4 boundaries by access gates, internal fences, ropes, and signs. Accordingly, this process option will be retained for all subunits.

Administrative Controls

Administrative controls provide passive measures to limit the potential for public and worker exposure to contamination on property. This option controls public exposure to on-property contamination by restricting access and use. This access control process option is applicable and will be retained for all subunits.

2.5.4 Containment General Response Action

Long-term containment consists of technologies that confine contaminated media at their current locations. These technologies limit the migration of contaminants and the associated potential for exposure, but they do not reduce contaminant toxicity or volume. These containment technologies include subsurface flow control, capping, run-on/runoff control, and silo renovation.

2.5.4.1 Subsurface Flow Control Technology

Subsurface contamination can be isolated by lateral barriers such as subsurface drains, slurry walls, pumping wells, sheet pilings, or grout curtains. There are two purposes for these technologies: 1) collect and control leachate flow, and 2) control clean groundwater from coming in contact with contaminated subsurface soils. The effectiveness of subsurface flow controls depends on the size of the affected area and the nature of the site-specific hydrogeological conditions. The following discussion presents the subsurface flow control process options considered.

Subsurface Drains

Subsurface drains include any type of buried conduit used to collect and convey groundwater or leachate by gravity flow. A subsurface drainage system often uses a perforated drain pipe or a gravel bed for conveying flow to a storage tank or sump. This process option was retained to potentially collect leachate from Subunits A, B, and C.

Slurry Walls

Slurry walls would isolate the subsurface soil contamination by diverting the groundwater around the contamination. Slurry walls are fixed, underground physical barriers that are formed by pumping slurry, usually a soil or cement, bentonite, and water mixture into a trench as excavation proceeds, allowing the slurry to set while backfilling. The slurry also maintains the trench during excavation. Slurry walls have been retained for additional evaluation for Subunit C due to the known subsurface soil contamination and for Subunits A and B in conjunction with other containment process options.

Pumping Wells

Pumping wells either extract or inject water to contain or remove a contamination plume, or to adjust groundwater levels to prevent plume migration. They can also be used in conjunction with other groundwater controls to maximize efficiency. This process option has been retained for additional evaluation for Subunit C because it could prevent groundwater contact with contaminated subsurface soil and for Subunits A and B in conjunction with other containment process options.

Sheet Pilings

Sheet pilings are constructed by permanently driving webbed sections of sheet piling into the ground. Sections are joined before being driven into the ground and initially are not watertight. However, the joints soon fill with fine- to medium-grained soil particles, which generally block groundwater flow. Because of costs and unpredictable wall integrity, sheet pilings are seldom used except for temporary dewatering for construction, or as erosion protection where another barrier intersects flowing water. Sheet pilings have been retained for additional evaluation for Subunit C as a process option that could isolate the subsurface soil contamination by diverting groundwater from the contamination source and for Subunits A and B in conjunction with other containment process options.

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Grout Curtains

Grout curtains are fixed underground barriers formed by injecting grout, either particulate (such as portland cement) or chemical (such as sodium silicate), into the ground. Grout curtains have been retained for Subunit C for further study because they make it possible to divert groundwater from the contaminated subsurface soil, which helps prevent contaminant migration and for Subunits A and B in conjunction with other containment process options.

2.5.4.2 Capping Technology

A contaminated area can be encapsulated by placing physical barriers (caps) on top of the waste. Capping of soil, sludge, and sediment could effectively limit airborne emissions and reduce precipitation-enhanced percolation and leaching. A stabilized surface fill would be required before cap placement. In situ capping of the silos in Subunits A and B would require filling void space in the individual silos to increase each silo's weight-bearing capacity. The following sections discuss the capping options that were considered.

Concrete-Based Cap

A single-layered cap composed of concrete can effectively control erosion and minimize generation of leachate from precipitation infiltration. Periodic application of special surface treatment may be required to maintain integrity. This process option has been retained for further evaluation for all subunits as a way to prevent or retard the contact of water with contaminated material.

Asphalt-Based Cap

This capping option is similar to the concrete-based cover except this technology uses a layer of asphalt to isolate the material. Again, periodic application of special surface treatment may be required to maintain integrity. The asphalt-based cover has been retained for additional evaluation for all subunits.

Soil-/Clay-Based Cap

A soil-/clay-based cap is a single layer cap that uses soil or clay with a lower permeability than the waste being capped to reduce or stop infiltration of precipitation. Although more susceptible than asphalt-based or concrete-based caps to cracking from freeze/thaw cycles, this option has been retained for all subunits for further evaluation since it is technically implementable.

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Chemical Sealant Cap

The chemical sealant cap mixes a chemical binder with the upper soil layer. Cement, quicklime, or other grouting materials can be applied to the surface to create a seal that minimizes infiltration of precipitation and erosive transport of contaminated surface soils. This process option has been retained for all subunits for further evaluation.

Multimedia Cap

A multimedia cap incorporates the most effective attributes of other capping options by using more than one barrier material to form multiple layers over the contaminated media. This layered design offers the highest effectiveness for capping by using the properties of the cap components to reduce or stop infiltration and control erosion while simultaneously providing protection (vegetation and drainage layers) against freeze/thaw damage, cracking, or other damaging actions. This capping option has been retained for all subunits for further evaluation.

Void Space Grout

The void space grout option involves filling the small void spaces in the silo domes with grout. This process option was retained for Subunits A and B because the void spaces over the contained wastes are relatively small. Completely filling the empty silos of Subunit C with grout may result in silo failure, given the structural condition of the silos. Therefore, this process option was not retained for Subunit C.

2.5.4.3 Run-on/Runoff Control Technology

Run-on/runoff controls are used to divert surface runoff around contaminated areas, thus minimizing the potential for contaminant resuspension. Graded contours, swales, and berms can effectively control surface water run-on/runoff and can limit contaminant migration. These measures have been effectively used on property (e.g., Operable Unit 1 - Waste Pit Area Runoff Control Project). Also, sediment traps such as siltation fences or bales may be used to intercept soil particles in runoff; however, their use requires active maintenance. Sedimentation basins or sediment traps could also be used in conjunction with surface diversions/controls for surface water control. The following discussion presents run-on/runoff control process options.

Sedimentation Basin/Sediment Trap

Sedimentation basins and sediment traps are used to control suspended solids entrained in surface flows. A sedimentation basin is usually constructed by placing an earthen dam across a waterway or

natural depression or by excavation, or by a combination of both. Sediment traps include silt fences or bales that intercept and collect soil particles in runoff. This process option has been retained for additional evaluation for all subunits because of the short-term potential for contaminated runoff to occur during storm events.

Diversion/Collection

Essential to surface water management, surface diversion and collection includes the use of dams, dikes, berms, channels, waterways, terraces/benches, chutes, seepage ditches/basins, levees, and flood walls as temporary or permanent measures for effective surface water control. Diversion/collection may be used to prevent flooding, control erosion, or direct surface runoff and can effectively prevent the contact of surface runoff with contaminated water or waste material. Diversion/collection has been retained for further evaluation for all subunits as a means to control potential surface water runoff.

Grading

By reshaping the land surface through grading, both surface water infiltration and runoff are managed while controlling erosion. Spreading and compaction of soils are commonly used in conjunction with grading. This process option will be evaluated further for all subunits as a way to manage surface water infiltration and control runoff.

Revegetation

Revegetation is a cost-effective method to stabilize the surface, especially when preceded by capping and grading. Revegetation decreases erosion by wind and water and contributes to the development of a naturally fertile and stable surface environment. This process option has been retained for further evaluation for all subunits as a way to stabilize the surface of regraded land or capping of the subunits.

2.5.4.4 Silo Renovation Technology

Silo Rehabilitation

This process option renovates the silos to help contain the contaminated media. Long-term renovation processes include application of paint, gunite, foam, concrete, or emulsions. Such applications can effectively control releases from contaminated surfaces. Silo renovation has not been retained for Subunit C because DOE has no intent to renovate the silos for future use, and is committed to removing the silos (if waste removal process options are selected for Subunits A and B) as part of

FEMP cleanup activities. This process option does not apply to Subunits A or B because there are no silo structures associated with these subunits.

### 2.5.5 Removal General Response Action

Removal of contaminated material is used before ex situ treatment and/or disposal that could reduce contaminant toxicity, mobility, or volume. Removal measures can be applied to all affected Operable Unit 4 media, and the appropriate technology and process option depend on the physical properties of the medium.

The waste removal technology encompasses five mechanical removal process options, a single hydraulic removal process option, three pneumatic removal process options, and 13 silo demolition process options. The proposed removal process options for Subunits A and B allow the contents of Silos 1, 2, and 3 to be removed with or without the silo domes in place.

#### 2.5.5.1 Mechanical Removal Technology

Loader/Dozer

A tracked or wheeled front-end loader or dozer uses a front-mounted bucket to excavate and move material. This process option was not retained for Subunits A and B because supporting such a vehicle on Silos 1, 2, or 3, given their structural condition, would be difficult. Also, there are concerns about the silo structure if the vehicle was placed on the berms surrounding Silos 1 and 2. This process option has been retained for Subunit C for removing the contaminated soil and debris from silo demolition.

Crane with Clamshell System

A clamshell suspended from a crane or other overhead structure could be used to remove the Subunit A residues or the berms, subsurface soil, and demolished silo structures of Subunit C. However, this process option has not been retained for Subunit B due to the clamshell's inability to remove the dry, powdery material without excessive fugitive dust emissions from Silo 3.

Conveyor System

A belt-type conveyor system with excavation buckets could be used to remove the berms and soil (Subunit C). The device would have to be placed on the berms for the Subunit A contents, which may be hazardous to the silo walls; therefore, this option was not retained for Subunit A. This device would have to be suspended from the silo structure to access the Subunit B contents, but due to the

material consistency and accessibility of Silo 3 (Subunit B), this process option has not been retained for Subunit B. Consequently, this process option was only retained for the soil in Subunit C.

Backhoe

A tracked or wheeled backhoe could be used to remove soil and other material. For Subunit A, the device would have to be mounted on the berm to excavate the waste and may require structural modifications to the silos. For Subunit B, the backhoe would have to be placed on an elevated platform to access the wastes. The demolished silos and the berms and soil could be removed directly by the backhoe. As a result, this process option was not retained for Subunits A or B because of silo structural concerns and restricted access to the waste material, respectively. Consequently, the backhoe process option has been retained only for Subunit C.

Dragline System

A dragline system is a crane-suspended excavation tool that is pulled across the surface of the media. This process option was not retained for Subunits A and B because it would not be effective with the sludge-like waste in Subunit A and the dry, powdery waste of Subunit B. The process option was retained for Subunit C for removal of the contaminated soil.

2.5.5.2 Hydraulic Removal Technology

Slurry Pump with Jetting Ring

The only hydraulic removal technology considered and retained for further evaluation would use a hydraulic mining pump, consisting of a slurry pump and a water jetting ring to remove any liquids in Silo 4 and the Subunits A and B waste as a slurry. This device could be supported from an overhead structure or used in conjunction with robotics. This process option is applicable to Subunits A, B, and C (Silo 4 water only).

2.5.5.3 Pneumatic Removal Technology

Pneuma/Oozer Dredging

A pneuma/oozer dredging system consists of a compressed air-driven pump that displaces and removes the wastes. This device would be suspended from an overhead structure. This process option is not applicable to Subunits A, B, and C due to material consistency.

Airlift Dredging

An airlift dredge uses expanding air introduced through a pipe that is driven into the waste to entrain the waste and force it upward. The dredge would then be suspended from an overhead structure. This process option has not been retained for Subunits A and B because the minimum depth for application is 6.1 to 9.1 m (20 to 30 ft). It also does not apply to Subunit C because of the nonheterogeneous solid materials that are not amenable to airlift dredging.

Vacuum with Cutterhead

A vacuum with a cutterhead could be used to loosen waste residue and displace it with negative pressure. This process option is applicable to Subunits A and B and will be retained for further evaluation because the waste consistency and accessibility are suitable. The vacuum with cutterhead option has been eliminated for Subunit C because Subunit C contains piping, soil, and concrete.

2.5.5.4 Silo Demolition Technology

Application of the various tools and techniques available in demolition depends on the physical and radiological conditions of the structure. The chosen technology should demolish the silos and other structures while maintaining control of the process, both radiologically and physically. Various commercial products are available to demolish structures.

Before demolition, the inner silo walls may have to be decontaminated to remove gross contamination, to the extent practical, to minimize the contamination hazard during demolition. The generation of contaminated dust is a concern during demolition activities. Because Subunits A and B contain no structures, the demolition options are not applicable to those subunits. The following process options were considered for Subunit C.

Controlled Blasting

Controlled blasting can be used to demolish radioactively contaminated concrete when massive, reinforced concrete sections are encountered. The process consists of drilling holes in the concrete, loading them with explosives, and detonating them using a delayed firing technique. Delayed firing increases the fragmentation and controls the direction of material movement. The process is well suited for demolishing heavily reinforced concrete because, with the proper selection of blast parameters, a high degree of fragmentation may easily be achieved. However, there is an inherent danger in blasting with regard to personnel safety and damage to nearby buildings. This process option is applicable to Subunit C.

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Impact Hammer

Impact hammers are used on floors to remove small areas that are inaccessible by larger equipment. They also may be used to expose reinforcing rods after controlled blasting to permit cutting of the rods. The major advantage of impact hammers is their ability to operate in relatively small work areas. This process option will be considered for Subunit C.

Flame Cutting

Flame cutting of concrete consists of a thermite reaction process whereby a powdered mixture of iron and aluminum oxides in a pure oxygen jet is ignited. The temperature in the jet typically ranges from 1982 to 2482°C (3600 to 4500°F), which rapidly decomposes the concrete contacting the jet. Reinforcing rods in the concrete add iron, which sustains the flame and assists the reaction. The major disadvantage with flame cutting is that large amounts of dust, smoke, and heat are produced. This process option will be considered for Subunit C.

Thermite Reaction Lance

The thermite reaction lance is a high-temperature flame cutting device that cuts irregularly shaped materials. This equipment consists of a combination of steel, aluminum, and magnesium wires packed inside an iron pipe through which a flow of oxygen gas is maintained. During cutting, the lance must be hand-held, and the operator must be equipped with fireproof protective clothing and a respirator. This process option is applicable for Subunit C.

Gas Torch

A gas torch could be used to cut both concrete and steel and would create little, if any, dust. Because the silo might collapse, this procedure should be performed remotely. This process option was retained for Subunit C.

Hydraulic Splitter

A hydraulic splitter can be used to cut both concrete and steel. This would generate little dust, but the water used would have to be collected and possibly treated. This process option is applicable for Subunit C.

Nonexplosive Demolition Compounds

The compound can be mixed with water and placed in holes that were drilled into the concrete along a fracture line of predetermined burden, spacing, and depth. Within 20 hours, pressure would develop to more than 31,027 kiloPascals (kPa) [4500 pounds per square inch (psi)], much greater than the tensile strength of most concrete. Cracks would form and propagate along the fracture line. The fractured burden may then be removed with a pavement breaker, backhoe, or bucket loader. The steel would have to be cut with a torch or other cutting device. Nonexplosive demolition compounds are applicable for Subunit C.

Circular Diamond or Carbide Saws

Circular diamond or carbide saws are used to minimize disturbance of the surrounding material. Large diamond or carbide-tipped saws are ordinarily used to cut concrete walls and floors. These saws can cut through reinforcing bars, although the bars tend to damage the blade. This process option is retained for Subunit C.

Diamond Rope Saw

Diamond rope saws are used to minimize the creation of airborne contaminants and vibration to surrounding structures. The diamond rope saw is a smooth cutting technology capable of much deeper cuts than the diamond or carbide-tipped saws. Diamond rope saws can be used to cut concrete up to 6 m (20 ft) thick.

The rope is fed through previously drilled holes. The ends are then joined securely and wrapped around a hydraulically driven flywheel. A small amount of water is added to the cut line for lubrication, cooling, and dust control. The diamond rope sawing equipment, including saw stand and hydraulics, should be placed as far from the actual work as necessary for personnel and equipment protection. This process option would also create little, if any, dust due to the water used for dust control; however, a collection system would be required for the water produced. The process option is retained for further consideration for Subunit C.

Diamond Chain Saw

A diamond chain saw consists of a saw that is equipped with a diamond-tipped chain. This device is powered with hydraulics and is capable of cutting through concrete and steel reinforcement. It uses a stream of water for cooling and dust control. A diamond chain saw is light-weight and is easily managed by a single person. Diamond chain saws were retained for Subunit C.

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Abrasive Water Jet

In the abrasive water jet process, a small diameter, high-velocity water jet and a stream of solid abrasives are introduced from separate feedports into a specially shaped abrasive jet nozzle. The water jet's momentum is transferred to the abrasives. Garnet sand is the abrasive most commonly used for cutting. When steel grit is used, it can be separated magnetically and reused. The major disadvantage with the abrasive water jet is the large volume of dirty and contaminated water it produces. Also, the system has its inherent dangers to personnel with the high pressure abrasives. Use of abrasive water jets was retained for Subunit C.

Core-Stitch Drilling

Core-stitch drilling is available for nonreinforced concrete, especially when surroundings should not be disturbed. The technique consists of drilling holes in the concrete. The center-line of the holes is located to correspond to the desired breaking plane in the concrete. The hole pitch is such that there is very little concrete left between the adjoining holes. A force is then applied to split the concrete along the line of the holes. This process option is applicable to Subunit C.

Wrecking Ball

A wrecking ball suspended from a crane would be effective in demolishing the silos, but a gas torch or other cutting device would be necessary to cut the steel wire and the reinforcement in the concrete. Wrecking balls are considered applicable for Subunit C.

### 2.5.6 Treatment General Response Action

This response action contains both in situ and ex situ treatment technologies. Ex situ treatment technologies discussed are waste stabilization, physical treatment, chemical treatment, thermal treatment, and decontamination and decommissioning.

#### 2.5.6.1 In Situ Treatment Technology

These technologies are applicable to Subunits A and B and the soils in Subunit C. They are not applicable for the nonsoil wastes in Subunit C because these materials are not amenable to in situ waste treatment options. Silo structures would, however, serve as containment in conjunction with in situ treatment technologies for Subunits A and B. These process options may be combined with containment process options to form alternatives. The following discussion presents in situ treatment process options.

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Shallow Soil Mixing

This process would add cement, flyash, and bentonite to soil or waste materials and blend the mixture with augers lowered into the material. Stabilization will cause the volume of the material to increase. Silo berms may need to be raised for the silo support, or the silo may need to be structurally modified to maintain silo integrity. Ex situ stabilization is much more applicable since the existing silos could not retain the stabilized material. This process option has not been retained for Subunits A and B; however, it has been retained for further evaluation for stabilization of the soils in Subunit C.

In Situ Vitrification

This process option would heat the silo wastes and/or soils by applying electrical energy until a molten mass is formed. Upon cooling, a monolithic glass waste form is achieved. Electrodes, through which a large current would pass, would be lowered into the waste in a closely spaced grid pattern. This process would continue until the waste formed a stable glass matrix. This process option, an innovative technology, has been retained for Subunits A, B, and C for further evaluation.

Surcharging

This process option induces densification and subsidence of waste by mounding or overburdening the material in place with a large quantity of soil for an extended time period. The overburden compacts the media and reduces the voids, while simultaneously evacuating liquids from the media. These liquids can then be collected for treatment. Surcharging has been eliminated for Subunits A, B, and C because very little waste compaction is expected or needed prior to in place containment. For alternatives involving removal, there is no merit in compacting the material in place.

Soil Aeration

Soil aeration is used to remove volatile contaminants from soil or a soil-like material by contacting the waste matrix with air and collecting the entrained volatiles. This process option has not been retained for any of the subunits because it cannot remove the inorganics or radionuclides present in the silo residues and because the concentrations of volatiles contained in the residues are low.

Steam Stripping

Steam stripping is used to evaporate volatile contaminants from an aqueous waste stream by injecting steam into the waste matrix and collecting the resultant volatile-contaminated water. This process option has been eliminated for all subunits because it cannot treat the inorganics or radionuclides present.

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2.5.6.2 Waste Stabilization Technology

Waste stabilization technologies immobilize the contaminants in a matrix to reduce or eliminate leachability and add structural rigidity to the waste form. The waste stabilization process options are asphalt-based stabilization, cement-based stabilization, thermoplastic encapsulation, vitrification, and lime/flyash stabilization. The process options considered for the stabilization technology are discussed in the following text.

Asphalt-Based Stabilization

The waste or soil is blended with molten asphalt in a heated mixer and extruded into a container for disposal. The asphalt encapsulates the contaminants in the matrix. The contaminants do not react chemically with the encapsulating material. This process option has been retained for Subunits A, B, and C for evaluation since both the waste materials and soil can be stabilized by asphalt.

Cement-Based Stabilization

The waste or soil is mixed with water and cement-based reagents in a mixer or pug mill and poured into containers for curing before disposal. The waste is incorporated into the rigid matrix of the hardened concrete. This method physically or chemically stabilizes the waste, depending on waste characteristics. However, most wastes are not chemically bound and therefore are subject to leaching. This process option has been retained for Subunits A, B, and C for evaluation since waste materials and soils can be stabilized by cement.

Thermoplastic Encapsulation

The waste or soil is mixed with an organic monomer and an initiating agent or a catalyst. This polymerized waste is then poured into a container, allowed to cure, and then placed into a disposal facility. Thermoplastic encapsulation has frequently been used to stabilize heavy metal waste. This process option has been retained for Subunits A, B, and C for evaluation.

Vitrification

The waste material or soil is mixed with vitrification reagents (i.e., alumina, silica, sodium) in a surge hopper and fed into a glass smelter for vitrification. This process heats the mixer by applying electrical energy until a molten mass is formed. The glassified waste form is cast into steel containers and cooled for final disposal. Leaching is usually minimal after this treatment process. Vitrification has been tested at numerous DOE facilities including Savannah River and Oak Ridge. This process option has been retained for Subunits A, B, and C for evaluation.

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Lime/Flyash Stabilization

The waste or soil is mixed with lime and flyash in a cement mixer or pug mill and poured into disposal containers for curing. With proper additives, this option has been used on a variety of waste. The site flyash piles could be used for the flyash. This process option has been retained for Subunits A, B, and C for evaluation.

2.5.6.3 Physical Treatment Technology

This technology contains physical treatment process options that provide varying levels of treatment. Many of these process options are simply pretreatment steps for other treatment process options such as those for chemical treatment and waste stabilization. They are summarized in the following text.

Air Stripping

Air stripping removes volatile contaminants from aqueous waste streams by introducing air counter currently to the waste stream to strip volatiles from the waste. This process option was not retained for any subunits because it does not effectively remove the inorganics present and because the levels of volatiles found in the subunit aqueous waste streams are relatively low.

Solid/Liquid Separation

This process option is a primary pretreatment step for other treatment process options that require specific solid/liquid ratios. Solid/liquid separation schemes typically use filtration (solids removal) and/or dewatering systems. This process option has been retained for Subunit A for evaluation due to the sludge-like consistency of the residues. The options for dewatering Subunit A material include belt filter press, vacuum, and centrifuge, among others. Solid/liquid separation was screened out for Subunit B because these materials have a dry powdery matrix. This process option is applicable to Subunit C; the options would include gravity filtration, pressure filtration, or precipitation.

Oil/Water Separation

Oil/water separation consists of removing a free oil phase from the carrier wastewater through a specific gravity differential. This process option will not be retained because there is no free oil phase present in any of the subunits in Operable Unit 4.

Polymerization

Polymerization uses catalysts to form polymers from a monomer or a low-order polymer of a particular compound. Because there are few polymerizable compounds present in any of the subunits, this process option has not been retained.

FEMP Advanced Wastewater Treatment Facility

The FEMP Advanced Wastewater Treatment (AWWT) facility is being built on the FEMP site and will be available for treating wastewater, including perched water encountered during remediation and any water in Silo 4. This system will utilize metals precipitation, ion exchange, and other treatment techniques to treat influent so that the effluent will meet all discharge criteria.

The treatment system will consist of two parallel treatment systems. Phase I will treat 265 liters per minute (lpm) (700 gpm) of contaminated storm water runoff from the FEMP storm water retention basin. When capacity is available, the treatment system will also treat uranium-contaminated groundwater to be extracted from the South Groundwater Contamination Plume prior to its discharge to the Great Miami River. The South Plume is located just south of the FEMP in a portion of the Great Miami Aquifer. Phase II will treat 1515 lpm (400 gpm) of wastewater from cleanup and other activities at the site. This consists of approximately 760 lpm (200 gpm) existing wastewater flows and 760 lpm (200 gpm) future remediation flows. The AWWT is designed to reduce uranium in the FEMP's wastewater discharges to less than the proposed Safe Drinking Water Standard of 20 parts per billion (ppb).

Each phase consists of the following major treatment steps:

- Flow equalization and pH adjustment to 11.5
- TRU/Clear® addition and clarification for bulk removal of radionuclides and heavy metals. TRU/Clear® is targeted at removal of radionuclides other than uranium; however, uranium will also be removed. The system will have the capability to use alternate coagulants if TRU/Clear® is not required.
- Clarifier effluent is directed to multitube filtration (solids collected from the clarifiers and filtration will be directed to Plant 8 for filtration)
- Filtered wastewater will pass through carbon filters for removal of any organic compounds
- pH adjustment to 8.0 using sulfuric acid (optimum for ion exchange)
- Ion exchange for uranium removal (Dowex 21-K)

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- Final pH adjustment to within NPDES limits (6.5 - 9.0)
- Final filtration

Metals precipitation is one of several methods that uses chemicals or other additives to remove/extract contaminants from a waste stream. One metals precipitation process that was developed for the precipitation of radionuclides and metals is the TRU/Clear® process. This process uses potassium ferrate as an inorganic coagulant to remove radionuclides and other priority pollutants from wastewaters.

Ion exchange is the process whereby hazardous/radioactive ions are removed from a solution by being exchanged with harmless ions held by the ion exchange material. The ion exchange material is typically a resin with ionic functional groups attached. The use of the FEMP AWWT facility as a process option applies to all subunits that may generate wastewater, and therefore, has been retained for Subunits A, B, and C for evaluation.

Soil Aeration

Soil aeration removes volatile contaminants from soil or a soil-like material by injecting the waste matrix with air and collecting the entrained volatiles. This process option has not been retained for any of the subunits due to the relatively low levels of volatile organics found in the waste residues and the ineffectiveness of this process option in removing inorganics or radionuclides.

Steam Stripping

Steam stripping is used to evaporate volatile contaminants from an aqueous waste stream by injecting steam into the waste matrix and collecting the resultant volatile-contaminated water. This process option has not been retained for any of the subunits due to the relatively low levels of volatile organics found in the waste liquids and the inability of this process option to remove inorganics or radionuclides.

2.5.6.4 Chemical Treatment Technology

Several chemical treatment process options are available for treating contaminated soil, sludge, water, and structural material. These process options are typically implemented following removal of the contaminated media.

Chemical Dechlorination

Chemical dechlorination involves the addition of a sodium reagent to strip chlorine atoms from chlorinated compounds. This process option has not been retained for any of the subunits because there are few chlorinated compounds found in the Operable Unit 4 wastes.

Oxidation/Ozonation/Photolysis

This process option represents those techniques commonly used to oxidize or prepare contaminants in a waste stream for oxidation. Photolysis uses UV radiation to make a compound more amenable to oxidation. Ozonation is the use of ozone, a chemically unstable molecule, to oxidize a compound. Oxidation is that chemical process by which the oxidation state of a compound is raised to change the solubility, stability, and/or separability of a compound. This process option has not been retained for any subunits because it cannot treat the radionuclide constituents found in the subunits. In addition, the Subunits A and B residue contaminants are already in oxidized forms.

Hydrolysis

Hydrolysis is the process of breaking a bond in a molecule (which is ordinarily not water soluble) so that it will go into ionic solution with water. This process option has not been retained for Subunits A and B because the residues in all of these subunits are fully hydrolyzed. This process option is not applicable to Subunit C because of the physical nature of the soil and debris.

Chemical Extraction

Chemical extraction is the process by which a solute is extracted from a solid. A liquid solvent is used to effect the transfer of the solute, which in turn is recovered from the solvent by evaporation or distillation. In an effort to minimize the volume of contaminated soils requiring disposal, the FEMP site is investigating soil washing as part of the Operable Unit 5 RI/FS. The goal of this chemical extraction is to extract contaminants (particularly uranium) from the soil, thereby creating an extractant stream which contains the contaminants and clean soil which may be returned to the environment. Chemical extraction is a viable process option for the Subunits A and B wastes and the soils within Subunit C.

Reduction

Reduction is the chemical process by which the oxidation state of a compound is reduced to change the solubility, stability, and/or separability of a compound. This process option was eliminated for all

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subunits because there are few reducible compounds in the Operable Unit 4 wastes and because reduction may result in more toxic contaminants.

2.5.6.5 Thermal Treatment Technology

This technology proposes several treatment process options that will thermally treat the wastes through drying/calcination, incineration, and thermal desorption. Process options are summarized in the following text.

Drying/Calcination

Drying and calcination are weight/volume reduction techniques that use heat to remove bound water from sludges or solids. Calcination can remove water by hydration due to the higher temperatures involved. These process options have been retained for Subunit A because they can be used in conjunction with other treatment technologies (i.e., vitrification). Because Subunit B contains little or no water and the Silo 3 contents were calcined before being placed in the silo, these process options have not been retained for Subunit B. Drying/calcination was also eliminated for Subunit C because it is inappropriate to the treatment of the inorganic or radionuclide contaminants found in the soils, structures, and debris.

Incineration

Waste material can be incinerated by rotary kiln, fluidized bed, slagging, and liquid injection incinerators. Rotary kiln and fluidized bed incineration are typically used to destroy organic contaminants. Rotary kilns are refractory-lined rotating cylinders positioned at a slight incline. Waste is introduced at the high end, and ash is collected from the bottom end. Flue gasses pass through a secondary chamber and control equipment before exiting to the atmosphere. Fluidized bed incinerators contain a bed of sized granular refractory material in a refractory-lined vessel. Waste is injected onto the bed and incinerated as air is forced up through the bed at a velocity sufficient to fluidize the burning material. This process option has not been retained for any of the subunits because it does not treat the inorganic or radionuclide contaminants present.

Thermal Desorption

Thermal desorption is a process by which the waste solids are sufficiently heated to volatilize organic compounds absorbed on the material. This process option has not been retained for further evaluation because it does not treat the inorganic or radionuclide contaminants. The relatively low

concentrations of volatiles present in the waste also preclude consideration of treating Operable Unit 4 waste with this option.

2.5.6.6 Biological Treatment Technology

Several biological treatment process options for treating contaminated soil, waste material, water, and structural material are available for consideration. Biological treatment process options use living organisms such as bacteria or fungi to detoxify or immobilize contaminants in waste. These process options are applied primarily to convert organic contaminants into nontoxic products. Bioremediation has also been used to degrade inorganic contaminants such as nitrates, and to detoxify or immobilize certain metals by changing their oxidation state.

Effective bioremediation technologies often require the use of amending agents and nutrients such as sewage sludge, hay, or manure for the remediation of solid material and a soluble organic compound such as glucose for the remediation of aqueous or slurry waste. The addition or control of oxygen, temperature, and pH are also commonly required. Use of microbes already present at the waste site is preferable to introducing other microbes that must be acclimated to site conditions. In bioremediation processes, limitations to microbial activity (e.g., nutrient deficiencies or improper oxygenation or temperature control) are identified and corrected to stimulate or accelerate naturally occurring processes. The following discussion presents potential bioremediation process options.

Biodenitrification

Biodenitrification is a microbial process by which nitrates and nitrites are reduced to molecular nitrogen. The nitrate/nitrite replaces the molecular oxygen in bioassimilation. This process option has been eliminated for all of the subunits because none of the subunits contain significant quantities of nitrates.

Biological Detoxification

This process utilizes biological processes to detoxify a waste stream by destroying the organic constituents. The processes are typically some form of aerobic respiration. This process option has not been retained for any of the subunits due to the insignificant quantities of organic constituents and the inability of this process option to treat inorganics and radionuclides.

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Land Farming

This process uses a microbial process to treat biodegradable contaminated soils or soil-like wastes. The wastes are spread to a thickness of 0.3 to 0.61 m (1 to 2 ft) over the land and mixed with the microorganisms and nutrients. The mixture is regularly wetted and mixed with a tiller to maintain the proper growth environment. This process option has not been retained for any subunits because the inorganics and radionuclides are usually concentrated in the soil and may migrate through the subsurface. Typically, no treatment occurs.

2.5.6.7 Decontamination and Decommissioning Technology

These D&D techniques apply only to the contaminated structural material in Subunit C. This technology does not apply to Subunits A and B because these subunits have no structures for D&D. D&D will remove gross contamination from the Silos 1, 2, and 3 surfaces. Because Silo 4 has not stored any residues, there is no gross contamination, and it will not require decontamination. Based on the porous nature of concrete, relative to structural steel, and lack of established free-release criteria, concrete in Operable Unit 4 would not be completely decontaminated. Application of the various tools and techniques available in D&D depends on the physical and radiological conditions of the structure. The chosen technology must decontaminate the silos and other structures while maintaining control of the process, both radiologically and physically. The process should also minimize, as much as possible, the quantity of waste for disposal. The D&D process options considered include vacuum scabbling, pressure washer, vacuum grit-blasting, acid washing, and strippable coatings.

Vacuum Scabbling

Scabbling removes the surface contamination by chipping away small amounts of the top layer of material (usually concrete), using a pneumatically-driven piston equipped with spikes that strike the surface and break away the concrete. A vacuum device can be used in conjunction with the scabbler to capture the generated dust and debris. This process is best suited for flat surfaces. Vacuum scabbling has been retained for evaluation for Subunit C.

Pressure Washing

High-pressure washing water can be used to decontaminate radioactively contaminated surfaces. The washing action and impaction of water removes loose surface contamination and dissolves soluble contaminants to an aqueous phase. The wash water would require treatment and disposal. This

technique is often used in areas where the contaminated surface is difficult to reach; therefore, this process option has been retained for Subunit C.

Vacuum Grit-Blasting

Vacuum grit-blasting is one of the most widely used decontamination techniques. A stream of abrasive grit material is propelled against the contaminated surface, and the resulting dust/particles are vacuumed away in a vacuum collar surrounding the abrasive cleaning head. This process option has been retained for Subunit C for removal of the contaminated surface material.

Acid Washing with Oxidizing Agents

Acid washing decontaminates concrete surfaces by removing surface contamination during generalized destruction of the concrete surface. The acid reacts chemically with the concrete matrix, thereby removing a thin layer of concrete along with the surface contamination. The acid can be applied either manually (brush or roller) or by spray. The dissolved concrete and associated contamination must be rinsed from the surface and collected for treatment and disposal or reuse. A waste treatment system for spent acid solutions is required. This process option could be applied for the silos and has been retained for Subunit C for removing a thin layer of the surface contamination.

Strippable Coatings

Strippable coatings remove loose contaminants from large surface areas by trapping the contaminants in a polymer matrix for removal and disposal. Strippable coatings are available as liquids that may be applied to surfaces by brushing or rolling. After application, these coatings are allowed to cure to a thin, solid coating that may be stripped from the surface and disposed. Strippable coatings have been retained for further evaluation for Subunit C as a way to remove surface contamination.

### 2.5.7 Disposal General Response Action

Several disposal technologies may be used following removal as part of the remedial action. Disposal technologies include both on-property and off-site disposal, either of which would require transportation using rail, truck, or a combination of the two. A discussion of the process options associated with the disposal technologies follows.

2.5.7.1 Waste Transportation Technology

Specific federal requirements for the off-site transport of chemically hazardous and/or radioactive material have been identified to address factors such as packaging and labeling. Many states, including Ohio, also have transportation requirements and many require advance notice for shipments of radioactive material.

The contaminated residues and waste generated which require packaging will be packaged in DOT specification containers and shipped "exclusive use" to assure proper handling of the radioactive materials. DOT specification 7A Type A containers, or Strong Tight Containers may be used for the residues generated during Operable Unit 4 remediation. DOT specification 7A Type A containers, constructed of carbon steel, will be used for the residues with a higher level of radioactivity (i.e., K-65 residues, cold metal oxides, and decant sump tank sludges). Soils, concrete, and other media may be packaged into 7A Type A containers and/or Strong Tight Containers or disposed in bulk, depending on their activities and disposal facility requirements. The basis for selecting 7A Type A containers for packaging is that the silos residues are classified as Low Specific Activity material as defined by 49 CFR 173.403(n). Activity levels for some contaminated media may be low enough to allow the use of Strong Tight Containers or may be shipped in bulk.

For the purposes of this document, it is assumed that 7A Type A containers will be used for transporting and storage of any hazardous materials generated in the proposed remedial alternatives which require packaging. The containers will be boxes with outer dimensions of approximately 1.2 m x 1.2 m x 1.2 m (4 ft x 4 ft x 4 ft). The shipments would be configured to assure that exposures from residues and wastes are within DOT limitations.

The process options for waste transportation include both truck and rail transport. Both of these process options will be retained for further evaluation for all subunits.

Rail Transport

The FEMP site can readily support rail transportation by using existing on-property rail spurs. Some off-site disposal options, such as the permitted commercial disposal site, have facilities with the capability of receiving the waste by rail. However, transportation to NTS may require a combination of truck and rail transport. Waste shipped by rail to NTS would go through the Las Vegas, Nevada terminal. In cases where exclusive use shipments are required, the waste would be placed within an International Storage Organization (ISO) (similar to a sealand in size) and placed on a flat bed rail

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car. At the Las Vegas terminal, the ISO would be removed from the train without losing exclusive use status and placed on flatbed trucks where they would be transported to NTS. The Las Vegas Terminal is a new facility which has been constructed to handle the transfer of hazardous materials, including radioactive material for the NTS. Although rail transport has a lower percentage of accidents per trip, the volume of material hauled per trip is many times higher. Rail transport is, however, more cost effective (approximately 25 percent lower) than truck transport.

Truck Transport

Truck transport can easily offer portal-to-portal service with the road system available at the FEMP site. The primary disadvantages with this process option are the relatively undeveloped and heavily traveled roads near the FEMP site and the higher cost to the public as compared to rail transport.

2.5.7.2 On-Property Disposal Technology

The on-property disposal technology consists of various land-based engineered process options designed to restrict contaminant migration, thereby reducing the threat to potential receptors.

Disposal options evaluated herein are limited to contaminated solids. Any perched water encountered during remediation or the liquids in Silo 4 would be transferred to a wastewater treatment plant at the site. The resultant treated water would be managed in accordance with the NPDES permit issued by the State of Ohio as identified in the ARARs for Operable Unit 4. Hence, the discussion of disposal generally focuses on soils, waste, and structural material.

Interim storage may also be used as a component of on-property disposal. Some wastes generated from the selected remedy for Operable Unit 4 may be placed into interim storage. Placement into interim storage would facilitate integration of technologies developed by other FEMP operable units for similar wastes.

The following sections discuss the process options for on-property disposal facilities.

Engineered Disposal Facility

An above-grade engineered disposal cell has been employed in the United States to dispose of low level radioactive waste. Engineered cells are constructed to satisfy the design requirements appropriate to the type of waste they would contain. The radioactive waste associated with Operable Unit 4 is classified as by-product material, as defined in Section 11(e)2 of the Atomic Energy Act;

such material is typically disposed in accordance with the requirements of 40 CFR § 192. In a cell engineered for this type of waste, e.g., waste contaminated with low concentrations of naturally occurring radionuclides (uranium, thorium, radium, and their radioactive decay products), the waste is placed on an impermeable liner which includes a leachate collection system to impede the percolation of free water from the cell into the ground. The waste is then covered with a radon barrier to limit radon emissions from the cell; a drain layer; a frost protection layer; and an erosion protection barrier to limit erosion, water infiltration, frost penetration, and biotic intrusion.

A number of designs for engineered disposal facilities are presently being employed throughout the United States for the disposal of low level radioactive wastes. One representative design has been adapted for purposes of this FS to represent this disposal process option. The adopted concept for an engineered disposal facility includes an on-grade reinforced concrete pad designed specifically for holding containerized, stabilized waste. The waste would then be covered by a multimedia cap designed to minimize water infiltration and prevent intrusion. An LC/DS is an integral part of the design. For those wastes requiring protection from inadvertent human/animal intrusion, such as those in Subunit A, a barrier of concrete or other relatively impermeable material can be incorporated into the design. This process option has been retained for all subunits.

Above-Grade Disposal Vault

Although vaults are structurally stable, they can be more permeable than clay and, as a result, disposal of leachable material within a vault would require an additional low-permeability lining of clay or other material to contain the waste. Compared with an engineered cell, incorporating design changes in a vault during planning and construction (e.g., to increase or decrease the size) is more difficult and could result in schedule delays. In addition, maneuverability within the vault during waste placement activities would be constrained by the structure.

The vault would be constructed of concrete and would be divided into individual cells. The vault slab and walls would act as a base for supporting the double liner system. Upon completion of material emplacement in the vault, a multimedia cap and appropriate drainage controls would be placed over the vault. This on-property disposal facility would also be equipped with an LC/DS. This process option has been retained for evaluation for all subunits.

Lined/Unlined Pits/Trenches

Unlined pits and trenches are not acceptable as permanent waste disposal facilities under current regulatory requirements. The process option of unlined pits and trenches was, therefore, eliminated from consideration.

Properly designed lined pits/trenches are equivalent to landfill disposal units under RCRA. These units have been employed throughout the industry for the disposal of hazardous wastes and to a lesser degree low level radioactive wastes. These disposal options typically involve excavation into native soils with the installation of a natural and synthetic multimedia lining system equipped with a LC/DS. Following emplacement of the wastes, the disposal cell is covered with a multi-layer capping system to minimize water infiltration. Landfills require the installation of a groundwater monitoring network.

An inground landfill design offers no significant advantages over the above-grade engineered disposal facility or disposal vault. Lacking noticeable advantages and the increased concern generated by this technology for the protection of the underlying aquifer, this process option was eliminated from further consideration for all subunits.

2.5.7.3 Off-Site Disposal Technology

Nonradioactive contaminated process chemicals could be disposed of off site at a commercial facility. Nonradioactive material determined to be hazardous under RCRA would be shipped to a RCRA-permitted treatment, storage, and disposal facility (TSDF) and would require meeting land disposal restrictions (LDRs). Nonhazardous, non-radiologically contaminated waste may be disposed in a sanitary, demolition, or solid waste landfill. Related requirements are presented in Appendix F.

The implementability of land disposal at an off-site facility is affected by the availability of disposal sites for the Operable Unit 4 waste. Only one commercial facility, located near Clive in Tooele County, Utah, is authorized to accept naturally occurring radioactive material and 11(e)2 by-product material.

Other off-site disposal options are currently limited to facilities that are owned and operated by DOE or newly constructed facilities. As identified in DOE Order 5820.2A, large quantities of 11(e)2 by-product material should normally be disposed of in the state in which it is generated. Disposal facilities for low-level radioactive waste are currently located at major DOE installations such as the Hanford site near Richland, Washington; the Idaho National Engineering Laboratory near Idaho Falls,

Idaho; the Savannah River Site near Aiken, South Carolina; and the NTS near Las Vegas, Nevada. However, no current DOE disposal facilities exist in the State of Ohio or in the surrounding states. The NTS was evaluated for potential off-site disposal as a reasonable, representative DOE facility, along with two newly constructed facilities.

Nevada Test Site

This process option calls for the disposal of the waste at an existing government facility located in an arid western environment. This facility is currently operating and accepting many types of DOE waste. Preliminary assessment of the Operable Unit 4 wastes indicated they either currently or with treatment would meet the NTS waste acceptance criteria. However, because NTS is a low-level waste facility, and the silo residues are by-product material, additional approval by NTS would be required. DOE Orders specify that small volumes of by-product material may be managed at low-level waste facilities. The wastes can be transported to the facility by truck or rail as discussed previously. Because the waste must be shipped over public transportation routes, the waste must be shipped per DOT requirements. NTS further requires that all waste be packaged. Containers sent to NTS must be able to withstand 19,500 kg/m$^2$ (4000 lb/ft$^2$) and not exceed 4082 kg (9000 lb). This is to facilitate stacking and handling. This process option has been retained for all subunits.

Permitted Commercial Disposal Site

This process option calls for the disposal of the wastes at an existing commercial facility located in an arid western environment. This facility is currently operating and accepting low-level radioactive and mixed waste that meets the LDR standards for disposal at the facility. Low-level waste may be shipped in DOT specification containers or in bulk. The wastes can be transported by truck or rail. The licensing restrictions embodied in the waste acceptance criteria for the permitted commercial disposal site limit the ability of the facility to receive wastes above certain radionuclide specific activity concentrations. Specifically, the permitted commercial disposal site waste acceptance criteria prohibits the receipt of waste exceeding 2,000 pCi/g and 15,000 pCi/g for Ra-226 and Th-230, respectively. The mean activity concentration of Ra-226 and Th-230 in Silos 1 and 2 exceeds these levels at 310,400 pCi/g and 55,300 pCi/g respectively. Similarly, the mean activity concentration of Ra-226 and Th-230 in Silo 3 residues exceeds these levels at 2,900 pCi/g and 51,200 pCi/g, respectively. Even considering the dilution effects of any additives to support cement-based solidification, these residues could not meet both of these limitations. Additional criteria for acceptance by the permitted commercial disposal site requires that the waste be dry. The process option of off-site disposal at the permitted commercial disposal site, therefore, has been eliminated for

Subunits A and B. The process option was retained for Subunit C. However, the implementability of such an alternative would be affected by existing DOE policy (DOE Order 5820.2A) precluding disposal of DOE wastes at non-DOE disposal facilities.

New Facility Constructed Adjacent to the FEMP Site

This process option calls for the disposal of the wastes at a hypothetical facility assumed to be constructed adjacent to the boundary of the FEMP site. This process option involves the siting of a new facility which could provide improved geologic siting conditions. It should be noted that no such sites have currently been investigated or identified for consideration. The facility would have waste acceptance criteria consistent with those established for the on-property disposal facilities. The wastes can be transported by truck or rail. This process option has been retained for all subunits.

New Facility Constructed Within 483 Kilometers (300 Miles) of the FEMP Site

This process option calls for the disposal of the wastes at a proposed facility to be constructed within a 483-km (300-mi) radius of the site. This facility, a federally owned regional disposal site, would be built in an area with desirable demographic and geologic conditions and would be shared by several regional DOE facilities. This facility is assumed to have waste acceptance criteria consistent with the on-property disposal facilities. The wastes can be transported by truck or rail. This process option has been retained for all subunits.

Deep Geological Repository

This process option calls for the disposal of the wastes with transuranic alpha-emitting radioisotopes of greater than 100 nanoCi/g activity in a mined geologic repository. This process option considers only those wastes deemed inappropriate for aboveground or shallow land disposal and would only be considered if available land disposal technologies are determined to inadequately protect human health and the environment. Such a disposal facility would offer isolation and protection of the wastes due to deep earth disposal and natural barriers. Presently, there is not a mined or deep geologic repository licensed to receive the Silos 1 and 2 contents. The Waste Isolation Pilot Plant (WIPP) in New Mexico is slated to receive only Defense Department transuranic waste and has limited capacity. Given that the K-65 material does not meet WIPP's waste acceptance criteria and that a new mined repository is not likely to be sited, constructed, and approved in time to receive the K-65 material under the current remediation schedule, this process option has been screened from further consideration for all subunits based on poor implementability.

## 2.6 EVALUATION OF TECHNOLOGIES AND PROCESS OPTIONS

Specific application of these technologies and process options to Operable Unit 4 subunits was evaluated to select representative options. The purpose of the evaluation is to obtain a reasonable number of options to combine in alternatives (Section 3.0). Options not carried forward can be reexamined by the designer. The process options were evaluated based on effectiveness, implementability, and cost. The evaluation was only relative to similar process options and did not compare process options between technologies.

### 2.6.1 Criteria for Evaluating Technologies and Process Options

The process options were evaluated using effectiveness, implementability, and cost as the criteria. These criteria were applied only to the process options and the purpose that they were intended to satisfy; they were not applied to the operable unit as a whole. The evaluation process primarily focuses on effectiveness factors with less emphasis on the implementability and cost evaluations. A description of each evaluation criteria follows.

#### 2.6.1.1 Effectiveness Evaluation

The various process options identified under each technology type in Section 2.5 were evaluated for effectiveness based on the following:

- The potential effectiveness of the process option for meeting the purpose of the technology
- The potential impacts to human health and the environment during the construction and implementation phase
- The reliability of the process option as it relates to the COCs and conditions within the Operable Unit 4 boundary

#### 2.6.1.2 Implementability Evaluation

The implementability evaluation includes both technical and administrative feasibility of implementing a process option. Examples of administrative feasibility include the availability of skilled workers to implement the process option; the ability to obtain permits for off-site actions; and the availability and capacity of TSDFs.

#### 2.6.1.3 Cost Evaluation

Each process option was evaluated as to whether costs were high, medium, or low relative to other process options of the same technology type.

### 2.6.2 No-Action General Response Action

The no-action GRA was retained for development into an alternative as required by CERCLA. Under the no-action GRA, no additional actions will be taken at Operable Unit 4. It is assumed that the silos would eventually fail, releasing their contents. Additionally, DOE would release the site for other unrestricted uses. The evaluation of this GRA follows.

- Effectiveness: This GRA is not effective. It provides no protection of human health and does nothing to reduce the toxicity, mobility, or volume of contaminants present. The potential for exposures to wildlife, trespassers, on-property workers, and off-site residents would increase over time as contaminants continued to be released to groundwater, surface water, soil, or air. Potential impacts to human health and the environment associated with no further action at Operable Unit 4 are discussed in Appendix D.

- Implementability: No technical or other issues exist that would affect implementation, but it would be difficult to gain public acceptance.

- Cost: There are no costs associated with this alternative.

### 2.6.3 Institutional Action General Response Action

The technologies considered for the institutional action GRA include monitoring and access control. Table 2-14 summarizes the results of the process option evaluations. A narrative discussion follows.

#### 2.6.3.1 Monitoring Technology

Process options evaluated for the monitoring technology include:

- Groundwater monitoring
- Leachate monitoring
- Radon monitoring
- Surface water/sediment monitoring

Groundwater Monitoring

Groundwater monitoring is a process option evaluated for Subunits A, B, and C as follows:

- Effectiveness: Monitoring wells are effective in determining contaminant migration and in evaluating the effectiveness of other remedial measures. The potential impact on human health and the environment during the construction and implementation phase of this option is negligible. The only additional exposure by contaminated groundwater monitoring is to sampling and analytical personnel.

- Implementability: A large number of monitoring wells currently exist at and near the FEMP site. Additional wells can be installed quickly, and required equipment and services are readily available.

## TABLE 2-14

## SUMMARY OF EVALUATION ANALYSIS FOR INSTITUTIONAL ACTION PROCESS OPTIONS

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| Monitoring | Groundwater Monitoring | A, B, C | Monitoring groundwater wells are effective in determining migration and evaluating effectiveness. | Readily implementable | Moderate |
| | Leachate Monitoring | A, B, C | Effective in detecting water infiltration. | Readily implementable | Low |
| | Radon Monitoring | A, B, C | A viable option for measuring the effectiveness of implementing other process options. | Readily implementable | Low |
| | Surface Water/Sediment Monitoring | A, B, C | Can be effective for determining migration and evaluating effectiveness of other process options. | Readily implementable | Low |
| Access Control | Physical Barriers | A, B, C | Can mitigate potential exposures on site by restricting access. | Readily implementable | Low |
| | Administrative Controls/Deed Restrictions | A, B, C | Can be effective in reducing contact between contaminants and receptors. | Readily implementable | Low |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.



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- Cost: Capital costs would only include the installation of additional monitoring wells. Major operations and maintenance (O&M) costs include well maintenance, sampling and analysis, data validation, database management, and payments to landowners. Overall, costs would be moderate.

The groundwater monitoring process option has been carried forward into the development of alternatives for Subunits A, B, and C.

Leachate Monitoring

Leachate monitoring is a process option evaluated for Subunits A, B, and C as follows:

- Effectiveness: Leachate monitoring is effective in detecting water that has infiltrated and passed through containment systems or waste sites. Leachate monitoring has negligible impact on human health and the environment.

- Implementability: Leachate monitoring requires taking samples of collected leachate and analyzing the samples. Equipment and services are readily available.

- Cost: The costs would include sampling and analyses. Overall, costs would be low.

Leachate monitoring has been carried forward to the development of alternatives for Subunits A, B, and C.

Radon Monitoring

Radon monitoring is a process option evaluated for Subunits A, B, and C as follows:

- Effectiveness: Radon monitoring is a mandate requirement of the FFCA for the control and abatement of radon emissions. Radon monitoring is also an effective means of measuring the success of remedial actions. The impact on human health and the environment during the construction and implementation of this process option is negligible.

- Implementability: The required equipment is readily available, and depending on the type of radon monitoring systems (passive, continuous, or filter), most systems can be easily implemented.

- Cost: Capital costs for most monitoring systems are relatively inexpensive as are O&M costs, which include periodic monitoring and maintenance. Overall, costs would be low.

Radon monitoring has been carried forward into the development of alternatives for Subunits A, B, and C.

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Surface Water/Sediment Monitoring

The surface water/sediment monitoring is a process option evaluated for Subunits A, B, and C as follows:

- Effectiveness: Surface water/sediment monitoring can be very effective for determining surface water contaminant migration and monitoring the performance of remedial actions.

- Implementability: Surface water/sediment monitoring is easily implemented and requires no specialized training or equipment.

- Cost: Costs for this process option would be very low. Laboratory analytical costs would constitute the largest part of the cost. Overall, costs would be low.

The surface water/sediment monitoring process option has been carried forward to the development of alternatives for Subunits A, B, and C.

2.6.3.2 Access Control Technology

Access control process options were considered for all the subunits. Process options evaluated for access control technology include:

- Physical barriers
- Administrative controls/deed restrictions

Physical Barriers

Use of physical barriers was evaluated as a process option for all the subunits as follows:

- Effectiveness: Physical barriers mitigate potential exposure to contamination on property by restricting entry. Physical barriers are typically used in conjunction with other remedial actions.

- Implementability: Barriers can be constructed quickly and safely, without disturbing the operation of existing facilities and the environment.

- Cost: The capital costs would be low because barriers are relatively inexpensive to install, depending on the level of security required. Also, O&M costs would be low because once the barrier is installed, little maintenance is required. The overall costs would be low.

The option of physical barriers has been carried forward to the development of alternatives for all subunits.

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Administrative Controls

Administrative controls were evaluated as a process option for all the subunits as follows:

- Effectiveness: Administrative controls can be highly effective in reducing contact between contaminants and receptors but often cannot be relied on as the sole method of remediation.

- Implementability: Administrative controls are easy to implement and are standard requirements at hazardous waste management facilities.

- Cost: Capital costs would be higher for administrative controls than for passive controls, and depending on the controls chosen, the O&M costs would be low. The overall costs would be low.

The option of administrative controls/deed restrictions has been carried forward to the development of alternatives for all subunits.

### 2.6.4 Containment General Response Action

The following technologies were considered for the containment GRA:

- Subsurface flow control
- Capping
- Run-on/runoff control

Table 2-15 summarizes the results of the process option evaluations. A narrative discussion follows.

#### 2.6.4.1 Subsurface Flow Control Technology

Subsurface flow control was determined to be a remedial technology potentially applicable for Subunits A, B, and C. Process options retained for evaluation for subsurface flow control include:

- Subsurface drains
- Slurry walls
- Pumping wells
- Sheet pilings
- Grout curtains

Subsurface Drains

Leachate collection/control through subsurface drains was evaluated for Subunits A, B, and C.

- Effectiveness: The effectiveness of drains to control leachate is dependent on their design. They are not as effective if installed on an existing disposal/storage unit as if installed prior to waste placement. However, they can still mitigate leachate release into the subsurface.

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## TABLE 2-15

## SUMMARY OF EVALUATION ANALYSIS FOR CONTAINMENT PROCESS OPTIONS

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| Subsurface Flow Control | Subsurface Drains | A, B, C | Less effective if installed under existing waste. Would still mitigate leachate release to subsurface. | Moderately difficult to implement | Moderate |
| | Slurry Walls | A, B, C | Most effective in controlling lateral migration and flow but do not eliminate the radioactive contaminants of the contained waste. Potential impact to human health and the environment is minimal. | Moderately difficult to implement | Moderate |
| | Pumping Wells | A, B, C | Moderately effective in controlling subsurface flow and diffusion and effectiveness is maintained only as long as pumping continues. | Moderately difficult to implement | High |
| | Sheet Pilings | A, B, C | Effective in controlling lateral migration and flow but not as effective as slurry walls. | Readily implementable | Moderate |
| | Grout Curtains | A, B, C | Less effective in controlling lateral diffusion and flow than slurry walls. | Difficult to implement | High |
| Capping | Concrete-Based Cap | A, B, C | Effective for erosion control and minimizing leachate generation; as an intrusion barrier will be more effective than asphalt cap. Susceptible to weathering and cracking. | Readily implementable | High |
| | Asphalt-Based Cap | A, B, C | Effective for erosion control and minimizing leachate generation. Serves as an intrusion barrier but very susceptible to weathering and cracking. | Readily implementable | Moderate |
| | Soil/Clay-Based Cap | A, B, C | Less effective for erosion control and minimizing leachate generation. Not very effective as an intrusion barrier. Very susceptible to weathering. | Readily implementable | Low |
| | Chemical Sealant Cap | A, B, C | Moderately effective for erosion control and minimizing leachate generation if maintained. Not as durable as concrete, asphalt, or clay caps. | Moderately difficult to implement | Moderate |
| | Multimedia Cap | A, B, C | Highly effective in preventing contaminant migration. It minimizes leachate generation, promotes surface drainage, prevents erosion and sediment transport of waste, and acts as an effective intrusion barrier. | Readily implementable | Moderate |
| | Void Space Grout | A, B | Effective in radon reduction and subsidence control but does not treat or remove the waste. | Readily implementable | Low |

Note: A, B, C, - Double underline indicates process option was retained for alternative development for that subunit.

TABLE 2-15
(Continued)

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| Run-On/Runoff Control | Sedimentation Basin/Sediment Trap | A, B, C | Effective for the removal of suspended solids. Unable to retain surface runoff. | Readily implementable | Low |
| | Diversion/Collection | A, B, C | Effective in preventing flooding, controlling erosion, and directing surface when used with other technologies. | Readily implementable | Moderate |
| | Grading | A, B, C | Highly effective in controlling site drainage and minimizing infiltration of water into contaminated areas. Some form of grading will be necessary for the development of all alternatives. | Readily implementable | Moderate |
| | Revegetation | A, B, C | Effective in controlling erosion. No apparent impact to human health and the environment. It stabilizes the surface of waste disposal facilities. | Readily implementable | Low |

Note: A, B, C, - Double underline indicates process option was retained for alternative development for that subunit.



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- Implementability: Installing drains near or under existing disposal/storage units can be moderately difficult, but achievable. There are minimal administrative issues.

- Cost: Capital costs are fairly low but there are moderate O&M costs. Overall costs are, therefore, rated moderate.

Subsurface drains for leachate collection will be carried forward to the development of alternatives for Subunits A, B, and C.

Slurry Walls

Slurry walls were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: As described in Section 1.4.1.1 on the FEMP site geology, a relatively continuous low permeability clay interbase underlays the FEMP site, which supports the effectiveness of slurry walls. These structures are effective as a barrier to confine contaminated groundwater that might otherwise flow from the site or to divert the flow of groundwater away from the contaminated media. Slurry walls do not eliminate the radioactive contaminants of the enclosed waste but inhibit the release of these contaminants through lateral migration. This technology is subject to several limiting criteria, such as type of waste to be contained, site geology, and construction. The potential impact to human health and the environment in the implementation of this structure is considered minimal.

- Implementability: Slurry walls are moderately difficult to install but can be constructed without disturbing the function or operation of existing facilities. Deep slurry walls could be difficult to install and would require deep trenching.

- Cost: Costs of construction equipment for trench construction, cost of grout, and removal of the contaminated material contribute to the expense of this process. Given the contaminants, periodic maintenance of slurry walls is not required if design considerations include selection of the most appropriate slurry mixture. Overall, costs would be moderate when compared to other control technologies.

Slurry walls will represent groundwater flow control processes and have been carried forward to the development of alternatives for Subunits A, B, and C.

Pumping Wells

Pumping wells were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: Pumping wells are moderately effective in controlling the lateral diffusion and flow of a contaminated plume, thereby restricting contaminant migration

in the soil and groundwater. This process option is proven to be reliable, and minimal impact should occur on human health. Effectiveness is maintained only as long as pumping operations continue.

- Implementability: Equipment and services for this process option are readily available. The groundwater can be pumped to the FEMP AWWT facility and treated before discharge to the Great Miami River through the NPDES. However, it is moderately difficult to keep the system operating as necessary to achieve the desired effects.

- Cost: The capital costs include equipment and installation and would be moderate. Pumps, screens, casings, and pipeline must be maintained to ensure proper water flow from the extraction well; also, maintenance is required to prevent loss of the well which would result in contaminant escape. Long-term costs for the pumping system would be very high. Additional costs for treating the pumped groundwater would be considered low because the pumped groundwater would only be a small portion of the total volume of water treated by the FEMP AWWT facility. Overall, costs would be considered high.

Pumping wells have not been carried forward to alternative development for any subunits due to the moderate effectiveness rating and high operating costs. Slurry walls will represent the groundwater control technology.

Sheet Pilings

Sheet pilings were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: Sheet pilings function similar to slurry walls in confining contaminated groundwater or diverting groundwater flow away from contaminated media. Sheet pilings are not as effective as slurry walls in diverting the groundwater flow because the joints of the sheets allow for leakage.

- Implementability: Sheet pilings are installed from the surface using a pile driver. This process option would be readily implementable because the Operable Unit 4 subsurface conditions offer little or no obstructions.

- Cost: The capital cost for the sheet pilings would be high compared to slurry walls. The maintenance of the sheet pilings would be low. Therefore, the overall costs would be moderate.

Sheet pilings have not been carried forward to alternative development in favor of slurry walls because of the low effectiveness and the higher capital cost when compared to slurry walls .

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Grout Curtains

Grout curtains were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: This process option is less effective in retarding groundwater flow than a slurry wall. The incremental nature of the installation process for the grout curtains results in more gaps in the barrier than that for a slurry wall. This process option is moderately effective.

- Implementability: This process requires extensive drilling and equipment for pressure injecting grout directly into the soil. Depending on the subsurface conditions, this process option could be difficult to implement.

- Cost: Cost of grout curtains can be three times as costly as a slurry wall. The O&M costs would include inspection, groundwater monitoring, and possible repairs. Overall, costs would be high on a comparative basis.

Grout curtains have not been carried forward to alternative development in favor of slurry walls as a result of the moderate effectiveness and implementation difficulty.

2.6.4.2 Capping Technology

Capping was determined to be a viable remedial technology for all subunits for long-term containment. Process options evaluated for capping include:

- Concrete-based cap
- Asphalt-based cap
- Soil-/clay-based cap
- Chemical sealant cap
- Multimedia cap
- Void space grout

Concrete-Based Cap

The concrete-based cap was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: A concrete-based cover is a moderately effective material used for building a single-layered cap. If properly constructed, the cap will control erosion and minimize leachate generation. However, it is susceptible to weathering and cracking. As an intrusion barrier, concrete will provide a greater degree of protection as compared to a single-layered asphalt cap.

- Implementability: A single-layered cap using concrete is readily built and requires standard construction equipment. The concrete vendors near the FEMP site could readily support the demand for large volumes of concrete.

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- Cost: For a single-layered concrete cap, the capital costs for raw construction materials would be approximately 30 to 35 percent more than a single-layered asphalt cap. The O&M costs of a single-layered concrete cap should be minimal. Overall, costs would be high.

The concrete-based capping option is not carried forward for the development of alternatives because it is not as effective as a multimedia cap.

Asphalt-Based Cap

The asphalt-based cap was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: An asphalt-based cover is a moderately effective material used for building a single-layered cap. Properly constructed, the cap will control erosion and minimize leachate generation. As an intrusion barrier, it will minimize direct contact between receptors and waste. Due to the year-round climate variations at the FEMP site, an asphalt-based cap could be subjected to considerable expansion and contraction forces that cause cracking in the asphalt layer. Although the effects of expansion and contraction can be lessened through additives and mesh-like membranes, significant maintenance is required and increases with time. It is less reliable than a multimedia cap.

- Implementability: A single-layered asphalt cap is readily constructed and requires standard construction equipment. Availability of the required asphalt quantity and favorable weather conditions are the primary considerations for construction. Local asphalt contractors are available and could support this effort.

- Cost: A single-layered asphalt cap would be moderate in cost compared with a multimedia cap. Fewer types of construction equipment and materials would be required. As the exposed surface would be asphalt, no mowing and maintenance would be required as with the vegetative layer of a multimedia cap. Special surface treatment would be required periodically and would increase in quantity and frequency with age. Overall, costs would be moderate.

The asphalt-based cap is not carried forward for any subunit for the development of alternatives because it is not as effective as the multimedia cap.

Soil-/Clay-Based Cap

The soil/clay-based cap was evaluated as a capping option for Subunits A, B, and C as follows:

- Effectiveness: For single-layered caps, natural soil/clay is not recommended due to its high susceptibility to cracking and weathering attributed to the freeze/thaw and shrink/swell cycles of the FEMP's climate. Infiltration through cracks will facilitate leaching. Cement or asphalt are more effective materials for single-layered caps. As an intrusion barrier, natural soil-/clay would be ranked as low. Effectiveness for this process option is low.

- Implementability: A single-layered soil/clay based cap could be easily constructed with only very basic construction equipment required. Availability of natural soil/clay, with a lower permeability than emplaced waste, is the primary construction consideration.

- Cost: The natural soil/clay single-layered cap is the most economical in both equipment and material costs as compared to single-layered caps using asphalt or concrete and multimedia caps. The O&M costs of a natural soil/clay cover would be low due to the nature of the materials used in maintaining cap integrity. Maintenance and inspection depend on weather conditions and may be more frequent than a single-layered cap using asphalt, concrete, or the vegetative layer of a multimedia cap. Overall, costs would be low.

The soil-/clay-based cap is not carried forward for any subunit due to its low effectiveness.

Chemical Sealant Cap

Chemical sealant was evaluated as a capping process option for Subunits A, B, and C as follows:

- Effectiveness: Chemical sealants can form a moderately effective seal on the surface of a waste form. The seal is not as durable as concrete, asphalt, or even clay. Chemical sealant ranks low as an intrusion barrier.

- Implementability: Chemical sealants have not been used as extensively as other capping options evaluated. The companies and trained personnel required to implement this process option are not as available as for the other process options. Overall, this process option was rated as moderately difficult to implement.

- Cost: The cost of implementing this process option is rated as moderate. The operating costs for this process option would be low, but the maintenance costs for a chemical cap is expected to be moderate.

Chemical sealant has not been carried forward for any subunit because of its low effectiveness and because it is moderately difficult to implement.

Multimedia Cap

The multimedia cap was evaluated as a capping process option for Subunits A, B, and C as follows:

- Effectiveness: A multimedia cap is a highly effective method of preventing contaminant migration. A well-constructed cap significantly reduces infiltration into waste, thereby minimizing leachate generation. It promotes surface drainage and prevents erosion and sediment transport of waste. It also acts as an intrusion barrier to prevent direct contact between receptors and waste.

- Implementability: Multimedia caps are readily constructed and require only standard construction equipment. Availability of construction materials, such as suitable clays, is the primary construction consideration.

- Cost: A multimedia cap involves significantly more capital equipment costs than other types of caps. The O&M costs for multimedia caps are higher than concrete caps because the exposed surface is a vegetative layer that requires mowing and maintenance. Overall, costs are rated moderate.

The multimedia cap is carried forward as the representative capping option to the development of alternatives for Subunits A, B, and C due to its high effectiveness.

Void Space Grout

Void space grout was evaluated as a process option to be used in conjunction with a capping technology for Subunits A and B. The void space grout was evaluated as follows:

- Effectiveness: This technology would use a grout to fill the void in the silos and would effectively control subsidence and reduce radon production; however, it does not treat or remove the waste. Void space grouting would be required before placing a cap over Silos 1 and 2 to increase stability of the silo domes.

- Implementability: Void space grout is readily implemented, the equipment and materials required are easily obtained, and similar activities have been implemented at the site (bentonite addition).

- Cost: This option would incur very low capital costs for the necessary equipment and materials. The O&M costs for this option could also be very low or none at all. The overall cost for this process option would be low.

The void space grout process option has been carried forward to alternative development as a support process option for the Subunits A and B capping technology.

2.6.4.3 Run-On/Runoff Control Technology

Run-on/runoff control technology was determined to be a remedial technology applicable for all of the subunits. Process options evaluated for run-on/runoff control include:

- Sedimentation basin/sediment trap
- Diversion/collection
- Grading
- Revegetation

Sedimentation Basin/Sediment Trap

The sedimentation basin/sediment trap was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: Sedimentation basins and sediment traps can effectively remove suspended solids; however, sediment traps are not effective for retaining surface runoff. The effluent concentration of suspended solids is regulated by local and/or federal government authorities. This process option provides a reliable method for removing suspended solids from a runoff waste stream, provided the particles will settle.

- Implementability: To implement this process option, flow characteristics are required, fill material must be properly prepared, and emergency spillway of the sedimentation basin should be stabilized with temporary vegetation. Storage requirements of material must be considered when constructing the sedimentation basin. These requirements vary from state to state. Also, in many states, the sediment can accumulate to a specific limit within the sedimentation basin. However, this process option has been implemented at virtually every construction site and has been proven to be easily implementable.

- Cost: The costs for sedimentation basins vary with size, location, and construction method. Installation includes costs for equipment, materials, and construction. The sedimentation basin for the Operable Unit 4 Study Area is economical; it carries low O&M costs. Overall, costs are considered relatively low.

The sedimentation basin and sediment trap have not been considered in the alternative development for any subunits due to its inability to retain surface runoff. However, it may be reconsidered by the designer for storm water flow control if needed.

Diversion/Collection

Diversion/collection was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: This surface water control method is used to prevent flooding, control erosion, and direct surface runoff. When used in conjunction with other remedial action technologies, this technology can be effective. Diversion of storm water runoff will reduce the amount of leachate produced.

- Implementability: This method can be easily and readily implemented using readily available equipment and materials and local contractors. Implementation of this method seldom poses significant risks to worker health and safety. Most excavation and grading equipment is available on property.

- Cost: Generally, cost of diversion and collection techniques usually is not high with the installation cost dependent on the site topography and geology. Low maintenance costs are common to almost all diversion and collection methods. Overall, costs are considered moderate.

Diversion/collection has been carried forward to the development of alternatives for Subunits A, B, and C.

Grading

Grading was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: Grading is a highly effective method of promoting and controlling site drainage and minimizing infiltration of water into contaminated areas. Grading can be used with in situ remediation alternatives as well as removal, treatment, and disposal alternatives. Some form of site grading will be used with any remediation alternative. Short-term fugitive dust emissions are the only concern to construction workers.

- Implementability: Grading can be easily implemented at the site and does not require specialized equipment. The techniques used in grading operations are well established and widely used. Personnel and equipment can usually be obtained locally.

- Cost: Capital costs would be moderate. Required equipment can be either purchased or leased. Periodic monitoring of the graded surface is necessary, and due to possible surface settling, smoothing operations may be required for several years. Also, O&M costs include annual inspections, mowing, erosion control, and drainage maintenance. Overall, costs are considered moderate.

Grading has been carried forward to the development of alternatives for Subunits A, B, and C.

Revegetation

Revegetation was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: Revegetation effectively establishes a vegetative cover that stabilizes the surface of waste disposal sites. This technique decreases erosion by wind and precipitation. No apparent impact to human health and the environment occurs from using this technique.

- Implementability: This process option is considered readily implementable due to the minimal equipment requirement. Planning involves the selection of suitable plant species, seed bed preparation, seeding/planting, mulching, fertilization, and maintenance.

- Cost: Relative to other technologies, revegetation is an inexpensive stabilization process. Periodic maintenance such as lining, fertilizing, mowing, replanting, and grading eroded slopes are O&M costs associated with this remedial technique. Overall, costs would be low.

Revegetation has been carried forward to the development of alternatives for Subunits A, B, and C.

### 2.6.5 Removal General Response Action

The following technologies have been retained for the removal GRA:

- Mechanical removal

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- Hydraulic removal
- Pneumatic removal
- Silo demolition

Table 2-16 summarizes the results of the process option evaluations for the GRA action. A narrative discussion follows.

2.6.5.1 Mechanical Removal Technology

The process options being evaluated for the mechanical removal technology include:

- Loader/dozer
- Crane with clamshell system
- Conveyor system
- Backhoe
- Dragline system

Loader/Dozer

Use of a wheeled or tracked front-end loader or dozer was evaluated under the mechanical removal technology for Subunit C as follows:

- Effectiveness: This process option is very effective in removing soil and debris for treatment or for waste packaging. There is the potential for dust suspension that would require the use of dust controls.

- Implementability: Front-end loaders and dozers are widely used for earth-moving activities and can be readily obtained. This process option is readily implementable.

- Cost: Capital costs would be low and would only include equipment cost. The O&M costs would be low and include equipment repair. Overall, costs would be low.

The loader/dozer has been carried forward for alternative development for Subunit C because it effectively removes contaminated soil and debris and is readily implementable.

Crane with Clamshell System

The crane and clamshell system was evaluated as a mechanical removal technology for Subunits A and C. The evaluation of this system is summarized as follows:

- Effectiveness: This system is used for material excavation and in rehandling materials. The health and safety of workers are of concern because of the minimal personnel protection provided. Fugitive dust emissions may result in environmental exposure to

## TABLE 2-16

## SUMMARY OF EVALUATION ANALYSIS FOR REMOVAL PROCESS OPTIONS

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| Mechanical Removal | Loader/Dozer | C | Very effective in removing soil and debris. | Readily implementable | Low |
| | Crane w/Clamshell System | A, C | Effective in removing sludges/soils, but provides little protection to personnel from contaminated material. Effective for Subunit C soils; not viable for Subunit A due to health and safety concerns. | Readily implementable | Low |
| | Conveyor System | C | Moderate effectiveness for removing solid materials but requires another method for loading material onto conveyor system. | Moderately implementable | Moderate |
| | Backhoe | C | Very effective in removing soil and debris. | Readily implementable | Low |
| | Dragline System | C | Effective in removing soil and debris but less effective than a backhoe or loader/dozer due to the larger area required for operation. | Readily implementable | Moderate |
| Hydraulic Removal | Slurry Pump with Jetting Ring | A, B, C | Effective in removing sludge-like material with accessibility problems. Not as effective for material consistency in Subunit B. | Readily Implementable | Moderate |
| Pneumatic Removal | Vacuum with Cutterhead | A, B | Most effective with dry material and not effective on materials with high moisture content (Subunit A). | Moderately difficult to implement | Moderate |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.





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**TABLE 2-16**
**(Continued)**

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| Silo Demolition | Controlled Blasting | C | Very effective for concrete demolition but hazards exist due to the use of explosives and fugitive dust emissions. | Readily implementable | Moderate |
| | Impact Hammer | C | Effective for removing small portions of concrete at a very slow removal rate. Dangers in controlling dust. | Readily implementable | Low |
| | Flame Cutting | C | Effective in cutting thick structures but creates large amounts of dust, smoke, and heat. Also has inherent operating dangers. | Moderately implementable | High |
| | Thermite Reaction Lance | C | Effective on almost any material and is suitable for irregular surfaces. Cuts rapidly but creates a large amount of dust, smoke, and heat. | Moderately difficult to implement | Moderate |
| | Gas Torch | C | Effective but represents a flame hazard while also creating large amounts of dust, smoke, and heat. | Readily implementable | Moderate |
| | Hydraulic Splitter | C | Not effective on steel-reinforced concrete. | Readily implementable | Moderate |
| | Nonexplosive Demolition Compounds | C | Only moderately effective on steel-reinforced concrete. Drilling holes in silos would weaken structures and pose a safety issue. | Readily implementable | Low |
| | Circular Diamond or Carbide Saw | C | Moderately effective for cutting thick concrete and steel-reinforced concrete. The dust produced is controlled with a water spray. | Readily implementable | Low |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

**TABLE 2-16**
**(Continued)**

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| | Diamond Rope Saw | C | Very effective on reinforced concrete. It is lightweight and easy to handle. | Moderately implementable | Moderate |
| | Diamond Chain Saw | C | Very effective on steel-reinforced concrete. It is lightweight and easy to handle. | Readily implementable | Low |
| | Abrasive Water Jet | C | Effective on steel-reinforced concrete but has inherent dangers with the high pressures involved. Also creates large volumes of contaminated water. | Moderately difficult to implement | Moderate |
| | Core-Stitch Drilling | C | Only moderately effective on steel-reinforced concrete. Would have to be combined with another demolition process. | Moderately implementable | Low |
| | Wrecking Ball | C | Effective in demolishing the silos but would create large amounts of contaminated dust. | Readily implementable | Moderate |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

the contaminated residues. The crane and clamshell system would be ineffective for removing water such as the rainwater that infiltrated Silo 4.

- Implementability: The use of the clamshell to remove the Subunit A residues would require removing the silo domes and using a secondary containment device. It rates low in implementability for Subunit A residues. The silo domes serve as primary containment structures for the silo residues. Control of radon emissions would be difficult once the bentonite caps are disturbed. This system is readily implemented for Subunit C residues because the equipment is easily obtained and the waste is accessible.

- Cost: Capital costs would include only the equipment cost. The O&M costs include labor and possible equipment repair costs. Overall, costs are low.

The crane with clamshell has been retained for alternative development for Subunit C due to its high implementability for soils. This process option has not been retained for Subunit A because of its low implementability for residues.

Conveyor System

A belt-type conveyor system was evaluated as a process option under the mechanical removal technology for Subunit C. The evaluation of the conveyor process is summarized as follows:

- Effectiveness: This process option could be used for moving the soils and debris. Personnel may be exposed to fugitive dust emissions. Overall, effectiveness is rated moderate.

- Implementability: Conveyor equipment is readily available but would require another means of loading material onto the conveyor system. Implementability is considered moderate.

- Cost: Costs would include equipment and labor. Overall, costs are considered moderate.

Due to its moderate effectiveness, implementability, and cost, the belt-type conveyor system has not been carried forward for alternative development for any subunit.

Backhoe

Use of a wheeled or tracked backhoe was evaluated as a process option for the mechanical removal technology for Subunit C. This evaluation is summarized as follows:

- Effectiveness: This process option would be very effective in removing soils and debris for treatment or disposal. There is the potential for dust suspension that could spread contamination. Dust control measures may be needed.

- Implementability: The backhoe option is readily implemented and the equipment is easily obtained.

- Cost: Capital costs would be low and would only include equipment cost. The O&M costs would be low and include equipment repair. Overall, costs would be low.

The backhoe has been retained for alternative development for Subunit C because of its effectiveness in removing contaminated soil and debris. This option is also attractive because it is easily implemented and has low capital and O&M costs.

Dragline System

A dragline system was evaluated for Subunit C as follows:

- Effectiveness: A dragline system could be effective in removing the soils and debris; however, it probably would require excavating a larger area than necessary due to the nature of its operation.

- Implementability: A dragline system would be readily implemented.

- Cost: Capital costs would be moderate and include only the equipment cost. The O&M costs would be low and include labor and equipment repair. Overall, costs are considered moderate.

The dragline system has not been carried forward for alternative development for any subunits because its costs are higher than the other removal process options. Also, it would be less effective than a backhoe or loader/bulldozer because it requires a larger area for operation.

2.6.5.2 Hydraulic Removal Technology

The only process option evaluated for the hydraulic removal technology was:

- Slurry Pump with Jetting Ring

Slurry Pump with Jetting Ring

The slurry pump with jetting ring process option was retained for evaluation for Subunits A, B, and C. The evaluation of this option is summarized as follows:

- Effectiveness: This option is highly effective in pumping liquids with varying solids content ranging from slurries to sludges. This process option would work well on the moist, sludge-like residues of Subunit A. The interaction of the water with the dry metal oxides, however, may make it difficult to pump the material in Subunit B.

- Implementability: Equipment is readily available and does not require highly trained personnel. There is potential for significant radon releases when the bentonite cover is breached in the silos.

- Cost: Capital costs vary depending on the options and type of power source. The O&M costs would consist of operator, labor, and fuel costs. Overall, costs are considered moderate.

The slurry pump with jetting ring has been carried forward for alternative development for Subunit A, but not for Subunit B. Subunit B residues are more effectively removed by another removal technology due to its low water content. Subunit C can use the slurry pump to remove any water, but a jetting ring would not be required.

2.6.5.3 Pneumatic Removal Technology

The only process option retained for evaluation for pneumatic removal technology was:

- Vacuum with Cutterhead

Vacuum with Cutterhead

The evaluation of the vacuum with cutterhead is summarized as follows:

- Effectiveness: The primary limitations on the effectiveness of pneumatic removal systems are the limited production rates when pumping materials with high moisture contents. This process option is more amenable to the dry material of Subunit B.

- Implementability: Pneumatic removal systems are readily available for many applications. Additional support systems may be required when removing wastes with high moisture contents. There is the potential for significant radon releases when the bentonite cover is breached in the silos. This process option is moderately difficult to implement.

- Cost: Capital costs for pneumatic removal systems are moderate and require a work platform, compressors, pumps, and intake and discharge lines. O&M costs for pneumatic removal systems are moderate. Overall, costs are considered moderate.

The vacuum with cutterhead process option has been carried forward to alternative development for Subunit B but will not be carried forward for Subunit A due to the reduced effectiveness on materials with a high moisture content.

2.6.5.4 Silo Demolition Technology

Process options retained for the evaluation of silo demolition technology for Subunit C include:

- Controlled blasting
- Impact hammer
- Flame cutting
- Thermite reaction lance
- Gas torch
- Hydraulic splitter
- Nonexplosive demolition compounds
- Circular diamond or carbide saws
- Diamond rope saw
- Diamond chain saw
- Abrasive water jet
- Core-stitch drilling
- Wrecking ball

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Controlled Blasting

Controlled blasting was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Controlled blasting is very effective for concrete demolition, provided noise and shock in adjoining areas are not of concern. It is well suited to heavily reinforced concrete because a high degree of fragmentation is possible with the proper selection of blast parameters. Also, very high removal rates are possible. There are inherent dangers in controlling blasting with regard to personnel safety and nearby building damage. Also, total dust control is difficult to achieve; therefore, airborne release of contamination is likely.

- Implementability: Controlled blasting is easily implemented, and the necessary equipment is readily available.

- Cost: The costs for controlled blasting range from low to moderately high. Capital costs comprise the major portion of the total cost. Overall, costs are considered moderate.

The substantial hazards due to the use of explosives and the generated dust render this process option unacceptable for use with any of the silo structures. Consequently, controlled blasting has not been carried forward for development of alternatives. Its usefulness may be reassessed by the designer.

Impact Hammer

The impact hammer was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Impact hammers or "jackhammers" are very useful for working in small areas. They are effective for removing portions of concrete without disturbing the surroundings; however, they have a very slow removal rate. There are inherent

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dangers in controlling dust and direct worker exposure to contaminated dust when working with contaminated materials.

- Implementability: The use of impact hammers is easily implemented and the equipment necessary is readily available.

- Cost: Costs for the impact hammer process option would be very low with low capital and O&M costs.

Because of the extremely slow removal rate and the amount of airborne dust created, the impact hammer is not being carried forward for the development of alternatives. It is being represented by other process options and may be reconsidered by the designer.

Flame Cutting

Flame cutting was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Flame cutting makes it possible to cut extremely thick structures and may be used when no vibrations are allowed. The major disadvantages are that during cutting, large amounts of dust, smoke, and heat are produced. Also, there are dangers inherent to the personnel operating the equipment and those near the equipment.

- Implementability: Flame cutting is moderately implementable because of equipment and operator availability.

- Cost: Costs for flame cutting would be moderate to high.

Due to the inherent risk to the workers and the environment, flame cutting has not been carried forward to the development of alternatives. It is being represented by other process options and may be reconsidered by the designer.

Thermite Reaction Lance

Thermite reaction lance is another silo demolition process option evaluated for Subunit C. The evaluation of this process option follows:

- Effectiveness: The thermite reaction lance can rapidly cut almost any material present at the silos and is also suitable for irregular surfaces. In less than six minutes, the lance can burn a hole 5.1 cm (2 in.) in diameter through reinforced concrete that is 1.1 m (3-ft, 6-in.) thick.

- Implementability: The thermite reaction lance is moderately difficult to implement. During use, large amounts of dust, smoke, and heat are produced. A control envelope and ventilation must be provided.

- Cost: The costs for this process option would be moderate and depends on the geometry of the cuts.

Due to the smoke and dust problems associated with this equipment, the thermite reaction lance has not been carried forward as a process option for the development of alternatives. It is being represented by other process options and may be reconsidered by the designer.

Gas Torch

The gas torch was retained for evaluation as a silo demolition process option for Subunit C. The evaluation of the gas torch is summarized as follows:

- Effectiveness: The gas torch uses a flame with temperatures ranging from 1980 to 2480°C (3600 to 4500°F) to effectively cut the concrete and steel reinforcement. The cutting does generate large amounts of dust, smoke, and heat, which could be removed using a flexible duct, pre-filters, and high efficiency particulate air (HEPA) filters. The intense flame represents a flame hazard.

- Implementability: The technology and personnel for the gas torch process option are readily available. This process option is readily implementable.

- Cost: The capital costs for this process option include the cost of the remotely controlled torch and monitoring frame. The capital costs would be moderate. The operating costs would include the cost of the gas fuel for the torch and periodic replacement of the torch tips. The O&M costs for this process option were rated as moderate. Overall, costs are considered moderate.

The gas torch has not been carried forward to development of alternatives due to the smoke, flame, and dust problems associated with this process option. It is being represented by other process options and may be reconsidered by the designer.

Hydraulic Splitter

The hydraulic splitter was evaluated as a silo demolition process option for Subunit C as follows:

- Effectiveness: A hydraulic splitter effectively demolishes concrete by expanding a wedge in predrilled holes along predetermined fault lines, thus causing the concrete to fracture. The amount of steel reinforcing in the silos will reduce the effectiveness of the splitter to cause fracture and the ability to predict the fracture path. Overall, this process option was rated with a low effectiveness for steel-reinforced concrete.

- Implementability: The resources required to implement this process option are readily available. The hole drilling and the operation of the hydraulic splitter can be operated manually or remotely.

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- Cost: The costs of the hydraulic splitter process option would range from moderate to high, depending on the amount of automation desired. For evaluation purposes, the capital costs for this process option were rated as high. Overall, costs are considered moderate.

The hydraulic splitter process option has not been carried forward to alternative development because it is not effective on steel-reinforced concrete. It may be reconsidered by the designer.

Nonexplosive Demolition Compounds

The use of nonexplosive demolition compounds was evaluated as a process option for silo demolition, which applies to Subunit C. The evaluation of nonexplosive demolition agent is summarized as follows:

- Effectiveness: Nonexplosive demolition agents are moderately effective in crumbling unreinforced concrete but they are not as effective on reinforced concrete.

- Implementability: The use of nonexplosive demolition agents on the silo would be readily implementable but would require drilling thousands of holes in the silo walls and dome. This would weaken the structure and present safety problems.

- Cost: The capital costs of this process option were rated as low. The capital costs include the drilling rig and application tools. The O&M costs of this process option were rated as low. Overall, costs for nonexplosive demolition systems are considered low.

Nonexplosive demolition agents were not carried forward for the development of alternatives because of the low implementability and moderate effectiveness on reinforced concrete. It may be reconsidered by the designer.

Circular Diamond or Carbide Saws

Circular diamond or carbide saws were retained for evaluation as possible silo demolition options for Subunit C. The evaluation of these process options follows:

- Effectiveness: Circular diamond or carbide saws are moderately effective. They may be used to cut thick concrete walls or floors and, also, can cut through reinforcing bars, although the bars tend to break off diamonds from the blade. The dust produced is controlled with a water spray.

- Implementability: This process option is easily implemented and requires no specialized equipment or personnel. A collection system for the water used for dust control would be required but can be readily installed.

- Cost: The capital costs are low and include purchasing the saws and installing a water collection system. The O&M costs would also be low and include periodic chain replacement and fuel purchases. Overall, costs of this process option would be low.

Circular diamond or carbide saws have not been carried forward to the development of alternatives because of the moderate effectiveness. The diamond rope saw is more effective and has a faster concrete removal rate and will represent demolition response options.

Diamond Rope Saw

The diamond rope saw was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Diamond rope saws are capable of cutting concrete up to 6.1 m (20 ft) thick. The resulting cuts are made much more quickly than those made with the diamond-tipped circular saw or carbide saw. The diamond rope saw can cut at any elevation and in any direction. The diamond rope saw mechanism, including saw stand and hydraulics, can be placed as far away from the actual work as necessary for personnel and equipment protection. It is highly effective for cutting concrete.

- Implementability: This process option is moderately implementable. The major disadvantage is that there is a significant setup time between cuts. Also, the rope saw is specifically configured for the project requirements such as thickness of the cut, type of aggregate in concrete, and the amount of reinforcement in the concrete.

- Cost: The costs are considered moderate. Initial capital costs include the equipment, and O&M costs mainly consist of replacing the rope saw and maintaining the equipment.

The diamond rope saw has been retained for alternative development for Subunit C due to its effectiveness.

Diamond Chain Saw

The diamond chain saw was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: The diamond chain saw effectively cuts concrete and steel reinforcement to depths of 38 cm (15 in.). Dust protection needs to be controlled.

- Implementability: The diamond chain saw is easy to implement. Portable power units are readily available as are vehicles capable of powering the chain saw. The saw is lightweight and can be handled by a single worker.

- Cost: The capital and O&M costs for this process option are low. O&M costs include replacing the diamond-tipped chain and labor. Overall, costs are considered low.

The diamond chain saw has been retained for alternative development for Subunit C.

Abrasive Water Jet

The abrasive water jet was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: The abrasive water jet is effective in cutting reinforced concrete. A shroud and vacuum system can be used to contain the generated waste with more than 90 percent efficiency. Hazards to personnel result from the high pressure associated with this process option.

- Implementability: The abrasive water jet is moderately difficult to implement with regard to other process options under consideration. A collection system is required for the large volume of dirty and contaminated water produced by the water jet.

- Cost: The costs for this process option are considered moderate. Initial capital costs would include purchase of equipment and the installation of a collection system. The O&M costs include recycling or purchasing the abrasives used for cutting.

The abrasive water jet process option has not been carried forward to alternative development because of the inherent dangers associated with the high pressures required. This option offers no advantages over other demolition process options under consideration but may be reconsidered by the designer.

Core-Stitch Drilling

Core-stitch drilling was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Core-stitch drilling is moderately effective because the concrete is reinforced. This process option would have to be combined with another process to cut the steel reinforcement before concrete removal.

- Implementability: The implementability for this process option is moderate. It requires drilling a very large number of holes to establish a fracture plane.

- Cost: The capital costs for core-stitch drilling include purchasing the equipment. These costs, along with the O&M costs, would be low. Overall, costs are considered low.

Core-stitch drilling has not been carried forward for the development of alternatives because it is only moderately effective. However, it may be reconsidered by the designer.

Wrecking Ball

The wrecking ball was retained for evaluation as a silo demolition process option for Subunit C. The evaluation of a wrecking ball is summarized as follows:

- Effectiveness: A wrecking ball would be effective in demolishing the silo but would produce large amounts of dust.
- Implementability: Implementing this process option would require a crane with a wrecking ball and a qualified operator, both of which are readily available.
- Cost: The costs of mobilizing the crane and operator to the site would be moderate. The operating costs for this process option would include the cost of operating the crane, health and safety oversight, and health physics monitoring. Overall, costs are considered moderate.

The wrecking ball has been eliminated from alternative development because of the hazards associated with dust produced from the operation.

### 2.6.6 Treatment General Response Action

The following treatment technologies have been evaluated:

- In situ treatment
- Waste stabilization
- Physical treatment
- Chemical treatment
- Thermal treatment
- Decontamination and decommissioning

Table 2-17 summarizes the results of the process option evaluations for the treatment general response action. A narrative discussion follows.

#### 2.6.6.1 In Situ Treatment Technology

In situ treatment was determined to be a viable remedial technology for Subunits A, B, and C. Process options retained for in situ treatment include:

- Shallow soil mixing
- In situ vitrification

## TABLE 2-17

## SUMMARY OF EVALUATION ANALYSIS FOR TREATMENT PROCESS OPTIONS

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| In Situ Treatment | Shallow Soil Mixing | C | Effective in limiting the transport of surficial contaminants through controlling erosion and limiting migration. | Very difficult to implement | Moderate |
| | In Situ Vitrification | A, B, C | Effective in destroying organics and immobilizing inorganics and radionuclides. | Difficult to implement | High |
| Waste Stabilization | Asphalt-Based Stabilization | A, B, C | Creates solid block with low permeability but does not reduce potential leaching. Safety concerns from organic vapor and dust generation. | Moderately difficult to implement | Moderate |
| | Cement-Based Stabilization | A, B, C | Moderately effective in treating wastes. The solidified matrix reduces exposed surface area and leachate generation. Most suitable for immobilizing metals. Large volume increase. | Moderately difficult to implement | Moderate |
| | Thermoplastic Encapsulation | A, B, C | Effective in stabilizing soluble, toxic materials, but not proven on large-scale projects. Waste and the matrix may not be compatible. | Difficult to implement | High |
| | Vitrification | A, B, C | Very effective in stabilizing wastes. Considered an innovative technology and BDAT for high-level nuclear waste. The noncrystalline solid is very effective for reducing the leachability. Volume reduction also occurs. | Difficult to implement | High |
| | Lime/Flyash Stabilization | A, B, C | As effective as cement stabilization but concerns exist with stability of final matrix. Volume increase will occur. | Moderately difficult to implement | Moderate |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

**TABLE 2-17**
**(Continued)**

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| Physical Treatment | Solid/Liquid Separation | A, C | Effective. | Readily implemented | Moderate |
| | FEMP AWWT | A, B, C | Metals precipitation is effective for separation when used with a series of filtering options. Ion exchange is effective on specific ions. Generally used as a final treatment in a series of filtering options. | Readily implementable | Low |
| Chemical Treatment | Chemical Extraction | A, B, C | Effective in removing heavy metals; not a stand-alone treatment. Large quantities of chemicals are required, introducing an additional waste stream. This process also requires post treatment to stabilize the primary waste streams before disposal. Not effective in removing contaminants below levels in Operable Unit 4 soils. | Difficult to implement | High |
| Thermal Treatment | Drying/Calcination | A | Not effective for remediation alone; does not treat radionuclides alone. Provides suitable pretreatment where liquid/solid ratio must be reduced before treatment. | Moderately implementable | Moderate |
| Decontamination and Decommissioning | Vacuum Scabbling | C | Effective for removing surface contamination only and will reduce fugitive dust emissions. | Readily implementable | Moderate |
| | Pressure Washing | C | Low effectiveness due to inability to remove subsurface contamination; only able to cleanse the surface. Ordinarily used as a pretreatment to remove loosely adhered contamination. Many safety risks associated with high pressure and high temperature operations. | Readily implementable | Low |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

**TABLE 2-17**
**(Continued)**

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| | Vacuum Grit Blasting | C | Not effective for removing contaminants strongly attached to the surface or within the subsurface. | Readily implementable | Moderate |
| | Acid Washing | C | Moderately effective for removing contaminated concrete. Effectiveness varies with depth. Requires special precautions and training. It also produces an additional waste stream for treatment. | Difficult to implement | High |
| | Strippable Coatings | C | Not effective for removing subsurface contamination | Readily implementable | Moderate |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

Shallow Soil Mixing

Shallow soil mixing was evaluated as an in situ treatment process option for Subunit C as follows:

- Effectiveness: This process is an effective way to stabilize in situ soils subject to erosion. Transport of surficial site soil to downstream locations will be limited by this technology (i.e., this technology facilitates a chemical or physical reduction of the mobility of hazardous constituents). This process option is effective if the contaminated material is completely stabilized. Leachate generation and contaminant mobility would be greatly reduced. Shallow soil mixing will not treat deeper subsurface soils.

- Implementability: Interference with below-grade structures such as the decant sump tank and process piping makes implementation more difficult. Complete stabilization must be verified. Implementability is rated as very difficult.

- Cost: Common construction machinery is required, such as backhoe, pullshovel, pumps, or front-end loader. Minimal maintenance is required due to weathering influences. Overall, costs are considered moderate.

Shallow soil mixing will not be carried forward to alternative development for Subunit C due to the difficulty in implementation.

In Situ Vitrification

Vitrification was evaluated as an in situ treatment process option for Subunits A, B, and C. The evaluation of in situ vitrification is summarized as follows:

- Effectiveness: This technology destroys the hazardous organics and immobilizes the hazardous material in a reduced, nonleachable, vitreous mass. The vitrified material would possess good mechanical integrity and would have long-term stability. Vitrification of radioactive wastes has been proven in various pilot and demonstration projects with various degrees of success and is an emerging technology. This process option results in a better stabilized waste product than shallow soil mixing and better overall performance.

- Implementability: This process is a very energy intensive operation that requires trained personnel and more sophisticated equipment. However, in situ vitrification is still in the development phase. Tests to date have shown difficulty in implementation, especially due to significant off-gases, inconsistent density of the material, and depths to which the residues extend. Implementation and verification of the extent and sufficiency of this process in a specific in situ application is difficult. Implementability is difficult for this process option.

- Cost: In situ vitrification has a high capital cost because it involves the design and construction of a localized facility using specialized equipment including an off-gas treatment system. This process will require highly trained professionals and has a high energy demand. Once the process is completed, no maintenance will be required;

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however, demolition and disposal costs will be incurred. The overall costs are considered high.

In situ vitrification has not been carried forward to alternative development for Subunits A, B, and C due to the required depths and the difficulty of implementation and high costs. Ex situ treatment process options will be selected as representative treatment options.

2.6.6.2 Waste Stabilization Technology

Process options evaluated for waste stabilization technology include:

- Asphalt-based stabilization
- Cement-based stabilization
- Thermoplastic encapsulation
- Vitrification
- Lime/flyash stabilization

Asphalt-Based Stabilization

Asphalt-based stabilization was evaluated as a process option for Subunits A, B, and C as follows.

- Effectiveness: As with other stabilization technologies, this asphalt-based technology creates a solid block of waste with relatively low permeability. Safety concerns are primarily related to protecting on-site personnel from organic vapor and/or fugitive dust generation. Environmental considerations include air, water, and land resources. This process option is moderately effective.

- Implementability: This technology requires complex, specialized mixing equipment and a trained operations staff to ensure safe, consistent operations. Compared to cement-based stabilization systems, the power consumption for this process option is quite high. This process option is moderately difficult to implement.

- Cost: Complex, specialized mixing equipment, extruders, and safety equipment are required. Operation staff, power consumption, and equipment repair are concerns for this technology. Overall, costs are considered moderate.

Asphalt-based stabilization will be represented by cement-based stabilizations, which have fairly similar evaluations.

Cement-Based Stabilization

Cement-based stabilization was evaluated as a process option for Subunits A, B, and C as follows.

- Effectiveness: Cement-based stabilization is moderately effective in treating wastes. The wastes are mechanically locked within a solidified matrix that significantly reduces the leachate generation but greatly increases waste volumes. Safety concerns include

organic vapors and dust generation. This process option is most suitable for immobilizing inorganic metals and is less effective for use in wastes with organics.

- Implementability: Cement-based stabilization is moderately difficult to implement. Major advantages include the readily available equipment and materials. Disadvantages are the increased volume and weight for disposal once the waste is stabilized.

- Cost: Cost for cement-based stabilization is rated moderate. The process would require construction of waste handling, mixing, and curing facilities. The O&M costs are expected to be moderate for cement-based stabilization. The operation will require additional materials (cement) and maintenance of the mechanical equipment, which must operate in a fairly caustic environment. Costs would be moderate when compared to other process options.

Cement-based stabilization has been carried forward to alternative development for Subunits A and B. This process option has not been carried forward for Subunit C because the increase in waste volumes for the slightly contaminated soils or concrete is not cost-effective.

Thermoplastic Encapsulation

Thermoplastic encapsulation was evaluated as a stabilization process option applicable for Subunits A, B, and C. The evaluation of thermoplastic encapsulation is summarized as follows:

- Effectiveness: This process option is useful in stabilizing very soluble, toxic materials. In using this technology, compatibility of the waste and the matrix must be given major consideration. Thermoplastic encapsulation has not been proven on a large scale but has been widely used in nuclear waste disposal. This process option is highly effective on a small scale, but its effectiveness is questionable on a large scale.

- Implementability: To implement this technology, treatability studies would be needed. Complex, specialized mixing equipment and a trained operations staff to ensure safe, consistent operations would be required for this process option. This process option is difficult to implement.

- Cost: This process option requires specialized equipment and materials, which can be expensive. The O&M costs associated with this process include labor and repair costs, and disposal costs following the process. Overall, costs are considered high.

The high costs, difficult implementability, and uncertain effectiveness precludes this process option from being selected as a representative process option.

Vitrification

Vitrification was considered for evaluation as a stabilization process option for Subunits A, B, and C. The evaluation of vitrification is summarized as follows:

- Effectiveness: Vitrification is highly effective in stabilizing certain wastes. The vitrification process involves converting the waste into a molten glass at a temperature of approximately 1350°C (2462°F). The resulting noncrystalline solid has an extremely low leach rate for most wastes. Considered an innovative technology, EPA determined that vitrification is the best demonstrated available technology (BDAT) for high-level nuclear waste. This process option is most suitable for immobilizing inorganic metals and radionuclides and is very effective for certain materials. However, its long-term effectiveness is unknown.

- Implementability: Vitrification is a relatively new technology without readily available equipment. The long lead times associated with the procurement of equipment should be considered in the schedule because this process option is innovative and vendors are not readily available. The process also requires high energy demands and trained personnel who are not readily available. An off-gas treatment system is also needed. This process option is difficult to implement.

- Cost: Capital costs for vitrification would be high. The process would require construction of a waste handling, processing, and curing facility and, as a relatively new technology, it will require special design and specifications. The O&M costs would be high. The system also requires a relatively extensive off-gas collection and cleaning system that must be maintained during processing. Overall, costs are considered high.

This process option is considered effective for immobilizing metals in a glass matrix. Waste configuration can be controlled to minimize the surface area subject to leachate. Volume reduction of the waste will reduce disposal costs. Vitrification has been carried forward to alternative development for Subunits A and B. Vitrification of Subunit C soils may occur if pilot studies indicate the soils are an effective additive to the waste. Otherwise, Subunit C materials have sufficiently low levels of contamination which does not make vitrification of soils cost-effective.

Lime/Flyash Stabilization

Lime/flyash stabilization was evaluated as a stabilization process option for Subunits A, B, and C as follows.

- Effectiveness: Although lime/flyash stabilization is often as effective as cement stabilization, this technology is not as effective on a wide range of waste matrixes as cement stabilization. Additionally, there is concern over the long-term stability of the final material and the potential for dust emissions. Treatability studies are important to ensure the compatibility of this process option to the waste matrix.

- Implementability: Lime/flyash stabilization is equivalent to cement-based stabilization with respect to implementability. The equipment is conventional and readily available as with cement-based stabilization. This process option is rated as moderately difficult to implement.

- Cost: Capital costs for lime/flyash stabilization are essentially the same as those for cement-based stabilization. The process would require construction of waste handling, mixing, curing, and bulk handling facilities. The capital costs for this process option are moderate. The lime/flyash process option would also require bulk quantities of lime and flyash, maintenance of the mechanical equipment, and storage containers for the stabilized waste. Overall, costs are considered moderate.

This process option can be as effective as cement-based stabilization; however, there are concerns over the long-term stability of the waste matrix. For this reason, lime/flyash stabilization has not been carried forward for alternative development for Subunits A, B, and C.

2.6.6.3 Physical Treatment Technology

Process options evaluated for physical treatment technology include:

- Solid/liquid separation
- FEMP AWWT facility

Solid/Liquid Separation

Solid/liquid separation was evaluated as a physical treatment process option for Subunits A and C as follows:

- Effectiveness: Solid/liquid separation options are effective, both for a dewatering purpose and for a solid removal process.

- Implementability: The equipment for solid/liquid separation is conventional and is manufactured and stocked by many companies. The personnel required to operate this equipment are readily available. This process option is considered readily implementable.

- Cost: Typical equipment used for solid/liquid separation include belt filter presses, centrifuges, filters, settling tanks or ponds, clarifiers, or hydrocyclones. Although the costs associated with each type of equipment vary, this process option was rated moderate for capital costs. Operating costs for this process option include the energy for pumping slurries or liquids and replacement of any filtering media. Maintenance would include the typical requirements for a pump and piping system. Overall, the O&M costs for the solid/liquid separation process option were rated as moderate. Overall, costs are considered moderate.

Solid/liquid separation through dewatering has been carried forward as an alternative development for Subunits A and C. The identification for a specific dewatering option will be a design decision.

FEMP Advanced Wastewater Treatment System

Treatment using the AWWT facility at the FEMP site was evaluated for encountered perched groundwater and other aqueous liquids generated during the remediation of Subunits A, B, and C. This facility will use a combination of wastewater treatment options to treat the FEMP site wastes. Metals precipitation and ion exchange are two options used to treat FEMP site wastewaters that contain inorganic metals and radionuclides, such as those that will be found in Operable Unit 4 wastewaters.

The evaluation of metals precipitation is summarized as follows:

- Effectiveness: Metals precipitation uses additives to wastewaters to aid in the precipitation process. This process option, used with a series of filtering options, is effective on a wide range of aqueous wastes. It has been rated as an effective process option.

- Implementability: Metals precipitation system for treating the quantity of water required for the treatment process would consist of adding potassium ferrate to remove radionuclides and metals. Studies would be helpful for optimizing the precipitation process for a specific waste stream. This process option would be moderately implementable. However, since the AWWT will already be present for alternative development, adding liquids to the system will be easy.

- Cost: The cost of metals precipitation depends on the quality of the water being received by the system, the desired quality of the water to be discharged from the system and the flow rate of water required by the process. It is expected that the capital costs for this process option would be moderate. The O&M costs are expected to be moderate. The overall costs to Operable Unit 4 alternatives however, are expected to be low since the capital costs will already have been incurred.

The evaluation of selective ion exchange is summarized as follows:

- Effectiveness: As with the other physical treatment processes, selective ion removal requires, as a minimum, a filtering pretreatment and is effective on aqueous wastes containing specific ions.

- Implementability: To select the proper resin for a selective ion removal system, tests would be performed with actual samples of the water to be treated to ensure that no components are present (either ionic or nonionic) that would interfere with the resins selectivity. Ion exchange equipment is manufactured and stocked by many companies. This process option is considered moderately implementable. However, since the AWWT will already be present for alternative development, adding liquids to the system will be easy.

- Cost: The resin for selective ion removal can be very expensive depending on the ions to be removed and the interference from the other components in the stream to be processed. Therefore, the capital costs for this process option were rated as high. Because resins need to be replaced periodically, the O&M costs for this process option

are rated as high. The overall costs to Operable Unit 4 alternatives, however, are expected to be low since the capital costs will already have been incurred.

The FEMP AWWT facility has been retained for development of alternatives for all of the subunits because it will be constructed on-line and will be readily available to receive wastewater from Operable Unit 4 remedial actions.

2.6.6.4 Chemical Treatment Technology

The only process option retained for evaluation for chemical treatment was:

- Chemical Extraction

Chemical Extraction

This process option was evaluated for Subunits A, B, and C as follows:

- Effectiveness: Chemical extraction is a separation technique that utilizes a liquid solvent to remove a solute from a solid mixture. This process option effectively removes heavy metals but is not a stand-alone treatment. Large quantities of chemicals would be required, generating additional waste. In addition, this process option requires post-treatment stabilization of the two primary waste streams. In the case of soil washing, current studies indicate that the contaminant levels in Operable Unit 4 soils are below levels considered achievable using the soil washing technology.

- Implementability: Depending on the application, this process option is relatively complicated and requires the effective and optional operation of multiple processes to achieve the desired results. This process option is rated difficult to implement.

- Cost: The costs of a chemical extraction system would be high due to the cost of the material handling equipment, process equipment, reagents, and labor.

Chemical extraction has been carried forward to alternative development for Subunit A because of the possible benefits obtained in generating a small volume of highly contaminated waste and a much larger volume of lesser contaminated waste. Disposal costs may ultimately be less expensive with this process option. Chemical extraction was not retained for Subunit B because of a probable low effectiveness due to its chemical makeup. The expense of this process option due to the limited quantity of soil in Operable Unit 4 caused it to not be carried forward for Subunit C. It should be noted that chemical extraction and other technologies are currently being examined under Operable Unit 5 to address the large quantity of site-wide soils at the FEMP potentially requiring remedial action. In the event such treatment becomes available at FEMP or elsewhere, consideration will be

given to employing the treatment as a waste minimization initiative for addressing Operable Unit 4 contaminated soils.

2.6.6.5 Thermal Treatment Technology

The only process option evaluated for thermal treatment was:

- Drying/Calcination

Drying/Calcination

The evaluation for this process option for Subunit A is summarized as follows:

- Effectiveness: Calcines can be used to heat treat and dry the Silos 1 and 2 material while at the same time, reducing the metal oxides and burning off any organic impurities. Calcination does not treat radionuclides and is, therefore, not an effective process option. However, calcination does provide suitable pretreatment for other treatment technologies where the liquid/solid mixture must be reduced before treatment.

- Implementability: Calcines are readily available from a number of manufacturers, so there would be no significant delay in constructing a system. Because a calciner emits air emissions, some type of scrubbing system or HEPA filtration for the off-gas would be required. Overall, this process option is rated as moderately implementable.

- Cost: The capital costs for the calciner would include the cost of the calciner, the required air quality equipment, and the material handling equipment. These costs are estimated to be moderate. The energy required to calcine the Operable Unit 4 material would constitute the major operating cost. Maintenance costs would include maintenance on the calciner, the material handling equipment, and the emissions control system. Overall, costs are rated as moderate.

Drying/calcination has not been carried forward to alternative development as a process option for Subunit A because of its low rating for effectiveness; however, it may be considered as a pretreatment option for another technology (i.e., cement stabilization or vitrification) by the designer, if appropriate.

2.6.6.6 Decontamination and Decommissioning Technology

Process options being evaluated for D&D include:

- Vacuum scabbling
- Pressure washing
- Vacuum grit blasting
- Acid washing with oxidizing agents
- Strippable coatings

Vacuum Scabbling

The scabbling process option was evaluated for Subunit C as follows:

- Effectiveness: Scabbling physically removes contamination from a wall or floor by using a piston equipped with spikes to chip away small amounts of the top layer of concrete or plaster. This option is effective for removing the top layer of contamination and can be used in conjunction with a vacuum system to reduce dusting and collection of the material.

- Implementability: The system can be operated remotely, requires no special worker training, and the equipment is readily available. This process option was rated as readily implementable. However, despite the vacuum system, a small amount of dust is generated and it either must be controlled or the workers protected.

- Cost: The cost for the scabbling equipment with provisions for remote operation and the vacuum collection system was rated as moderate. The O&M costs for this process option rated as moderate. Overall, costs are considered moderate.

Scabbling has been carried forward to alternative development for Subunit C as a decontamination process option because it removes contamination to greater depth than any of the other process options.

Pressure Washing

Pressure washing was evaluated as a possible D&D process option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Pressure washing techniques effectively remove loose surface contamination but cannot remove subsurface contamination. Large volumes of water are required; yet, dust is not produced. Pressure washing is ordinarily used as a pretreatment step prior to the use of other methods of removing embedded contamination.

- Implementability: Pressure washing is easily implemented. Water is nonhazardous and does not require special handling by personnel prior to use. Spraying and pumping equipment are inexpensive and readily available. Relatively few personnel and training are required. A disadvantage is the safety risks associated with high-pressure and high temperature operations. In addition, the wastewater will require collection (line the floor) treatment before disposal. The water can be removed with standard pumping equipment.

- Cost: Overall, costs would be extremely low. Water is inexpensive in comparison to other solvents. Capital costs include the purchase of pumping and spraying equipment.

Pressure washing has been retained for the development of alternatives for Subunit C as a pretreatment step to remove loosely adhered contamination due to its easy implementation and effectiveness in removing contamination without generating large amounts of dust.

Vacuum Grit Blasting

Vacuum grit blasting is another D&D process option that was retained for evaluation for Subunit C. The evaluation follows:

- Effectiveness: This option is not effective for removing contaminants strongly adhered to the surface or within the subsurface. This process option is typically used for limited areas of contamination.

- Implementability: Grit blasting is easily implemented. It requires no specialized equipment and little training for personnel is needed. Two waste disposal systems are required because contaminated material is broken into two waste streams via a cyclone separator. There is the potential for dust generation.

- Cost: Costs are typically higher than those for pressure washing for both equipment and maintenance. Overall, costs are moderate.

The vacuum grit blasting has not been carried forward to the development of alternatives for any subunits because of its low effectiveness in removing strongly adhered contamination, the large surface areas of the silo structures, and the generation of dust which must be controlled.

Acid Washing with Oxidizing Agents

Acid washing with oxidizing agents was retained for evaluation as a potential process option for the D&D technology. The evaluation of this process option for Subunit C is as follows:

- Effectiveness: This process option is moderately effective for dissolving/removing contaminated concrete. The effectiveness varies with depth because subsurface contamination could require several applications.

- Implementability: Acid washing requires special precautions and training to protect workers handling the chemicals. A liner is placed on the floor to collect the water. In addition, the process results in a waste stream that must be collected and treated before disposal. As a result, this process option is difficult to implement.

- Cost: The costs for acid washing could be high due to the required treatment of the waste stream and precautionary measures required by the worker. Overall, costs are considered high.

Because of its difficult implementability, high cost, and danger to personnel, acid washing has been eliminated from the development of alternatives.

Strippable Coatings

Strippable coatings were also retained as a process option for the D&D remedial technology. The evaluation of this process option for Subunit C follows:

- Effectiveness: This process option is not effective for removing subsurface contamination. However, dust emissions and waste production are minimized.
- Implementability: Strippable coatings are easily implemented. Extensive training and equipment are not required for implementation.
- Cost: The costs of strippable coatings are considered moderate primarily due to labor and materials.

This option cannot remove subsurface contamination and its cost are higher than pressure washing and offer no additional benefit; therefore, strippable coatings will not be carried forward to the development of alternatives for any subunits.

### 2.6.7 Disposal General Response Action

The following disposal technologies have been evaluated:

- Waste transportation
- On-Property disposal
- Off-Site disposal

Table 2-18 summarizes the results of the process option evaluations.

#### 2.6.7.1 Waste Transportation Technology

Waste transportation options retained for evaluation are:

- Rail transport
- Truck transport

Rail Transport

The evaluation of rail transport is summarized as follows:

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## TABLE 2-18

## SUMMARY OF EVALUATION ANALYSIS FOR DISPOSAL PROCESS OPTIONS

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| Waste Transportation | Rail Transport | A, B, C | Effective form of transportation because of the reduced risk to human life. Rail spurs may need to be upgraded. | Readily implementable | Low |
| | Truck Transport | A, B, C | Effective but less reliable than rail transportation. Truck transportation is required for on-property disposal. | Readily implementable | Moderate |
| On-Property Disposal | Engineered Disposal Facility | A, B, C | Effective by providing isolation from the groundwater and isolating waste from surface environment. Also provides intrusion barrier. | Moderately difficult to implement | High |
| | Above-Grade Vault | A, B, C | Effective disposal of highly hazardous or radioactive waste forms. Provides long-term waste immobilization and environmental protection. | Moderately difficult to implement | High |
| Off-Site Disposal | Nevada Test Site | A, B, C | Very effective disposal of stabilized or solid Operable Unit 4 waste. | Moderately difficult to implement | Moderate |
| | Permitted Commerical Disposal Site | C | Very effective disposal of stabilized or solid waste from Subunit C. | Difficult to implement | High |
| | New Facility Adjacent to FEMP | A, B, C | Less effective disposal than the permitted commercial disposal site or NTS because the site would be above or adjacent to Great Miami Aquifer and near a large population area. | Difficult to implement | High |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.



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**TABLE 2-18**
**(Continued)**

| Remedial Technology | Process Option | Applicable Subunit | Effectiveness | Implementability | Cost |
|---|---|---|---|---|---|
| | New Facility Within 300 Miles of FEMP | A, B, C | Less effective option than the permitted commercial disposal site or NTS but slightly better than the new facility adjacent to the FEMP site because it would not have to be above the Great Miami Aquifer. | Difficult | High |

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.



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- Effectiveness: The rail transport process option is an effective option for off-site transportation. By transporting waste by rail, large tonnages of waste can be hauled at one time. On a per trip basis, there are less accidents by rail than by truck. However, should a rail accident occur, much larger quantities of contaminants could be exposed to the public.

- Implementability: Rail transport is readily implementable because rail transport at the FEMP site can be accommodated by the existing on-site rail spur. However, the rail transport process option is susceptible to route availability and coordination with state and local agencies along the route.

- Cost: The rail transport process option is expected to be moderately costly because of the following requirements: upgrading of the on-site rail spur and the need to build or upgrade loading and unloading waste handling facilities. The O&M costs are expected to be low for the rail transport process option because of the limited need for machinery, equipment, and maintenance items. In addition, historical records indicate that railway components have a relatively long life span and require little maintenance as compared to other transportation systems. Overall, costs are considered low.

Rail transportation has been retained for the development of alternatives for all subunits.

Truck Transport

The evaluation of truck transport is summarized as follows:

- Effectiveness: Truck transport is effective for short distances but is not as effective as rail transport for the distances required for the off-site disposal option at NTS and perhaps the 483 km (300 mi) disposal option, depending on the availability of rail spurs. Truck transport would be effective but less reliable than rail transport. Truck transportation would be required for on-property disposal.

- Implementability: Truck transport would be easily implemented at the site.

- Cost: The capital costs associated with this process option would include the construction of access roads. The overall capital costs would be moderate. Operation costs include the fees charged by the trucking company for each trip and the salaries of the employees who load the trucks. Maintenance costs include the maintenance of the access road and the loading terminal. Overall, costs are considered moderate.

Truck transportation has been retained for the development of alternatives for all subunits.

2.6.7.2 On-Property Disposal Technology

On-property disposal is a remedial technology that may be applied for Subunits A, B, and C. A possible component of the on-property disposal technologies includes interim storage. Process options retained for evaluation include:

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- Engineered disposal facility
- Above-grade disposal vault

Engineered Disposal Facility

The engineered disposal facility was evaluated as an on-property disposal option for Subunits A, B, and C. The evaluation of the engineered disposal facility is summarized as follows:

- Effectiveness: A properly designed engineered disposal facility will dispose of the waste effectively by isolating the waste from the groundwater and the surface environment. A compacted concrete intrusion barrier will reduce inadvertent human contact.

- Implementability: This process option consists of covering/capping waste that has been placed on a stable structural pad with an underlying leachate collection system. Once designed, the construction and implementation of the engineered disposal facility should occur without delay. This process option would be moderately difficult to implement.

- Cost: The engineered disposal facility will be constructed of concrete designed for permanent waste disposal as well as an intrusion barrier made of concrete. These concrete layers will contribute to the high cost as will the detailed construction of the vegetative layers, drainage layer, and the clay layers of the cap. Furthermore, the facility will consist of a cap with leachate collection system that will also inflate the cost. The O&M costs are expected to be moderate. The costs are primarily associated with mowing, cap inspection, and groundwater monitoring. Overall, costs are considered high.

The characteristics of the engineered disposal facility are essentially the same as the above-ground disposal vault except that the latter encapsulates the disposed material in a concrete vault. Because of this, coupled with the fact that neither on-property disposal option emerges as clearly superior, the vault was selected as the representative process option; the engineered disposal facility was not retained for any subunits.

Above-Grade Disposal Vault

The above-grade disposal vault was evaluated as an on-property disposal option for Subunits A, B, and C as follows:

- Effectiveness: The vault concept permits disposal of unsorted, highly hazardous/ radioactive (mixed) waste forms. This structure provides effective isolation of waste from both the surface and subsurface environment. All designs are structured to withstand environmental and structural stresses and to provide long-term waste immobilization and environmental protection.

- Implementability: The vault is constructed directly on grade with a liner system and leachate collection system and requires a cap that can be placed over the closed

structure. Once designed, the construction and implementation of the vaults should occur without delay. This facility is considered moderately difficult to implement.

- Cost: This vault structure will consist of a liner system, a leachate collection system, and a structural support slab (depending on particular design). Furthermore, the facility will consist of a cap that will also inflate the cost. This disposal technology requires regularly scheduled monitoring and a facility maintenance program throughout some specified postclosure period. Overall, costs are considered high.

Because neither of the on-property disposal options clearly emerges as superior and the above-grade disposal vault provides additional containment via a concrete vault, the above-grade disposal vault was retained for alternative development for Subunits A, B, and C.

2.6.7.3 Off-Site Disposal Technology

Process options being evaluated for off-site disposal technology include:

- NTS
- Permitted commercial disposal site
- New facility adjacent to the FEMP site
- New facility within 483 km (300 mi) of the FEMP site

Nevada Test Site

NTS was retained for evaluation as an off-site disposal process option for Subunits A, B, and C. This evaluation is summarized as follows:

- Effectiveness: NTS is currently in operation and should be able to accept Operable Unit 4 media. NTS was rated as very effective for storage of stabilized or solid Operable Unit 4 media.

- Implementability: NTS is more than 3219 km (2000 mi) from the FEMP site. This process option would be moderately difficult to implement since treatment may be required to meet waste acceptance criteria. The FEMP site also has an approved NTS waste shipment and certification program that is periodically audited by NTS. Efforts have been initiated to amend the current program to include Operable Unit 4 materials.

- Cost: The capital costs would include the disposal fee, which is rated as moderate. There would be no O&M costs with this process option. Overall, costs are considered moderate.

The NTS process option has been carried forward to alternative development for Subunits A, B, and C.

Permitted Commercial Disposal Site

The permitted commercial disposal site was retained for evaluation as an off-site disposal process option for Subunit C. This evaluation is summarized as follows:

- Effectiveness: The permitted commercial disposal site is currently in operation and should be capable of accepting waste from Subunit C. Wastes from Subunit C exceeding acceptance criteria (i. e., concrete in contact with residues) would be segregated and handled consistent with Subunit A.

- Implementability: Similar to the NTS process option, the representative permitted commercial disposal site is a relatively long distance from the FEMP site. Additionally, a variance from DOE Order 5280.2A restricting DOE radioactive wastes from disposal at a commercial facility would be needed. This option is considered administratively difficult to implement.

- Cost: The disposal costs for this process option are essentially three times higher than those for the NTS. There would be no O&M costs with this process option. Overall, costs are rated high.

The permitted commercial disposal site has been carried forward to alternative development for Subunit C.

New Facility Adjacent to the FEMP Site

A new disposal facility adjacent to the FEMP site was retained for evaluation as an off-site disposal process option for Subunits A, B, and C. This evaluation is summarized as follows:

- Effectiveness: The construction of an off-site disposal facility adjacent to the FEMP site was rated as less effective than NTS or the permitted commercial disposal site process options because the site would either be above or adjacent to the Great Miami Aquifer and near a large population area.

- Implementability: This facility would have to be sited, property purchased, permits obtained, and construction completed before disposal of any Operable Unit 4 media. This process option was rated as more difficult to implement than NTS or the permitted commercial disposal site process options.

- Cost: Capital costs for this process option were rated as high and include: the purchase of property, the design, and the construction of the disposal facility. The O&M costs for this process option would be approximately the same as for on-property disposal options.

This process option will not be carried forward to alternative development for any of the subunits because this process option is essentially identical to the on-property engineered disposal facility, but has a lower rating for implementability and cost.

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New Facility Within 483 Kilometers (300 Miles) of FEMP

The new facility within 483 km (300 mi) of the FEMP site was evaluated as an off-site disposal option for Subunits A, B, and C. This evaluation is summarized below:

- Effectiveness: This process option was considered only slightly better than the adjacent disposal facility because a site could be chosen to ensure that its location is not on top of an aquifer or in an area of high population.

- Implementability: As with the adjacent disposal facility, this facility would have to be sited, property purchased, permits obtained, and construction completed before any disposal of any Operable Unit 4 subunit wastes. This process option was rated less implementable than NTS or the permitted commercial disposal site process options.

- Cost: Capital costs for this process option were rated as high and include: the purchase of property, the design, and the construction of the disposal facility. The O&M costs for this process option would be approximately the same as for on-property disposal process option.

This process option will be carried forward to alternative development for Subunits A, B, and C.

# 3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

## 3.1 INTRODUCTION

This section presents the development and screening of remedial alternatives assembled from combinations of technologies and associated process options evaluated in Section 2.0. Section 3.2 presents the development and description of a range of alternatives based on the GRAs discussed in Section 2.0. Section 3.3 presents the initial screening of alternatives evaluated against the three broad criteria of effectiveness, implementability, and cost. Section 3.4 summarizes the initial screening of alternatives. Figure 3-1 illustrates the elements of the FS process that are addressed in Section 3.0.

The purpose of the FS and the overall remedy selection process is to implement remedial actions that eliminate, reduce, or control risks to human health and the environment (40 CFR 300). The national program goal for the FS process, as defined in the NCP, is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The criteria for identifying potentially applicable technologies to achieve these goals are provided in EPA guidance (EPA 1988b) and in the NCP (EPA 1990). A strong statutory preference for remedies that will result in a permanent and significant decrease in toxicity, mobility, or volume and provide long-term protection is identified in Section 121 of CERCLA, as amended. The primary requirements for the final remedy are that it be both protective of human health and the environment and comply with ARARs; hence, alternative screening focuses on these criteria.

In addition to the above objectives, the NCP defines certain expectations in developing and screening remedial action alternatives.

- The expectation to use treatment to address the principal threats posed by a site, wherever practical.
- The expectation to use engineering controls, such as containment, for waste that poses a relatively low long-term threat and for which treatment is impractical.
- The expectation to use a combination of methods, as appropriate, to achieve protection of human health and the environment. In appropriate site situations, treatment of principal threats will be combined with engineering controls (such as containment) and institutional actions for treatment residuals and untreated waste.
- The expectation to use institutional actions, such as water controls and deed restrictions, to supplement engineering controls for short- and long-term management to prevent or limit exposures to hazardous substances, pollutants, or contaminants.

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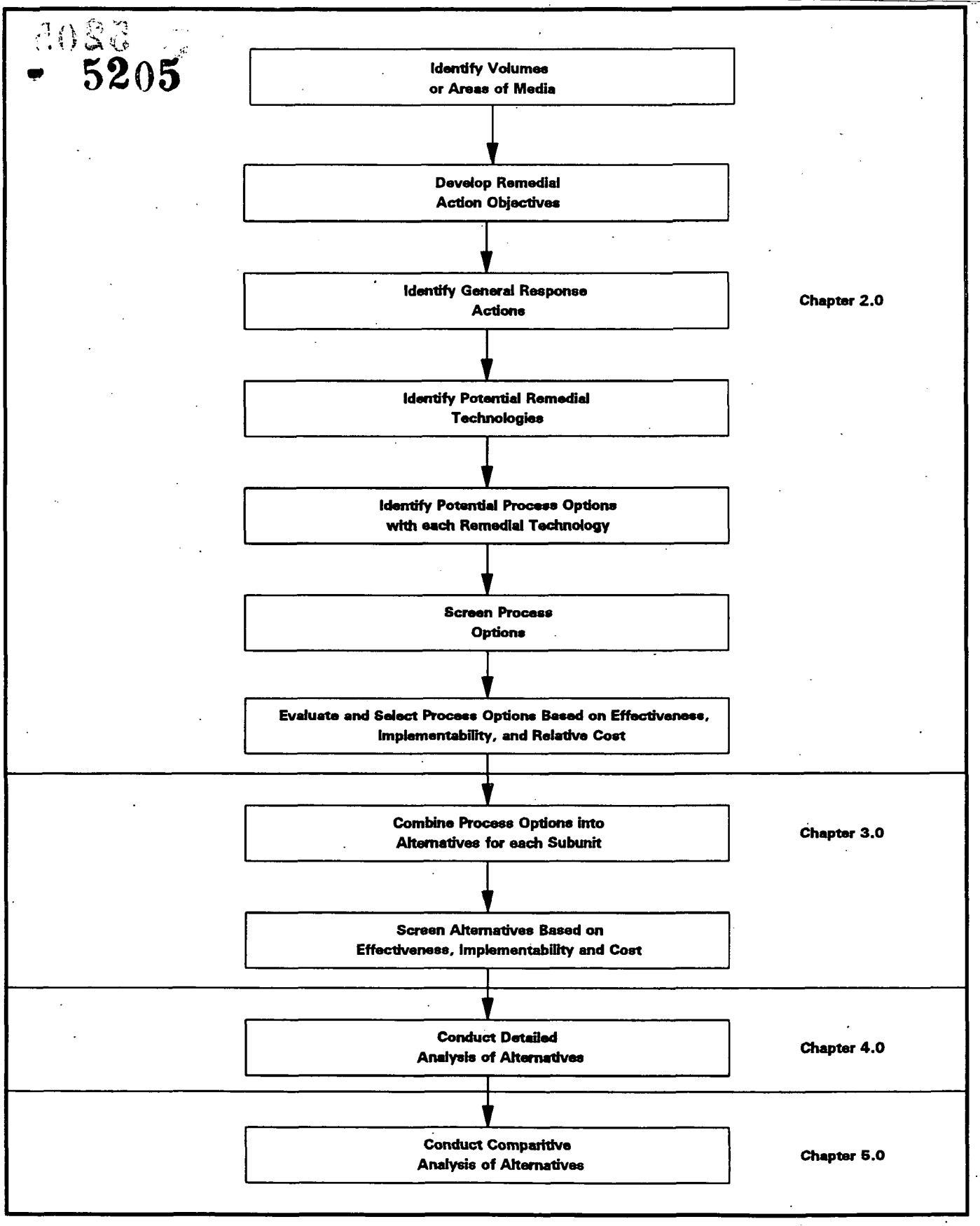


**FIGURE 3-1**
**ELEMENTS OF THE FS PROCESS**

- The expectation to consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.

- The expectation to return environmental media such as groundwater to their beneficial uses, wherever practical, within a time frame that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practical, EPA expects to prevent further migration of the plume, prevent exposures to contaminated groundwater, and evaluate further risk reduction.

These expectations have been applied in the development and screening of alternatives which follow.

Section 2.0 identifies the Operable Unit 4 subunits for which GRAs, and subsequently remedial alternatives, are being developed and assembled. They are repeated here for reference.

- Subunit A: Silos 1 and 2 contents and the sludge in the decant sump tank

- Subunit B: Silo 3 contents

- Subunit C: Silos 1, 2, 3, and 4 structures, the berms, the subsurface soil, the surface soil, the existing RTS, the K-65 Drum Handling Building pad, standing water within Silo 4 (if any), the decant sump tank and the liquid within, the process piping and trenches, and any rubble or debris (i.e., D&D of waste treatment facility) generated consequential to the implementation of remedial actions for all Operable Unit 4 subunits

## 3.2 DEVELOPMENT OF PRELIMINARY ALTERNATIVES

### 3.2.1 Criteria for Developing Preliminary Alternatives

The EPA has established an approach for developing remedial action alternatives that are appropriate to the specific conditions at the FEMP site. In this approach, the scope, characteristics, and complexity of the site are considered in developing a range of alternatives that would be protective of human health and the environment. Protection can be achieved by eliminating, reducing, and/or controlling risks posed by each pathway at a site. The assembled alternatives differ from those proposed in the ISA Report in that several off-site disposal process options have been added, and in situ treatment alternatives were removed.

### 3.2.2 Factors Common to All Subunits

For the Operable Unit 4 subunits, certain common strategies will be applied to address contaminated media and materials or to assemble technologies and process options into alternatives. These common factors are discussed in this section.

#### 3.2.2.1 On-Property Disposal Facility

A series of alternatives for each of the subunits involve the construction of an on-property above-grade disposal vault. For the purposes of developing alternatives for this FS and for performing a NEPA evaluation on the potential impact of the alternatives, a representative location of the disposal vault was tentatively selected in a suitable area of the FEMP property. This location in no way constitutes siting of the on-property disposal facility. Siting of an on-property disposal facility is subject to Operable Unit 5 RI/FS hydrogeological site characterization and detailed evaluations on the ability to demonstrate compliance with federal and state ARAR/TBCs. Again, approval of this FS would not constitute approval of the preliminary location of the representative on-property disposal facility. Compliance with the requirements must still be demonstrated. The final location of any on-property disposal facilities selected for Operable Unit 4 would be dictated by the Operable Unit 5 ROD as part of the site-wide disposal strategy for the FEMP. Subsequent modification to the NEPA impact analysis discussion would be performed at that time.

#### 3.2.2.2 Groundwater Monitoring

Groundwater monitoring will be a part of all remedial alternatives for each subunit that leave material on property, which includes the no-action alternative, in situ alternatives, and removal and on-property disposal alternatives. Groundwater monitoring networks will be designed to 1) be consistent with ARAR/TBC requirements and will continue until site-wide RAOs are attained and 2) satisfy any post closure monitoring or CERCLA five-year review requirements.

### 3.2.3 Summary of Preliminary Alternatives

The process options evaluated and selected in Section 2.0 represent process options for each technology. These process options will be combined into specific remedial action alternatives to fulfill the RAOs. These alternatives represent a full range of potentially viable remedial actions for each subunit. The alternatives for each medium provide for no action; material containment; and material removal, treatment, and disposal. The no-action alternative is presented as a basis for comparison. Sections 3.2.3.1 through 3.2.3.3 summarize the alternatives. Sections 3.2.4 through 3.2.6 provide the descriptions and document the development of the alternatives.

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3.2.3.1 Subunit A

The following nine alternatives were developed for Subunit A, which includes the contents of Silos 1 and 2 and the sludge in the decant sump tank.

- Alternative 0A - No Action
- Alternative 1A - In Situ Containment
- Alternative 2A - Removal, Stabilization, and On-Property Disposal
- Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS
- Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site
- Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal
- Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS
- Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site
- Alternative 6A - Removal and On-Property Disposal

3.2.3.2 Subunit B

The following six alternatives were developed for Subunit B, which includes the contents of Silo 3.

- Alternative 0B - No Action
- Alternative 1B - In Situ Containment
- Alternative 2B - Removal, Stabilization, and On-Property Disposal
- Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS
- Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site
- Alternative 4B - Removal and On-Property Disposal

3.2.3.3 Subunit C

The following six alternatives were developed for Subunit C, which includes the Silos 1, 2, 3, and 4 structures, soils, and debris.

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- Alternative 0C - No Action

- Alternative 1C - Demolition and Containment
- Alternative 2C - Demolition, Removal, and On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS
- Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at the Permitted Commercial Disposal Site
- Alternative 3C.3 - Demolition, Removal, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

These alternatives are further described for each of the subunits in Sections 3.2.4 through 3.2.6. The descriptions include a brief description of the remedial alternative including the technologies, process options, and other features that constitute each alternative as well as preliminary estimates of the following information.

- Size and configuration
- Remediation time frame
- Spatial requirements
- Packaging/transportation requirements
- Waste generated

More detailed estimates are provided in Section 4.0, Detailed Analysis of Alternatives passing the initial screening process.

### 3.2.4 Subunit A Preliminary Alternatives

Figure 3-2 outlines the development of Subunit A preliminary alternatives. A discussion of alternative development follows.

#### 3.2.4.1 Alternative 0A - No Action

Description

The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken, and the material is considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. This alternative does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and does not provide for any active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

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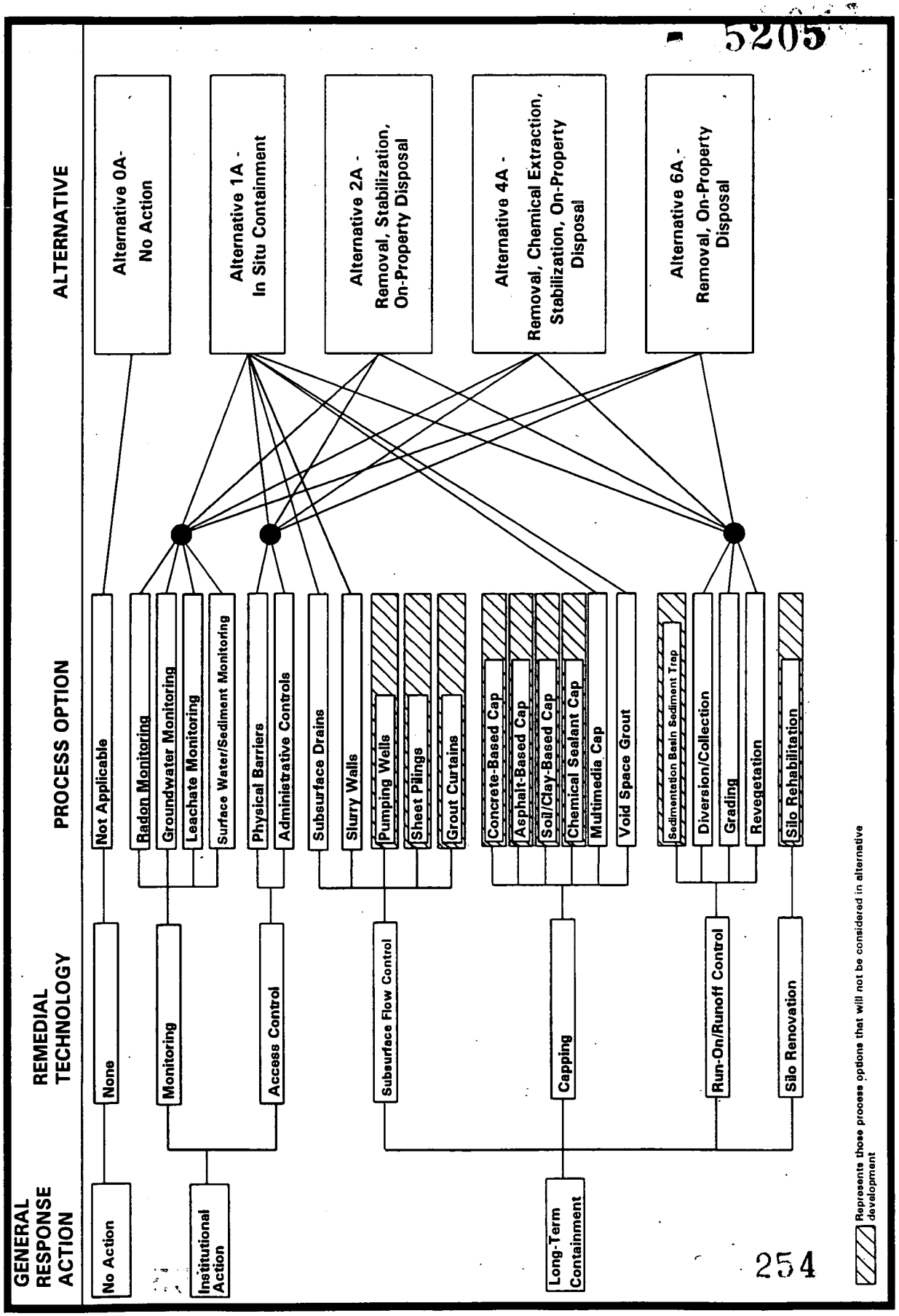


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FIGURE 3-2
SUBUNIT A
DEVELOPMENT OF ALTERNATIVES

FERNALD\OU4\FIG3-2A.DRW/RSS/08/24/93

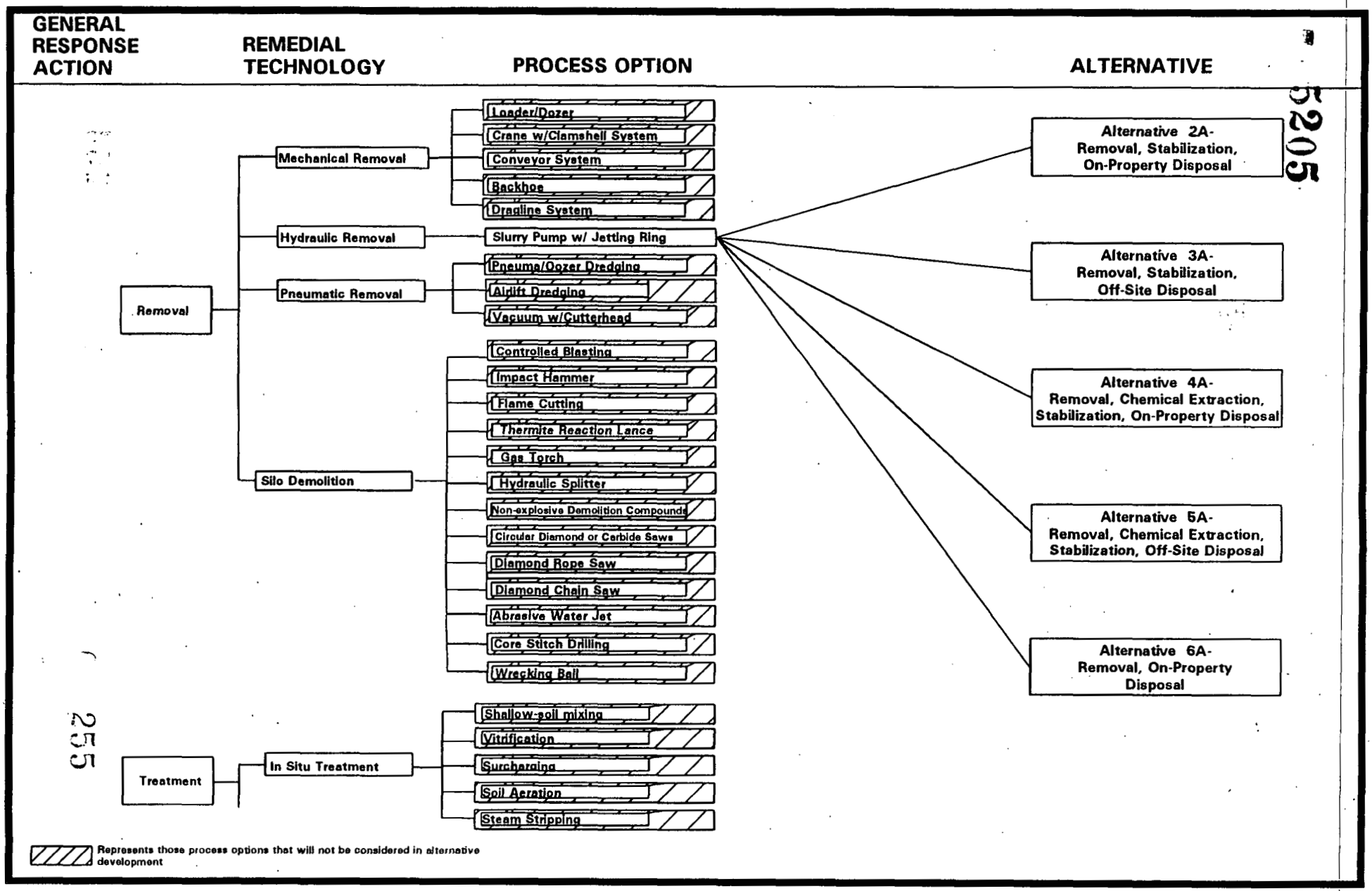


FIGURE 3-2
(Continued)

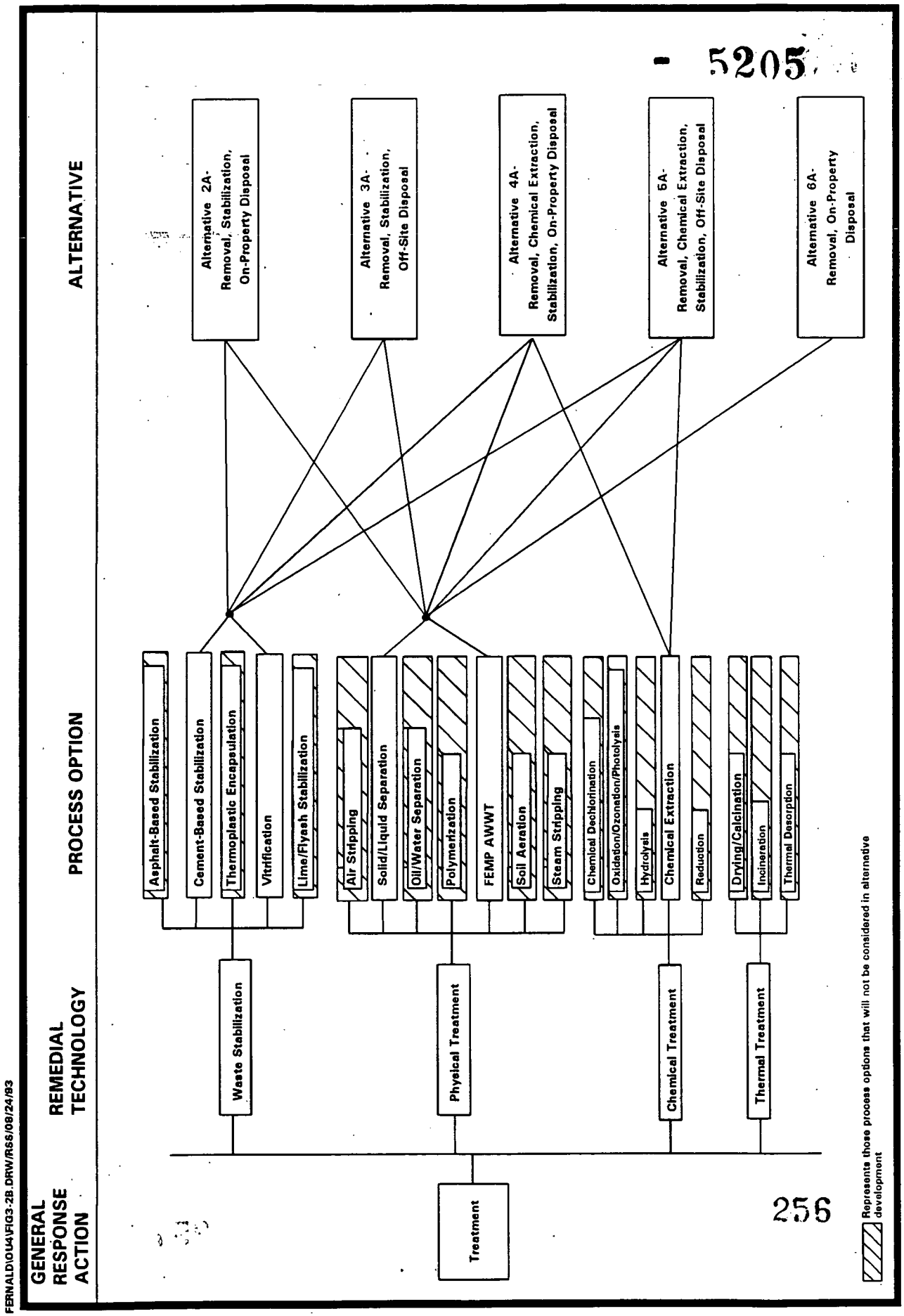


FIGURE 3-2
(Continued)

FERNALD\OU4\FIG3-2B.DRW/RGS/08/24/93

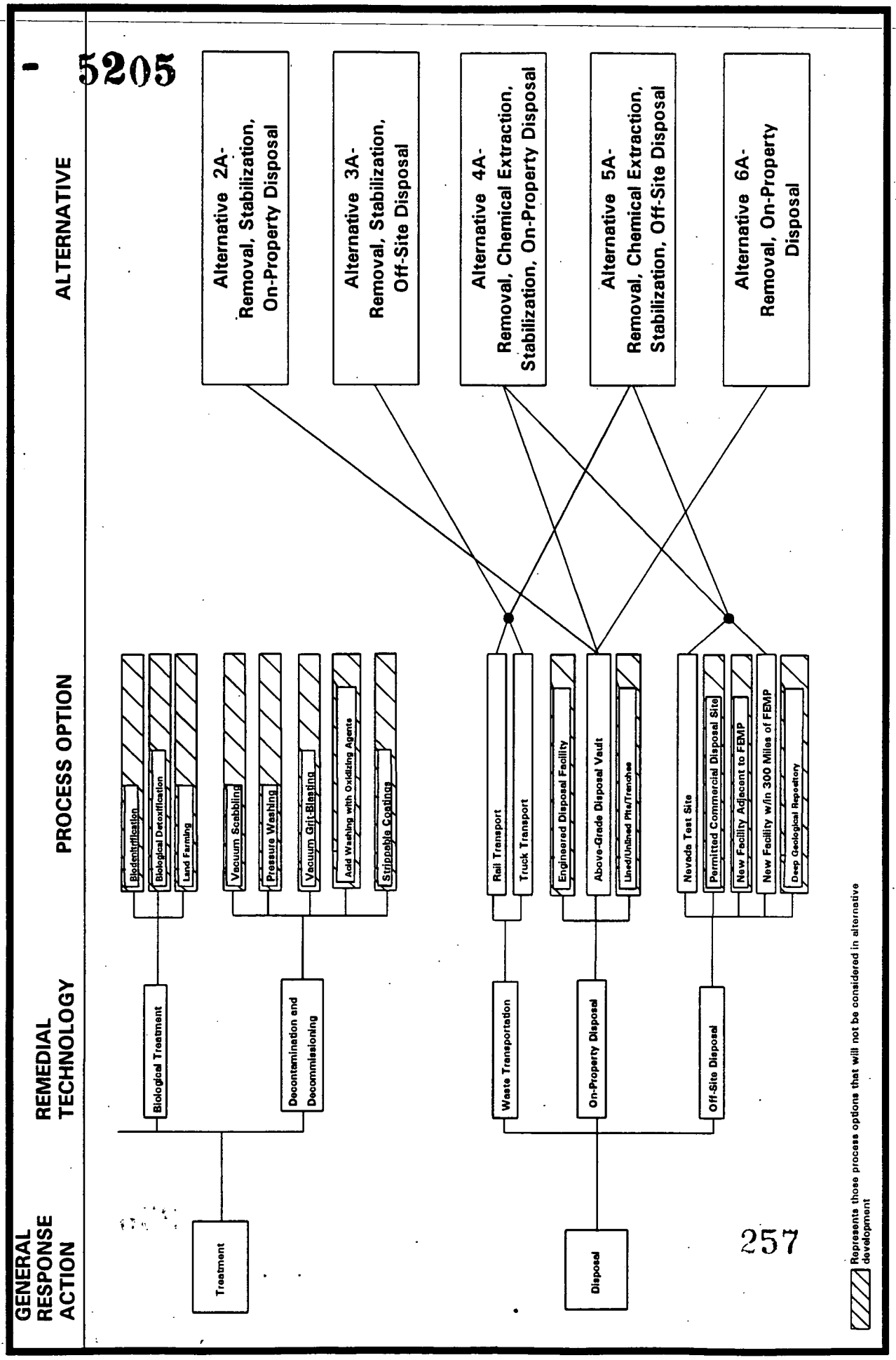


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FIGURE 3-2
(Continued)

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### 3.2.4.2 Alternative 1A - In Situ Containment

Description

This containment alternative for the Subunit A contents is intended to isolate the contents of the silos and the decant sump tank sludge from the environment and to minimize the generation and release of contaminated leachate to the underlying Great Miami Aquifer. The technologies implemented by this alternative are subsurface flow control, capping, run-on/runoff control, monitoring, and access controls. This alternative includes the introduction of structural grout into the silo void spaces, the installation of an LC/DS beneath the silos, construction of a slurry wall around Silos 1 and 2, relocation of Paddys Run, and construction of a multimedia cap over the silos (see Figure 3-3). Figure 3-4 illustrates a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows.

Subsurface Flow Control

- Subsurface drains - A basic LC/DS would be installed underneath the silos before the cap is installed. The system would consist of slotted piping inserted underneath the silos and would be connected to leachate extraction wells.

- Slurry Walls - To divert groundwater flow around the silos and decant sump tank, a soil-bentonite slurry wall will be constructed along three sides of the perimeter of Silos 1 and 2 and will extend into the sand/gravel layer of the Great Miami Aquifer. The bentonite will be obtained commercially and mixed on property with existing acceptable soils to produce a 0.9-m (3-ft) wide slurry wall with an approximate depth of 15.2 m (50 ft). The purpose of the slurry wall is to prevent any leachate that may be generated from migrating laterally to Paddys Run.

Capping

- Void space grout - Structural grout would be introduced into the silos through the manways to fill the silo void space. This process would minimize the possibility that the silo domes will subside under the weight of the multimedia cap during construction and after the cap is installed. The grout would also serve as a radon barrier and an inadvertent intrusion barrier. A containment device (i.e., glove bag) would be used at the grout injection piping/silo dome interface to mitigate release of contamination during grout injection. A temporary batch plant would be used to provide the required structural grout.

- Multimedia cap - A multimedia cap would be installed to minimize the infiltration of rainwater into the silos and decant sump tank. The cap would consist of the following elements to control erosion and minimize generation of leachate as a result of rainwater infiltration.

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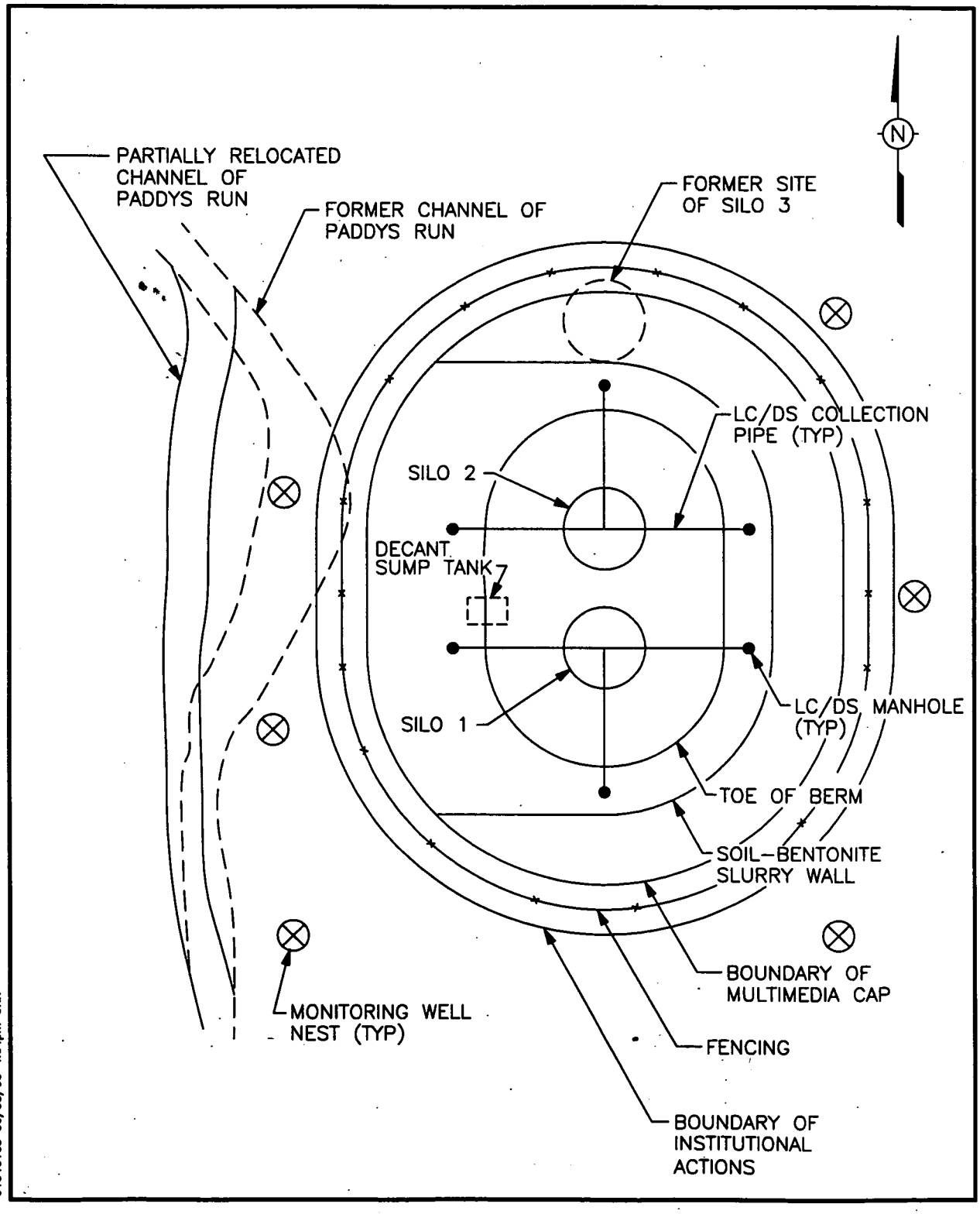


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FIGURE 3-3 PLAN VIEW FOR ALTERNATIVE 1A

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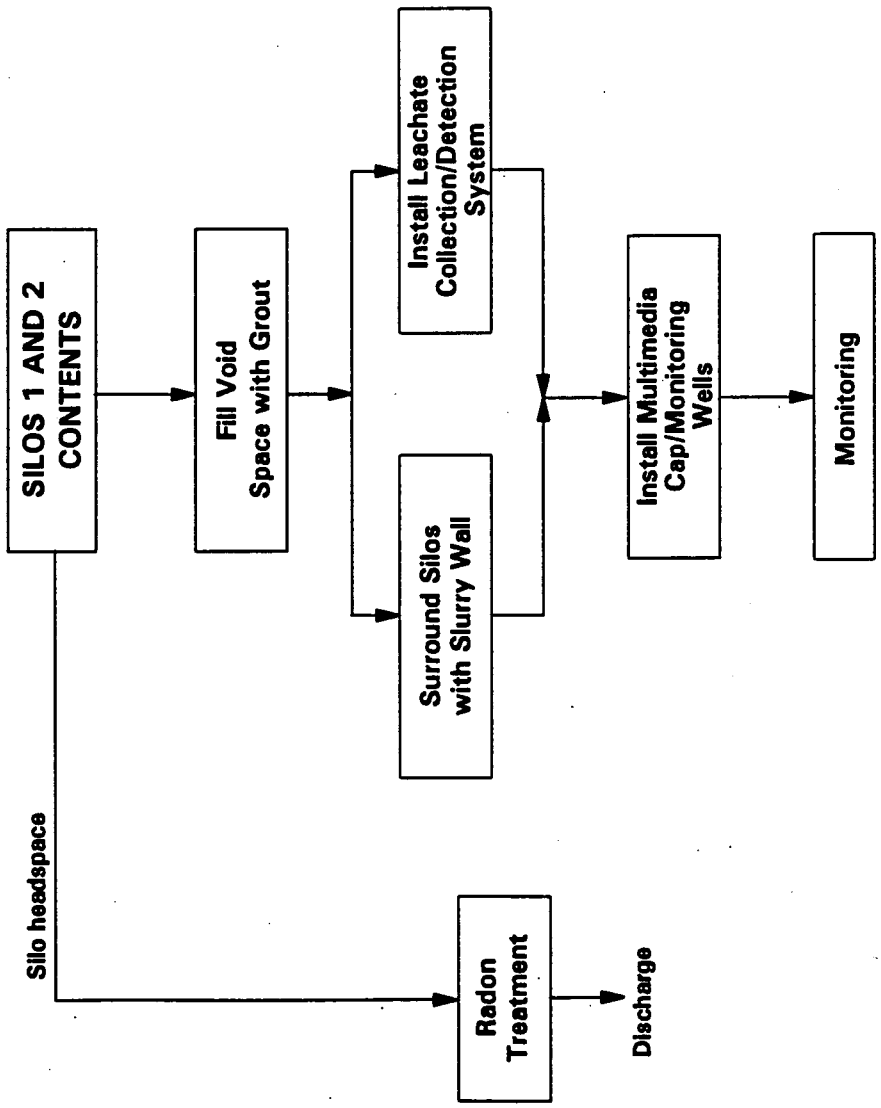


FERNALD\OU4\FIG3-3.DRW/RSS/08/24/93

**FIGURE 3-4**
**ALTERNATIVE 1A - IN SITU CONTAINMENT CONCEPTUAL FLOW DIAGRAM**

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- Upper vegetative layer
- Drainage layer
- Low permeability clay layer with a maximum vertical permeability of $1 \times 10^{-7}$ cm/s
- Geomembrane layer of 40-mil minimum thickness

The spatial requirements for the multimedia cap would require the partial relocation of Paddys Run to minimize the possibility of lateral erosion.

Run-on/Runoff Control

- Diversion/collection - The area around the cap would contain small berms, channels, and waterways to redirect runoff.
- Grading - The area around the cap would be contoured or graded to redirect and control runoff.
- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the cap to detect and warn of radon emanating from the material underneath the cap. Monitoring would continue as required to demonstrate compliance with relevant ARAR/TBCs and in support of CERCLA five-year reviews.
- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the cap and routinely sampled to monitor containment system performance.
- Leachate monitoring - The installed LC/DS would be routinely checked to monitor the cap performance.
- Surface water/sediment monitoring - The surface water and sediment near the cap would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.
- Administrative controls - Access to the site would be confined to authorized personnel through the use of fences, and/or guards, until site-wide RAOs (including Operable Unit 5) are attained. The need or requirement for the application of long-term administrative controls will be examined in the detailed analysis phase (Section 4.0) if this alternative is retained.

The following system is required to support the implementation of the process options.

- RTS - A newly designed RTS consisting of dehumidification media, carbon absorbers, high efficiency particulate air (HEPA) filters, and a blower would be used to treat the radon and other airborne contaminants displaced by the grout injection.

Size and Configuration

The following lists the approximate sizes and numbers of the various components for this alternative. These are preliminary and subject to change based upon additional information acquired for each alternative during detailed analysis.

- Slurry wall - less than 300 m (1000 ft) long by 15 m (50 ft) deep
- Monitoring wells - 6 nests/4 wells per nest
- Grout injection - less than 3100 $m^3$ (4000 $yd^3$)

Remediation Time Frame

Remediation is estimated to take approximately two years from the initial staging of construction equipment to the final capping and isolation of the silos.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 5 ha (12 acres) of which approximately 4 ha (10 acres) would be used by the cap.

Packaging/Transportation Requirements

The only transportation requirement identified is transporting the grout, cap materials, and bentonite closure materials to the site.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, HEPA filters, etc.,)
- Equipment not feasible to decontaminate
- Clean nonhazardous solid waste from debris and equipment

Rubble, equipment, contact waste, and other debris will be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation will be characterized prior final to disposition.

3.2.4.3 Alternative 2A - Removal, Stabilization, and On-Property Disposal

As previously identified in Section 1.0 of this FS, the residues within Subunit A have three significant characteristics contributing to the hazard of the material involved. That is, the residues: 1) contain highly elevated activity concentrations of gamma emitting radionuclides; 2) represent a significant source of radon; and 3) exhibit leachable concentrations of radionuclides and heavy metals. To address these hazards for alternatives considering removal of the residues and on-property disposal, the following considerations were taken into account in the development of alternatives and the identification of ARARs.

1. Potential on-property removal actions must provide reasonable assurance of the long-term protection of inadvertent intruders into the disposed residues.

2. Due to the high concentration and leachability of the radionuclides and other heavy metals, remedial alternatives must provide a reasonable assurance of the long-term protection of the underlying sole-source aquifer.

3. Remedial alternatives must provide a reasonable assurance of the long-term mitigation of the radon emanation from the disposed residues.

These criteria were taken into consideration during evaluation of the alternatives.

Description

This alternative requires removal of the Silos 1 and 2 contents and the sludge in the decant sump tank, stabilization of the material by vitrification or cement stabilization, and on-property disposal of the stabilized material. The sludge in the decant sump tank would also be removed and stabilized along with the contents of the silos. The technologies implemented by this alternative are hydraulic removal, physical treatment, waste stabilization, on-property disposal, run-on/runoff controls, monitoring, and access controls.

The contents of Silos 1 and 2 and the decant sump tank sludge would be removed under this alternative with a hydraulic mining device introduced through the silos' domes. This equipment would be supported by a platform that will span the silos. The material would then be pumped to a material processing facility for cement stabilization or vitrification. The stabilized material would

then be disposed in an above-grade disposal vault with an inadvertent intrusion barrier constructed on property. Figure 3-5 illustrates a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows.

Hydraulic Removal

- Slurry pump with jetting ring - The silos' contents and decant sump tank sludge would be removed with a hydraulic mining device supported by a work platform placed over the silos. The removal device would be introduced into the silos through the four perimeter manways and the off-center manway. The hydraulic mining device would consist of a circumferential jetting ring that would use high pressure water to dislodge and liquify the material and a slurry pump to pump the slurried material from the silos to the material processing facility. The slurry would contain 80 percent water as it is removed from the silos. The majority of the water used would be recycled to the hydraulic removal system. A glove box would be used at the interface of the silo domes and would, in conjunction with the silo domes, function as the silo containment system. In order to maintain the integrity of the silo walls, berm soil will be removed from the outside of the silo at the same rate as material is removed from the inside to maintain an equal level.

Physical Treatment

- Solid/liquid separation - Before stabilizing, the material slurry would be dewatered as necessary using a horizontal belt filter and a water recycle tank and pumps. The water removed would be recycled for use in the hydraulic removal process. The dewatered slurry would be sent to the cement mixing unit or the vitrification unit.

- FEMP AWWT - All contaminated process and decontamination water would be transported to and treated at the FEMP AWWT facility.

Waste Stabilization

- Vitrification or Cement Stabilization - The silos' contents would be stabilized by vitrification or cement stabilization. The vitrification process would add sodium oxide and calcium oxide to produce a monolithic glass product with excellent wear and leach characteristics. The process would use additive storage silos, an additive and material slurry mixer, a glass melter, a fume hood/cap, and an off-gas treatment system. The cement stabilization system would add cement, flyash, and blast furnace slag to the material slurry to provide a monolithic concrete product with very good wear and leach characteristics. The majority of the water used in removing the material would be used in the cement stabilization process. The process would require additive storage silos, screw feeders, and an additive/material slurry mixer.

On-Property Disposal

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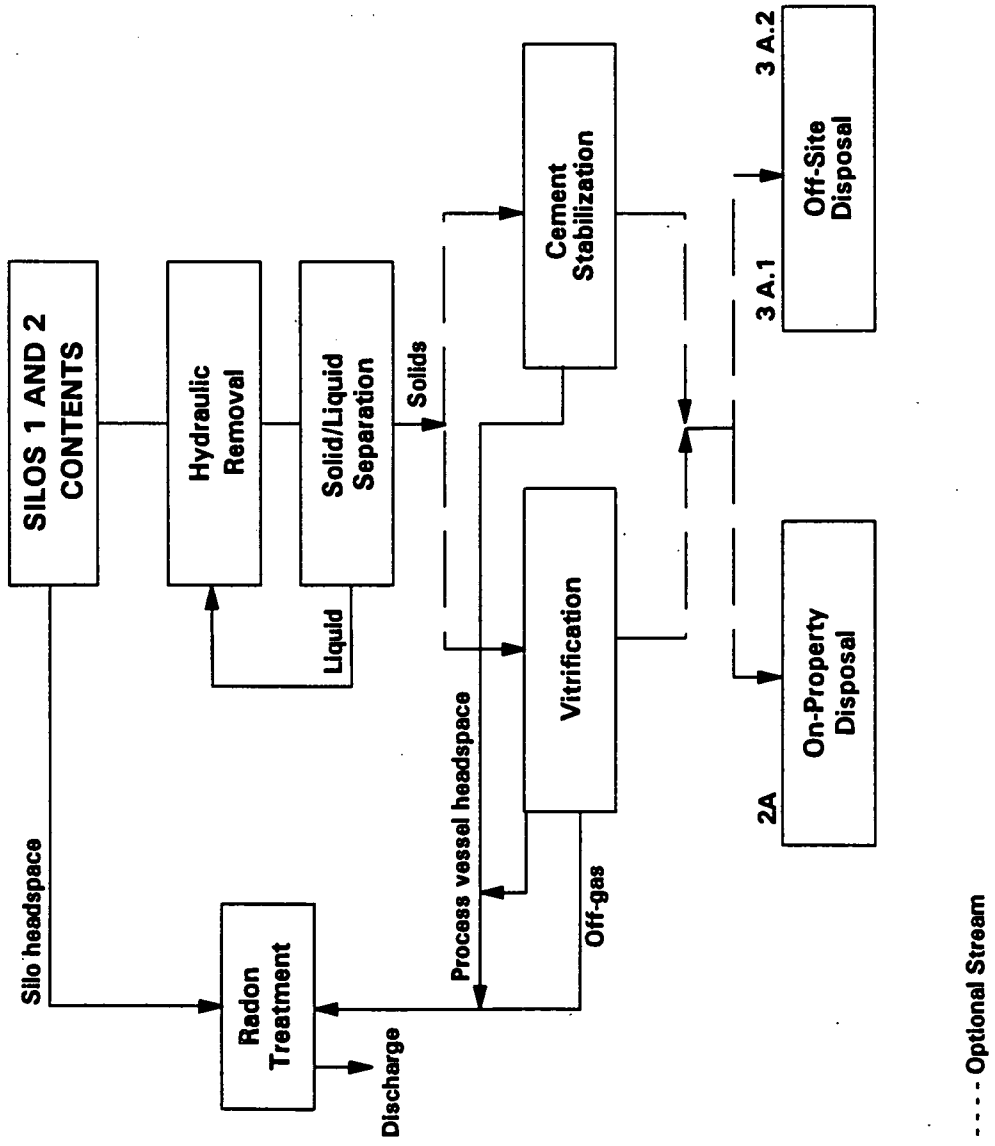


FERNALD\OU4\FIG3-4.DRW/RSS/08/24/93

FIGURE 3 - 5
ALTERNATIVES 2A, 3A - REMOVAL, TREATMENT AND DISPOSAL
CONCEPTUAL FLOW DIAGRAM

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- Above-grade disposal vault - The stabilized material would be disposed in an above-grade disposal vault. This facility would be constructed at grade and would include an LC/DS, a liner system (including both man-made and natural components), a multimedia type cap, and an inadvertent intrusion barrier. To facilitate construction of the disposal vault, engineering controls may be applied to supplement existing geologic conditions at the proposed siting location. These controls may include, but not be limited to, the excavation or grout injection of sand lenses within the till and the installation of a slurry wall to preclude horizontal flow within the till.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.

- Grading - The area around the cap would be contoured or graded to redirect and control runoff.

- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the disposal facility containing the stabilized material to detect radon that emanates from the facility.

- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the disposal facility and sampled routinely to monitor containment system performance.

- Leachate monitoring - The installed LC/DS would be routinely checked to monitor the performance of the facility.

- Surface water/sediment monitoring - The surface water and sediment near the disposal facility would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.

- Administrative controls - The need or requirement to provide administrative controls will be addressed in the detailed analysis phase (Section 4.0) if this alternative is retained.

The following systems are designed to support the implementation of the process options.

- RTS - A newly designed RTS using dehumidifiers, carbon absorbers, and HEPA filters would reduce the radon in the silo dome void space during removal operations. The

system would maintain the silo headspace under negative pressure to minimize the possibility of leakage.

- Material processing facility - A material processing facility would be constructed to house the processing, packaging, and storage of material from sampling/assaying operations. It would incorporate shielding, air treatment systems, and negative ventilation to minimize emissions.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tons per day (tpd)
- Processing rate (stabilized product)
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd
- Volume disposed
  - Cement-stabilized product - approximately 18,000 $m^3$ (24,000 $yd^3$)
  - Vitrified product - approximately 2800 $m^3$ (3,600 $yd^3$)

Estimated treated volumes for disposal are based upon benchscale treatability study data and literature values from similar operations at other sites. The results of more detailed treatability studies will be presented in the Detailed Analysis section.

Remediation Time Frame

Site preparation, construction of the material processing facility, and installation of the material removal and processing equipment would take approximately three years. Removing, processing, and packaging the material would take an additional three years. The total remediation time for this alternative would be approximately six years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 4.5 ha (11 acres) for vitrification and approximately 6 ha (14 acres) for cementation, of which approximately 3 ha (7 acres) for vitrification and approximately 4.5 ha (11 acres) for cementation would be used for the disposal vault. Of the area required for the disposal vault for each alternative, the cap sloping requires a 33m (111 ft) wide area around the perimeter of the vault, and institutional controls implementation requires an additional 30m (100 ft) wide area around the perimeter of the cap.

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Packaging/Transportation Requirements

The on-property disposal facility would accept only stabilized and/or rigidly-containerized material. The cement stabilized or vitrified material would be poured directly into the disposal containers, DOT specification 7A Type A containers, and transported and disposed in the above-grade disposal vault.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)
- Contact waste (anti-contamination clothing, gloves, HEPA filters, carbon adsorption media, etc.,)
- Equipment not feasible to decontaminate
- Process water contained in the process piping at the completion of material processing
- Berm soils staged as removal of silo contents progresses
- Clean, nonhazardous, solid waste from debris and equipment

Equipment, rubble, soil, contact waste, and other debris will be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation will be characterized prior to final disposition.

3.2.4.4 Alternative 3A- Removal, Stabilization, and Off-Site Disposal

A number of programmatic and residue specific considerations were factored into the development of alternatives for residue removal and off-site disposal options. The considerations included:

1. the need to adhere to waste acceptance criteria for the disposal facility including constituent specific leachability requirements.
2. the need to reduce or control radon emanation rates to meet disposal facility acceptance requirements.
3. the need to reduce exposures during loading, transport, and disposal operations consistent with ALARA principles.

In accordance with these considerations, only alternatives which employed residue stabilization were considered for off-site disposal. Waste stabilization, through cement stabilization or vitrification, accommodates these considerations by reducing the leachability of the metal constituents to below disposal facility acceptance thresholds, attenuating radon emanation rates to ensure disposal facility

acceptance, and by reducing the volume (vitrification) or direct radiation (cement stabilization) to minimize exposures associated with the handling, transport, and disposal of the residues.

Description

This alternative requires removal of the Silos 1 and 2 contents and the decant sump tank sludge, stabilization of the contents by vitrification or cement stabilization, and off-site disposal of these stabilized materials. This alternative is identical to Alternative 2A with the exception that the on-property disposal, run-on/runoff control, monitoring, and access control technologies have been replaced by the waste transportation and off-site disposal technologies. Material would be disposed at the NTS or a hypothetical facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be transported to the disposal facility by rail and/or truck. These disposal alternatives are discussed separately as Alternatives 3A.1 and 3A.2, respectively. Figure 3-5 provides a conceptual flow diagram for these two alternatives.

The additional process options for this alternative's technologies are described as follows.

Waste Transportation

- Rail or truck transport - The FEMP site can support rail transport to either disposal facility by using existing on-property rail spurs. A rail spur can be built at the off-site disposal facilities, or, in the case of NTS, a combination of rail and truck transport can be used. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system at the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The stabilized material would be shipped to NTS for disposal. Residues would be treated emphasizing stabilization technologies to the extent necessary to meet NTS waste acceptance criteria. All necessary approval and certifications would be received prior to shipment.

- New facility within 483 km (300 mi) - The stabilized material would be shipped to a facility to be constructed within 483 km (300 mi) of the FEMP site. The stabilized material must meet the new facilities waste acceptance criteria.

These process options would be supported by a newly designed RTS and a material processing facility as described previously under Alternative 2A.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

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- Removal rate - 10 to 15 tpd
- Processing rate (stabilized product)
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd
- Volume transported and disposed
  - Cement-stabilized product - approximately 18,000 $m^3$ (24,000 $yd^3$)
  - Vitrified product - approximately 2800 $m^3$ (3600 $yd^3$)

Remediation Time Frame

Site preparation, construction of the material processing facility, and installation of the material removal and processing equipment would take approximately three years. Removing, processing, and packaging the material would take an additional three years. The total remediation time for this alternative would be approximately six years. The material would be shipped and disposed as it is processed. All shipments are planned to be completed shortly after the material processing is completed.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 1.5 ha (3 acres) for vitrification and cementation.

Packaging/Transportation Requirements

The stabilized product would be poured directly into the disposal containers. The treated material would be transported by truck or rail/truck combination to NTS, or by rail or truck to the disposal facility built within 483 km (300 mi) of the FEMP site. The material would be temporarily placed in the processing facility staging area until proper release tests have been performed.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)
- Contact waste (anti-contamination clothing, gloves, HEPA filters, carbon adsorption media, etc.,)
- Equipment not feasible to decontaminate
- Process water contained in the process piping at the completion of material processing
- Clean, nonhazardous, solid waste from debris and equipment
- Berm soils staged as removal of silo contents progresses

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Rubble, soil, equipment, contact waste, and other debris would be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS

Under Alternative 3A.1, treated material would be disposed off site at NTS, which is a DOE-owned facility that currently accepts low-level radioactive waste from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 3A.2, off-site disposal would occur at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional DOE disposal facility. Material for disposal must meet the waste acceptance criteria for this facility when developed.

### 3.2.4.5 Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal

Description

This alternative requires removal of the Silos 1 and 2 contents and the decant sump tank sludge, chemical extraction of the radioactive and chemical constituents (high-activity component) from the material, stabilization of this extract residue by cement stabilization or vitrification, and on-property disposal of the stabilized high-activity component and the remaining low-activity component. This alternative uses the same technologies as those for Alternative 2A with the exception that the material undergoes a chemical extraction process before stabilization.

The proposed chemical treatment process would use an ethylenediaminetetraacetic acid (EDTA) leaching process to remove the high-activity component from the waste stream. This component would then be cement stabilized or vitrified. The material remaining after the high-activity component is extracted (the low-activity component) would not be treated further, although it may ultimately have to be stabilized. Both streams would then be disposed on property. The high-activity component and low-activity component would be disposed in an above-grade disposal vault

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with an inadvertent intrusion barrier (due to elevated levels of long-lived, alpha-emitting radionuclides). The chemical extraction process is intended to greatly reduce the volume of material containing elevated levels of long-lived, alpha-emitting radionuclides. Figure 3-6 provides a conceptual flow diagram for this alternative.

The additional process options for this alternative's technologies are described as follows.

Chemical Treatment

- Chemical extraction - Chemical extraction would be accomplished with a multi-stage extraction process using an EDTA solution as the extractant. The Silos 1 and 2 contents would be removed from the silos as a slurry of 20 percent solids. The slurry would be pumped to the chemical extraction process where the solids will be separated from the slurry with a belt filter. The solids material would be transferred to a potassium chloride (KCl) soak tank to prepare them for a six-stage extraction with the EDTA solution. The slurry would be pumped from the KCl soak tank to a belt filter. Solids from the belt filter would drop into the stage extraction tank to be extracted with weak extract solution. The slurry would be recirculated from the Stage 1 extraction tank through a steam injector to maintain a temperature of 80°C (176°F). A slip stream of about 37.9 L/min (10 gpm) would be processed in the Stage 1 belt filter, and the solids from this filter would drop into the Stage 2 extraction tank. Five more extractions would be performed in Stages 2 through 6 using the same technique as for Stage 1. EDTA would be conserved by reusing weak extract solutions from the last stages of the extraction process and by recovering EDTA through crystallization.

  Chemical extraction equipment would likely consist of a series of agitated batch tanks, precipitation tanks, and associated piping and hardware. The equipment would be remotely operated in a separate material processing building.

Waste Stabilization

- Cement stabilization - The high-activity component would be stabilized in a cement stabilization process identical to that described for Alternative 2A with the exception that the stabilization additives are cement, flyash, clinoptilolite, and blast furnace slag.

- Vitrification - The high-activity component would be stabilized in a vitrification process identical to that described for Alternative 2A with the exception that the vitrification additives are site flyash and soda ash.

These process options would be supported by a newly designed RTS and a material processing facility as described previously under Alternative 2A.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tpd

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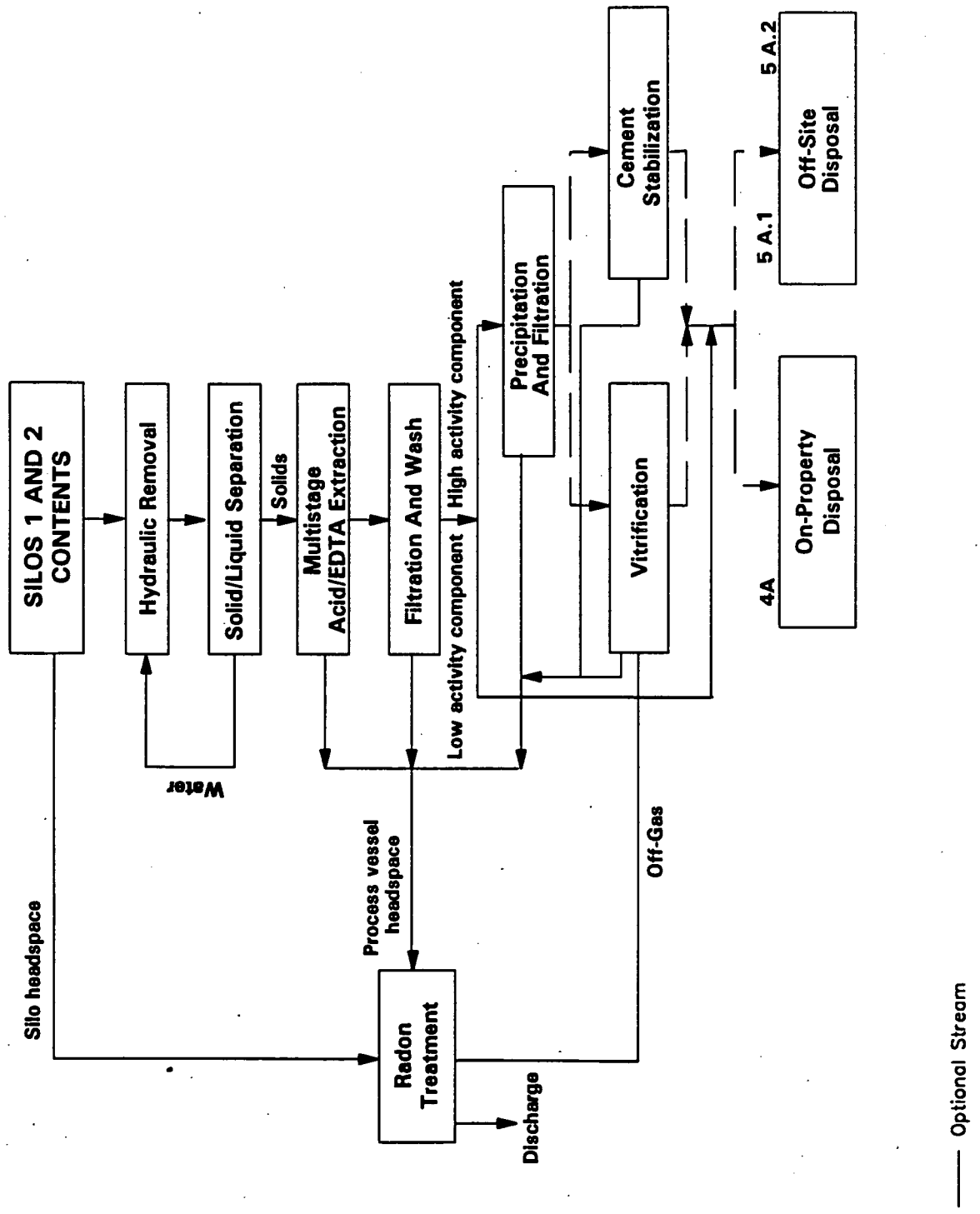


FERNALD\OU4\FIG3-5.DRW/RSS/8/24/93

FIGURE 3 - 6
ALTERNATIVES 4A, 5A - REMOVAL, CHEMICAL EXTRACTION, STABILIZATION AND DISPOSAL
CONCEPTUAL FLOW DIAGRAM

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- Processing rate (treated product)
  - Vitrification (high-activity component) - up to 5 tpd
  - Cement stabilization (high-activity component) - up to 40 tpd
  - Low-activity component - up to 25 tpd

- Volume disposed
  - Vitrified product - approximately 340 $m^3$ (440 $yd^3$)
  - Cement-stabilized product - approximately 7600 $m^3$ (10,000 $yd^3$)
  - Low-activity component - approximately 7400 $m^3$ (9700 $yd^3$)

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately three years. Removal of the material, chemical extraction, stabilization, packaging, and disposal would take an additional three years. The total remediation time for this alternative would be approximately six years. During site preparation, facility construction, and equipment installation, the on-property disposal facility would be built.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is 5 ha (12 acres) for vitrification and 5.5 ha (13 acres) for cementation, of which the disposal vault would utilize approximately 3 ha (8 acres) for vitrification and 4 ha (10 acres) for cementation.

Packaging/Transportation Requirements

The on-property disposal facilities would accept only stabilized and/or rigidly containerized material. The stabilized material would be poured directly into DOT specification 7A Type A or strong tight containers.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)
- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.,)
- Equipment not feasible to decontaminate
- Secondary wastewater streams from the chemical extraction process
- Clean, nonhazardous, solid waste from debris and equipment
- Berm soils staged as removal of silo contents progresses

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Rubble, soil, equipment, contact waste, and other debris would be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

3.2.4.6 Alternative 5A - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal

Description

This alternative requires removal of the Silos 1 and 2 contents and the decant sump tank sludge, chemical extraction of significant quantities of radioactive and chemical constituents (high-activity component) from the material, stabilization of this extract residue by cement stabilization or vitrification, and off-site disposal of the stabilized high-activity component and the remaining low-activity component. This alternative is identical to Alternative 4A with the exception that the on-property disposal, run-on/runoff control, monitoring, and access control technologies have been replaced by the material transportation and off-site disposal technologies. Material would be disposed at NTS or a facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be transported to the disposal facility by rail and/or truck. These disposal alternatives are discussed separately as Alternatives 5A.1 and 5A.2, respectively.

The additional process options for this alternative's technologies are described as follows.

Waste Transportation

- Rail or truck transport - The FEMP site can support rail transport to either disposal facility by using existing on-property rail spurs. A rail spur can be built at the off-site disposal facility, or, in the case of NTS, a combination of rail and truck transport can be used around the facility. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system at the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The stabilized material would be shipped to NTS for disposal. Residues would be treated to the extent necessary to meet the NTS waste acceptance criteria. All necessary approvals and certifications would be received prior to shipping.

- New facility within 483 km (300 mi) - The stabilized material would be shipped to an above-grade disposal vault facility to be constructed within 483 km (300 mi) of the FEMP site. The stabilized material and debris must meet the new facility's waste acceptance criteria when developed.

These process options would be supported by a newly designed RTS and a material processing facility as described previously under Alternative 2A.

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- Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tpd

- Processing rate (treated product)
  - Vitrification (high-activity component) - up to 5 tpd
  - Cement stabilization (high-activity component) - up to 40 tpd
  - Low-activity component - up to 25 tpd

- Volume transported and disposed
  - Vitrified product - approximately 340 $m^3$ (440 $yd^3$)
  - Cement-stabilized product - approximately 7600 $m^3$ (10,000 $yd^3$)
  - Low-activity component - approximately 7400 $m^3$ (9700 $yd^3$)

Remediation Time Frame

Site preparation, construction of the material processing facility, and installation of the material removal and processing equipment would take approximately three years. Removing, processing, packaging, transportation, and disposal of the material would take an additional three years. The total remediation time for this alternative would be approximately six years.

Spatial Requirements

Overall area at the FEMP required for implementation of this alternative is approximately 1.5 ha (3 acres) for both vitrification and cementation.

Packaging/Transportation Requirements

The packaging option selected for the high-activity component and low-activity component is DOT specification 7A Type A or strong tight container.

The material would be shipped by truck or rail/truck combination to NTS, or by rail or truck to the disposal facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be temporarily placed in the processing facility staging area until proper release tests have been performed.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)

- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.,)

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- Equipment not feasible to decontaminate
- Secondary wastewater streams from the chemical extraction process
- Clean, nonhazardous, solid waste from debris and equipment
- Berm soils staged as removal of silo contents progresses

Rubble, soil, equipment, contact waste, and other debris would be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS

Under Alternative 5A.1, material would be disposed off site at NTS, which is a DOE-owned facility that currently accepts low-level radioactive waste from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 5A.2, material would be disposed of off site at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional DOE disposal facility to be developed later. Disposed material must meet the waste acceptance criteria for this facility when developed.

3.2.4.7 Alternative 6A - Removal and On-Property Disposal Description

This alternative requires removal of the Silos 1 and 2 contents and the sludge in the decant sump tank, and on-property disposal of the untreated material. This alternative is identical to Alternative 2A, with the exception that it does not include stabilization. The technologies implemented by this alternative are hydraulic removal, solid/liquid separation, on-property disposal, run-on/runoff controls, monitoring, and access controls.

The silos contents would be removed with a hydraulic mining device introduced through the silos' domes. This equipment would be supported by a work platform that would span the silos. The material would then be pumped to a materials processing facility for dewatering and packaging. The water removed would be recycled for use in the hydraulic removal process. The packaged material

would then be disposed in an above-grade disposal vault with an inadvertent intrusion barrier constructed on property. Figure 3-7 provides a conceptual flow diagram for this alternative.

Size and Configuration

The following are estimates based upon data available during the initial screening process.

- Removal rate - 10 to 15 tpd
- Volume disposed - 6790 $m^3$ (8890 $yd^3$)

Remediation Time Frame

Site preparation and the installation of the material removal equipment would take approximately one year. Removing and packaging the material would take two additional years. The total remediation time for this alternative would be approximately three years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 4.5 ha (11.1 acres). Of this, the area of the disposal vault would be approximately 3 ha (7.5 acres). Of the area required for the disposal vault for each alternative, the cap sloping requires a 33 m (111 ft) wide area around the perimeter of the vault, and institutional controls implementation requires an additional 30 m (100 ft) wide area around the perimeter of the cap.

Packaging/Transportation Requirements

The on-property disposal facility would accept only rigidly containerized material. The material would be placed directly into DOT specification 7A Type A or strong tight containers.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, dehumidification media, etc.,)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris
- Wastewater from hydraulic removal (recycled where possible)
- Berm soils staged as removal progresses

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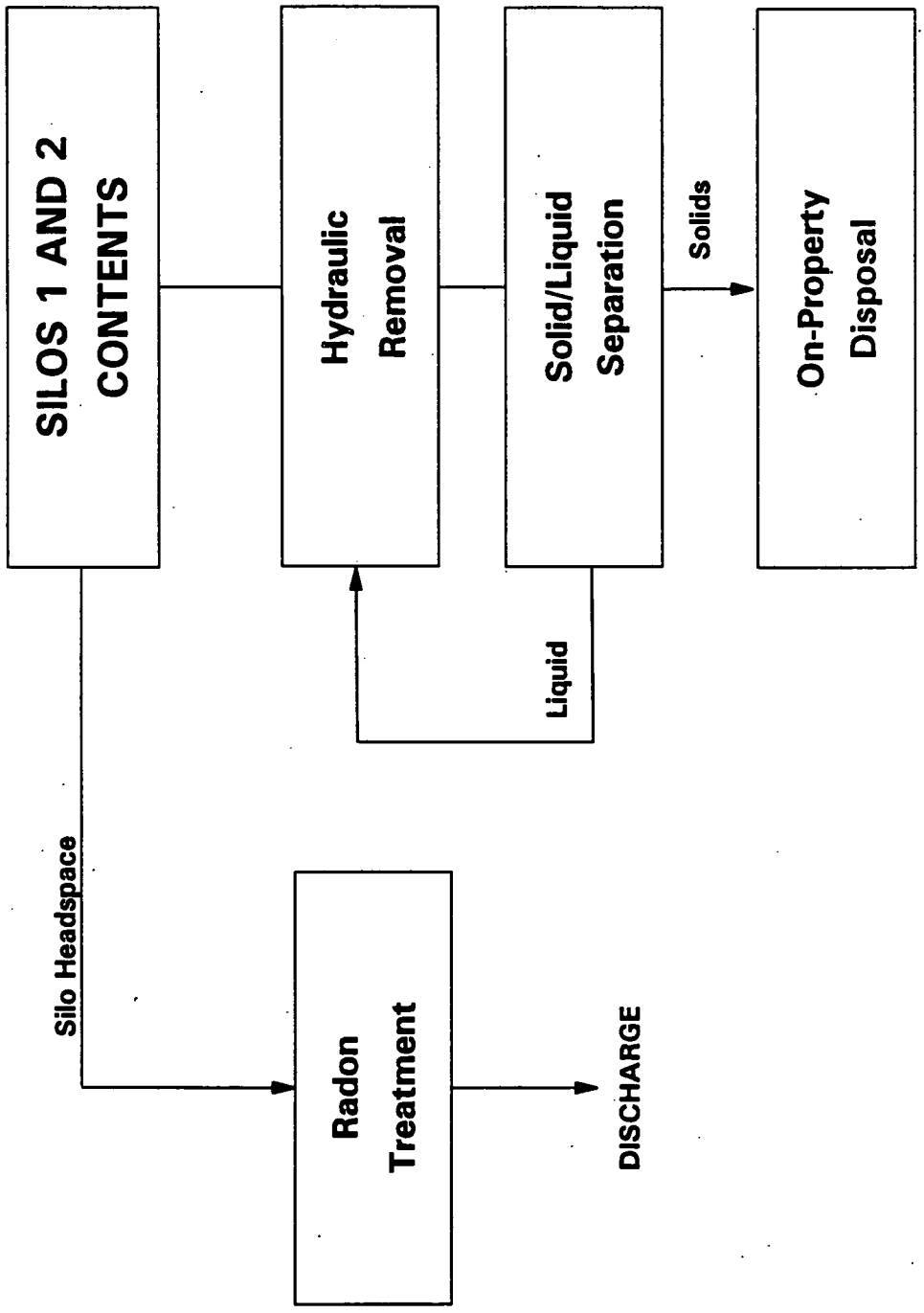


FIGURE 3 - 7
ALTERNATIVE 6A - REMOVAL, DISPOSAL
CONCEPTUAL FLOW DIAGRAM

FERNALD\OU4\FIG3-4.DRW/RSS/08/24/93

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Contaminated rubble, equipment, contact waste, and other debris would be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

### 3.2.5 Subunit B Preliminary Alternatives

Figure 3-8 outlines the development of Subunit B preliminary alternatives. Narrative discussion of the alternative development follows.

#### 3.2.5.1 Alternative 0B - No Action

Description

The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action would be taken and the material is considered to be left "as is," without the implementation of any containment, removal, treatment, or other mitigating actions. This alternative does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and does not provide for active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

#### 3.2.5.2 Alternative 1B - In Situ Containment

Description

This containment alternative for the Silo 3 contents is intended to isolate the silo contents from the environment and to minimize the generation and release of contaminated leachate to the underlying Great Miami Aquifer. The technologies implemented by this alternative are subsurface flow control, capping, run-on/runoff control, monitoring, and access control. This alternative includes introducing structural grout into the silo void spaces, installing an LC/DS beneath the silos, building a slurry wall around the silos, relocating Paddys Run, and constructing a multimedia cap over the silos (see Figure 3-9). Figure 3-10 provides a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows:

Subsurface Flow Control

- Subsurface drains - A basic LC/DS would be installed underneath the silo before the cap is installed. The system would consist of slotted piping inserted underneath the silo and connected to leachate extraction wells.

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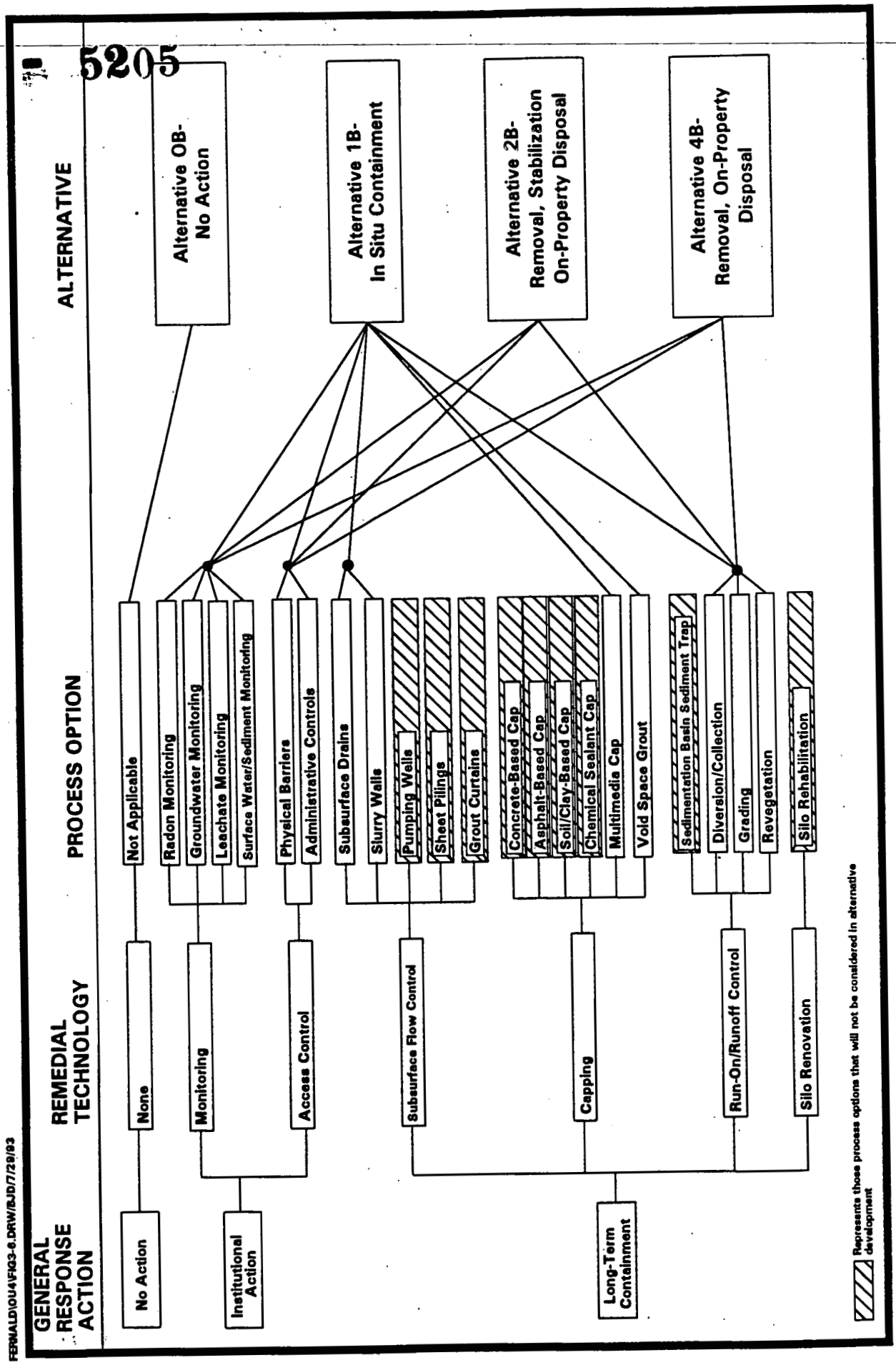


FIGURE 3-8
SUBUNIT B
DEVELOPMENT OF ALTERNATIVES

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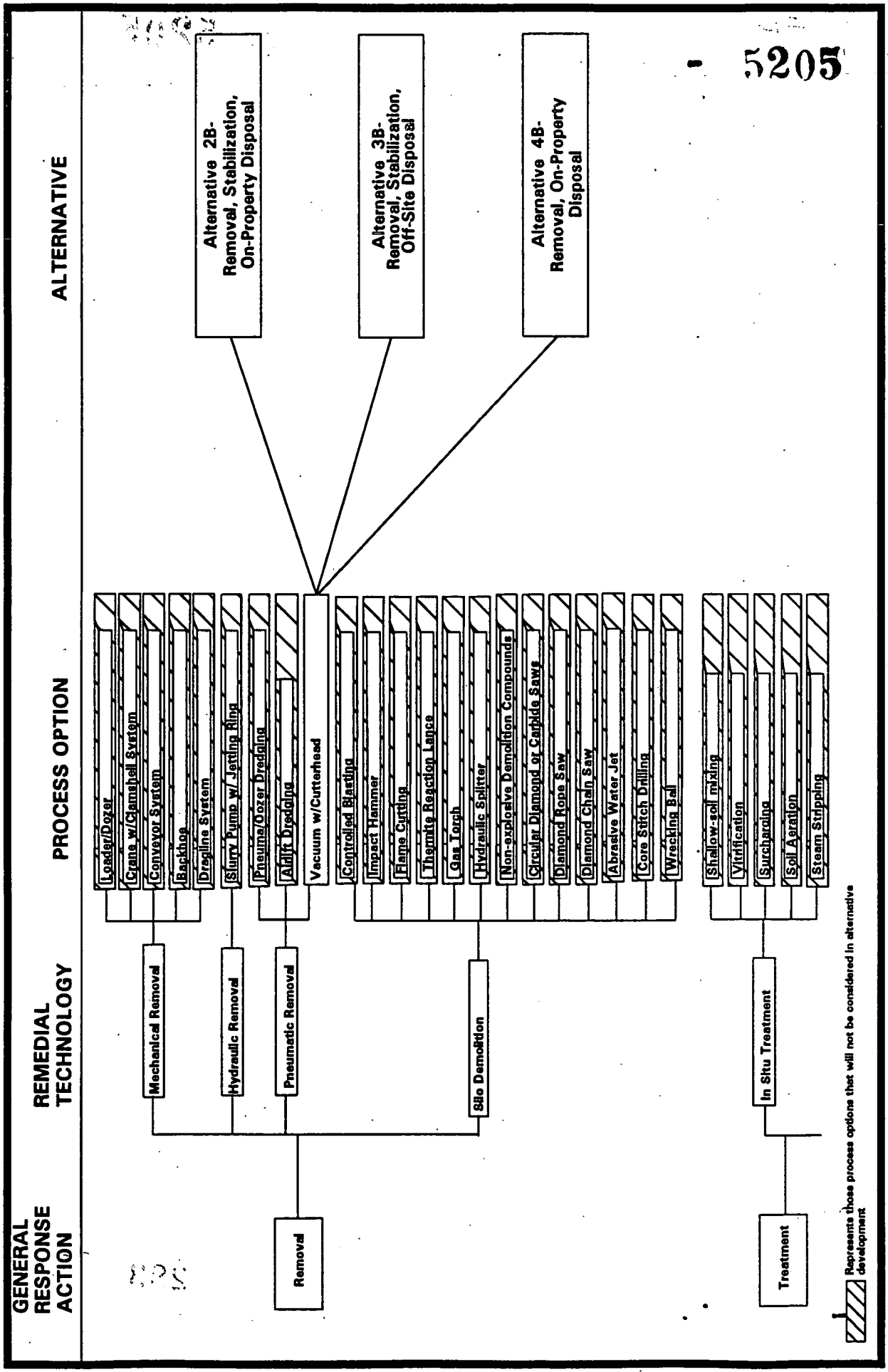


FIGURE 3-8
(Continued)

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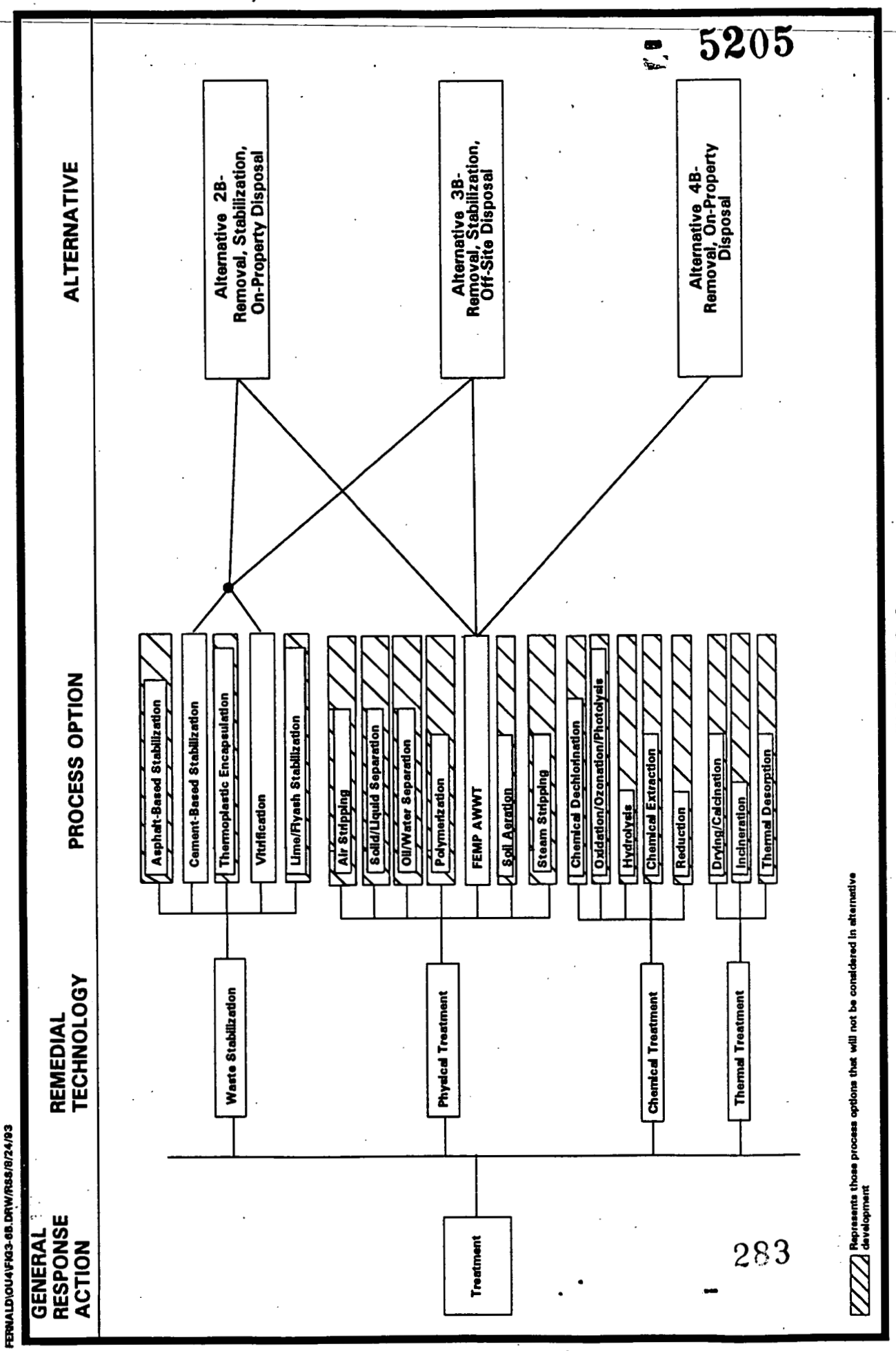


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FIGURE 3-8
(Continued)

FERNALD\OU4\FIG3-8C.DRW/RSS/8/24/93

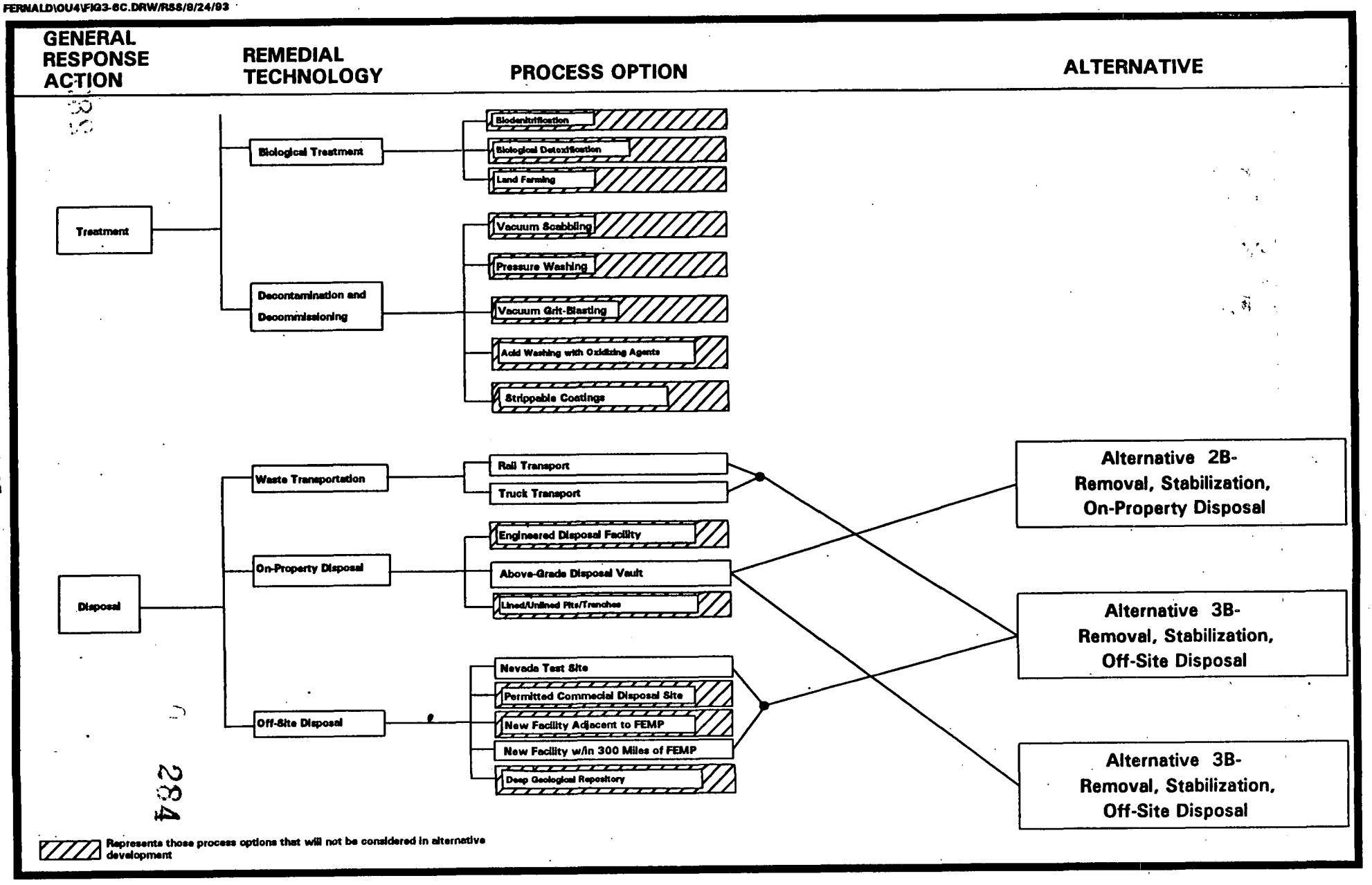


**FIGURE 3-8**
**(Continued)**



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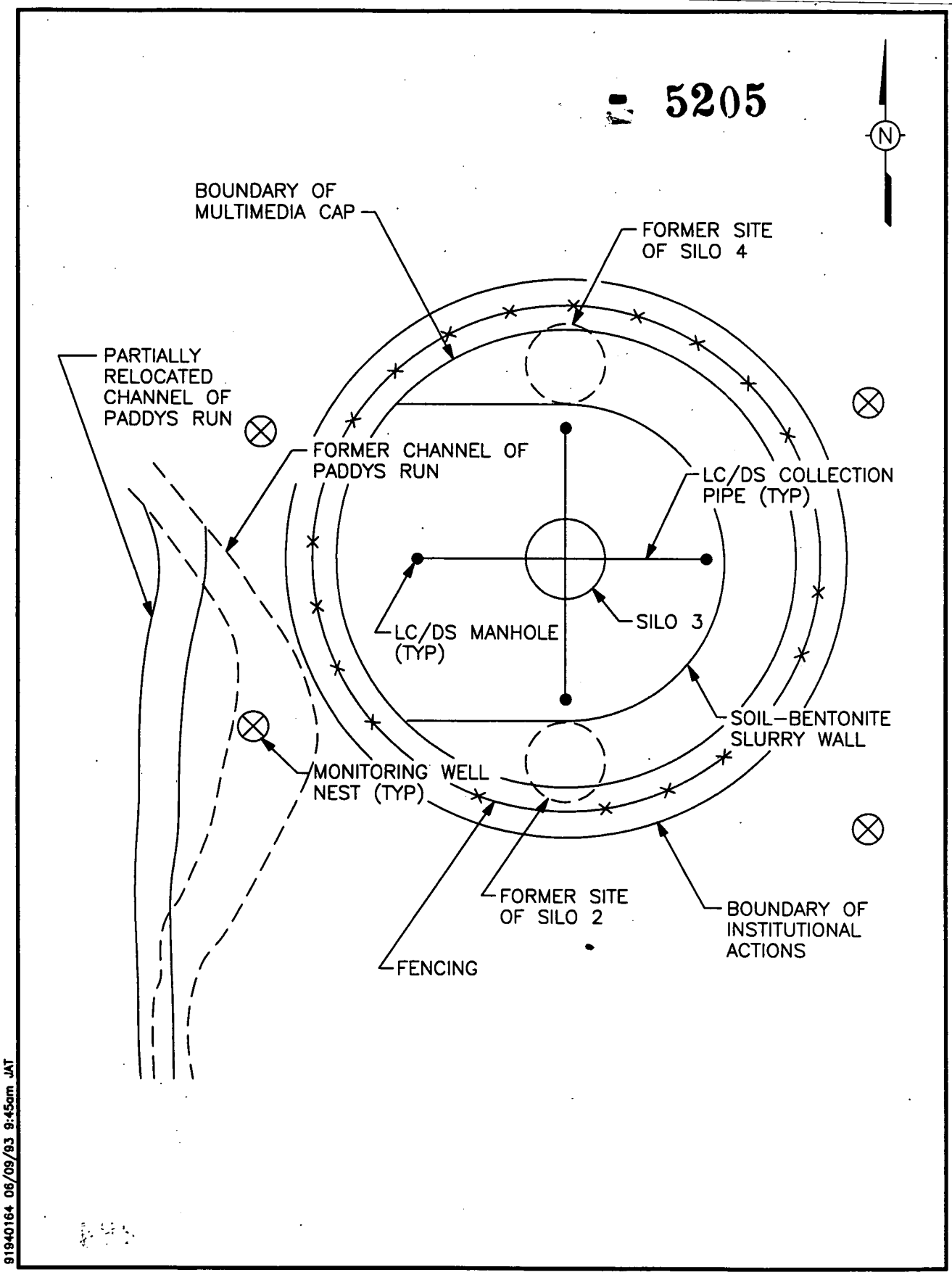


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FIGURE 3–9 PLAN VIEW FOR ALTERNATIVE 1B

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FERNALD\OU4\FIG3-6.DRW/RSS/08/24/93

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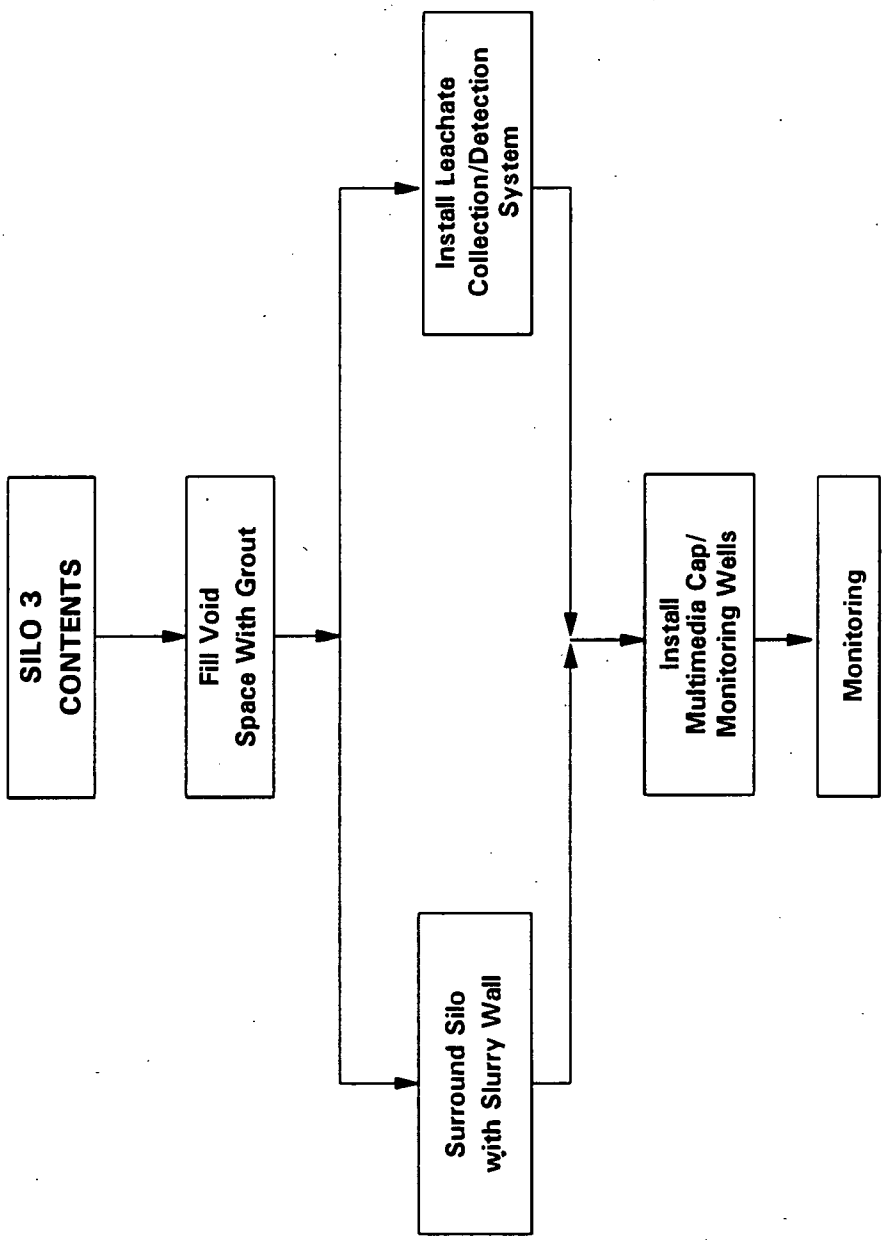


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FIGURE 3 - 10
ALTERNATIVE 1B - IN SITU CONTAINMENT
CONCEPTUAL FLOW DIAGRAM

- Slurry Walls - To divert groundwater flow around the silo, a soil-bentonite slurry wall will be constructed along three sides of the perimeter of Silo 3 and will extend into the sand/gravel layer of the Great Miami Aquifer. The bentonite will be obtained commercially and mixed on property with existing acceptable soils to produce a 0.9-m (3-ft) wide slurry wall with an approximate depth of 15.2 m (50 ft). The purpose of the slurry wall is to prevent any leachate that may be generated from migrating laterally to Paddys Run.

Capping

- Void space grout - Structural grout would be introduced into the silo through the manways to fill the silo void space. This grout would minimize the possibility for the silo dome to subside under the weight of the multimedia cap during construction and after the cap is installed. A local containment device (i.e., glove bag) would be used at the grout injection piping/silo dome interface to mitigate contaminant release during grout injection. A temporary batch plant would be used to provide the required structural grout.

- Multimedia cap - A multimedia cap would be installed to minimize the infiltration of rainwater into the silo. The cap would consist of the following elements to control erosion and minimize leachate generation as a result of rainwater infiltration.

  - Upper vegetative layer

  - Drainage layer

  - Low permeability clay layer with a maximum vertical permeability of $1 \times 10^{-7}$ cm/s

  - Geomembrane layer of 40 mil minimum thickness

  The spatial requirements for the multimedia cap would require the partial relocation of Paddys Run to minimize the possibility of lateral erosion.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.

- Grading - The area around the cap would be contoured or graded to redirect and control runoff.

- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the disposal facility containing the material to detect radon that emanates from the facility.

- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the cap and sampled routinely to monitor containment system performance.

- Leachate monitoring - The installed LC/DS would be routinely checked to monitor the cap performance.

- Surface water/sediment monitoring - The surface water and sediment near the cap would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.

- Administrative controls - Access to the site would be confined to authorized personnel. Permanent physical markers would also be used to identify disposal areas. The need or requirement for the application of long-term administrative controls will be examined in the detailed analysis phase (Section 4.0) if this alternative is retained.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process.

- Slurry wall - less than 300 m (1000 ft) long x 15 m (50 ft) deep

- Monitoring wells - 6 nests/4 wells per nest

- Grout injection - less than 750 $m^3$ (1,000 $yd^3$)

Remediation Time Frame

Remediation would take approximately two years from the initial staging of construction equipment to the final capping and isolation of the silo.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 3 ha (7.5 acres), of which 2 ha (5 acres) would be used by the cap.

Packaging/Transportation Requirements

The only identified transportation requirement is shipping the grout, bentonite, and bentonite closure materials to the site.

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Waste Generated

- Contact waste (anti-contamination clothing, gloves, HEPA filters, etc.,)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris

Rubble, equipment, contact waste, and other debris would be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

3.2.5.3 Alternative 2B - Removal, Stabilization, and On-Property Disposal

Description

This alternative requires removal of the Silo 3 contents, stabilization of the contents by vitrification or cement stabilization, and on-property disposal of the stabilized material. The technologies implemented by this alternative are pneumatic removal, waste stabilization, on-property disposal, physical treatment, run-on/runoff controls, monitoring, and access controls.

The silo contents would be removed with a pneumatic device introduced through the silo dome. This equipment would be supported by a work platform that would span the silo. The material would then be pneumatically conveyed to a material processing facility for cement stabilization or vitrification. The stabilized material would then be disposed in an above-grade disposal vault. Figure 3-11 provides a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows:

Pneumatic Removal

- Vacuum with cutterhead - The silo contents would be removed with a vacuum and cutterhead device. The device would be supported by a work platform placed over the silo and would be introduced into the silos through the four perimeter manways and the off-center manway. The device consists of a cutterhead that would dislodge the material and a vacuum nozzle that would pneumatically remove the material.

  A glove bag would be used at the interface of the silo domes and would, in conjunction with the silo domes, function as the silo containment system.

FERNALD\OU4\FIG3-8.DRW/RSS/08/24/93

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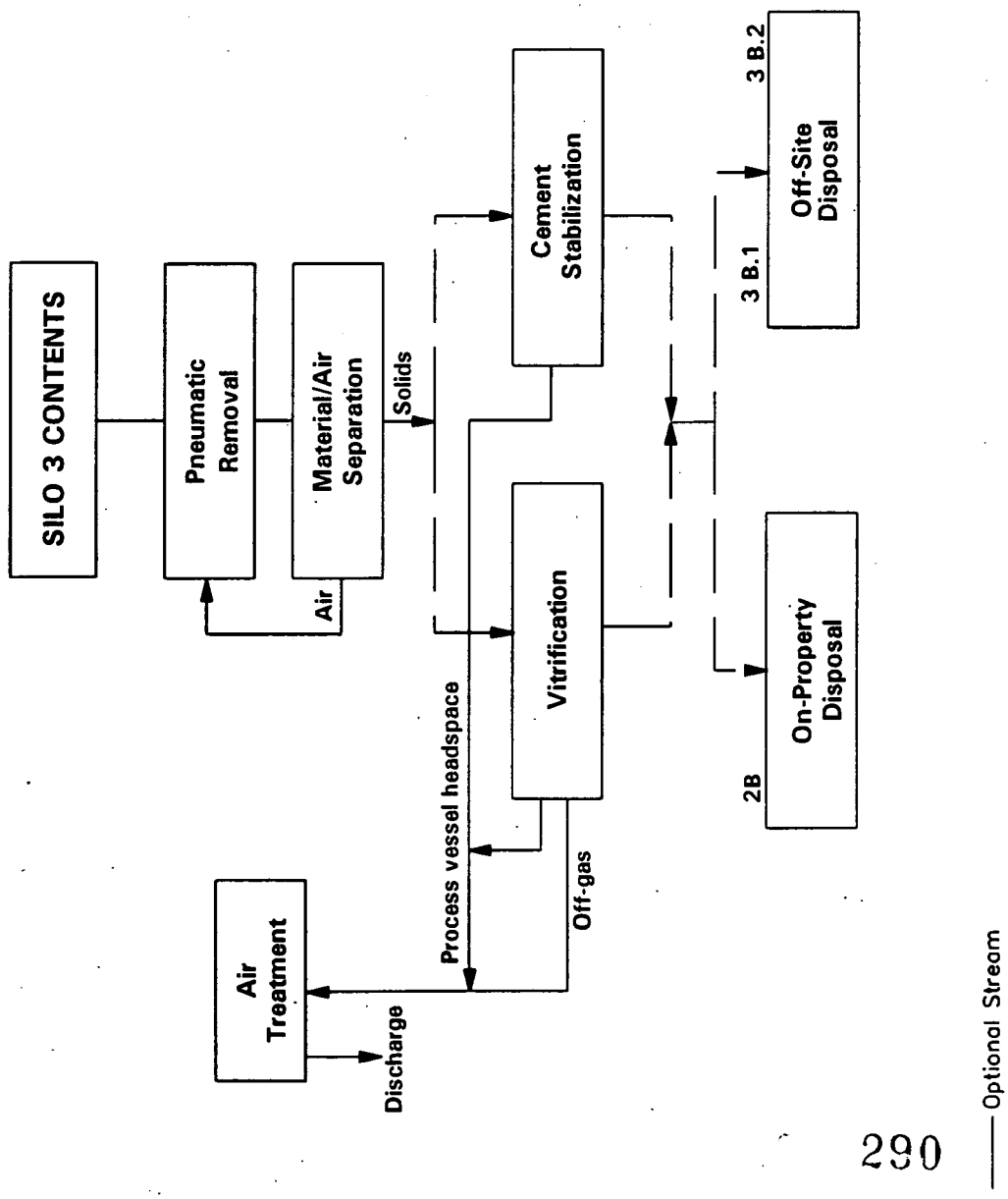


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FIGURE 3 - 11
ALTERNATIVES 2B, 3B - REMOVAL, TREATMENT, DISPOSAL
CONCEPTUAL FLOW DIAGRAM

Waste Stabilization

- Vitrification or Cement-Based Stabilization - The silo contents would be stabilized by vitrification or cement stabilization. The vitrification process would add silica, alumina, and borate to produce a monolithic glass product with excellent wear and leach characteristics. The process would use additive storage silos, an additive and material slurry mixer, a glass melter, a fume hood/cap, and an off-gas treatment system. The cement stabilization system would add cement, flyash, and blast furnace slag to the material slurry to provide a concrete product with very good wear and leach characteristics. The process would require additive storage silos, screw feeders, and an additive/material slurry mixer.

On-Property Disposal

- Above-grade disposal vault - The resultant stabilized material would be disposed in an above-grade disposal vault. This facility would use an LC/DS, a multimedia cap, and a multilayered lining system.

Physical Treatment

- FEMP AWWT - All contaminated process and decontamination water would be transported to and treated at the FEMP AWWT facility.

Run-on/Runoff Control

- Diversion/collection - The area around the cap would contain small berms, channels, and waterways to redirect runoff.

- Grading - The area around the cap would be contoured or graded to redirect and control runoff.

- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the disposal facility containing the stabilized material to detect radon that emanates from the facility.

- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the facility and sampled routinely to monitor containment system performance.

- Leachate monitoring - The installed LC/DSs would be routinely checked to monitor the facility's performance.

- Surface water/sediment monitoring - The surface water and sediment near the disposal facility would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.

- Administrative controls - Site access would be confined to authorized personnel during implementation of remedial activity. Permanent physical markers would be used. The need for long-term administrative controls will be addressed during the detailed analysis phase (Section 4.0) if this alternative is retained.

These process options would be supported by a local containment at the point of silo entry and a material processing facility.

Size and Configuration

The following are estimates based upon data available during the initial screening process.

- Removal rate - 10 to 15 tpd

- Processing rate (stabilized product)
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd

- Volume disposed
  - Cement-stabilized product - less than 6000 $m^3$ (7,900 $yd^3$)
  - Vitrified product - less than 1,500 $m^3$ (1,900 $yd^3$)

Remediation Time Frame

Site preparation, construction of the material processing facility, and the installation of the material removal and processing equipment would take approximately three years. Removing, processing, and packaging the material would take an additional year. The total remediation time for this alternative will be approximately four years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 4 ha (10 acres) for vitrification and 4.5 ha (11 acres) for cementation. Of this area, the disposal vault would utilize approximately 2.5 ha (6 acres) for vitrification and approximately 3 ha (7.5 acres) for cementation. Of the total area required by the disposal vault for each alternative, the cap sloping requires a 33m

(111 ft) wide area around the perimeter of the vault and a 30m (100 ft) wide area around the perimeter of the cap.

Packaging/Transportation Requirements

The on-property disposal facility would accept only stabilized and/or rigidly containerized material. The cement stabilized or vitrified material would be poured directly into DOT specification 7A Type A or strong tight containers.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.,)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris

Rubble, equipment, contact waste, and other debris would be dispositioned in accordance with the selected alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

3.2.5.4 Alternative 3B - Removal, Stabilization, and Off-Site Disposal

In order to attain waste acceptance criteria at the off-site disposal facility pertaining to the leachability of heavy metals, all alternatives developed for Subunit B involving off-site disposal include a waste stabilization processing step.

Description

This alternative requires removal of the Silo 3 contents, stabilization of the contents by vitrification or cement stabilization, and off-site disposal of these materials. This alternative is identical to Alternative 2B with the exception that the on-property disposal, run-on/runoff controls, monitoring, and access control technologies have been replaced by the waste transportation and off-site disposal technologies. Material disposal would be at NTS or a facility to be constructed within 483 km (300 mi) of the FEMP site. The material will be shipped to the disposal facility by rail or truck. These disposal alternatives are discussed separately as Alternatives 3B.1 and 3B.2, respectively.

The process options for this alternative's additional technologies are described as follows:

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Waste Transportation

- Rail or truck transport - The FEMP site can support rail transport to either disposal facility by using an existing on-property rail spur. A rail spur can be built at the off-site disposal facility, or a combination of rail and truck transport can be used around the facility. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system in the vicinity of the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The stabilized material would be shipped to NTS for disposal. Stabilized material would be treated to meet the NTS waste acceptance criteria. All necessary approvals and certifications would be received prior to shipping.

- New facility within 483 km (300 mi) - The stabilized material would be shipped to a facility to be built within 483 km (300 mi) of the FEMP site. The stabilized material must meet the new facility's waste acceptance criteria when developed.

These process options will be supported by a local containment at the point of silo entry, and a material processing facility.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tpd

- Processing rate (stabilized product)
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd

- Volume transported and disposed
  - Cement-stabilized product - less than 6000 $m^3$ (7,900 $yd^3$)
  - Vitrified product - less than 1,500 $m^2$ (1,900 $yd^3$)

Remediation Time Frame

Site preparation, construction of the material processing facility, and the installation of the material removal and material processing equipment would take approximately three years. Removing, processing, and packaging the material would take an additional year. The total remediation time for this alternative would be approximately four years.

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Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 1.5 ha (3 acres) for vitrification and cementation.

Packaging/Transportation Requirements

The stabilized Silo 3 contents would be shipped in DOT specification 7A Type A or strong tight containers. The material would be transported by truck or rail/truck combination to NTS, or by rail or truck to the disposal facility proposed to be built within 483 km (300 mi) of the FEMP site. The material would be temporarily placed in the processing facility staging area until proper release tests have been performed.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.,)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris

Rubble, equipment, contact waste, and other debris would be dispositioned in accordance with the alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS

Under Alternative 3B.1, material would be disposed off site at NTS. NTS is a DOE-owned facility that currently accepts low-level radioactive waste from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 3B.2, material would be disposed off site at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional DOE disposal facility to be developed later. Disposed material must meet the waste acceptance criteria for this facility when developed.

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### 3.2.5.5 Alternative 4B - Removal and On-Property Disposal

Description

This alternative requires removal of the Silo 3 contents, packaging, and on-property disposal of the untreated material. This alternative is identical to Alternative 2B, with the exception that it does not include treatment. The technologies implemented by this alternative are pneumatic removal, on-property disposal, run-on/runoff controls, monitoring, and access controls.

The silo contents would be removed with a pneumatic device introduced through the silo dome. This equipment would be supported by a work platform that would span the silo. The material would then be pneumatically conveyed to a materials processing facility for packaging. The packaged material would then be disposed in an above-grade disposal vault. Figure 3-12 provides a conceptual flow diagram for this alternative.

Size and Configuration

The following are estimates based upon data available during the initial screening process.

- Removal rate - 10 to 15 tpd
- Volume disposed - 3890 $m^3$ (5088 $yd^3$)

Remediation Time Frame

Site preparation and the installation of the material removal equipment would take approximately one year. Removing and packaging the material would take one additional year. The total remediation time for this alternative would be approximately two years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 4.3 ha (10.6 acres). Of this, the area of the disposal vault would be approximately 2.8 ha (6.8 acres). Of the total area required for the disposal vault for each alternative, the cap sloping requires a 33 m (111 ft) wide area around the perimeter of the vault, and institutional controls implementation requires an additional 30 m (100 ft) wide area around the perimeter of the cap.

Packaging/Transportation Requirements

The on-property disposal facility would accept only rigidly containerized material. The material would be placed directly into DOT specification 7A Type A or strong tight containers.

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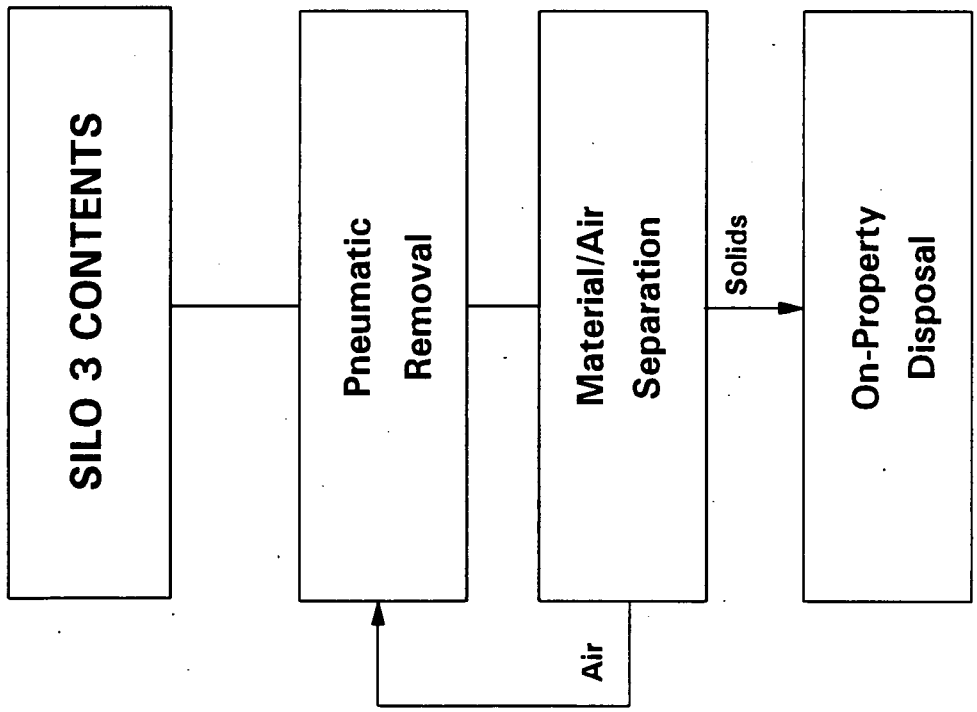


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FIGURE 3 - 12
ALTERNATIVES 4B - REMOVAL, DISPOSAL
CONCEPTUAL FLOW DIAGRAM

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Waste Generated

- Contact waste (anti-contamination clothing, gloves, dehumidification media, etc.,)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris

Contaminated equipment, contact waste, rubble or other debris will be dispositioned in accordance with the alternative for Subunit C. All waste generated during remediation would be characterized prior to final disposition.

### 3.2.6 Subunit C Preliminary Alternatives

The alternatives presented for this subunit (except no action) would be combined with Subunit A and B alternatives that remove the silo contents and the berms surrounding Silos 1 and 2. Also, the berms will have been assayed and segregated. The in situ containment alternative for Subunits A and B would preclude selection of a Subunit C alternative since the cap for Subunits A and/or B would cover Subunit C components. In the event that the in situ containment process option was chosen for Subunits A and B, then Silo 4 would be removed. Figure 3-13 outlines the development of Subunit C preliminary alternatives. Narrative discussion of the alternatives development follows.

#### 3.2.6.1 Alternative 0C - No Action

Description

The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken, and the material is considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. This alternative does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and does not provide for active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

#### 3.2.6.2 Alternative 1C - Demolition and Containment

Description

This treatment/containment alternative involves demolition, decontamination, and disposition of the Silos 1, 2, 3, and 4 structures, the existing RTS for Silos 1 and 2, any rubble, equipment, contact waste, or debris generated during implementation of Subunit A and B alternatives, placement of the containerized contaminated material and containerized contaminated berm in the former location of

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FERNALD\OU4\FIG3-9.DRW/RSS/8/24/93

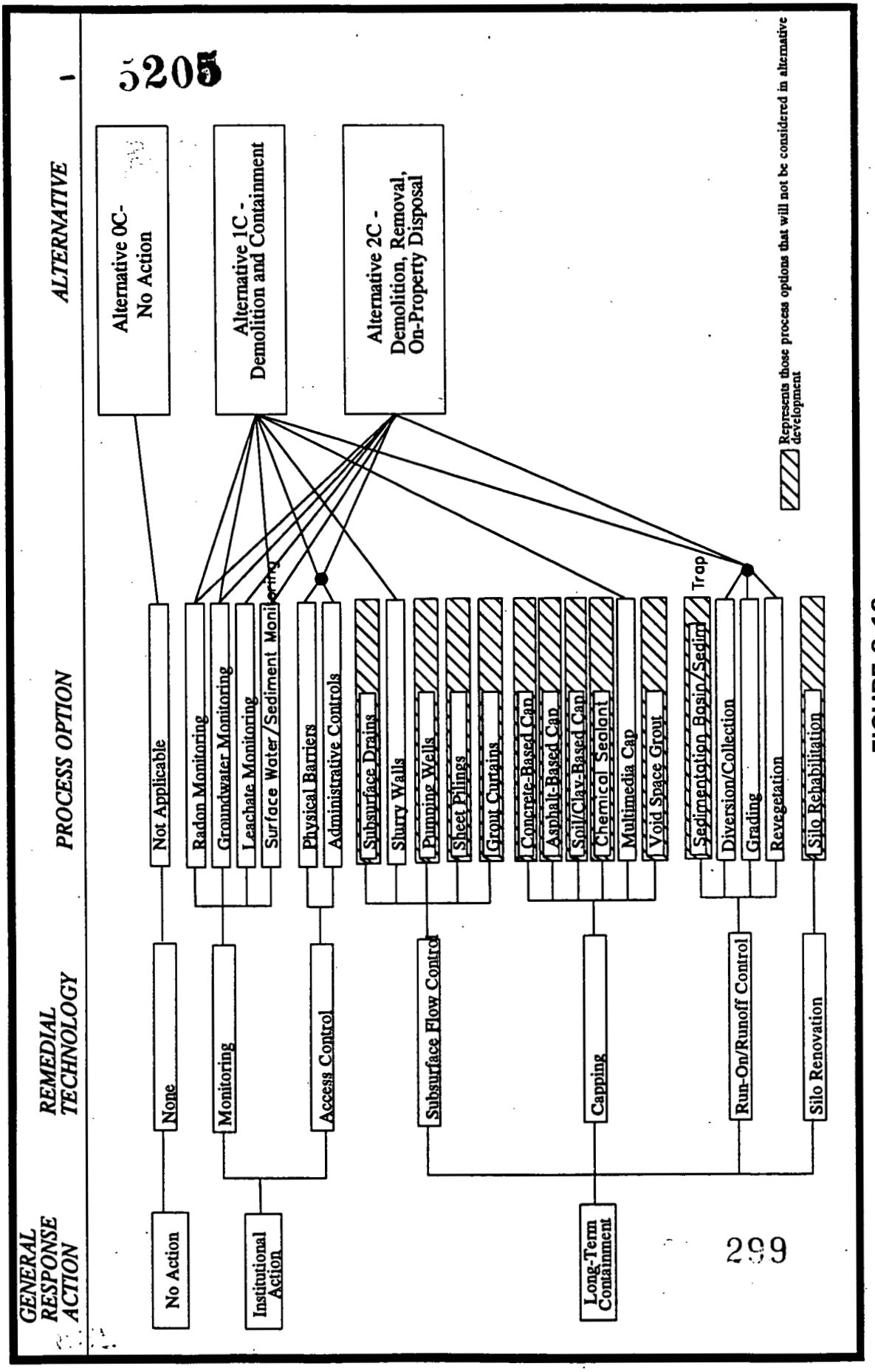


FIGURE 3-13
SUBUNIT C
DEVELOPMENT OF ALTERNATIVES

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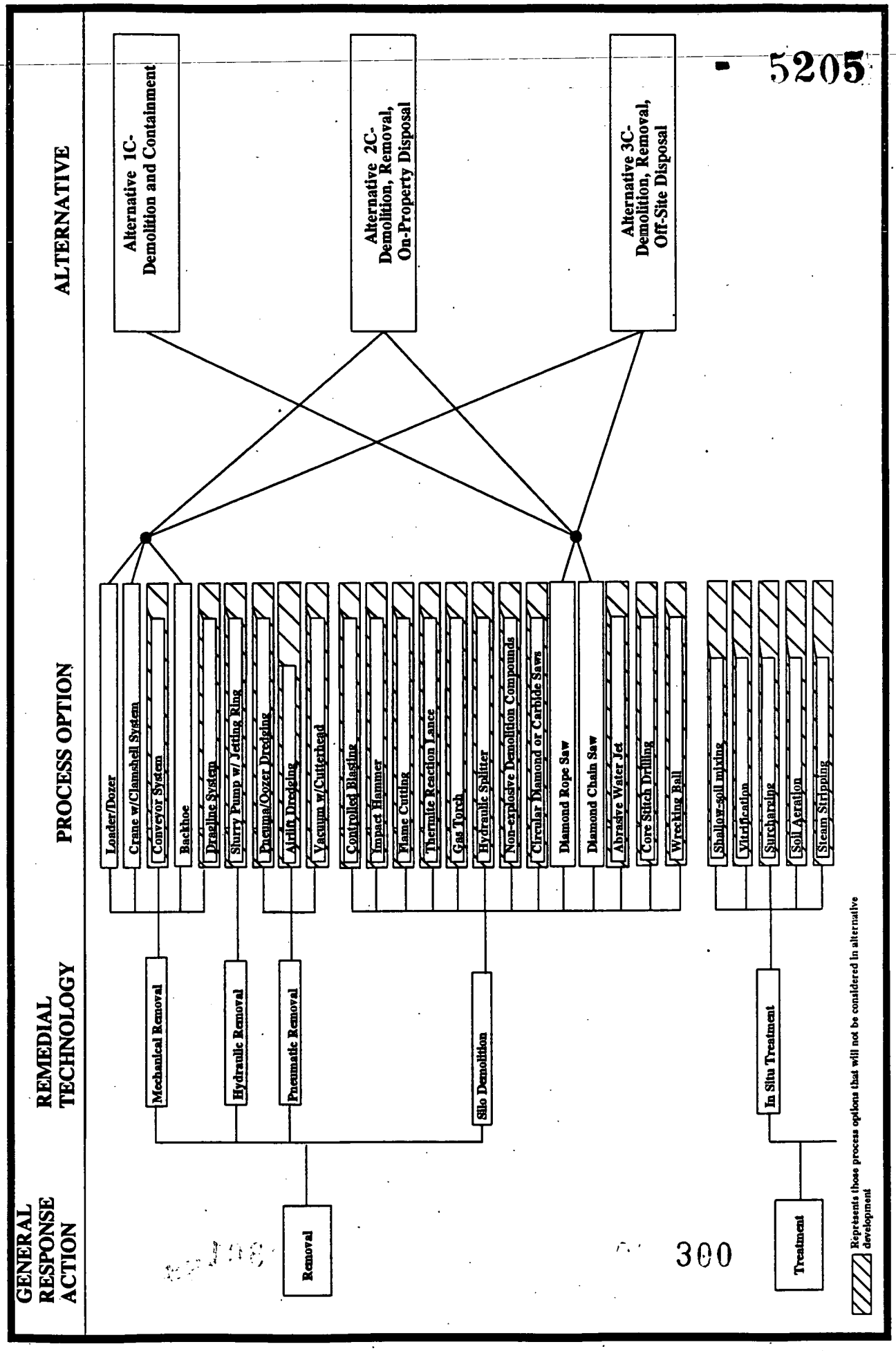


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FIGURE 3-13
(Continued)

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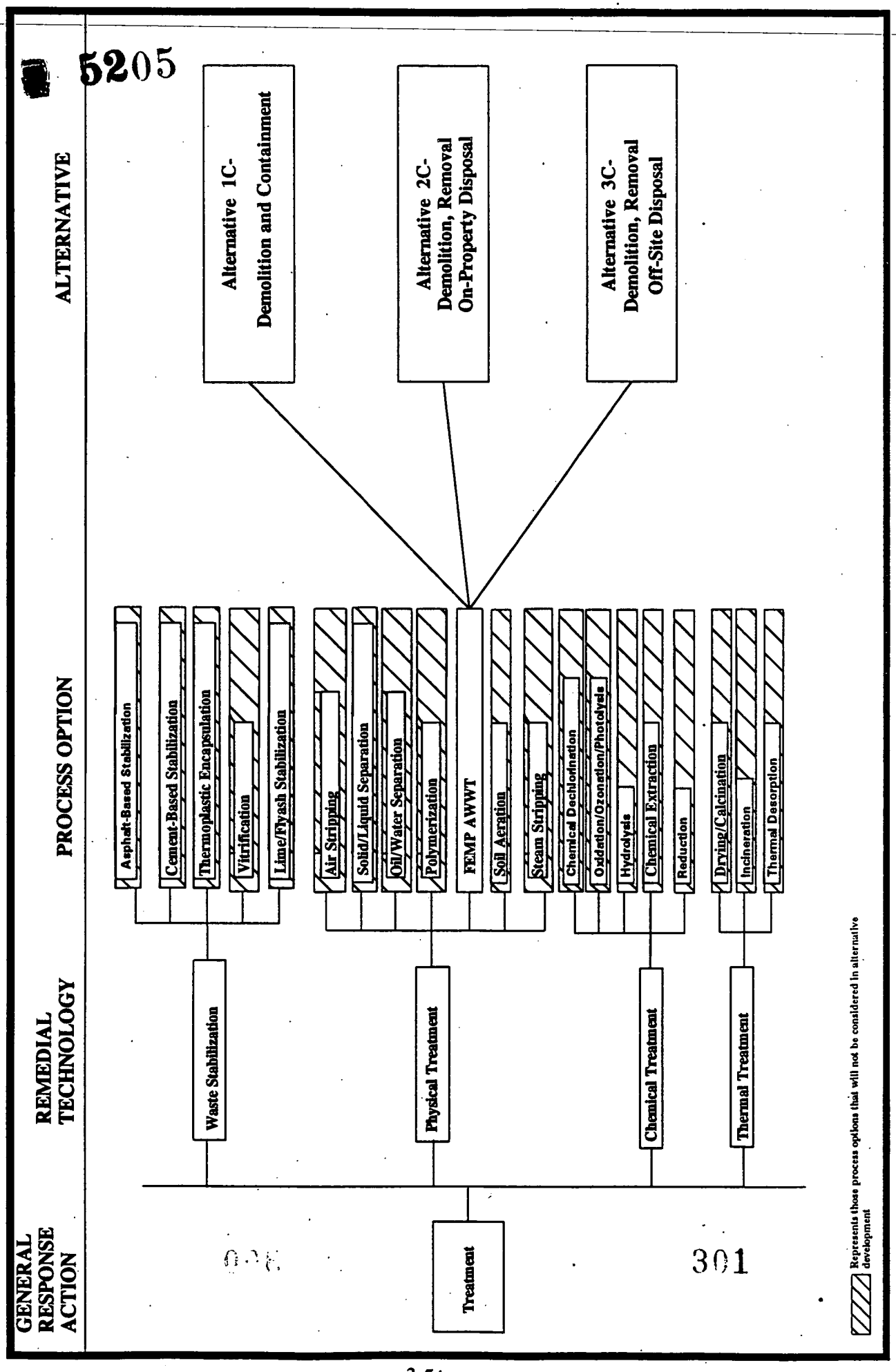


FIGURE 3-13
(Continued)

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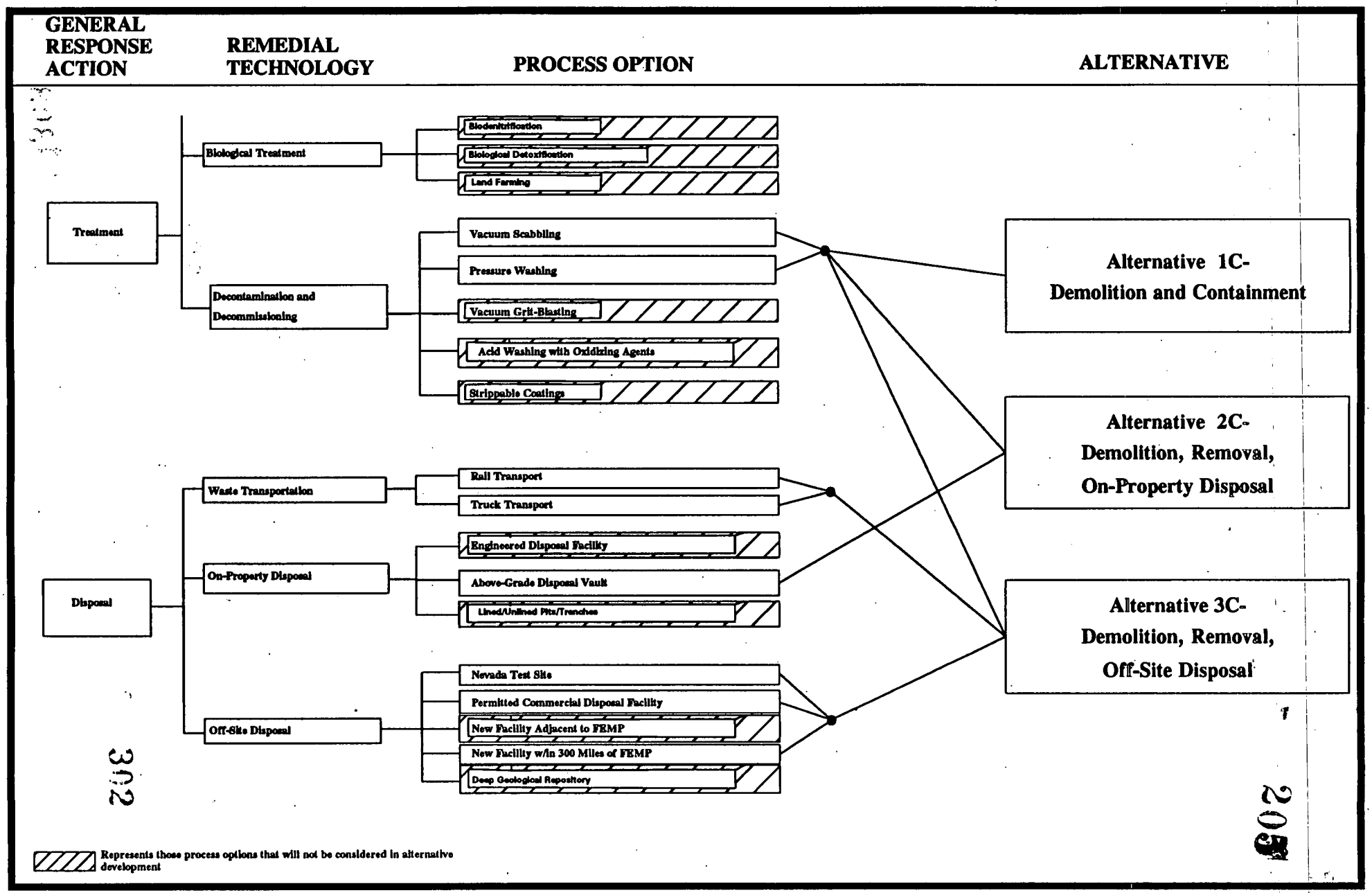


FIGURE 3-13
(Continued)

Silos 1 and 2, and the placement of a multimedia cap over the material. The surface soil within the Operable Unit 4 boundary would be removed to meet the soil remediation goals. For the purpose of the initial screening process, the soil is assumed to be removed such that: the Silo 1 and 2 berms are removed entirely; surface soils within the Operable Unit 4 boundary are removed to a depth of 15 cm (6 in); and soils beneath Silo 1 and 2 and the decant sump are removed to a depth of five feet. The technologies implemented by this alternative are silo demolition, D&D, physical treatment, subsurface flow control, capping, run-on/runoff control, monitoring, and access controls.

This alternative assumes that the silos' contents and the berms have been removed under Subunits A and B. Once the silo contents have been removed, the silo structures would be characterized both structurally and radiologically. Data from the structural characterization would be used to determine the safest approach to demolition, and data from the radiological characterization would be used to determine the depths to which the concrete must be removed to facilitate removal of gross contamination. Due to the porous nature of concrete and lack of established criteria, no concrete would be free-released. For the purposes of this FS, Silo 4 concrete would not be free-released, but would be handled similar to the concrete from the other silos. Any material generated during remediation which meets the free release criteria, as presented in DOE Order 5400.5, would be disposed in a solid waste/sanitary landfill, reused, or recycled. Materials which are amenable for free-release include steel fencing, structural steel, and tools. Some contaminated materials, such as concrete, gloves, tyvex, and other personal protective clothing, are not amenable to decontamination and would be disposed as radioactive waste. The subsurface soil, decant sump tank, and process piping and trenches would not be removed in this alternative, although they would be covered by the multimedia cap. Any water remaining in the decant sump tank would be evacuated, and the tank would be filled with grout before capping to prevent future infiltration of water into the tank. Any facilities constructed to temporarily support remediation in Operable Unit 4 will be decontaminated and demolished. Figure 3-14 provides a conceptual flow diagram for this alternative.

The process options for this alternative's technologies are described as follows:

Subsurface Flow Control

- Slurry walls - To divert groundwater flow around the former silo area, a soil-bentonite slurry wall would be constructed along three sides of the perimeter of the former location of Silos 1 and 2 (see Figure 3-15) and would extend into the sand/gravel layer of the Great Miami Aquifer. The bentonite would be obtained commercially and mixed

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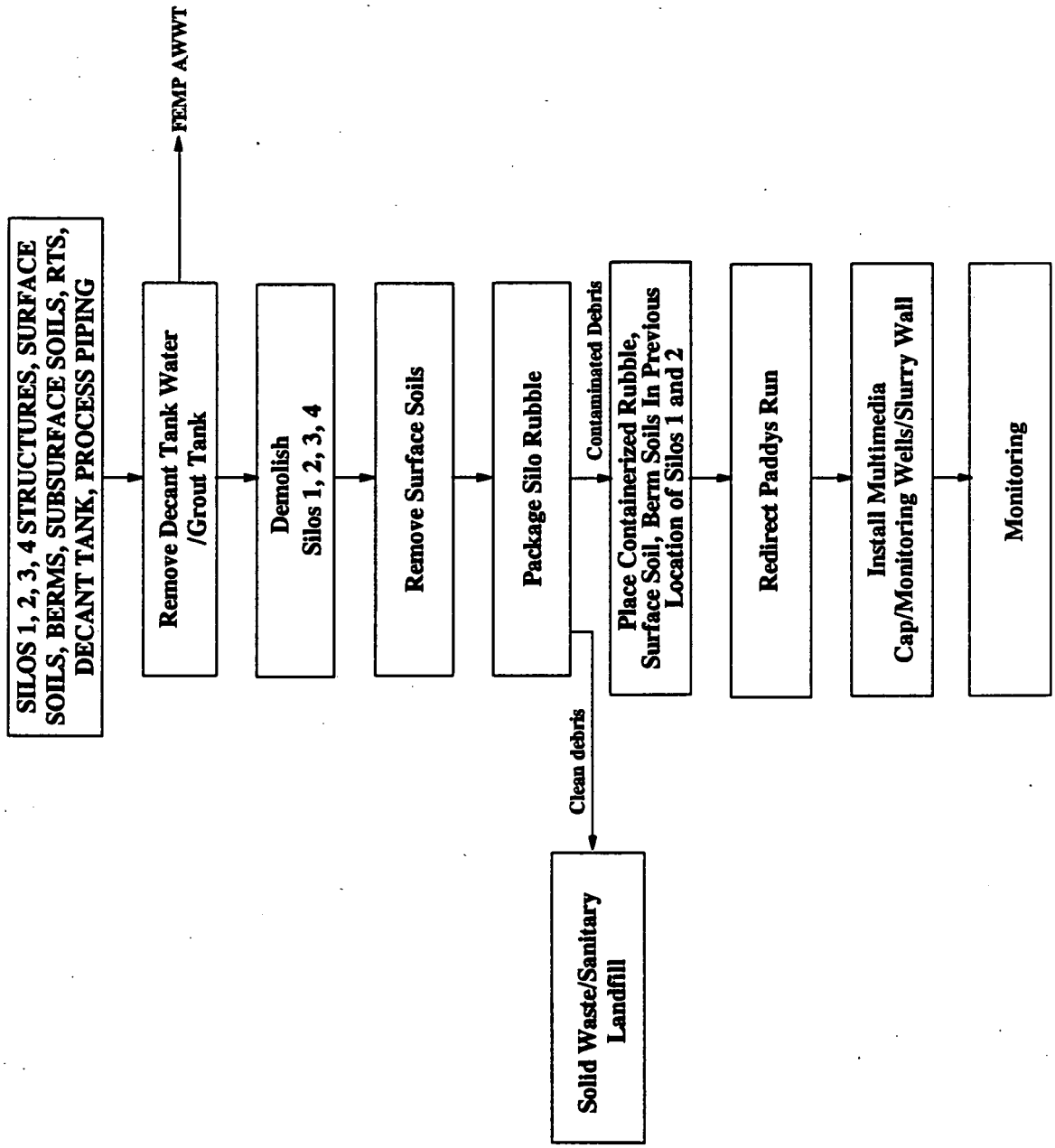
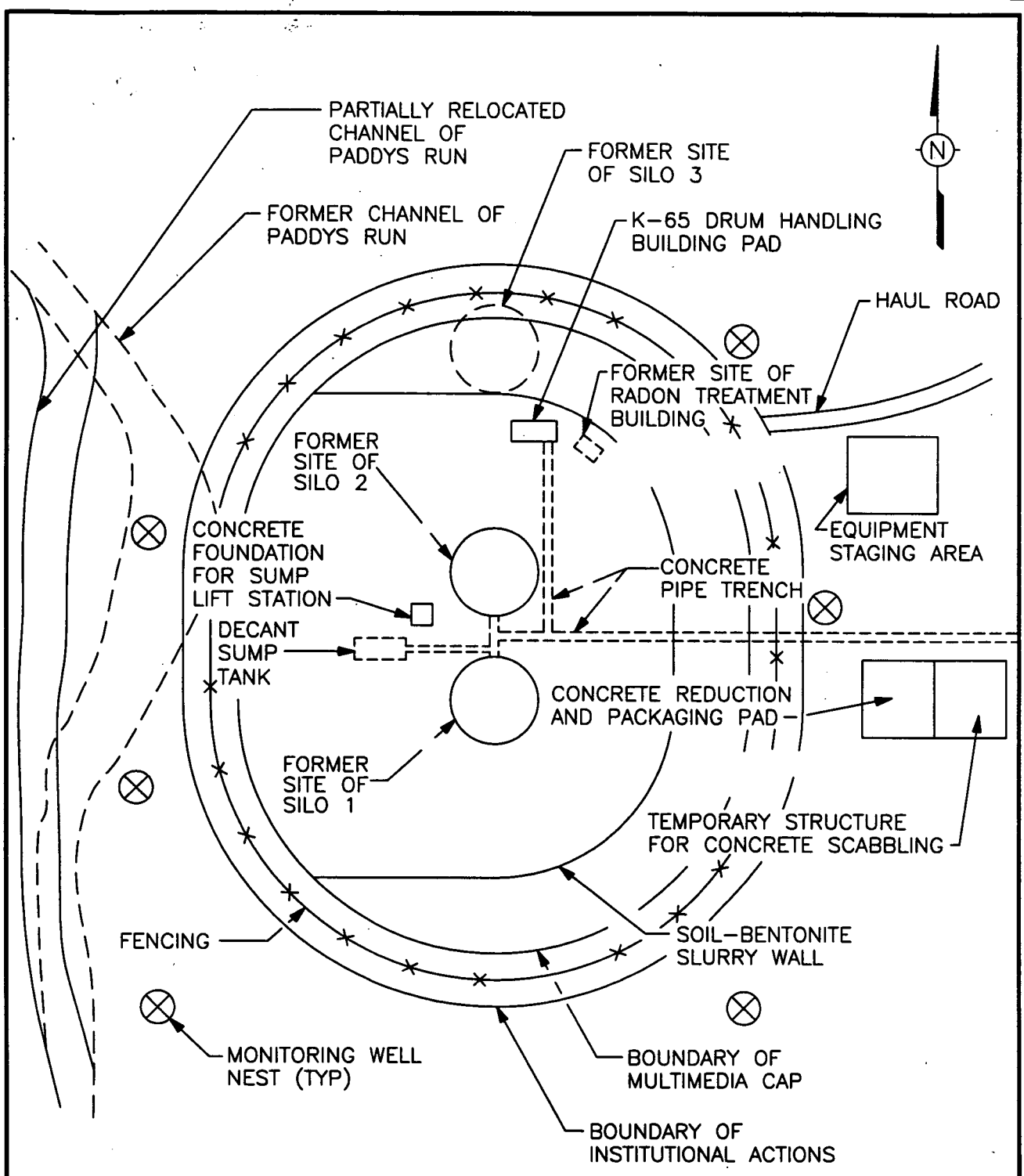



FIGURE 3 - 14
ALTERNATIVE 1C - DEMOLITION and CONTAINMENT
CONCEPTUAL FLOW DIAGRAM




NOTE:

1. SURFACE SOIL WITHIN THE BOUNDARY OF OPERABLE UNIT 4 WILL BE SCRAPED TO A DEPTH OF 6 INCHES BELOW EXISTING GRADE FOR DISPOSAL BENEATH MULTIMEDIA CAP.

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FIGURE 3-15 ALTERNATIVE 1C SITE PLAN

on property with existing acceptable soils to produce a 0.9-m (3-ft) wide slurry wall with an approximate depth of 15.2 m (50 ft).

Silo Demolition

- Diamond rope or chain saw - A diamond wire rope saw would be used to cut the silo domes into sections for removal. Cranes would be used to remove the cut sections of the dome and to support the remaining dome. The cut sections of the dome would be lifted to the decontamination and packaging pad for decontamination, size reduction, and packaging. The silo walls would be cut into sections with the diamond chain saw and lifted to the pad with the crane for similar treatment. The silo floors and footers would remain in place.

Decontamination and Decommissioning

- Pressure washing - The loose interior concrete and loose interior contamination can be removed with a remotely controlled, robotic high-pressure water jet or an abrasive water jet. The collected water and debris can be removed with the hydraulic material removal device and sent to the FEMP AWWT facility for treatment.

- Vacuum scabbling - The contaminated concrete layers would be removed with a vacuum scabbling device. This device would use small, pneumatically actuated pistons or hammers to strike the concrete surface, chipping the upper concrete layer for removal by the vacuum system.

Physical Treatment

- FEMP AWWT - All contaminated process and decontamination water would be transported to and treated at the FEMP AWWT facility.

Capping

- Multimedia cap - A multimedia cap would be installed to minimize the infiltration of rainwater into the disposal area. The cap would consist of the following elements to control erosion and minimize leachate generation as a result of rainwater infiltration.

  - Upper vegetative layer
  - Drainage layer
  - Low-permeability clay layer with a maximum vertical permeability of $1 \times 10^{-7}$ cm/s
  - Geomembrane layer of 40-mil minimum thickness

  The spatial requirements for the multimedia cap would require the partial relocation of Paddys Run to minimize the possibility of lateral erosion.

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Run-on/Runoff Control

- Diversion/collection - The area around the cap would contain small berms, channels, and waterways to redirect runoff.
- Grading - The area around the cap would be contoured or graded to redirect and control runoff.
- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon Monitoring - Radon monitors would be installed around the cap to detect and warn of radon emanating from the material underneath the cap. Monitoring would continue as required to demonstrate compliance with relevant ARARs/TBCs and in support of CERCLA five-year reviews.
- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the cap and routinely sampled to monitor containment system performance.
- Surface Water/Sediment Monitoring - The surface water and sediment near the cap would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.
- Administrative controls - Access to the site would be confined to authorized personnel during the implementation of remedial actions. Permanent physical markers would be used to mark the disposal unit. The need for long-term administrative controls will be addressed during the detailed analysis phase (Section 4.0) if this alternative is retained.

The following are descriptions of activities that would support the implementation of the process options.

- Decant sump tank evacuation - The liquid from the decant sump tank material would be evacuated with a sludge pump to a tanker truck, and the liquid would be transported to the FEMP AWWT facility for treatment. The decant sump tank would then be filled with grout to prevent water from infiltrating into the tank.
- Existing Silo RTS demolition - The existing RTS piping, HEPA filters, fan, dehumidification media, and carbon adsorption canisters would be dismantled and

packaged for disposal. The concrete block building where this equipment is kept would also be demolished and packaged for disposal.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process.

- Slurry wall - approximately 270 m (900 ft) x 15 m (50 ft)
- Material disposed in multimedia cap
  - Silo debris - approximately 2000 $m^3$ (2700 $yd^3$)
  - Contaminated berm soil and surface soils - approximately 11,000 $m^3$ (15000 $yd^3$)
- Grout injected into decant sump tank - approximately 40 $m^3$ (50 $yd^3$)
- Volume of decant sump tank water sent to the AWWT facility - approximately 30,280 L (8000 gallons)

Remediation Time Frame

It would take approximately three months to prepare the site and stage the remediation equipment, nine months to demolish and package the silo structures, and one year to relocate Paddys Run and construct the multimedia cap. The overall duration for this alternative would be approximately two years.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 5 ha (12.5 acres), of which approximately 4 ha (10 acres) would be used by the cap.

Packaging/Transportation Requirements

The contaminated silo debris and contaminated berm and surface soils would be placed in DOT specification 7A Type A or strong tight containers before disposal.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, etc.,)
- Equipment not feasible to decontaminate
- Decontamination water from high pressure washing

All waste generated during remediation would be characterized prior to final disposition.

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### 3.2.6.3 Alternative 2C - Demolition, Removal, and On-Property Disposal

Description

This demolition, removal, and on-property disposal alternative would demolish the Silos 1, 2, 3 and 4 structures and would excavate the silo subsurface soil, as well as the Operable Unit 4 surface soil, decant sump tank, process piping, and trenches. This alternative would also demolish and dispose of the existing RTS for Silos 1 and 2 and dispose of any rubble, equipment, contact waste, or debris generated during implementation of Subunits A and B selected alternatives. The contaminated material, in addition to the contaminated berm material, would be disposed in an above-grade disposal vault constructed on property. This alternative is identical to Alternative 1C except that the silo floors, silo subsurface soil, decant sump tank, process piping, and trenches that were left in situ in the previous alternative would now be excavated and disposed on property. The technologies implemented by this alternative are silo demolition, D&D, mechanical removal, physical treatment, on-property disposal, run-on/runoff control, monitoring, and access controls.

Once the silo contents have been removed, the silo structures would be characterized both structurally and radiologically. Data from the structural characterization would be used to determine the safest approach to demolition, and data from the radiological characterization would be used to determine the depths to which concrete with gross contamination must be removed. As in Alternative 1C, no concrete would be free released. Any material generated during remediation which meets the free release criteria, as presented in DOE Order 5400.5, would be disposed in a solid waste/sanitary landfill, reused, or recycled. Materials which are amenable for free-release include steel fencing, structural steel, and tools. Some contaminated materials, such as concrete, gloves, tyvex, and other personal protective clothing, are not amenable to decontamination and would be disposed as radioactive waste. Figure 3-16 illustrates the logic of this alternative.

Contaminated soil and debris generated from the selected remedy for Operable Unit 4 may be placed into interim storage, and final disposition of that material would be determined as part of the Record of Decision for Operable Units 3 and 5. Placing the Operable Unit 4 on-property disposal decision in abeyance permits an integrated site-wide disposal approach for soil and debris. In addition, Operable Unit 4 would be able to take advantage of any applicable waste minimization initiatives developed for soil and debris by Operable Units 3 and 5.

The additional process options for this alternative's technologies are described as follows:

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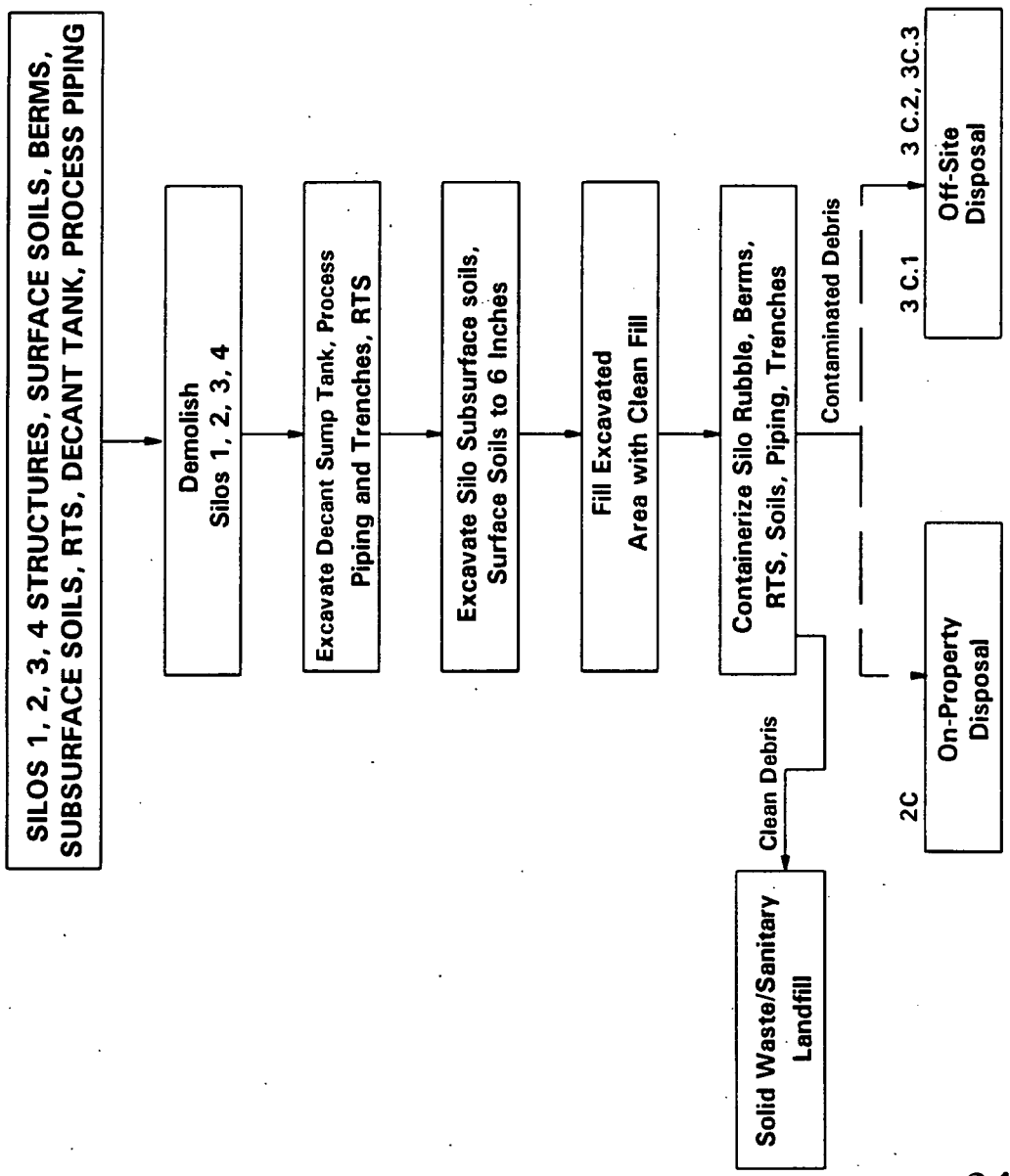


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Optional Stream

FIGURE 3 - 16
ALTERNATIVES 2C, 3C - DEMOLITION, REMOVAL, DISPOSAL
CONCEPTUAL FLOW DIAGRAM

Silo Demolition

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- Diamond rope or chain saw - In addition to the silo demolition process option previously described for the silo domes and walls (diamond rope saw/diamond chain saw), the silo floors would be scored with a masonry saw in a crisscross pattern and divided and transported by front-end loader to the decontamination and packaging pad. The silo footers would be fractured with a backhoe-mounted pneumatic hammer and transported to the decontamination pad with a front end-loader.

Mechanical Removal

- Loader/dozer, crane with clamshell, backhoe - This equipment would be used to excavate the silo floors and foundations, the silo subsurface soil, the surface soil, the decant sump tank, and the process piping and trenches.

  After removal of the silo structures and the decant sump tank, the silo subsurface soil would be excavated using a backhoe. For the purpose of the cost estimate, the soil would be excavated to a depth of approximately 1.5 m (5 ft) and laterally to the toe of the berm. The volume is a conservative estimate of contaminated hot spots of soil and any other soil above the remediation goals. Regardless of the volume estimated, all soil exceeding the applicable remediation goals would be excavated as part of this alternative. The surface soil within the Operable Unit 4 Study Area would be excavated with a dozer to a depth of 15 cm (6 in.). The soil will be assayed, segregated, and disposed of appropriately as it is removed. The effected areas of excavated soil would be backfilled to grade with clean soil. This six inches of backfill soil is not to be considered protective for future users.

  The decant sump tank would be excavated and transferred to the decontamination pad for demolition and disposal. The soil above, around, and to a depth of 1.5 m (5 ft) below the tank would be excavated and segregated for disposal or use as clean fill.

  The process piping in the piping trench would be cut into manageable sections for disposal without being decontaminated. The concrete piping trench would be fractured using a backhoe-mounted pneumatic hammer and would be excavated using a backhoe or clamshell. This concrete would be shipped to the decontamination pad for scabbling, if necessary.

  The silo berms are assumed to have been removed, assayed, and staged during the removal of the Silos 1 and 2 contents.

Decontamination and Decommissioning

- Pressure washing - The loose interior concrete and loose interior contamination can be removed with a remotely controlled, robotic high-pressure water jet or an abrasive water jet. The collected water and debris can be removed with the hydraulic material removal device and sent to the FEMP AWWT facility for treatment.

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- Vacuum scabbling - The contaminated concrete layers would be removed with a vacuum scabbling device. This device would use small, pneumatically actuated pistons or hammers to strike the concrete surface, chipping the upper concrete layer for removal by the vacuum system.

Physical Treatment

- FEMP AWWT - All contaminated process and decontamination water would be transported to and treated at the FEMP AWWT facility.

On-Property Disposal

- Above-grade disposal vault - The resultant material would be disposed on property in an above-grade disposal vault. This facility would include an LC/DS and a multimedia cap.

Run-on/Runoff Control

- Diversion/collection - The area around the cap would contain small berms, channels, and waterways to redirect runoff.

- Grading - The area around the cap would be contoured or graded to redirect and control runoff.

- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon Monitoring - Radon monitors would be installed around the disposal facility containing the material to measure radon that emanates from the facility.

- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the disposal area and routinely sampled to monitor containment system performance.

- Leachate monitoring - The installed LC/DSs would be routinely checked to monitor the facility's performance.

- Surface water/sediment monitoring - The surface water and sediment near the disposal facility would be monitored to determine if contaminants from the material have been released to these media.

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Access Controls

- Physical Barriers - A security fence topped with barbed wire would surround the disposal area to discourage intruders. A security force would patrol the area while access controls are in effect.

- Administrative Controls - During the access control period, access to the site would be confined to authorized personnel. Permanent physical markers would also be used to restrict access.

The following are descriptions of activities that would support the implementation of the process options.

- Decant sump tank evacuation - The liquid from the decant sump tank material would be evacuated with a sludge pump to a tanker truck, and the liquid would be transported to the FEMP AWWT facility for treatment.

- Existing Silo RTS demolition - The existing RTS piping, HEPA filters, fan, dehumidification media, and carbon adsorption canisters would be dismantled for disposal. The concrete block building where this equipment is kept would also be demolished for disposal.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process.

- Material disposed in above-grade disposal vault.
  - Contaminated silo debris - approximately 2,000 $m^3$ (2,700 $yd^3$)
  - Decant sump tank, process piping, piping trenches, and RTS - approximately 280 $m^3$ (370 $yd^3$)
  - Contaminated berm soils - approximately 8000 $m^3$ (10,500 $yd^3$)
  - Contaminated subsurface soils and surface soils - approximately 14,500 $m^3$ (19,000 $yd^3$)

- Volume of water sent to AWWT facility - approximately 80,000 L (21,000 gal.)

Remediation Time Frame

Approximately three months would be required to prepare the site and stage the remediation equipment; 15 months would be required to demolish and decontaminate the silo structures, as well as to excavate the silo subsurface soil, decant sump tank, and process piping trenches. The above-grade disposal vault would be constructed during this time. The overall duration of this alternative will be 18 months to two years.

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Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 6 ha (14 acres), of which approximately 5 ha (12 acres) would be used by the disposal vault. Of the total area required by the disposal vault for each alternative, the cap sloping requires a 33m (111 ft) wide area around the perimeter of the vault and a 30m (100 ft) wide area around the perimeter of the cap.

Packaging/Transportation Requirements

The only transportation required is movement of the contaminated material to the disposal vault.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, etc.,)
- Equipment not feasible to decontaminate
- Decontamination water from high pressure washing

All waste generated during remediation would be characterized prior to final disposition.

### 3.2.6.4 Alternative 3C - Demolition, Removal, and Off-Site Disposal

Description

This demolition, removal, and off-site disposal alternative would demolish and decontaminate the Silos 1, 2, 3, and 4 structures and would excavate the silo subsurface soil as well as the Operable Unit 4 surface soil, decant sump tank, and process piping and trenches. This alternative would also demolish and dispose of the existing RTS for Silos 1 and 2 and dispose of any rubble, equipment, contact waste, or debris generated during implementation of Subunits A and B selected alternatives. The contaminated material, in addition to the contaminated berm material, would be packaged (if required) and disposed in an off-site disposal facility. This alternative is identical to Alternative 2C with the exception that the on-property disposal, access control, run-on/runoff control, and monitoring technologies have been replaced by the waste transportation and off-site disposal technologies. Contaminated material would be disposed at NTS, the permitted commercial disposal site, or a facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be shipped to the disposal facility by rail or truck. These disposal alternatives are discussed separately as Alternatives 3C.1, 3C.2, and 3C.3, respectively.

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Any material generated during remediation which meets the free release criteria, as presented in DOE Order 5400.5, would be disposed in a solid waste/sanitary landfill, reused, or recycled. Materials which are amenable for free-release include steel fencing, structural steel, and tools. Some contaminated materials, such as concrete, gloves, tyvex, and other personal protective clothing, are not amenable to decontamination and would be disposed as radioactive waste.

The additional process options for this alternative's technologies are described as follows.

Material Transportation

- Rail or truck transport - The FEMP site can support rail transport to any of the disposal facilities by using an existing on-property rail spur or truck transport. A rail spur can be built at the off-site disposal facility, or a combination of rail and truck transport can be used around the facility. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system around the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The contaminated soils, berm, and debris would be packaged and shipped to NTS for disposal. Based on evaluation of the contaminated berm and debris, it would meet the NTS waste acceptance criteria. Approvals and certifications would be received prior to shipment.

- Permitted commercial disposal site - The contaminated soils, berm, and debris would be shipped in bulk to the permitted commercial disposal site for disposal. Based on evaluation of the contaminated berm and debris, it would meet the permitted commercial disposal site waste acceptance criteria. Approvals and certifications would be received prior to the shipment.

- New facility within 483 km (300 mi) - The material and demolition debris would be shipped to a facility to be constructed within 483 km (300 mi) of the FEMP site. All waste shipped to a new facility must meet the new facility's waste acceptance criteria when developed.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Material volume transported to off-site disposal facility.
  - Silo debris - approximately 2,000 $m^3$ (2,700 $yd^3$)
  - Decant sump tank, process piping, trenches, and RTS - approximately 280 $m^3$ (370 $yd^3$)
  - Contaminated berm soils - approximately 8000 $m^3$ (10,500 $yd^3$)

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- Contaminated subsurface soil and surface soil -- approximately 14,500 $m^3$ (19,000 $yd^3$)

- Volume of water sent to AWWT facility - approximately 80,000 L (21,000 gal.)

Remediation Time Frame

Approximately three months would be required to prepare the site and stage the remediation equipment. An additional 15 months would be required to demolish and box the silo rubble, and excavate and box the remaining material. The overall duration of this alternative will be 18 months to two years.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 1 ha (2 acres).

Packaging/Transportation Requirements

All contaminated material would be placed in DOT specification 7A Type A or strong tight containers or shipped in bulk, by rail or truck. Removed material would be temporarily placed in a staging area while final release tests are conducted.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, etc.,)
- Equipment not feasible to decontaminate
- Decontamination water from high pressure washing

All waste generated during remediation would be characterized prior to final disposition.

Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS

Under Alternative 3C.1, material would be disposed off site at NTS. NTS is a DOE-owned facility that currently accepts low-level radioactive waste from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at the Permitted Commercial Disposal Site

Under Alternative 3C.2, material would be disposed off site at the permitted commercial disposal site in Clive, Utah, located approximately 3058 km (1900 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3C.3 - Demolition, Removal, and Off-Site Disposal at a Facility to be Located Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 3C.3, material would be disposed at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional DOE disposal facility to be developed later. Material must meet the waste acceptance criteria for this facility when developed.

## 3.3 SCREENING OF ALTERNATIVES

The alternatives presented in the previous subsection were evaluated against three broad criteria: effectiveness (short- and long-term), implementability, and cost. The criteria for evaluating alternatives are provided in EPA guidance (EPA 1988b) and in the NCP (40 CFR 300) (EPA 1990). Of these criteria, effectiveness was given the highest consideration. Because this screening reduced the number of alternatives undergoing a more extensive and qualitative analysis, alternatives were evaluated more generally in this phase than during the subsequent detailed analysis task. The no-action alternative was retained as a baseline against which other alternatives were compared. Consistent with the NCP, nine specific criteria are emphasized to perform the Detailed Analysis of Alternatives. Seven of these criteria are taken into consideration during the initial screening of alternatives. The relationship between the three screening criteria and the seven specific detailed analyses criteria is illustrated in Figure 3-17.

Alternatives with innovative technologies were carried through the screening process if there was reason to believe that they offered significant advantages in performance or implementability. Technologies are classified as innovative if they are fully developed but lack sufficient cost or performance data for routine use at CERCLA-regulated cleanup sites. An example of an innovative technology is the vitrification of removed residues.

Effectiveness Evaluation

The key aspect of the screening evaluation is the assessment of the alternatives ability to meet the RAOs in order to provide protection of human health and the environment in both the short term and

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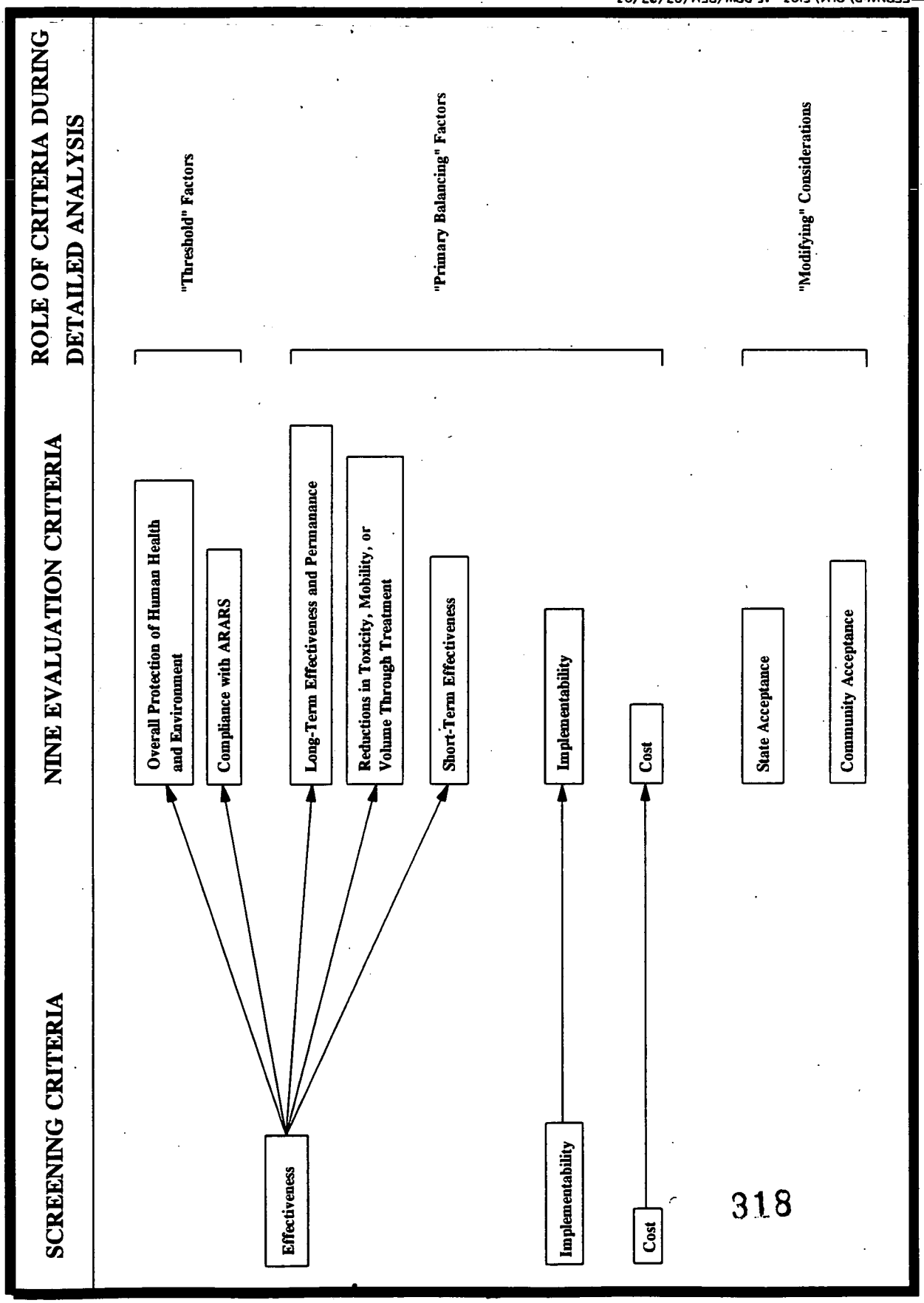


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FIGURE 3-17
RELATIONSHIP OF SCREENING CRITERIA TO THE NINE EVALUATION CRITERIA

long term. Measures of effectiveness include (1) reduction of contaminant toxicity, mobility, or volume through treatment; (2) long-term protection of human health and the environment; and (3) short-term protection of human health and the environment during the remedial action.

Implementability Evaluation

Implementability is the measure of (1) the technical feasibility and (2) administrative feasibility to construct, operate, and maintain a remedial action alternative, and (3) the availability of services and materials. This criterion provides a way to evaluate the potential of an alternative to be adapted to site-specific conditions.

The technical feasibility evaluation considered the following.

- Constructability
- Reliability (e.g., demonstrated performance and operation)
- Maintenance

The administrative feasibility evaluation considered the following.

- Ability to obtain permitting and licensing approval

The availability of services and materials evaluation considered the following.

- Availability of on-property/off-site treatment, storage, and disposal facilities and capacity
- Availability of equipment
- Availability of design, operation, and support personnel

Cost Evaluation

Cost estimates were prepared for each alternative to compare similar alternatives. The cost estimates were based on a variety of cost-estimating data such as cost curves, generic unit costs, vendor information, conventional cost-estimating guides, commercial remedial costs, and previous similar estimates as modified by site-specific information.

The categories of costs considered were (1) capital cost and (2) O&M cost. The capital cost includes the cost of constructing remediation facilities, disposal facilities, and purchasing equipment. Cost estimates were prepared to aid in the evaluation of alternatives using information currently available. The cost estimates presented are order-of-magnitude estimates with an intended accuracy range of +50 percent to -30 percent. Estimates are considered to be order-of-magnitude because of the

uncertainties in the information used to develop the alternatives. More detailed cost estimates are provided to support the analysis conducted on the alternatives in Section 4.0.

O&M costs include short-term and long-term O&M costs. Short-term O&M costs include labor and material costs incurred during remediation. Long-term O&M costs include those annual costs incurred after remediation is complete and typically include cap or disposal facility maintenance, sampling and analytical costs, and any monitoring activities. The monitoring costs will be associated with all alternatives that leave waste materials on the property, except for the no-action alternative.

Present worth costs combine capital, short-term costs (assuming a discount rate of seven percent and a construction period), and long-term O&M costs (assuming a discount rate of seven percent and an O&M period of 30 years).

### 3.3.1 Subunit A - Residues Within Silos 1 and 2 and Decant Sump Sludge

#### 3.3.1.1 Alternative 0A - No Action

A description of this alternative is provided in Section 3.2.4.1.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment. Under this alternative, Subunit A would remain unchanged except for conditions resulting from the completion of any removal actions that have already been completed or approved. Because the material is not treated or further contained, the material's toxicity, mobility, and volume would not be reduced.

Long-Term Protection of Human Health and the Environment. The material is not contained, treated, or modified under the no-action alternative. RAOs for Silos 1 and 2 residues are not altered under the no-action alternative. As described in the Baseline Risk Assessment, the potential ILCR to a number of evaluated receptors exceeds the generally accepted risk range as defined in the NCP. The assessment of the risks due to no action for the residues is based upon an assumption that continued deterioration would lead to dome collapse on Silos 1 and 2. This collapse would lead to an exposure of the bentonite cover over the residues to the atmosphere. While the baseline risk assessment assumes the long-term integrity of the bentonite cover following a hypothetical dome collapse, it is conceivable that this cover on the dome side walls could be breached due to the effects of erosion or

other internal or intruder actions. Potential exposures to both on- and off-property receptors under such release scenarios would greatly exceed those calculated under the baseline risk assessment. Hypothetical loss of containment scenarios would also lead to significant detrimental impacts to the regional environment, including degradation of the sole-source aquifer. This alternative would not comply with numerous ARARs.

Short-Term Protection of Human Health and the Environment. The no-action alternative provides for the protection of both human health and the environment during the duration of ongoing site access controls and active maintenance programs. Loss of these controls would produce unacceptable risks to inadvertent intruders. Radon flux standards under the National Emission Standards for Hazardous Air Pollutants (NESHAP) would continue to be exceeded.

Screening Criteria - Implementability

Technical Feasibility. This alternative is technically feasible because no construction or maintenance activities would be performed.

Administrative Feasibility. No permits or licenses are required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials. No equipment or personnel are required to implement this alternative.

Screening Criteria - Cost

Capital Cost. No capital costs are associated with this alternative.

O&M Cost. There are no short-term or long-term O&M costs associated with this alternative.

Summary

This alternative does not meet RAOs and does not reduce the toxicity, mobility, or volume of wastes. Protection of human health and the environment can only be assured during the duration of active access controls and maintenance. The no-action alternative is readily implementable and has the least

cost. The no-action alternative was retained for detailed analysis as a baseline comparison to other remediation alternatives.

3.3.1.2 Alternative 1A - In Situ Containment

A description of this alternative is provided in Section 3.2.4.2.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by the multimedia cap, LC/DS, slurry wall, and run-on/runoff controls, the waste material would not be treated; therefore, as with the no-action alternative, there is no reduction of contaminant toxicity, mobility, or volume. The volume of contaminated material actually increases due to the injection of structural grout into the headspace of the silos.

Long-Term Protection of Human Health and the Environment. While Alternative 1A would preclude direct contact and ingestion of the residues through containment within a capping system, the long-term protection of human health and the environment could not be assured because this alternative relies exclusively on institutional controls and perpetual maintenance and does not utilize treatment to stabilize contaminants. These active contracts would be required to preclude access to and release from the disposal system. The potential exposures to receptors due to loss of residue containment would be significant and approach baseline conditions.

The feasibility of installing an effective LC/DS under the existing silos is also questionable. Failure of the system coupled with cap degradation could result in significant releases to the underlying soil and groundwater. Such releases could approximate baseline conditions.

The geologic siting conditions present at the Silos 1 and 2 area provide additional uncertainty as to the ability of Alternative 1A to effectively attain RAOs. Underlying the silo area is a fairly continuous silty sand lens providing a preferential horizontal flow path within the till toward Paddys Run. Additionally, only a limited thickness of low permeability clays underlay this sand lens to protect the Great Miami Aquifer. Based on lack of groundwater protection, this alternative would not comply with ARARs. Current preliminary data from a September 1993 Sloan's crayfish survey indicate populations residing in northern sections of Paddys Run on property and southern sections of Paddys

Run off property near New Haven Road. Relocation of Paddys Run could impact this state-threatened species.

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Short-Term Protection of Human Health and the Environment. Potential short-term impacts associated with construction of the multimedia cap include the disturbance of soil, airborne emissions due to dust, and the displacement or loss of vegetation. Appropriate mitigative measures would be applied during remedial actions to ensure appropriate worker and public health basic exposure requirements are attained. This alternative is protective of both human health and the environment during remediation because the planned activities minimize handling of the waste material; the waste material and bentonite layer remain in place, thereby minimizing the release of radon gas and direct contact with the waste material during remediation. It achieves ALARA criteria and requires minimal additional worker protection measures.

Because of the proximity of residents to Paddys Run and the temporary displacement of the fence in this area, the potential exists for exposure to trespassing children during the partial relocation of Paddys Run, which is needed to prevent lateral erosion to the cap due to the spatial requirements for the multimedia cap. However, based on the short duration of this activity (28 weeks) and administrative controls to preclude such access, the potential for exposure is minimal.

Minimal impacts to wetlands and floodplain areas are anticipated. However, relocation of Paddys Run could impact aquatic habitat, specifically the state-threatened Sloan's crayfish. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action alternative due to earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. Although the proposed containment technologies are widely used and well tested, a moderate level of difficulty would be experienced in construction of the multimedia cap, LC/DS, and slurry wall, and in relocation of Paddys Run. In particularly, the installation of the LC/DS would require boring horizontal holes through the soil underneath the silo structures and inserting slotted piping. Because the piping would be placed underneath an existing structure, a drainage layer and a filter layer could not be included with the system. Both of these layers are recommended by EPA guidance and would improve the efficiency of the LC/DS. Lack of these layers could allow leachate to by-pass the piping and migrate into the groundwater. Only a minimal

amount of maintenance would be required for the multimedia cap to continue to provide the necessary level of containment for the untreated material, and this can be accomplished using readily available resources.

Administrative Feasibility. No permits or licenses are required to implement this alternative. Although minimal impacts are anticipated, the relocation of Paddys Run will invoke ARARs related to floodplain, wetlands, and fish and wildlife protection. This will require coordination with the COE in addition to the State of Ohio and EPA Region V. While necessary deed restrictions and marking could be readily implemented, the long-term maintenance of these restrictions and ownership rights are questionable.

Availability of Services and Materials. The cap will be designed for an effective life of at least 1,000 years. No special equipment is required to implement this alternative. Installing an HDPE liner requires a specialty contractor. Resources required for maintenance and monitoring should be readily available.

Screening Criteria - Cost

The total present worth cost of this alternative is approximately $17 million.

Capital Cost. The major components of capital cost include grouting, cap installation, slurry wall construction, monitoring systems, and partial relocation of Paddys Run.

O&M Cost. Short-term O&M costs include those costs necessary to monitor operations and maintain access controls. Long-term O&M costs include maintaining institutional actions forever and conducting a review every five years to ensure that the remedy continues to provide adequate protection. Cap maintenance is expected to be minimal (e.g., patching and mowing) for the first 1,000 years. After that point, cap replacement may be needed. The present worth calculations do not consider O&M costs past 30 years.

Summary

There is significant uncertainty as to the ability of Alternative 1A to attain RAOs for the long term. Additional site conditions associated with the silo area provide significant uncertainty as to the ability to attain ARARs. The alternative does not reduce the toxicity or mobility of wastes, but it does increase the volume of waste. Migration of and exposure to contaminants are reduced, but the long-

term effectiveness is less certain than the remaining alternatives due to the dependence on institutional control and cap maintenance without using treatment to stabilize contaminants. There would be moderate difficulty in installing an effective LC/DS, which also impacts long-term protectiveness. Relocation of Paddys Run contributes to additional short-term impacts. The cost of this alternative is higher than the cost of the no-action alternative, but lower than the costs for all other Subunit A alternatives. This alternative was screened from further evaluation in the detailed analysis of alternatives because protectiveness cannot be adequately assured and goals of waste reduction/treatment cannot be met.

3.3.1.3 Alternative 2A - Removal, Stabilization, and On-Property Disposal

A description of this alternative is provided in Section 3.2.4.3.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Cement stabilization and vitrification have been effectively implemented to treat radiological and hazardous waste materials. Current testing of the vitrification process on FEMP residues has been limited to bench-scale level testing. To better understand the applicability and effectiveness of these treatment processes on the contents of Silos 1, 2, and 3, treatability studies were conducted. The treatability studies evaluated the process options of cement stabilization and vitrification for the contents of Silos 1, 2, and 3, and chemical extraction for the contents of Silos 1 and 2. The objectives of these studies were to determine the ability of the process options to effectively treat the residues by evaluating volume changes, compressive strengths, and leachability. A more detailed discussion of these treatability studies is provided in Appendix C of this document and in other supporting documents (Cement Stabilization/Chemical Extraction Treatability Study Report for Operable Unit 4 and the Operable Unit 4 Treatability Report for the Vitrification of Residues from Silos 1, 2, and 3; DOE 1993a and b, respectively).

Based on the results of the treatability studies performed for the cement stabilization and vitrification process options (see Appendix C), cement stabilization and vitrification achieved similar reductions in the toxicity characteristics of the material and the mobility of the contaminants. However, the resultant material volume increased by a range of 236 to 316 percent for the material from Silos 1 and 2 for the cement stabilization option and decreased by approximately 55 percent for the vitrification option. Vitrification achieves a reduction in contaminant volume and, through organic

destruction, a slight reduction in toxicity. Contaminants remaining in the vitrified mass are relatively immobile. Cement stabilization only reduces mobility by reducing the leachability of contaminants. After treatment with either option, the material will be stored in an above-grade disposal vault with a multi-media cap, LC/DS, and run-on/runoff controls to minimize the potential for contaminant migration. Residuals will, however, be generated as a by-product of the air emissions control system required for each process. Residuals will be disposed in the vault. Liquid residuals will be treated at the AWWT.

Long-Term Protection of Human Health and the Environment. While the stabilized material is very resistant to leaching, the direct radiation associated with residues would remain relatively unchanged. No treatment technology is available to reduce the direct radiation from radioactive materials. Direct radiation can only be reduced through natural decay. The treated residues would be disposed in an above-grade disposal vault with an LC/DS. The material disposal vault would be located over a sole-source aquifer in an area of moderate rainfall. The disposal facility would be designed for a 1,000-year life with features for intruder protection, and minimization of infiltration into and migration from the disposal facility. Performance of the disposal facility will be measured by a monitoring system. Monitoring systems were integrated into the disposal system designed for easy detection of migration from or infiltration into the disposal unit. Therefore, this alternative is considered to be protective of human health and the environment for the long term. The difficulty associated with the long-term effectiveness of this alternative is significantly less than Alternative 1A since the material will be immobilized (through treatment) and placed in an above-grade disposal vault. This alternative would comply with all pertinent ARARs. Compliance with the OAC 3745-27-07 prohibition on the location of a solid waste disposal vault over a sole source aquifer would be based on demonstrating the substantive technical criteria for an exemption to this requirement can be attained.

Short-Term Protection of Human Health and the Environment. In addition to those short-term impacts discussed for Alternative 1A, increased short-term exposure to workers is anticipated due to the additional material handling associated with the removal, treatment, disposal, and construction of the various remediation facilities. Of primary concern will be the risks from radon emissions after breaching the bentonite cover in the silos. By processing material in a facility that employs ALARA criteria and DOE Orders, such as air emission control systems, shielding, and appropriate personal protective equipment for the remediation workers, risks due to contaminant exposure should be controlled to acceptable levels.

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No impacts to wetlands, floodplain, or wildlife are anticipated. Specific to waste removal activities, potential short-term concerns are associated with removal of berm material and the silo contents. The berm currently provides structural stability to the silo structures. As the silo contents are removed, the berm material opposite the silo wall will be removed to ensure that the forces are balanced. However, the potential risk of silo collapse, though minimal, exists. Removal of the silo contents will be performed by a hydraulic mining device but will require that personnel be on the work platform over the silo domes once a week for approximately two hours, thus increasing the workers' physical and exposure hazards. Although this alternative presents greater potential short-term impacts, these impacts can be effectively controlled. Thus, this alternative will provide short-term protection to human health and the environment.

Screening Criteria - Implementability

Technical Feasibility. Although the cement stabilization technology is well understood and widely applied, its full-scale application to these materials has yet to be demonstrated. Vitrification of the silo residues is considered an innovative technology and as such, in spite of successful bench-scale treatability studies, the technical feasibility of implementing an effective full-scale system for this material is undetermined. A high level of difficulty would be experienced in the removal of the residues from the silos. Considerable worker protection techniques would be needed during the hydraulic removal of residues. The construction of the new RTS, vault, and treatment facility are readily implementable. Monitoring of influent conditions, additive mixtures, effluent characteristics, and off gases would be needed. Residuals from the off-gas system and liquid residuals would require treatment and/or disposal. The disposal facility would be designed to preclude the need for long-term maintenance. Similar facilities are in use throughout the hazardous and low-level waste disposal industry. Due to these factors, the technical feasibility of this alternative is less than that of Alternatives 0A and 1A.

Administrative Feasibility. No permits or licenses will be required. However, the substantive technical requirements of air emissions permits would need to be demonstrated.

Availability of Services and Materials. The equipment and engineering required for full-scale vitrification are not as readily available as that for cement stabilization, and its construction and operation are more complex. The availability of trained and experienced operators of joule-heated

melters is limited. Maintenance is also considered to be greater for vitrification. As a result, the implementability of the vitrification process option is the lower of the two.

Screening Criteria - Cost

The total present worth cost of this alternative using the vitrification process option is approximately $44 million. The total present worth cost of this alternative using the cement stabilization process option is approximately $74 million.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs include costs associated with maintaining access controls and monitoring systems, and operation and maintenance of the treatment system. Annual long-term costs include costs associated with maintaining monitoring systems.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. However, to ensure worker protection, significant monitoring, remote operations, and shielding would be required. Residue removal and treatment system operations contribute to the difficult implementability of this alternative. This alternative has higher costs than Alternatives 0A and 1A, but it is also more effective because it treats contaminants. Although the equipment costs for both process options are comparable, the disposal vault costs for the cement stabilization process are estimated to be nearly two times that of the vitrification option due to the increase in material volume resulting from the cement stabilization process. Although it is difficult to implement and more expensive, this alternative was retained for detailed evaluation because of its increased long-term effectiveness, relative to Alternative 1A, achieved through treatment and vaulting.

3.3.1.4 Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.4.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Alternative 3A.1 includes the same treatment process options as Alternative 2A, and, therefore, provides the same level of reduction in toxicity, mobility, and volume.

Long-Term Protection of Human Health and the Environment. As with Alternative 2A, this alternative will meet the RAOs of preventing direct contact with or ingestion of the material and preventing the release or migration of residues because the residues will be treated and disposed in a secure facility. Long-term reliability is likely greater than that of Alternative 2A for both treatment options because the material would be disposed off site in a remote location with little rainfall, sparse population, and a greater depth to groundwater. Since this alternative provides for removal and treatment of all the residues in Silos 1 and 2 and the sludge in the decant sump tank, no residuals will remain at Subunit A; thus, no residual risks will exist at the FEMP site. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. Alternative 3A.1 includes the same site preparation, construction, and material processing options as Alternative 2A and, thus, provides the same short-term protection of human health and the environment as Alternative 2A, with the exception of the disposal component of this alternative. Although the hazards associated with construction of the above-grade disposal vault are eliminated for Alternative 3A.1, packaging, shipping, and disposal of the material lowers the short-term protectiveness of human health due to material shipment hazards associated with additional material handling. Measures to reduce exposures to ALARA and to meet DOE Orders during packaging, shipping, and disposal operations, such as use of mechanical equipment and shielding, will be implemented. Shipment to NTS currently requires rail transport on the CSX rail lines, transfer to the Union Pacific rail lines in St. Louis, Missouri, and transfer of the material to trucks for road transportation in Las Vegas, Nevada. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of radioactive materials. The exposure, however, would be limited due to the treated form of the waste. Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required, thus increasing transportation risks.

Screening Criteria - Implementability

Technical Feasibility. The same issues related to the process options exist as those described for Alternative 2A. This alternative is slightly more technically straightforward than Alternative 2A because no on-property disposal is included in this alternative. Preliminary evaluation of the treated residue conducted as part of the treatability studies indicates the treated wastes would meet the NTS waste acceptance criteria. No long-term maintenance or monitoring, except as required by NTS, is associated with this alternative.

Administrative Feasibility. NTS is a DOE-owned facility which the FEMP has been utilizing for waste disposition since August 1985. Approval from the appropriate DOE field organization would be required to enable management of this 11(e)2 by-product material at NTS as low-level waste. Also, an addendum to the current "FEMP Application to Ship Waste to the Nevada Test Site" would be required because this stream would be considered a new waste stream not covered by the current application. This addendum would also require approval from NTS. This alternative will require agency approvals and coordination for the interstate shipment of the material. As with Alternative 2A, the substantive technical requirements of air emissions permits would also need to be demonstrated.

Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 2A.

Screening Criteria - Cost

The total present worth cost of the alternative using the vitrification process option is estimated at $44 million and the total present worth cost using the cement stabilization option is approximately $73 million.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with monitoring, maintaining access controls, and operating and maintaining the treatment system. There are no long-term monitoring costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. This alternative would be moderately difficult to implement although feasible. The administrative feasibility is more difficult than Alternatives 0A, 1A, and 2A. This alternative has a much higher cost than Alternatives 0A and 1A, but is approximately equal to the cost of Alternative 2A. This alternative was retained for detailed evaluation.

### 3.3.1.5 Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.4.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Reduction of contaminant toxicity, mobility, or volume is the same as Alternatives 2A and 3A.1.

Long-term Protection of Human Health and the Environment. RAOs are achieved by this alternative. The long-term protection of this alternative is improved over Alternative 2A because it is assumed that the 483-km (300-mi) facility can be sited in a location with slightly better performance characteristics than the on-property facility; however, the 483-km (300-mi) facility, with its siting in a temperate climate and a populous region, may not offer the long-term protection potentially achieved by disposal at NTS. The long-term effectiveness of each of three disposal options [on-property, NTS, and off-site within 483 km (300 miles)] are uncertain due to the lack of performance data on the long-term reliability of the disposal systems. The effectiveness of disposal systems in arid climates such as NTS would be expected to exceed similar disposal concepts in humid climates such as the FEMP site. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. The short-term protection of human health and the environment is identical to Alternative 2A during the construction and remediation phase. The potential risk due to material shipment off site to the 483-km (300-mi) facility may be lower than Alternative 3A.1 because this facility is closer than NTS. However, the risk is dependent on whether rail or truck is used because the transportation mode is directly related to the volume of material and thus, the potential exposure if an accident were to occur during shipment (e.g., injuries or deaths per ton-mile). The risk of transport is also dependent on the nature of loading/unloading

cycles, traffic patterns, roadbed conditions, or load configurations (for railroads). Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required, thus increasing transportation risks for the cement stabilization process option.

Screening Criteria - Implementability

Technical Feasibility. The technical feasibility is identical to that of Alternative 2A, except that additional effort is required for transportation of the treated material to the off-property storage facility.

Administrative Feasibility. The implementability of this alternative with respect to administrative feasibility would be difficult because it is unlikely that a new radioactive waste disposal facility can be sited, constructed, and the necessary agency and community approvals obtained in a timely manner. The difficulties that have been encountered by the State Compacts, in siting congressionally mandated radioactive waste disposal facilities, are likely to be encountered when implementing this alternative. Also, the substantive technical requirements of air emissions permits would need to be demonstrated.

Availability of Services and Materials. Availability of services and materials is comparable to that for Alternative 2A.

Screening Criteria - Cost

The total present worth cost of the alternative using the vitrification process option is approximately $44 million, and the total present worth cost using the cement stabilization process option is approximately $73 million. There is a significant uncertainty in these cost estimates due to the uncertainties in facility siting, permitting, etc.,.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include monitoring, maintaining access controls, and operation and maintenance of the treatment system. There are no long-term O&M costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. Construction of the removal system, treatment of the waste, and the administrative requirements related to siting a new disposal facility contribute to the very difficult implementability of this alternative. This alternative has a much higher cost than Alternatives 0A and 1A, but is comparable to the costs of Alternatives 2A and 3A.1. This alternative was screened out from further analysis because it is difficult to implement and provides less long-term protection than Alternative 3A.1.

3.3.1.6 Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal

A description of this alternative is provided in Section 3.2.4.5.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Chemical extraction has been shown to be effective in treating radioactive waste at other sites. To better understand the applicability and effectiveness of this treatment process on the contents of Silos 1 and 2, treatability studies were conducted. The objectives of these studies were to determine the ability of chemical extraction to effectively remove RCRA metals, uranium, thorium, polonium, protactinium, actinium, and radium. A more detailed discussion of these treatability studies is provided in Appendix C of this FS report and in a supporting document (Cement Stabilization/Chemical Extraction Treatability Study Report for Operable Unit 4; DOE 1993a).

Based on the results of the treatability studies performed, the chemical extraction process option combined with a stabilization process was determined to be technically feasible in reducing the raw material to a small volume of leach-resistant, vitrified, high-activity material; however, a much larger volume of low-activity material is generated. The activity level of this second waste stream is significantly less than that found in the raw residues, but it can not be considered clean material. Insufficient removal occurred during the studies to result in a fraction that could be disposed as nonhazardous, nonradiological waste.

Long-Term Protection of Human Health and the Environment. The long-term protection of human health and the environment is provided because the majority of the radiological and hazardous constituents of the raw material have been concentrated in a smaller quantity of vitrified or cement

stabilized product. The remaining material, although much greater in volume, contains significantly less activity than the raw material. The issues of protection for Alternative 2A are similar for this alternative. However, some of the contamination would not be stabilized prior to disposal. Therefore, despite the added treatment process, long-term reliability is slightly decreased. This alternative would comply with all pertinent ARARs. Compliance with the OAC 3745-27-07 prohibition on siting a solid waste disposal vault over a sole-source aquifer would be based on demonstrating the substantive technical requirements for an exemption to this requirement.

Short-Term Protection of Human Health and the Environment. This alternative has similar short-term protection as Alternative 2A.

Screening Criteria - Implementability

Technical Feasibility. Although the components of the material processing system, except for the vitrification unit, are readily available and commonly used, the constructability and reliability of this alternative are low because the chemical extraction process is complex and relies on many interdependent subprocesses. Increased shielding will be required to handle the high-activity component. Additionally, the vitrification process has yet to be demonstrated on this scale for these materials.

Maintenance of the processing equipment is expected to be higher than that for other removal and treatment alternatives, and long-term maintenance is required for the on-property disposal facility.

Administrative Feasibility. The substantive technical requirements of air emissions permits would need to be demonstrated, as described for Alternative 2A.

Availability of Services and Materials. This is the same as Alternative 2A.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $83 million, and the total present worth cost of the cement stabilization alternative is approximately $95 million.

Capital Cost. The major components of capital cost for this alternative include the chemical extraction, vitrification, and cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include monitoring, maintaining access controls, and operation and maintenance of the treatment system. Long-term O&M costs include costs associated with monitoring.

Summary

This alternative has similar pros and cons as Alternative 2A. However, treatability studies have shown that clean material cannot be achieved with chemical extraction. Therefore, this alternative was not retained for detailed analysis because the additional difficulty, effort, and cost of this alternative provide no benefits over Alternative 2A.

### 3.3.1.7 Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.4.6.

Screening Criteria Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. This alternative is less effective in reducing contaminant toxicity, mobility, or volume than Alternative 3A.1 because of the lower effectiveness of the chemical extraction process (refer to Alternative 4A for detailed discussion of chemical extraction effectiveness).

Long-Term Protection of Human Health and the Environment. The long-term protection is lower than for Alternative 3A.1 because clean material cannot be achieved with chemical extraction and some of the contamination would not be stabilized prior to disposal. Therefore, despite the added treatment process, long-term reliability is slightly decreased. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. This alternative has similar short-term protection as Alternative 3A.1.

Screening Criteria - Implementability

Technical Feasibility. The constructability and reliability of this alternative are lower than for Alternative 3A.1 because the chemical extraction process is complex and relies on many

interdependent subprocesses. Increased shielding would be required to handle the high-activity component. Maintenance of the processing equipment is expected to be higher than for Alternative 3A.1.

Administrative Feasibility. This administrative feasibility is the same as Alternative 3A.1.

Availability of Services and Materials. Availability of resources for this alternative is the same as that described for Alternative 3A.1.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $83 million, and the total present worth cost of the cement stabilization alternative is approximately $94 million.

Capital Cost. The major components of capital cost for this alternative include the chemical extraction, vitrification, and cement stabilization process equipment.

O&M Cost. Short-term O&M costs include costs associated with monitoring, maintaining access controls, and operation and maintenance of the treatment system. There are no long-term monitoring costs associated with this alternative for either process option because no material remains on the property.

Summary

This alternative is similar to Alternative 3A.1, but is not as effective since clean material cannot be achieved with chemical extraction. Therefore, this alternative was not retained for detailed analysis because the additional effort and cost of this alternative provide no benefits over Alternative 3A.1.

### 3.3.1.8 Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.4.6.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. This alternative is less effective in reducing contaminant toxicity, mobility, or volume than Alternative 3A.2 because of the

lower effectiveness of the chemical extraction process (refer to Alternative 4A for detailed discussion of chemical extraction effectiveness).

Long-Term Protection of Human Health and the Environment. The long-term protection is lower than for Alternative 3A.2 because clean material cannot be achieved with chemical extraction, and some of the contamination would not be stabilized prior to disposal. Therefore, despite the added treatment process, long-term reliability is slightly decreased. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. This alternative has similar short-term protection as Alternative 3A.2.

Screening Criteria - Implementability

Technical Feasibility. The constructability and reliability of this alternative are lower than for Alternative 3A.2 because the chemical extraction process is complex and relies on many interdependent subprocesses. Increased shielding will be required to handle the high-activity component. Maintenance of the processing equipment is expected to be higher than for Alternative 3A.2.

Administrative Feasibility. This administrative feasibility is similar to that of Alternative 3A.2.

Availability of Services and Materials. Availability of resources for this alternative is the same as described for Alternative 3A.2.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $83 million; the total present worth cost of the cement stabilization alternative is approximately $96 million.

Capital Cost. The major components of capital cost for this alternative include the chemical extraction, vitrification, and cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with monitoring, access controls, and operation and maintenance of the treatment system. There are no

long-term monitoring costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative has similar advantages and disadvantages as Alternative 3A.2. However, this alternative was not retained for detailed analysis because the additional effort and cost of this alternative provide no benefits over Alternative 3A.2.

3.3.1.9 Alternative 6A - Removal and On-Property Disposal

A description of this alternative is provided in Section 3.2.4.7.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by the vault, LC/DS, and run-on/runoff controls, the waste material would not be treated; therefore, there is no reduction of contaminant toxicity, mobility, or volume.

Long-Term Protection of Human Health and the Environment. This alternative would meet RAOs in the short term, but long-term compliance is uncertain. The residues would be placed in containers and in an above-grade disposal vault. The vault would be designed for a life of 1,000 years with the requirement for no continued maintenance. Placement of the packaged residues in the vault helps to reduce potential future exposures. While Alternative 6A would preclude direct contact and ingestion of the residues through containment within a vault, the long-term protection of human health and the environment could not be assured because of the reliance of this alternative exclusively on institutional controls and not on treatment to stabilize contaminants. This would be required to preclude access to and release from the disposal system. The potential exposures to receptors due to loss of residue containment could be significant and approach baseline conditions.

Alternative 6A would not comply with all ARARs. The vault would be sited at a location of the property that provides better geologic conditions (e.g., distance from aquifer and characteristics of overburden) than the current silos locations. However, it would be sited over a sole-source aquifer. The leaching rate of the waste form would be unchanged. Based on hydrogeologic modeling performed, U-238 is the only contaminant predicted to reach the aquifer. Treatability data for the vitrification process option (Appendix C, Table C.3-18) indicated that the ratio of the activity of U-

238 in the leachate from the untreated Silos 1 and 2 residues to the activity in the leachate from vitrified Silos 1 and 2 residues ranged from 75 to 70:1. The leaching of the contaminants from the untreated material using conservative assumptions would result in an unacceptable risk. Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the untreated material by future human and biota receptors. Exposures to receptors through these pathways (i.e., groundwater, air, etc.,) in the event of disposal vault failure would be expected to be significant due to the lack of treatment of the wastes. In addition, direct radiation exposure could be significant in the event of failure due to the presence of significant activity concentrations of long-lived gamma emitting radionuclides. Eventually, the risks from complete failure in the future could approach baseline risk conditions. Although compliance with the OAC 3745-27-07 prohibition on the location of a solid waste disposal facility over a sole-source aquifer could be met by demonstrating the substantive technical criteria could be achieved, adequate protection of the groundwater for use as drinking water could not be achieved.

Short-Term Protection of Human Health and the Environment. Potential short-term impacts associated with removal and packaging of the silos contents and construction of the vault include the disturbance of the silos contents and soil, airborne emissions due to dust, and the displacement or loss of vegetation. Appropriate mitigative measures would be implemented to ensure that DOE Orders for exposure and other worker and public health protection requirements are attained. This alternative is protective of both human health and the environment during remediation because the planned activities minimize handling of the silos contents; the silos contents would be removed hydraulically and placed directly into containers, thereby minimizing the release of radon gas which emanates from the silos residues and direct contact with the residues during remediation. By employing ALARA criteria and DOE Orders, such as use of appropriate protective equipment for the remediation workers, exposure risks would be controlled to acceptable levels.

Minimal impacts to wetlands and floodplain areas are anticipated. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action and in situ containment alternatives due to the earth-moving activities.

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Screening Criteria - Implementability

Technical Feasibility. A moderate level of difficulty would be experienced in removal of the residues and construction of the vault. Monitoring would be required since materials remain on the property. Since only a minimal amount of maintenance would be required for the vault to continue to provide the necessary level of containment for the untreated material, this can be accomplished using readily available resources. Therefore, this alternative is technically feasible.

Administrative Feasibility. No permits or licenses are required to implement this alternative. While necessary deed restrictions and markings could be readily implemented, the long-term maintenance of these restrictions and ownership rights are questionable.

Availability of Services and Materials. The vault would need to be designed for an effective life of at least 1,000 years. No special equipment is required to implement this alternative. Resources required for monitoring should be readily available.

Screening Criteria - Cost

The total present worth cost of this alternative is approximately $36 million.

Capital Cost. The major components of capital cost for this alternative include the removal equipment, packaging, and construction of the disposal vault.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with maintaining access controls and the collection/monitoring networks. Long-term maintenance costs include costs associated with required monitoring.

Summary

This alternative is not effective in reducing the toxicity, mobility, or volume of contaminants through treatment, but it reduces the migration and exposure to contaminants. This alternative would not comply with ARARs. There is some uncertainty as to the ability of Alternative 6A to attain RAOs for the long term. Residue removal and construction of the removal system and the vault provide a moderate level of difficulty to the implementability of this alternative. This alternative has higher costs than Alternatives 0A and 1A, but it is also more effective in reducing the mobility of the contaminants because it provides removal and placement of packaged material in an area of the site

with better geologic conditions (e.g., greater distance from the aquifer) than those alternatives. This alternative was screened from further evaluation in the detailed analysis because: protectiveness cannot be assured; goals of waste reduction/treatment cannot be met; and ARARs are not expected to be attained.

### 3.3.2 Subunit B - Residues Within Silo 3

#### 3.3.2.1 Alternative 0B - No Action

A description of this alternative is provided in Section 3.2.5.1.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Under this alternative, Subunit B would remain unchanged, except for conditions resulting from the completion of any removal actions that have already been completed or approved. Because the material is not treated or further contained, the material's toxicity, mobility, and volume would not be reduced.

Long-Term Protection of Human Health and the Environment. The material is not contained, treated, or modified. This alternative does not meet the RAOs of preventing the release or migration of residues. The potential risk to human health and the environment is increased due to the lack of 1) access controls and, in the event of structural failure of the silos, 2) any barrier preventing direct contact with Silo 3 material, particularly if this alternative is coupled with the no-action alternative for the silo structures (Subunit C). The long-term protection of current on-property workers would be increased since the existing facilities would no longer be operated or maintained. The overall current risks to potential receptors are increased and would be consistent with the baseline risk assessment results. The long-term risks, when exposed to the residues, exhibit risk exceeding the generally accepted risk range as defined in the NCP. This alternative would not comply with numerous ARARs.

Short-Term Protection of Human Health and the Environment. This alternative would provide short-term protection of both human health and the environment because there is no remediation and, therefore, no additional exposure risk to the public, workers, or the environment associated with waste handling.

Screening Criteria - Implementability

Technical Feasibility. This alternative is technically feasible because no construction or maintenance activities would be performed.

Administrative Feasibility. No permits or licenses are required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials. No equipment or personnel are required to implement this alternative.

Screening Criteria - Cost

Capital Cost. No capital costs are associated with this alternative.

O&M Costs. There are no short-term or long-term O&M costs associated with this alternative.

Summary

This alternative does not meet long-term RAOs and does not reduce the toxicity, mobility, or volume of wastes. It does provide additional short-term protection to human health and the environment. The no-action alternative is readily implementable and has the least cost. The no-action alternative was retained for detailed analysis as a baseline comparison to other remediation alternatives, as required by the NCP.

3.3.2.2 Alternative 1B - In Situ Containment

A description of this alternative is provided in Section 3.2.5.2.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by the multimedia cap, LC/DS, slurry wall, and run-on/runoff controls, the residues will not be treated; therefore, as with the no-action alternative, there is no reduction of contaminant toxicity, mobility, or volume. The volume of contaminated material actually increases due to the injection of structural grout into the headspace of the silos.

Long-Term Protection of Human Health and the Environment. While Alternative 1B would preclude direct contact and ingestion of the residues through containment within a capping system, the long-term protection of human health and the environment could not be assured because this alternative relies exclusively on institutional controls and perpetual maintenance and does not utilize treatment to stabilize contaminants. These institutional controls would be required to preclude access to and release from the disposal system. The potential exposures to receptors due to loss of residue containment could be significant and approach baseline conditions.

The feasibility of installing an effective LC/DS under the existing silo is also questionable. Failure of the system coupled with cap degradation could result in significant releases to the underlying soil and groundwater. Such releases could approximate baseline conditions.

The geologic siting conditions present at the Silo 3 area provide additional uncertainty as to the ability of Alternative 1B to effectively attain RAOs. Underlying the silo area is a fairly continuous silty sand lens, providing a preferential horizontal flow path within the till toward Paddys Run. Additionally, only a limited thickness of low permeability clays underlay this sand lens to protect the Great Miami Aquifer. Based on lack of groundwater protection, this alternative would not comply with ARARs. Current preliminary data from the September 1993 Sloan's crayfish survey indicate populations residing in northern sections of Paddys Run on property and southern sections of Paddys Run off property near New Haven Road. Relocation of Paddys Run could impact this state threatened species.

Short-Term Protection of Human Health and the Environment. Potential short-term impacts associated with construction of the multimedia cap include the disturbance of soil, airborne emissions due to dust, and the displacement or loss of vegetation. Appropriate mitigative measures would be implemented to ensure that DOE Orders for exposure and other worker and public health protection requirements are attained. This alternative is protective of both human health and the environment during remediation because the planned activities minimize handling of the residues; the residues remain in place, thereby minimizing the release of radon gas and direct contact with the residues during remediation. It achieves ALARA criteria and requires minimal additional worker protection measures.

Because of the proximity of residents to Paddys Run and the temporary displacement of the fence in this area, the potential exists for exposure to trespassing children during the partial relocation of

Paddys Run, which is needed to prevent lateral erosion to the cap due to the spatial requirements for the multimedia cap. However, based on the short duration of this activity (28 weeks), and the administrative controls to preclude such access, the potential for such exposures is minimal.

Minimal impacts to wetlands and floodplain areas are anticipated. However, relocation of Paddys Run could impact aquatic habitat, specifically the state threatened Sloan's crayfish. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action alternative due to the earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. Although the proposed containment technologies are widely used and well tested, a moderate level of difficulty would be experienced in construction of the multimedia cap, LC/DS, and slurry wall, and in relocation of Paddys Run. In particularly, the installation of the LC/DS would require boring horizontal holes through the soil underneath the silo structures and inserting slotted piping. Because the piping would be placed underneath existing structure, a drainage layer and a filter layer could not be included with the system. Both of these layers are recommended by EPA guidance and would improve the efficiency of the LC/DS. Lack of these layers could allow leachate to by-pass the piping and migrate into the groundwater. Since only a minimal amount of maintenance would be required for the multimedia cap to continue to provide the necessary level of containment for the untreated material, this can be accomplished using readily available resources.

Administrative Feasibility. No permits or licenses are required to implement this alternative. Although minimal impacts are anticipated, the relocation of Paddys Run will invoke ARARs related to floodplain, wetlands, and fish and wildlife protection. This will require coordination with the COE in addition to the State of Ohio and EPA Region V. While necessary deed restrictions and markings could be readily implemented, the long-term maintenance of these restrictions and ownership rights are questionable.

Availability of Services and Materials. The cap will need to be designed for an effective life of at least 1,000 years. No special equipment is required to implement this alternative. Installing an HDPE liner requires a specialty contractor. Resources required for maintenance and monitoring should be readily available.

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Screening Criteria - Cost

The total present worth cost of the alternative is approximately $12 million.

Capital Cost. The major components of capital cost include grouting, cap installation, slurry wall construction, monitoring systems, and partial relocation of Paddys Run. Although some of the cost components are the same as those for Alternative 1A, this is not taken into consideration in the present worth cost of this alternative.

O&M Cost. Short-term O&M costs include monitoring and access controls. Long-term O&M costs include required monitoring. Cap maintenance is expected to be minimal (e.g., patching and mowing) for the first 1,000 years. After that point, cap replacement may be needed. The present worth calculations do not consider O&M costs past 30 years.

Summary

There is significant uncertainty as to the ability of the Alternative 1B to attain RAOs for the long term. Additionally, site conditions associated with the silo area provide significant uncertainty as to the ability to attain ARARs. This alternative does not reduce the toxicity or mobility of wastes, but it does increase the volume of waste. Migration of and exposure to contaminants are reduced, but the long-term effectiveness is less certain than the remaining alternatives due to the dependence on institutional controls and cap maintenance without using treatment to stabilize contaminants. There would be moderate difficulty in installing an effective LC/DS, which also impacts long-term protectiveness. Relocation of Paddys Run contributes additional short-term impacts. The cost of this alternative is higher than the cost of the no-action alternative, but lower than the costs for all other Subunit B alternatives. This alternative was screened from further evaluation in the detailed analysis of alternatives because protectiveness cannot be adequately assured; goals of waste reduction/treatment cannot be met; and ARARs are not expected to be attained.

3.3.2.3 Alternative 2B - Removal, Stabilization, and On-Property Disposal

A description of this alternative is provided in Section 3.2.5.3.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Cement stabilization and vitrification have been effectively implemented to treat radiological and hazardous waste

materials. Current testing of the vitrification process on FEMP residues has been limited to bench-scale level testing. To better understand the applicability and effectiveness of these treatment processes on the contents of Silos 1, 2, and 3, treatability studies were conducted. The treatability studies evaluated the process options of cement stabilization and vitrification for the contents of Silos 1, 2, and 3.

Based on the results of the treatability studies performed for the cement stabilization and vitrification process options (see Appendix C), cement stabilization and vitrification achieved similar reductions in the toxicity characteristics of the material and the mobility of the contaminants. However, the resultant material volume increased by a range of 152 percent to 163 percent for the cement stabilization option and decreased by approximately 68 percent for the vitrification option. Vitrification achieves a reduction in contaminant volume. Contaminants remaining in the vitrified mass are relatively immobile. Cement stabilization only reduces mobility by reducing the leachability of contaminants. After treatment with either option, the material would be stored in an above-grade disposal vault with a cap, LC/DS, and run-on/runoff controls to minimize the potential for contaminant migration. Residuals would, however, be generated as a by-product of the air emissions control system required for each process. Residuals would be disposed in the vault. Liquid residuals would be treated at the FEMP AWWT.

Long-Term Protection of Human Health and the Environment. RAOs would be attained through the implementation of this alternative. The stabilized material would be very resistant to leaching. The limited radon emanation from Silo 3 residues would be essentially eliminated from the treated residues. The treated residue would be placed in an above-grade disposal vault. The vault would be designed for a life of 1,000-years with the requirement for no continued maintenance. Placement of the residues in the vault supplements the treatment process and promotes added assurance that potential future exposures would be negligible. In the event there was future degradation or inadvertent intrusion into the residue, the potential exposure to such receptors would not be expected to be significant as a result of the characteristics of the treated residue. This alternative would comply with all pertinent ARARs. Compliance with the OAC 3745-27-07 prohibition on the location of a solid waste disposal vault over a sole-source aquifer would be based on demonstrating the substantive technical criteria for an exemption to this requirement can be met.

Short-Term Protection of Human Health and the Environment. In addition to those short-term impacts discussed for Alternative 1B, increased short-term exposure to workers is anticipated due to

the additional residue handling associated with the removal, treatment, disposal, and construction of various remediation facilities. By processing material in a facility that employs ALARA criteria and DOE Orders, such as the application of air emission control equipment and appropriate personal protective equipment for the remediation workers, risks due to contaminant exposure should be controlled to acceptable levels.

Screening Criteria - Implementability

Technical Feasibility. Although the cement stabilization technology is well understood and widely applied, its full-scale application to these materials has yet to be demonstrated. Vitrification of the silo residues is considered an innovative technology and as such, in spite of successful bench-scale treatability studies, the technical feasibility of implementing an effective full-scale system for this material is undetermined. A moderate level of difficulty would be experienced in the removal of the waste, construction of the treatment facility and vault, and operation of the treatment system. Monitoring of influent conditions, additive mixtures, effluent characteristics, and off gases would be needed. Residuals from the off-gas system and liquid residuals would require treatment and/or disposal. Due to these factors, the technical feasibility of this alternative is less than that of Alternatives 0B and 1B.

Administrative Feasibility. No permits or licenses would be required. However, the substantive technical requirements of air emissions permits would also need to be demonstrated.

Availability of Services and Materials. The equipment and engineering required for full-scale vitrification are not as readily available as that for cement stabilization, and its construction and operation are more complex. The availability of trained and experienced operators of joule-heated melters are limited. Maintenance is also considered to be greater for vitrification. As a result, the implementability of the vitrification process option is the lower of the two.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $28 million, and the total present worth cost of the cement stabilization alternative is approximately $37 million.

Capital Cost. The major components of capital cost for this alternative include the vitrification and cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with maintaining access controls, operating and maintaining treatment equipment, and monitoring networks. Long-term maintenance costs include costs associated with required monitoring.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. Waste removal, construction of the various facilities required, and treatment system operation provide a moderate level of difficulty to the implementability of this alternative. This alternative has higher costs than Alternatives 0B and 1B, but it is also more effective because it provides treatment to reduce the mobility of the contaminants. Although the equipment costs for both process options are comparable, the disposal vault costs for the cement stabilization process are nearly 1.5 times that of the vitrification option due to the increase in material volume resulting from the cement stabilization process. This alternative was retained for detailed evaluation because of its increased long-term effectiveness, relative to 1B, achieved through treatment and placement in the vault.

3.3.2.4 Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.5.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Alternative 3B.1 includes the same treatment process options as Alternative 2B, and, therefore, provides the same level of reduction in toxicity, mobility, and volume.

Long-Term Protection of Human Health and the Environment. As with Alternative 2B, this alternative would meet the RAOs of preventing direct contact with or ingestion of the material and preventing the release or migration of residue because the residue would be treated and secured in a disposal facility. Long-term reliability is likely greater than that of Alternative 2B for both treatment options because the material would be stored off site in a remote location with little rainfall, sparse population, and a greater depth to groundwater. Since this alternative provides for removal and treatment of all the residue in Silo 3, no residuals would remain at Subunit B and thus, no residual risks would exist at the FEMP site. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. Alternative 3B.1 includes the same site preparation, construction, and material processing options as Alternative 2B and, thus, provides the same short-term protection of human health and the environment as Alternative 2B, with the exception of the disposal component of this alternative. Although the hazards associated with construction of the above-grade disposal vault are eliminated for Alternative 3B.1, packaging, shipping, and disposal of the material lowers the short-term protectiveness of human health due to material shipment hazards associated with additional material handling. Measures to reduce exposures to ALARA and to meet DOE Orders during packaging, shipping, and disposal operations, such as use of mechanical equipment and shielding, will be implemented. Shipment to NTS currently requires rail transport on the CSX rail lines, transfer to the Union Pacific rail lines in St. Louis, Missouri, and transfer of the material to trucks for road transportation in Las Vegas, Nevada. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of radioactive material. This exposure would be limited due to the characteristics of the treated waste. Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required, thus increasing transportation risks.

Screening Criteria - Implementability

Technical Feasibility. The same issues related to the process options exist as those described for Alternative 2B. This alternative is slightly more technically straightforward than Alternative 2B because no on-property disposal is included in this alternative. Preliminary evaluation of the treated residues completed as part of the treatability studies indicates the treated residues would meet the NTS waste acceptance criteria. No long-term maintenance or monitoring, except as required by NTS, is associated with this alternative.

Administrative Feasibility. NTS is a DOE-owned facility which the FEMP has been utilizing for waste disposition since August 1985. Approval from the appropriate DOE field office would be required to enable management of this 11(e)2 by-product material at NTS as low-level waste. Also, an addendum to the current NTS waste shipping application would be required for this new waste stream. This alternative would require agency approvals and coordination for the interstate shipment of the material. As with Alternative 2B, compliance with substantive requirements of air permits would be required. This would likely require as much effort as obtaining the approvals for construction of the on-property storage for Alternative 2B.

Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 2B.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $28 million, and the total present worth cost of the cement stabilization alternative is approximately $36 million.

Capital Cost. The major components of capital cost for this alternative include the vitrification and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include access control costs, monitoring, and operation and maintenance of treatment systems. There are no long-term monitoring costs associated with this alternative for either process option because no material remains on the property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. This alternative would be moderately difficult to implement although feasible. The administrative feasibility is similar to that of Alternative 2B, but more difficult than Alternatives 0B and 1B. This alternative has a much higher cost than Alternatives 0B and 1B, but has cost comparable to Alternative 2B. This alternative was retained for detailed evaluation.

### 3.3.2.5 Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.5.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Reduction of contaminant toxicity, mobility, or volume is the same as Alternatives 2B and 3B.1.

Long-Term Protection of Human Health and the Environment. RAOs are achieved by this alternative. The long-term protection of this alternative is improved over Alternative 2B because it is assumed that the 483-km (300-mi) facility can be sited in a location with slightly better performance

characteristics than the on-property facility; however, the 483-km (300-mi) facility, with its siting in a temperate climate and a populous region, may not offer the long-term protection achieved by disposal at NTS. The long-term effectiveness of each of three disposal options [on property, NTS, and off site within 483 km (300 miles)] are uncertain due to the lack of performance data on the long-term reliability of the disposal systems. The effectiveness of disposal systems in arid climates such as at NTS would be expected to exceed similar disposal concepts in humid climates as in the region of the FEMP. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. The short-term protection of human health and the environment is identical to Alternative 2B during the construction and remediation phase. The potential risk due to material shipment off site to the 483-km (300-mi) facility may be lower than Alternative 3B.1 because this facility is closer than NTS. However, the risk is dependent on whether rail or truck is used because the transportation mode is directly related to the volume of material and, thus, the potential exposure if an accident were to occur during shipment (e.g., injuries or deaths per ton-mile). The risk of transport is also dependent on the nature of loading/unloading cycles, traffic patterns, roadbed conditions, or load configurations (for railroads). Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required, thus increasing transportation risks for the cement stabilization process option.

Screening Criteria - Implementability

Technical Feasibility. The technical feasibility is identical to that of Alternative 2B, except additional effort is required for transportation of the treated material to the off-site storage facility.

Administrative Feasibility. The implementability of this alternative with respect to administrative feasibility would be difficult because it is unlikely that a new radioactive waste facility can be sited, constructed, and the necessary agency and community approvals obtained in a timely manner. The difficulties that have been encountered by the State Compacts, in siting congressionally mandated radioactive waste facilities, are likely to be encountered when implementing this alternative. Additionally, compliance with the substantive requirements of air permits will have to be demonstrated.

Availability of Services and Materials. Availability of services and materials is comparable to that for Alternative 2B.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $28 million, and the total present worth cost of the cement stabilization alternative is approximately $37 million. There is significant uncertainty in these cost estimates due to the uncertainties on facility siting, permitting, design, etc.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with monitoring and maintaining access controls, and operation and maintenance of the treatment system. There are no long-term O&M costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. Construction of the removal system, treatment of the waste, and the administrative requirements related to the substantive requirements of air permits and to siting a new disposal facility contribute to the very difficult implementability of this alternative. This alternative has a much higher cost than Alternatives 0B and 1B, but is comparable to the costs of Alternatives 2B and 3B.1. This alternative was screened out from further analysis because it is difficult to implement, and it provides less long-term protection with similar costs as Alternative 3B.1.

3.3.2.6 Alternative 4B - Removal and On-Property Disposal

A description of this alternative is provided in Section 3.2.5.5.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by the vault, LC/DS, and run-on/runoff controls, the waste material would not be treated; therefore, there is no reduction of contaminant toxicity, mobility, or volume.

Long-Term Protection of Human Health and the Environment. RAOs would be attained through the implementation of this alternative. The residues would be placed in containers and in an above-grade

disposal vault. The vault would be designed for a life of 1,000 years with the requirement for no continued maintenance. Placement of the packaged residues in the vault helps to reduce potential future exposures. This would be required to preclude access to and release from the disposal system. The potential exposures to receptors due to loss of residue containment could be significant and approach baseline conditions.

Alternative 4B would comply with all ARARs. The vault would be sited at a location of the property that provides better geologic conditions (e.g., distance from aquifer and characteristics of overburden) than the current silo location. However, it would be sited over a sole-source aquifer, thereby requiring a similar demonstration to meet the technical requirements for an exemption from OAC 3745-27-07(B)(5), as required by Alternative 2B.Vit.

Short-Term Protection of Human Health and the Environment. Potential short-term impacts associated with removal and packaging of the silo contents and construction of the vault include the disturbance of the silo contents and soil, airborne emissions due to dust, and the displacement or loss of vegetation. Appropriate mitigative measures would be implemented to ensure that DOE Orders for exposure and other worker and public health protection requirements are attained. This alternative is protective of both human health and the environment during remediation because the planned activities minimize handling of the silo contents; the silo contents is removed pneumatically and placed directly into containers, thereby minimizing the release of the limited amount of radon gas which emanates from the residues and direct contact with the residues during remediation. By employing ALARA criteria and DOE Orders, such as use of appropriate protective equipment for the remediation workers, exposure risks would be controlled to acceptable levels.

Minimal impacts to wetlands and floodplain areas are anticipated. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action and in situ containment alternatives due to the earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. A moderate level of difficulty would be experienced in removal of the residues and construction of the vault. Monitoring would be required since materials remain on the property. Since only a minimal amount of maintenance would be required for the vault to continue to

provide the necessary level of containment for the untreated material, this can be accomplished using readily available resources. Therefore, this alternative is technically feasible.

Administrative Feasibility. No permits or licenses are required to implement this alternative. While necessary deed restrictions and markings could be readily implemented, the long-term maintenance of these restrictions and ownership rights are questionable.

Availability of Services and Materials. The vault will need to be designed for an effective life of at least 1,000 years. No special equipment is required to implement this alternative. Resources required for monitoring should be readily available.

Screening Criteria - Cost

The total present worth cost of this alternative is approximately $22 million.

Capital Cost. The major components of capital cost for this alternative include the removal equipment, packaging, and construction of the disposal vault.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with maintaining access controls and the collection/monitoring networks. Long-term maintenance costs include costs associated with required monitoring.

Summary

This alternative is not effective in reducing the toxicity, mobility, or volume of contaminants through treatment, but it reduces the migration and exposure to contaminants. This alternative would comply with ARARs. RAOs would be achieved. Residue removal and construction of the removal system and the vault provide a moderate level of difficulty to the implementability of this alternative. This alternative has higher costs than Alternatives 0B and 1B, but it is also more effective in reducing the mobility of the contaminants because it provides removal and placement of packaged material in an area of the site with better geologic conditions (e.g., greater distance from the aquifer) than those alternatives. This alternative was retained for detailed evaluation because of its increased long-term effectiveness, relative to Alternative 1B, achieved through placement in the vault, relative ease of implementation, and lower cost than all treatment alternatives.

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### 3.3.3 Subunit C - Silos Structures and Soils

#### 3.3.3.1 Alternative 0C - No Action

A description of this alternative is provided in Section 3.2.6.1.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Because the soil and structures are not treated, there is no reduction in toxicity, mobility, or volume.

Long-Term Protection of Human Health and the Environment. The risks from exposure to soil would be consistent with levels presented in the Baseline Risk Assessment, and would, therefore, be unacceptable. Erosion of the soil would continue to Paddys Run, resulting in off-site migration of contaminants. Without mitigative measures, the silos will deteriorate and collapse. This alternative would not comply with numerous ARARs.

Short-Term Protection of Human Health and the Environment. This alternative would provide short-term protection of both human health and the environment because there is no remediation and, therefore, no additional exposure risk to the public, workers, or the environment associated with waste handling.

Screening Criteria - Implementability

Technical Feasibility. This alternative is technically feasible because no construction or maintenance activities would be performed.

Administrative Feasibility. No permits or licenses are required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials. No equipment or personnel are required to implement this alternative.

Screening Criteria - Cost

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Capital Cost. No capital costs are associated with this alternative.

O&M Cost. There are no short-term or long-term O&M costs associated with this alternative.

Summary

This alternative does not meet RAOs and does not reduce the toxicity, mobility, or volume of wastes. The no-action alternative is readily implementable and has the least cost. The no-action alternative was retained for detailed analysis as a baseline comparison to other remediation alternatives, as required by the NCP.

3.3.3.2 Alternative 1C - Demolition and Containment

A description of this alternative is provided in Section 3.2.6.2.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Investigations are currently underway within Operable Units 3 and 5 to examine technologies to minimize waste volumes required for disposal. Technologies being examined include surface decontamination techniques, such as vacuum scabbling for construction materials and washing techniques for soil. Such techniques would be employed to the extent feasible by Alternative 1C to minimize the volume of demolition debris and soil requiring containment. Concrete exhibiting highly elevated direct radiation fields would be segregated from Subunit C wastes for disposition in accordance with the selected alternative for Subunit A or Subunit B.

Long-Term Protection of Human Health and the Environment. The long-term protection of human health and the environment is improved by this alternative because the material is contained under a multimedia cap, which will significantly reduce the infiltration of rainwater and subsequent leachate generation. However, this alternative would not comply with groundwater protection ARARs. The cap would be designed to preclude active maintenance for 1,000 years. If there is no failure of these components, this alternative prevents access to the residues, minimizes leachate production, prevents erosion to Paddys Run, and protects against direct contact with the soil. Physical hazards due to the silos are also removed. Current preliminary data from the September 1993 Sloan's crayfish survey

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indicate populations residing in northern section of Paddys Run on property and southern sections of Paddys Run off property near New Haven Road. Relocation of Paddys Run could impact this state threatened species.

Short-Term Protection of Human Health and the Environment. During the implementation of Alternative 1C, the general public is not likely to be exposed to contaminants because this alternative does not involve handling of the silo contents. However, potential short-term impacts associated with demolition of the silos and construction of the multimedia cap include the disturbance of soil, airborne emissions due to dust, injury to workers due to overhead construction activities using a crane, and the displacement or loss of vegetation. Through the implementation of appropriate mitigative measures and the use of personal protective equipment and construction equipment with emission controls, these impacts would meet DOE Orders for exposure to workers and the public. This alternative is protective of both human health and the environment during remediation because the planned activities eliminate handling of the residues and minimize the direct contact with the concrete and soil through use of in situ capping of demolished silo structures, berm, and soil material. It achieves ALARA criteria and requires minimal additional worker protection measures.

Because of the proximity of residents to Paddys Run and the temporary displacement of the fence in this area, the potential exists for exposure to trespassing children during the partial relocation of Paddys Run, which is needed to prevent lateral erosion to the cap due to the spatial requirements for the multimedia cap. However, based on the short duration of this activity (28 weeks), and in consideration of the active access controls in place, this risk is not considered significant.

Minimal impacts to wetlands and floodplain areas are anticipated. However, relocation of Paddys Run could impact aquatic habitat, specifically the state threatened Sloan's crayfish. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action alternative due to demolition and earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. The feasibility of this alternative is very good because the proposed silo decontamination process option (e.g., vacuum scabbling) has been successfully demonstrated at other facilities on similar media. Diamond wire cutting is an industry-accepted method for cutting concrete at other nuclear facilities, but with heavy, reinforced concrete, it would be a high-maintenance item

and would require water coolant for the cable. This alternative can be readily implemented using available resources.

Administrative Feasibility. No permits or licenses will be required. Although minimal impacts are anticipated, the relocation of Paddys Run would invoke ARARs related to floodplain, wetlands, and fish and wildlife protection. This would require coordination with the COE in addition to the State of Ohio and EPA Region V. Necessary deed restrictions and ownership rights are questionable.

Availability of Services and Materials. Monitoring could be readily implemented for the long-term maintenance of the deed restrictions, and the cap would need to be designed for an effective life of at least 1,000 years. No special equipment is required to implement this alternative. Resources required for maintenance and monitoring should be readily available.

Screening Criteria - Cost

The total present worth cost of the alternative is approximately $33 million.

Capital Cost. The major components of capital cost for this alternative include the cap and monitoring systems.

O&M Cost. Short-term O&M costs associated with this alternative are limited and include only monitoring. Long-term O&M costs include costs associated with required monitoring.

Summary

Alternative 1C meets RAOs. Migration of and exposure to contaminants are reduced, but the long-term effectiveness is uncertain. The cost of this alternative is higher than the cost of the no-action alternative, but lower than the costs for all other Subunit C alternatives. This alternative was screened from further consideration because of the improbability of meeting ARARs.

3.3.3.3 Alternative 2C - Demolition, Removal, and On-Property Disposal

A description of this alternative is provided in Section 3.2.6.3.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Investigations are currently underway within Operable Units 3 and 5 to examine technologies to minimize waste volumes required for disposal. Technologies being examined include surface decontamination techniques such as vacuum scabbling for construction materials and washing techniques for soil. Such techniques would be employed to the extent feasible by Alternative 2C to minimize the volume of demolition debris and soil requiring disposal. Concrete exhibiting highly elevated direct radiation fields would be segregated from Subunit C wastes for disposition in accordance with the selected alternative for Subunit A or Subunit B.

Long-Term Protection of Human Health and the Environment. Contaminated soils, concrete, and other debris would be placed in an above-grade disposal vault with a design life of 1,000 years. The long-term performance of such systems is uncertain. Modeling studies conducted to support the siting of similar units across the United States have projected reliable long-term performance. Similar disposal concepts, fulfilling equivalent design requirements (i.e., 1,000 year design life), have been adopted for the disposal of untreated uranium mill tailings and associated debris in compliance with 41 CFR 192 Subpart A. These design concepts have been employed in humid climates, much like that existing at the FEMP.

In the event the disposal system was breached through long-term erosion or intrusion, exposures would be expected to be minimal due to the low concentration levels of the contaminated wastes.

Alternative 2C will be effective in attaining RAOs for residual soils in the Operable Unit 4 area. Soil excavations within Operable Unit 4 will continue until defined cleanup goals are attained. Discussions on proposed cleanup goals are presented on the detailed analysis of Subunit C alternatives in Section 4.0. Long-term protectiveness would be attained through cleanup to these levels and placement of clean soils over excavated areas. The need or requirement for continued administrative controls to preclude intrusion activities to remaining residuals will be addressed in Section 4.0. This alternative would meet all pertinent ARARs. Compliance with the OAC 3745-27-07 prohibition on the location of a solid waste disposal vault over a sole-source aquifer would be based on demonstrating the substantive technical criteria for an exemption to this requirement can be met.

Short-Term Protection of Human Health and the Environment. In addition to those short-term impacts discussed for Alternative 1C, increased short-term exposure to workers is anticipated due to the additional residue handling associated with the removal, disposal, and construction of the various facilities. By employing ALARA criteria and appropriate mitigative measures, risks due to contaminant exposure should be controlled to acceptable levels.

Minimal impacts to wetlands, floodplain, or wildlife are anticipated. Thus, this alternative would provide short-term protection to human health and the environment.

Screening Criteria - Implementability

Technical Feasibility. The constructability and reliability of this alternative is moderate when compared to Alternative 1C because of the additional activities required for subsurface soil, decant sump tank, and process piping excavation.

Administrative Feasibility. No permits or licenses are required.

Availability of Services and Materials. Personnel and equipment required should be readily available.

Screening Criteria - Cost

The total present worth cost of the alternative is approximately $34 million. There is uncertainty on the volume of soils to be removed to attain cleanup goals.

Capital Cost. The major components of capital cost for this alternative include the disposal facility and monitoring system.

O&M Cost. Short-term O&M costs associated with this alternative are limited to monitoring costs. Long-term O&M costs include required monitoring.

Summary

Alternative 2C meets RAOs. Migration of and exposure to contaminants are reduced, but there is some uncertainty as to the long-term effectiveness of the disposal system. Potential risks in the event of degradation of the disposal vault are projected to be low due to the low concentration of contaminants in Subunit C wastes. The cost of this alternative is higher than the cost of the no-action

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alternative and Alternative 1C, the same as Alternative 3C.3, but lower than the costs for the remaining Subunit C alternatives. This alternative was selected for further evaluation in the detailed analysis of alternatives.

3.3.3.4 Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.6.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Investigations are currently underway within Operable Units 3 and 5 to examine technologies to minimize waste volumes required for disposal. Technologies being examined include surface decontamination techniques such as vacuum scabbling for construction materials and washing techniques for soil. Such techniques would be employed to the extent feasible by Alternative 3C.1 to minimize the volume of demolition debris and soils requiring disposal. Concrete exhibiting highly elevated direct radiation fields would be segregated from Subunit C wastes for disposition in accordance with the selected alternative for Subunit A or Subunit B.

Long-Term Protection of Human Health and the Environment. As with Alternative 2C, this alternative would meet the RAOs of preventing direct contact with or ingestion of the material and preventing the release or migration of waste material because the waste material would be disposed in a secure facility. Long-term reliability is likely greater than that of Alternative 2C because the material would be disposed off site in a remote location with little rainfall, sparse population, and a greater depth to groundwater.

Alternative 3C.1 would be effective in attaining RAOs for residual soils in the Operable Unit 4 area. Soil excavations within Operable Unit 4 would continue until defined cleanup goals are attained. Discussions on proposed cleanup goals are presented in the detailed analysis of Subunit C alternatives in Section 4.0. Long-term protectiveness would be attained through cleanup to these levels and placement of clean soils over excavated areas. The need or requirement for continued administrative controls to preclude intrusion activities to remaining residuals will be addressed in Section 4.0. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human and the Environment. Alternative 3C.1 includes the same site preparation, construction, and decontamination as Alternative 2C and, thus, provides the same short-term protection of human health and the environment as Alternative 2C, with the exception of the disposal component of this alternative. Although the hazards associated with construction of the above-grade disposal vault are eliminated for Alternative 3C.1, packaging and shipping the material off site to NTS lowers the short-term protectiveness of human health due to material shipment hazards associated with additional material handling. Measures to reduce exposures to ALARA and to meet DOE Orders during packaging, shipping, and disposal operations will be implemented. Shipment to NTS under this alternative currently requires rail transport on the CSX rail lines, transfer to the Union Pacific rail lines in St. Louis, Missouri, and transfer of the material to trucks for road transportation in Las Vegas, Nevada. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of low concentration radioactive material. The risks due to such accidents would be limited due to the low concentrations of contaminates in the wastes.

Screening Criteria - Implementability

Technical Feasibility. Preliminary evaluation of the material generated by this alternative indicates it would meet the NTS waste acceptance criteria No long-term maintenance, except as required by NTS, is associated with this alternative.

Administrative Feasibility. NTS is a DOE-owned facility, which has been employed by the FEMP for waste disposition since August 1985. The wastes generated in this alternative are similar to currently approved waste streams. Approval from the appropriate DOE field office would be required to enable management of this 11(e)2 by-product material for disposal at NTS.

Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 2C.

Screening Criteria - Cost

The total present worth cost of the alternative is estimated at $76 million.

Capital Cost. The major components of capital cost for this alternative include removal, packaging, transport, and disposal of wastes.

O&M Cost. Short-term O&M costs associated with this alternative would be limited to monitoring. There are no long-term O&M costs associated with this alternative.

Summary

RAOs would be achieved. The administrative feasibility is more difficult than Alternatives 0C, 1C, and 2C. This alternative has a much higher cost than Alternatives 0C, 1C, and 2C. This alternative was retained for detailed evaluation.

### 3.3.3.5 Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at a Permitted Commercial Disposal Site

A description of this alternative is provided in Section 3.2.6.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. The reduction in toxicity, mobility, or volume for this alternative is identical to that for Alternative 3C.1.

Long-Term Protection of Human Health and the Environment. The long-term protection for this alternative is almost identical to that for the NTS disposal option (Alternative 3C.1) because both facilities are located in arid climates with sparse populations. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. This alternative includes the same site preparation, construction, material processing, and disposal options as Alternative 3C.1 and, thus, provides essentially the same short-term protection of human health and the environment. However, short-term protection would be slightly greater because additional handling required during transportation and packaging for Alternative 3C.1 is not needed. Measures to reduce exposures to ALARA and to meet DOE Orders during shipping operations will be implemented. Shipment to the permitted commercial disposal site contemplates rail transport. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of low concentration radioactive material.

Screening Criteria - Implementability

Technical Feasibility. Technical feasibility is the same as Alternative 3C.1.

Administrative Feasibility. DOE Order 5820.2A prohibits DOE material from being disposed in a commercial facility. To implement this alternative, an exemption to this DOE Order would be required. Such exemptions have been previously granted on a limited basis for small quantities of select waste streams.

Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 3C.1.

Screening Criteria - Cost

The total present worth cost of the alternative is estimated at $44 million.

Capital Cost. The major components of capital cost for this alternative include transport and disposal of wastes.

O&M Cost. Short-term O&M costs associated with this alternative are limited. There are no long-term O&M costs associated with this alternative for either process option because no material remains on the property.

Summary

RAOs would be achieved. This alternative is moderately difficult to implement based on technical feasibility and administrative feasibility issues, such as disposal at a commercial facility. Costs are the highest of any Subunit C alternative, other than Alternative 3C.1. This alternative was retained for detailed evaluation.

### 3.3.3.6 Alternative 3C.3 - Demolition, Removal, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.6.4.

Screening Criteria - Effectiveness

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Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. The reduction in toxicity, mobility, or volume for this alternative is identical to that for Alternative 3C.1.

Long-Term Protection of Human Health and the Environment. RAOs are achieved by this alternative. The long-term protection of this alternative is improved over Alternative 2C because it is assumed that the 483-km (300-mi) facility can be sited in a location with slightly better performance characteristics than the on-property facility; however, the 483-km (300-mi) facility, with its siting in a temperate climate and a populous region, may not offer the long-term protection achieved by disposal at a facility in an arid climate. This alternative would comply with all pertinent ARARs.

Short-Term Protection of Human Health and the Environment. The short-term protection of human health and the environment is identical to Alternative 3C.1 during the construction and remediation phase. The potential risk due to material shipment off site to the 483-km (300-mi) facility may be lower than Alternative 3C.1 because this facility is closer than NTS. However the risk is dependent on the nature of loading/unloading cycles, traffic patterns, roadbed conditions, or load configurations (for railroads).

Screening Criteria - Implementability

Technical Feasibility. The technical feasibility is identical to that of Alternative 3C.1.

Administrative Feasibility. The implementability of this alternative with respect to administrative feasibility would be difficult because it is unlikely that a new radioactive waste disposal facility can be sited, constructed, and the necessary agency and community approvals obtained in a timely manner. The difficulties that have been encountered by the State Compacts, in siting congressionally mandated radioactive waste disposal facilities, are likely to be encountered when implementing this alternative.

Availability of Services and Materials. Availability of services and materials is comparable to that for Alternative 2C.

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Screening Criteria - Cost

The total present worth cost of the alternative is approximately $34 million.

Capital Cost. The major components of capital cost for this alternative include the transport and disposal of waste.

O&M Cost. Short-term O&M costs associated with this alternative are limited to monitoring. There are no long-term O&M costs associated with this alternative for either process option because no material remains on property.

Summary

RAOs would be achieved. This alternative is moderately difficult to implement based on technical feasibility, but is extremely difficult based on administrative feasibility issues. This alternative was not retained for detailed evaluation because the administrative requirements related to siting a new disposal facility contribute to the very difficult implementability of this alternative.

## 3.4 ALTERNATIVE SCREENING SUMMARY

The alternatives have been evaluated against the three general criteria of effectiveness, implementability, and cost. The intent of this evaluation and screening was to select those alternatives for a given GRA that best represent the range of options available for that GRA. If a GRA offered several alternatives that provided similar levels of effectiveness, then those alternatives that were most implementable for the least cost were selected for evaluation in the detailed analysis of alternatives. For those GRAs that possessed a number of alternatives offering different treatment processes with similar overall performance, the best alternative representing each treatment option was selected.

### 3.4.1 Subunit A

The following alternatives have been selected for further evaluation in the detailed analysis of alternatives:

- Alternative 0A - No Action
- Alternative 2A - Removal, Stabilization, and On-Property Disposal
- Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS

The selected alternatives represent the most viable and cost-effective alternatives for the no-action, institutional, containment, removal, treatment, and disposal GRAs. The material treatment provided in the selected alternatives include vitrification and cement stabilization. The removal and treatment alternatives offer both on-property and off-site disposal to provide additional flexibility in material disposal.

The following alternatives have been eliminated from the alternative screening process:

- Alternative 1A - In Situ Containment
- Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site
- Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal
- Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS
- Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site
- Alternative 6A - Removal and On-Property Disposal

All alternatives that included chemical extraction were eliminated from further analysis because chemical extraction was determined to not provide additional benefits relative to the increased costs. All alternatives that dispose of the material at a facility to be constructed within 483 km (300 mi) of the FEMP site were not retained for evaluation in the detailed analysis because of the significant concerns for implementability. The proposed disposal facility does not currently exist, and given the present political and social climate concerning radioactive waste disposal facility siting and the fact that no new radioactive waste disposal facility has been constructed and licensed recently, it is extremely unlikely that this facility could be designed, sited, approved, constructed, and made ready to receive material at the conclusion of material processing operations. The in situ containment and disposal with no treatment alternatives were eliminated because protectiveness cannot be assured; goals of reduction/treatment cannot be met; and all ARARs would not be attained.

### 3.4.2 Subunit B

The following alternatives have been selected for further evaluation in the detailed analysis of alternatives:

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- Alternative 0B - No Action

- Alternative 2B - Removal, Stabilization, and On-Property Disposal
- Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS - 5205
- Alternative 4B - Removal and On-Property Disposal

The selected alternatives represent the most viable and cost-effective alternatives for the no-action, institutional, containment, removal, treatment, and disposal GRAs. The vitrification and cement stabilization treatment options proposed in the selected alternatives provide distinctly different but viable treatment options. The removal and treatment alternatives offer both on-property and off-site disposal to provide additional flexibility in material disposal.

The following alternatives have been eliminated in the alternative screening process:

- Alternative 1B - In Situ Containment
- Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

The alternatives that proposed material disposal at a facility to be constructed within 483 km (300 mi) of the FEMP site were not retained for evaluation in the detailed analysis because of the significant concerns for implementability. The proposed disposal facility does not currently exist, and given the present political and social climate concerning radioactive waste disposal facility siting and the fact that no new radioactive waste disposal facility has been constructed and licensed recently, it is extremely unlikely that this facility could be designed, sited, approved, constructed, and made ready to receive material at the conclusion of material processing operations. The in situ containment alternative was eliminated because protectiveness cannot be assured; goals of reduction/treatment cannot be met; and all ARARs would not be attained.

### 3.4.3 Subunit C

The following alternatives have been selected for further evaluation in the detailed analysis of alternatives:

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, and On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS
- Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at a Permitted Commercial Disposal Site

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The selected alternatives preserve the full range of the GRAs and offer the flexibility of on-property or off-site disposal for all material.

The following alternatives have been eliminated from the alternative screening process:

- Alternative 1C - Demolition and Containment
- Alternative 3C.3 - Demolition, Removal, Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

The alternatives that proposed material disposal at a facility to be constructed within 483 km (300 mi) of the FEMP site were eliminated for the reasons discussed in Section 3.4.1 and 3.4.2. The in situ containment alternative was eliminated because of existing geological conditions, and it would not meet all ARARs.

Tables 3-1 through 3-3 summarize the alternative screening for each subunit. Shading is used to designate those alternatives eliminated from further evaluation.

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## TABLE 3-1

## ALTERNATIVE SCREENING ANALYSIS FOR SUBUNIT A

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| 0A - No Action | • NA | Does not meet long-term RAOs. Waste is not treated; thus, there are no reductions in toxicity, mobility, and volume. Would not meet ARARs. | Readily implementable | Low |
| 1A - In Situ Containment | • Radon monitoring<br>• Groundwater monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Subsurface Drains<br>• Slurry wall<br>• Multimedia cap<br>• Void space grout<br>• Diversion/collection<br>• Grading<br>• Revegetation | Meets short-term RAOs. Long-term protection cannot be assured. Does not reduce toxicity or mobility of wastes, but increases volume. Migration of contaminants reduced. Would not meet ARARs. | Technically implementable with moderate difficulty. Long-term maintenance and ownership is questionable. | Low |
| 2A - Removal, Stabilization, and On-Property Disposal | • Radon monitoring<br>• Groundwater monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Diversion/collection<br>• Grading<br>• Revegetation<br>• Slurry pump w/jetting ring<br>• Cement-based stabilization<br>• Vitrification<br>• Solid/liquid separation<br>• FEMP AWWT<br>• Above-grade disposal vault | Effective in reducing the toxicity, mobility, or volume of wastes. RAOs achieved. However, short-term effectiveness is moderate due to the required construction activities, and long-term effectiveness is uncertain due to the potential risks associated with intrusion into the treated waste. Would meet ARARs. | Moderately difficult to implement due to the operation treatment process and meeting substantive requirements of air permits | Medium |



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**TABLE 3-1**
**(Continued)**

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| 3A - Removal, Stabilization, and Off-Site Disposal | • Slurry pump w/jetting ring<br>• Cement-based stabilization<br>• Vitrification<br>• Solid/liquid separation<br>• FEMP AWWT<br>• Rail/truck transport<br>• Nevada Test Site (3A.1) | 3A.1 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. Long-term effectiveness is greater than 2A because waste will be disposed off site in a remote location, with better geologic conditions and no residuals remain at Subunit A. Short-term effectiveness is moderate due to the required construction activities and hazards of waste shipments. Would meet ARARs. | Moderately difficult to implement due to operation of treatment system; meeting substantive requirements of air permits, and obtaining disposal approvals | Medium |
| | • New facility within 483 km (300 mi) (3A.2) | 3A.2 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. However, short-term effectiveness is moderate due to the required construction activities, but is lowered due to hazards with waste shipments. Long-term effectiveness is greater than 2A because waste will reside off site, but not as great as 3A.1. Would meet ARARs. | Difficult to implement due to operation of treatment system, siting new facility, and meeting substantive requirements of air permits | Medium |
| 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal | • Radon monitoring<br>• Groundwater monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Diversion/collection<br>• Grading<br>• Revegetation<br>• Slurry pump w/jetting ring<br>• Solid/liquid separation<br>• FEMP AWWT<br>• Chemical extraction<br>• Above-grade disposal vault | Similar short-term and long-term effectiveness as Alternative 2A. However, some contamination is not stabilized prior to disposal, thus long-term reliability is decreased. Would meet ARARs. | Difficult to implement due to complex treatment and reliance on interdependent processes | High |

**TABLE 3-1**
**(Continued)**

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| 5A - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal | • Slurry pump w/jetting ring<br>• Cement-based stabilization<br>• Vitrification<br>• Solid/liquid separation<br>• FEMP AWWT<br>• Chemical extraction<br>• Rail/truck transport<br>• Nevada Test Site (5A.1) | 5A.1 - Less effective than Alternative 3A.1 because of lower effectiveness of chemical extraction process. Would meet ARARs. | More difficult than Alternative 3A.1 due to complex treatment and reliance on interdependent processes | High |
| | • New facility within 483 km (300 mi) (5A.2) | 5A.2 - Less effective than Alternative 3A.2 because of lower effectiveness of chemical extraction process. Would meet ARARs. | More difficult than Alternative 3A.2 due to complex treatment and reliance on interdependent processes | High |
| 6A - Removal and On-Property Disposal | • Radon monitoring<br>• Groundwater monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Diversion/collection<br>• Grading<br>• Revegetation<br>• Slurry pump w/jetting ring<br>• Solid/liquid separation<br>• FEMP AWWT<br>• Above-grade disposal vault | Does not reduce the toxicity, mobility, or volume of wastes. However, short-term effectiveness is moderate due to the required construction activities, and long-term effectiveness is uncertain due to the potential risks associated with intrusion into the untreated waste. Would not comply with ARARs. | Moderately difficult to implement due to the residue removal and construction of the removal system and vault. | Medium |

NOTE: Shading designates those alternatives eliminated from further evaluation.



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## TABLE 3-2

## ALTERNATIVE SCREENING ANALYSIS FOR SUBUNIT B

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| 0B - No Action | • NA | Does not meet long-term RAOs. Waste is not treated; thus, there are no reductions in toxicity, mobility, and volume. Would not meet ARARs. | Readily implementable | Low |
| 1B - In Situ Containment | • Groundwater monitoring<br>• Radon monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Subsurface drains<br>• Slurry wall<br>• Multimedia cap<br>• Void space grout<br>• Diversion/collection<br>• Grading<br>• Revegetation | Meets short-term RAOs. Long-term protection cannot be assured. Does not reduce toxicity or mobility of wastes, but does increases volume. Migration of contaminants reduced. Would not meet ARARs. | Technically implementable with moderate difficulty. Long-term maintenance and ownership is questionable. | Low |
| 2B - Removal, Stabilization, and On-Property Disposal | • Groundwater monitoring<br>• Radon monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Diversion/collection<br>• Grading<br>• Revegetation<br>• Vacuum w/cutterhead<br>• Cement-based stabilization<br>• Vitrification<br>• FEMP AWWT<br>• Above-grade disposal vault | Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. However, short-term effectiveness is moderate due to the required construction activities. Some uncertainty in long-term effectiveness related to performance of disposal facility. Risks due to degradation of the disposal system are considered low due to the characteristics of the treated wastes. Would not meet ARARs. | Moderately implementable due to treatment process and meeting substantive requirements of air permits | Medium |

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**TABLE 3-2**
**(Continued)**

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| 3B - Removal, Stabilization, and Off-Site Disposal | • Vacuum w/cutterhead<br>• Cement-based stabilization<br>• Vitrification<br>• FEMP AWWT<br>• Rail/truck transport<br>• Nevada Test Site (3B.1) | 3B.1 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. Alternative provides long-term effectiveness. Short-term effectiveness is moderate due to the required construction activities and hazards of waste shipments. Would meet ARARs. | Moderate difficulty in implementation due to operation of treatment system and administrative requirements | Medium |
| | • New facility within 483 km (300 mi) (3B.2) | 3B.2 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. The long-term and short-term effectiveness are consistent with 3B.1 except for a reduction in long-term effectiveness relevant to climate of new facility. Would meet ARARs. | Difficult to implement due to siting new facility and operation of treatment system. | |
| 4B - Removal and On-Property Disposal | • Groundwater monitoring<br>• Radon monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Diversion/collection<br>• Grading<br>• Revegetation<br>• Vacuum w/cutterhead<br>• FEMP AWWT<br>• Above-grade disposal vault | Does not reduce the toxicity, mobility, or volume of wastes. RAOs are achieved. However, short-term effectiveness is moderate due to the required construction activities. Some uncertainty in long-term effectiveness related to performance of disposal facility and the disposal of the untreated waste form. Would meet ARARs. | Moderately implementable due to residue removal and construction of the removal system and vault. | Medium |

Note: Shading designates those alternatives eliminated from further evaluation.



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## TABLE 3-3

## ALTERNATIVE SCREENING ANALYSIS FOR SUBUNIT C

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| 0C - No Action | • NA | Does not meet long-term RAOs. Waste is not treated thus is no reduction in toxicity, mobility, and volume. Would not meet ARARs. | Readily implementable | Low |
| 1C - Demolition and Cap | • Radon monitoring<br>• Groundwater monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Slurry wall<br>• Multimedia cap<br>• Diversion/collection<br>• Grading<br>• Revegetation<br>• FEMP AWWT<br>• Vacuum scabbling<br>• Pressure washer<br>• Diamond rope<br>• Diamond chain saw | Meets RAOs. Long-term effectiveness is uncertain. Migration of and exposure to contaminants are reduced. Would not meet ARARs. | Technically feasible to implement. Long-term maintenance and ownership is questionable. | Medium |



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**TABLE 3-3**
**(Continued)**

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| 2C - Demolition, Removal, and On-Property Disposal | • Radon monitoring<br>• Groundwater monitoring<br>• Leachate monitoring<br>• Surface water/sediment monitoring<br>• Physical barriers<br>• Administrative controls<br>• Diversion/collection<br>• Grading<br>• Revegetation<br>• Loader/dozer<br>• Crane w/clamshell system<br>• Backhoe<br>• Vacuum scabbling<br>• Pressure washing<br>• FEMP AWWT<br>• Diamond rope saw<br>• Diamond chain saw<br>• Above-grade disposal vault | Meets RAOs. Alternative provides an effective, long-term solution with some uncertainty. Short-term effectiveness is moderate due to the required construction activities. Would meet ARARs. | Moderate difficulty in implementation due to the additional construction activities | Medium |
| 3C - Demolition, Removal, and Off-Site Disposal | • Loader/dozer<br>• Crane w/clamshell system<br>• Backhoe<br>• Vacuum scabbling<br>• Pressure washing<br>• FEMP AWWT<br>• Diamond rope saw<br>• Diamond chain saw<br>• Rail/truck transport | | | |
| | • Nevada Test Site (3C.1) | 3C.1 - Meets RAOs. Provide effective permanent solution. Would meet ARARs. | Moderate difficulty in implementation due to administrative requirements | High |



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**TABLE 3-3**
**(Continued)**

| Alternative Title | Applicable Process Option | Effectiveness | Implementability | Cost |
|---|---|---|---|---|
| | • Permitted Commercial Disposal Site (3C.2) | 3C.2 - Slightly greater than 3C.1 due to less handling required for waste. Would meet ARARs. | Moderate difficulty in implementation due to administrative requirements for disposal at commercial facility | Medium |
| | • New facility within 483 km (300 mi) (3C.3) | 3C.3 - Same as 3C.2, but long-term effectiveness may not be as great due to the better climate and lower population at existing disposal facilities. Would meet ARARs. | Very difficult due to siting new facility | Medium |

NOTE: Shading designates those alternatives eliminated from further evaluation.



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# 4.0 DETAILED ANALYSIS OF ALTERNATIVES

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## 4.1 INTRODUCTION

This section presents the detailed analysis of alternatives which passed the screening process conducted previously in Section 3.0. Five alternatives were selected for detailed analysis for Subunit A, six were selected for Subunit B, and four were selected for Subunit C. Table 4-1 summarizes the alternatives to be assessed by the detailed analysis. Reference is also made to Tables 3-1 through 3-3, which highlight the results of the screening of alternatives performed in Section 3.0.

### 4.1.1 Purpose of the Detailed Analysis

The detailed analysis includes a presentation and assessment of relevant information which provides the basis for selecting an alternative and preparing a ROD. The detailed analysis evaluates each alternative against nine criteria which have been developed by EPA to address CERCLA requirements. Building upon the development and screening of alternatives, the detailed analysis presents more in-depth information, including treatability study and pertinent RI data, which are used in the assessment of the alternatives relative to the CERCLA criteria. Following the detailed analysis, a comparative analysis of the alternatives will be presented in Section 5.0. The comparative analysis evaluates the alternatives relative to two threshold criteria which must be met. This is followed by an assessment of the alternatives against the five balancing criteria, highlighting the key advantages, disadvantages, and tradeoffs which are considered as part of the selection process. The Proposed Plan documents selection of a preferred alternative and solicits community and state agency comments, which are incorporated into an assessment of the alternatives against the two modifying criteria of state and community acceptance.

### 4.1.2 Overview of the Detailed Analysis

Specific statutory requirements for remedial actions are specified under CERCLA Section 121, as amended. These requirements include protection of human health and the environment, compliance with ARARs, a preference for permanent solutions which incorporate treatment as a principal element (to the maximum extent practicable), and cost-effectiveness. To assess whether alternatives meet the requirements, EPA has identified nine criteria in the National Oil and Hazardous Substances Pollution Contingency Plan that must be evaluated for each alternative retained through the screening stage [Section 300.430(e)(9)(iii)]. Provided below are summaries of the factors that comprise the nine criteria and an overview of the approach taken by this FS to address the criteria. Because the first two criteria, overall protection of human health and the environment and compliance with ARARs,

## TABLE 4-1

## OPERABLE UNIT 4 SUBUNIT ALTERNATIVES SELECTED FOR DETAILED ANALYSIS

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| Operable Unit 4 Subunit | Alternative Designation | Description |
|---|---|---|
| SUBUNIT A: | 0A | No Action |
| Silos 1 and 2 contents - K-65 residues and decant tank sludge | 2A/Vit | Removal, Vitrification, On-Property Disposal |
| | 2A/Cem | Removal, Cement Stabilization, On-Property Disposal |
| | 3A.1/Vit | Removal, Vitrification, Off-Site Disposal (NTS) |
| | 3A.1/Cem | Removal, Cement Stabilization, Off-Site Disposal (NTS) |
| SUBUNIT B: | 0B | No Action |
| Silo 3 Contents - Cold metal oxides | 2B/Vit | Removal, Vitrification, On-Property Disposal |
| | 2B/Cem | Removal, Cement Stabilization, On-Property Disposal |
| | 3B.1/Vit | Removal, Vitrification, Off-Site Disposal (NTS) |
| | 3B.1/Cem | Removal, Cement Stabilization, Off-Site Disposal (NTS) |
| | 4B | Removal, On-Property Disposal |
| SUBUNIT C: | 0C | No Action |
| Silos 1, 2, 3, and 4 - Structures, soils, and debris | 2C | Demolition, Removal, On-Property Disposal |
| | 3C.1 | Demolition, Removal, Off-Site Disposal (NTS) |
| | 3C.2 | Demolition, Removal, Off-Site Disposal (Commercial Facility) |

are the threshold criteria that relate directly to statutory findings that must be made in the ROD, additional detail regarding these criteria is provided for the discussions. Where appropriate, reference is made to related discussions elsewhere in this report.

4.1.2.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides an assessment of whether the alternative achieves and maintains adequate protection of human health and the environment, in accordance with the remedial action objectives established in Section 2.0. Because the scope of this criterion is broad, it also reflects the discussions of the four criteria which follow below. Evaluation of this criterion should describe how site risks, posed through each pathway that is being addressed by the FS, are eliminated, reduced, or mitigated through treatment, engineering, or institutional controls. The acceptable risk levels under CERCLA for known or suspected carcinogens are generally concentration levels in environmental media that represent an excess upper bound of lifetime cancer risk to an individual between $10^{-4}$ to $10^{-6}$. To achieve this level of human health protection for the entire FEMP site, the initial point of departure for remediation of Operable Unit 4 is less than or equal to $10^{-6}$. This will help to ensure that the remediation goal for the entire FEMP site will not exceed $10^{-4}$ as remedial alternatives are selected for other operable units. The remedial action objectives previously identified in Section 2.2 were developed consistent with this methodology.

To evaluate the alternatives for the attainment of protection of human health (and the associated criteria of compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness), FS risk assessment was performed employing the methodologies identified in the Risk Assessment Work Plan. The FS risk assessment is included as Appendix D of this report. To assess protectiveness, two viable land use scenarios were evaluated along with representative receptors to provide a boundary of risk information to decision makers. The land use scenarios examined included a Future Land Use without Continued Federal Ownership scenario and a Future Land Use with Continued Federal Ownership scenario. The assumptions for these scenarios are summarized below.

Future Land Use without Continued Federal Ownership Scenario

This scenario was examined to assess risk for the least restrictive future land use assumption. Under this scenario, the facility is assumed to revert to the primary land use of the land surrounding the FEMP site, a family farm. For this risk scenario, both an on and off-property farmer are examined. For the on-property farmer, two hypothetical receptors are examined, a RME and CT resident

farmer. The RME resident farmer uses risk parameters to provide an upper bound estimate of the risk an on-property farmer could reasonably be expected to receive. Under the CT resident farmer receptor, risk parameters are adjusted as identified in Appendix D to provide an estimate of the risk the on-property farmer could reasonably be expected to receive under typical living conditions. For this land use scenario, active operations and maintenance by DOE are assumed to continue until site-wide remedial action objectives are attained. After this time, active maintenance is assumed to be discontinued. Five-year CERCLA statutory reviews are assumed to continue. The residue containment system is assumed to remain relatively unchanged with no direct intrusion into the waste materials occurring. Exfiltration from the capped residues is estimated to increase to 1.3 cm/yr to the underlying Great Miami Aquifer. The on-property farmer is assumed to withdraw his drinking, crop irrigation, and livestock water from the Great Miami Aquifer from a point adjacent to the on-property disposal vault or within the Operable Unit 4 boundary.

Future Land Use with Continued Federal Ownership Scenario

This scenario was examined to provide risk information for a viable future site land use which incorporates passive institutional controls. Under this scenario, the FEMP site is assumed to remain under the ownership of the federal government. The government is assumed to continue to exercise its rights as owner of the property to preclude further development of the site. Continued federal ownership would preclude certain activities on the property including homesteading, farming, and contrived recreational use. Active access controls are assumed to be discontinued following the attainment of site remedial action objectives.

To provide an upper bound estimate of the risk contribution reasonably expected to be received under this land use, a hypothetical expanded trespasser is examined in addition to the off-property farmer. The expanded trespasser is assumed to be an individual who plays on the property as a child and uses the property less frequently for recreational purposes as an adult. Assumptions for operations and maintenance and exfiltration rates from the capped residues are consistent with the other land use scenario described above.

To evaluate the alternatives for attainment of overall protection of the environment, the remaining pathways to environmental receptors were examined to determine the degree to which the alternatives mitigate environmental degradation. Section 2.0 summarizes benchmark values which are considered to be protective of ecological receptors. These can be compared to contaminant concentrations determined by the fate and transport modeling conducted for assessing alternative performance. The

prevention of degradation of the Great Miami Aquifer due to migration of contaminants from residual wastes and soils is a remedial action objective which is protective of both human health and the environment. Attainment of this objective can be measured primarily by compliance with MCLs, proposed MCLs, and MCLGs established under the SDWA. Each alternative is also assessed for its short-term and long-term effects on soil and geology, water quality and hydrology, air quality, biotic resources, and wetlands and floodplains.

4.1.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

This criterion addresses the attainment of compliance with promulgated federal and state environmental regulatory requirements. If an alternative cannot meet an ARAR, a determination may be made that a waiver under CERCLA may be appropriate and a basis for justifying the waiver discussed. ARARs consist of two types of requirements, those that are applicable and those that are relevant and appropriate. Applicable requirements are those promulgated substantive standards or limitations that specifically address the situation at a CERCLA site, or otherwise satisfy the jurisdictional prerequisites for the application of the regulation. Relevant and appropriate requirements are those promulgated controls or requirements that are not applicable, but address sufficiently similar situations such that their use is well suited to the occasion. In certain cases, standards may not exist in the form of a promulgated regulation that address the proposed action or the COC. In these cases, nonpromulgated advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states are to be considered (TBC) in conducting activities or establishing remedial action objectives that are protective of human health and the environment. In addition, there are other requirements which do not fall within the EPA-established criteria for ARARs. These other requirements include DOE Orders[1] which pertain only to DOE facilities. EPA's Compliance with Other Laws Manual (OSWER Directive 9234.1-01) states "...DOE orders are not promulgated requirements and are not potential ARARs." The manual further states that "to the extent that DOE orders are more stringent or cover areas not addressed by existing ARARs, they should be considered when necessary to develop a protective remedy." In this document, DOE Orders are identified as TBCs only when no promulgated ARAR exists to ensure adequate protection

[1]AEA requirements for DOE's waste management are incorporated into DOE Orders, developed under DOE's AEA authority. The Orders are generally consistent with and typically include technical requirements similar or equivalent to those in NRC regulations and that are appropriate for DOE facilities. DOE Order substantive requirements are "To-Be-Considered" (TBC) requirements, which, when included in a DOE CERCLA ROD, are enforceable cleanup standards under CERCLA. Substantive technical requirements of promulgated and non-promulgated NRC requirements may be "Relevant and Appropriate" or TBCs to ensure protection of human health and the environment.

of human health and the environment. A table summarizing other requirements pertinent to Operable Unit 4 remediation is included in Appendix F.

Types of ARAR/TBCs

In addressing a requirement that may affect a remedial action being considered for a site, a determination is made regarding its relationship to: (1) the location of the action; (2) the contaminants involved, and (3) the specific components of the action, such as factors unique to a certain technology. Three types of ARARs result from this process: chemical-specific ARARs, location-specific ARARs, and action-specific ARARs.

Chemical-specific ARARs are usually health- or risk-derived numerical values that establish an acceptable level or concentration of chemical or radionuclide that may remain in specific environmental media after remediation is complete. These levels are deemed to be protective of human health and are used to help establish remedial cleanup goals.

Location-specific ARARs generally restrict certain activities or dictate where certain activities may be conducted solely because of geographical, hydrologic, or land use concerns.

Action-specific ARARs are usually restrictions on the conduct of certain activities or the operation of certain technologies at the site.

Summary of Key ARAR/TBCs

Appendix F of this report provides a complete listing and an analysis of compliance with potential ARARs and TBCs for Operable Unit 4. Included are tables which present the documentation of ARARs for each of the alternatives. The approach adopted by this FS is to focus the evaluation discussion in this section on the alternatives' ability to comply with key ARARs which are critical to meeting this threshold criterion. The key ARAR/TBCs identified for Operable Unit 4 include the following:

Chemical-Specific ARAR/TBCs

- SDWA: 40 CFR § 141 (various citations) - MCLs for organics and inorganics.
- SDWA: 40 CFR § 141.51 - nonzero MCLGs.
- CAA: 40 CFR § 61 Subpart H - radionuclides other than radon.

- CAA: 40 CFR § 61 Subpart Q - radon-222 flux.
- UMTRCA: 40 CFR § 192.02(b) - average annual radon-222 concentrations.

Location-Specific ARAR/TBCs

- RCRA: OAC 3745-27-07 - solid waste disposal design and location criteria.
- NEPA/DOE: 10 CFR § 1022 - floodplain/wetlands environmental review requirement.

Action-Specific ARAR/TBCs

- RCRA: 40 CFR § 264 Subpart B (various citations) - general standards for treatment, storage, and disposal facility.
- RCRA: 40 CFR § 264 Subpart F (various citations) - releases from solid waste management units (groundwater monitoring).
- RCRA 40 CFR § 264 Subpart G (various citations) - closure and post-closure requirements.
- RCRA: 40 CFR § 264 Subpart I (various citations) - container storage requirements.
- RCRA: 40 CFR § 264 Subpart J (various citations) - tank system requirements.
- RCRA: 40 CFR § 264.310 - protection and marking of landfill capping systems.
- RCRA: 40 CFR § 264 Subpart S (various citations) - corrective action management units and temporary units.
- DOE Order 5400.5 - annual effective dose equivalent from all pathways.
- NRC: 10 CFR § 61 (various citations) - intruder protection requirements for capping systems.
- AEA: 40 CFR § 191.03(b) and 40 CFR § 191 Subpart B (various citations) - standards for management, storage, and disposal of spent nuclear, high level, and transuranic wastes.
- AEA/DOE: 10 CFR § 1021.2 - NEPA implementation.
- UMTRCA: 40 CFR § 192 (various citations) - cleanup standards for residual radioactive material.

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4.1.2.3 Long-term Effectiveness and Permanence

This criterion evaluates the extent to which an alternative achieves an overall reduction in risk to human health and the environment after the response objectives have been met. It considers the degree to which the alternative provides sufficient long-term controls and reliability to maintain exposures to human and environmental receptors within protective levels. The principal factors addressed by this criterion include magnitude of residual risk and adequacy and reliability of controls. Also discussed are the uncertainties associated with both of these factors.

This FS evaluates the magnitude of residual risk to human health in terms of a risk evaluation under the land use scenarios previously discussed in Section 4.1.2.1. The basis of this evaluation is presented in Appendix D. The evaluation considers the characteristics of any remaining untreated and treated waste forms which pose potential risks in the future. The magnitude of residual risk to environmental receptors is assessed in a qualitative manner. This discussion is further supported by describing the potential long-term environmental impacts of the alternative on soil and geology, water quality and hydrology, air quality, biotic resources, and wetlands and floodplains. Impacts on socioeconomics, land use, and cultural resources are also considered.

The evaluation of adequacy and reliability of controls assesses the effectiveness of any treatment, containment, or institutional measures which are part of the alternative. Factors considered include performance characteristics, maintenance requirements, and expected durability. Information and data from treatability studies, past performance, and similar technology applications are incorporated into the evaluation as appropriate. Institutional controls are considered where they potentially improve the effectiveness of engineered measures.

4.1.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion reflects the statutory preference for remedial alternatives containing a principal component which substantially reduces toxicity, mobility, or volume of hazardous substances. The evaluation considers the extent to which remedial action process technologies can effectively and irreversibly fix, transform, immobilize, and/or reduce the volume of waste materials and contaminated media.

Two treatment technologies are principal components of several alternatives selected for this detailed analysis. Vitrification and cement stabilization are assessed for their ability to reduce the toxicity, mobility, and volume of the contents of Silos 1, 2, and 3. The evaluation includes the results of

treatability studies which were conducted during the RI/FS. The treatability study results are presented in Appendix C and Appendix H of this document. The treatability studies compare key characteristics (e.g., leachability of constituents of concern, reduction of radon emanation) of the untreated and treated waste forms in order to assess the reduction of risk afforded by the treatment processes. Additional tests were conducted to determine the expected long-term performance of the treated waste forms in maintaining the level of protectiveness achieved.

#### 4.1.2.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative during the construction and implementation phase until the remedial action objectives are achieved. The evaluation considers the effects on human health and the environment posed by operations conducted during the remedial action. Both the potential impacts and associated mitigative measures are examined for maintaining protectiveness for the community, remedial action workers, and environmental receptors over the duration of the activities.

Appendix D of this FS provides an evaluation of short-term risks to the public and workers under various scenarios associated with an alternative's operations. Potential short-term risks to the public include inhalation of radon gas released during waste removal and treatment operations, radiological exposure and physical injury during waste transport off site, and potential exposure to a trespassing child postulated to intrude on site during remedial activities. Potential short-term risks to workers include: direct radiation exposures during construction, waste treatment, and transportation; physical injury or death during construction and transportation activities; and non-remediation worker exposures to airborne radioactive and chemical contaminants during soil removal operations. The alternative analysis also includes an assessment of mitigative measures such as engineering and institutional controls which are expected to minimize potential risks to the public and workers.

#### 4.1.2.6 Implementability

This criterion examines the technical and administrative factors affecting implementation of an alternative and considers the availability of services and materials required during implementation. Technical factors to be assessed include the ease and reliability to initiate construction and operations, the prospects for implementing any needed future actions, and the adequacy of monitoring systems to detect failures. Administrative factors examined include permitting and coordination requirements among the lead agency and regulatory agencies. Services and materials considerations include:

treatment, storage, and disposal capacities; equipment and operator availability; and prospective technology applicability or development requirements.

Where proven technologies are proposed for use by an alternative, the assessment of technical feasibility examines the performance history of the technologies in direct applications, or considers the expected performance for similar applications. For innovative technologies, data from bench-scale tests are evaluated for expected scale-up performance characteristics; and, the feasibility of scaling up bench tests to pilot tests is reviewed. Any uncertainties associated with construction, operation, and performance monitoring are also addressed.

The evaluation of administrative feasibility includes a discussion of those actions required to coordinate with regulatory agencies to establish the framework for complying with any key substantive technical requirements which must be attained by an alternative. Additionally, alternatives involving off-site transportation are reviewed to assess the feasibility of implementing interstate transportation and disposal.

The availability of services and materials is addressed by analyzing the material components of the proposed technologies to determine the locations and quantities of those materials, and by reviewing process operations to identify any special services, operator skills, or training required to readily implement the process.

4.1.2.7 Cost

The cost criterion reviews capital costs (direct and indirect) and O&M costs. A present worth analysis evaluates costs that occur over different time periods. A sensitivity analysis may be conducted if there is sufficient uncertainty concerning specific assumptions.

This FS presents cost information for Subunits A, B, and C alternatives on an individual basis. The approach adopted by this FS includes a presentation of capital costs, along with a summary of assumptions used to estimate the capital cost for each major component of the alternative. A cost estimate table provides detail for each of the major cost elements of each alternative, including O&M costs and total present worth costs. Sensitivity analyses are provided in Section 5.2.

When compared with each other, many of the alternatives in Subunits A and B have duplicate cost components that are accounted for individually. Because it is not known in the FS which remedial

alternative would be identified in the Proposed Plan as the preferred alternative for each of the subunits, it is not known which cost components can be considered as duplicate costs between different subunit alternatives.

The Proposed Plan will provide a total cost for the combined, preferred alternatives from each subunit. This total cost will eliminate any duplicate cost components.

4.1.2.8 State Acceptance

This criterion measures the extent to which the comments made by the OEPA on the alternatives being considered for site remediation are satisfactorily addressed. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.1.2.9 Community Acceptance

This criterion measures the extent to which the comments made by the community on the alternatives being considered are satisfactorily addressed. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.1.3 Overview of Section 4.0

Sections 4.2 through 4.4 present the detailed analysis of alternatives for Subunits A, B, and C, respectively. Consistent with the approach of presenting Operable Unit 4 alternatives for each of Subunits A, B, and C, the detailed analysis evaluates the respective subunit alternatives against the CERCLA criteria.

The remaining sections include: Section 4.5, Monitoring and Mitigative Measures; Section 4.6, Unavoidable Adverse Impacts; Section 4.7, Irreversible and Irretrievable Commitment of Resources; Section 4.8, Impacts of Potential Loss of Institutional Actions; and Section 4.9, Short-Term Uses and Long-Term Productivity. Although these sections (4.5 through 4.9) are not required by CERCLA, they have been adopted by this FS in order to supplement the CERCLA documentation with NEPA values pursuant to DOE implementing regulations (10 CFR § 1021). It is DOE policy to integrate the NEPA requirements into the procedural and documentation requirements of the RI/FS process wherever practical as previously discussed in Section 1.3.

## 4.2 SUBUNIT A

Source Term Description

It was identified in the RI Report for Operable Unit 4 that Silos 1 and 2 contain 6120 $m^3$ (8012 $yd^3$) of K-65 residues and 670 $m^3$ (878 $yd^3$) of bentonite clay for total content of 6790 $m^3$ (8890 $yd^3$).

As part of the RI for Operable Unit 4, Subunit A was sampled for a full range of analyses including radionuclides, organic, and inorganic chemicals. The materials are primarily a silty clay with an average moisture content of 40 percent. Present within the waste volumes of the two silos are in excess of 3700 Curies of Ra-226, 600 Curies of Th-230, and 1900 Curies of Pb-210. It is also estimated that the silos contain more than 27 metric tons (30 tons) of uranium. As a result of these activity concentrations of radionuclides, the K-65 residues exhibit a significantly elevated direct radiation field. Additionally, the residues represent a significant source for the generation of radon gas. The strength of the direct radiation field and the concentrations of radon in the vicinity of the silos are further discussed in Section 1.0 of this Report and Section 4.0 of the RI Report for Operable Unit 4.

Other significant metals include more than 118 metric tons (130 tons) of barium, 830 metric tons (915 tons) of lead, and 2.6 metric tons (2.9 tons) of arsenic. The silos also contain low concentrations of Aroclor-1248, Aroclor-1254, and Aroclor-1260 (PCBs) and tributyl phosphate (a solvent used for uranium extraction).

TCLP results show that the concentration of lead (approximately 500 ppm) exceeds the RCRA regulatory limit of 5.0 ppm. However, based upon the generation process of the residues stored in the silos, they are classified as by-product material as defined in Section 11(e)2 of the AEA and, therefore, are excluded from regulation under RCRA.

In addition, the analytical results presented in the RI Report for Operable Unit 4 confirmed that the radiological and inorganic contaminants present in the decant sump tank liquid are consistent with the relative concentrations of contaminants found in Silos 1 and 2.

Eighteen organic compounds were detected in the decant sump tank liquids at concentrations near the detection limits. With the exception of toluene, all volatile compounds detected were at or below the CRQL or were common laboratory contaminants.

Principal Threats

The NCP describes principal threats as those involving liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials. Consistent with the NCP, the RI Report for Operable Unit 4 provided a detailed characterization of the source term within Silos 1 and 2 and identified those contaminants which contributed to an ILCR value greater than $1 \times 10^{-6}$ and a hazard quotient greater than 1.0. The RI Report for Operable Unit 4 identified that the principal threats to human health and the environment posed by the Silos 1 and 2 contents are from the following contaminant/transport pathways:

Direct Radiation

- Direct exposure to gamma radiation from radioactive constituents within the silos residues.

Air Emissions

- Dispersion of radon that escapes from the silos into the atmosphere.

Groundwater Transport

- Leaching of contaminants from the silo contents via subsurface soils to underlying perched water.

Potential remedial alternatives for Subunit A were developed in order to mitigate the short-term and long-term exposure and associated risks from gamma radiation, reduce radon emanation rates from the waste materials and minimize the mobility of contaminants from the waste materials.

4.2.1 Analysis of Alternative 0A - No Action

The no-action alternative is retained throughout the FS process as required by the NCP (40 CFR § 300.430[e][6]). This alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken. In the no-action alternative, the material is considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. The contents of Silos 1 and 2 and the remaining sludges in the decant sump tank would remain in place. Alternative 0A does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and Alternative 0A does not provide for access control actions to be taken to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

4.2.1.1 Overall Protection of Human Health and the Environment

The no-action alternative does not meet the remedial action objectives for Subunit A. The Baseline Risk Assessment, previously summarized in Section 1.6.3, presented information on the risks to a number of representative receptors for the no-action alternative under varied land use assumptions. Upon comparison of the results of the Baseline Risk Assessment with the generally accepted risk range of $10^{-4}$ to $10^{-6}$, the no-action alternative would not be adequately protective of human health under all evaluated land use scenarios, except current land use conditions with continuation of access controls. For these land use scenarios, at least one receptor receives risks which are calculated to exceed $10^{-4}$.

4.2.1.2 Compliance with ARARs

With no further action, certain ARAR/TBCs would not be met. Eventual failure of the silos would result in exceedances of radon release limits under 40 CFR § 61 Subpart Q, and release of material from the silos that would violate State of Ohio water quality standards for receiving surface waters, and exposure limits to the public from radionuclides established under DOE Order 5400.5. Drinking water MCLs and MCLGs would most likely be exceeded if the released material were to migrate into groundwater of the Great Miami Aquifer.

In addition, design standards and closure requirements for a RCRA solid or hazardous waste disposal vault, or for intruder protection from direct radiation hazards associated with radioactive waste disposal would not be met.

CERCLA Section 121 cleanup standards, including compliance with ARARs, apply only to remedial actions that EPA determines should be taken under CERCLA Sections 104 and 106 authority. A no-action decision can only be made when no remedial action is necessary to reduce, control, or mitigate exposure because the site is already protective of human health and the environment. If the alternative passes the protectiveness threshold criteria, then compliance with ARARs is not pertinent to the selection of Alternative 0A.

#### 4.2.1.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

This alternative does not provide a long-term solution that is effective and permanent, as previously identified in the Baseline Risk Assessment. Under the no-action alternative, continued deterioration of the containment system for Silos 1 and 2 and the decant sump can be expected. In the event DOE or other responsible parties do not control this deterioration, it is reasonable to expect the existing silo domes to collapse and the decant system to corrode. This loss of containment would lead to increased infiltration of storm water and increased infiltration from the silos to the underlying perched groundwater zone. Increased contamination levels in the perched zone will consequently lead to higher concentrations of contaminants in Paddys Run surface water and sediment, and the Great Miami Aquifer. Additionally, radon flux rates could be expected to increase, leading to increased ambient radon concentration in the surrounding atmosphere and increased plate out of radon daughters in the berm and surface soils. These increased concentrations of contaminants in the environmental media surrounding Operable Unit 4 would lead to additional overall risks to human and environmental receptors.

As previously discussed, the risks due to carcinogenic and non-carcinogenic contaminants present within Operable Unit 4 exceed generally accepted regulatory levels for all foreseeable future land use scenarios.

Adequacy and Reliability of Controls

Deterioration of residue containment systems could be expected to increase the concentration of contaminants in surface water reaching adjacent biotic resources. The existing Waste Pit Area Storm Water Runoff Control System currently limits such discharges. Additionally, the current level of radon exposures to biological receptors could be expected to increase with the loss of containment on Silos 1 and 2. Current levels of radon exposures to species near Operable Unit 4 are near

background levels. No threatened and endangered species or critical habitats for these species occur in or adjacent to Operable Unit 4 and, thus, are unaffected by the conditions within the study area.

Long-Term Environmental Impacts

Alternative 0A would not be protective of human health and the environment in the long term because it does not protect against the potential exposure to waste materials and the possibility of silo collapse. Silo collapse and subsequent loss of containment could lead to increased contamination levels in the perched groundwater zone and in surface water and sediment in the 100- and 500-year floodplain, i.e., Paddys Run and the 0.36 ha (0.76 acre) wetland south of Silos 1 and 2.

#### 4.2.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The no-action alternative does not provide any reduction in toxicity, mobility, or volume of contaminants.

#### 4.2.1.5 Short-Term Effectiveness

This evaluation criteria addresses the effectiveness of the alternative during the construction and implementation of the remedial action. Under the no-action alternative, no remedial action would be taken; therefore, there would be no increase in short-term risks.

#### 4.2.1.6 Implementability

Under the no-action alternative, no remedial action would be taken; therefore, there would not be any difficulties or uncertainties with construction. The no-action alternative is included in the detailed analysis of alternatives for a baseline comparison.

#### 4.2.1.7 Cost

There are no costs associated with Alternative 0A-No Action.

#### 4.2.1.8 State Acceptance

This criterion addresses the comments made by the State of Ohio on Alternative 0A. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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#### 4.2.1.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 0A. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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### 4.2.2 Analysis of Alternative 2A/Vitrification

This alternative requires the removal of Silos 1 and 2 contents and the remaining sludge from the bottom of the decant sump tank, stabilization of the materials by vitrification, and on-property disposal of the treated materials. The silo contents and decant sump tank sludge would be retrieved with a hydraulic mining device introduced through manways in the structures. The equipment would be supported from a work platform that spans the silos. The material would then be transferred to a processing facility for vitrification. The treated material would then be placed in an above-grade disposal vault constructed on property. Treated residues may be staged and/or placed into interim storage, as required pending availability of on-property disposal capacity. The above-grade disposal vault would feature an inadvertent intrusion barrier and a radon barrier. The contaminated debris from the dismantlement of the material processing facility, the hydraulic removal device, and the work platform would be dispositioned consistent with the selected remedy for Subunit C. Approximately 3785 L (1000 gal.) of sludge from the decant sump tank would be mixed with the silo contents and vitrified. The alternative would include the placement of permanent markers to define waste disposal areas, the use of deed restrictions, and the provision of continued federal ownership of the property to preclude drilling or residential development.

#### Site Preparation and Construction

Site preparation would begin with the clearing and grubbing of vegetated areas near and to the east of the silos. In preparation for the construction of the material processing facility, the packaging pad for the removed berm material, the material slurry transfer trench, and the construction of roads and equipment staging areas, approximately 3.2 ha (8 acres) would be cleared and grubbed. In addition to the clearing and grubbing activities, the southern area of the remediation site would be filled, as required, to level the site. The volume of fill soil is estimated to be approximately 11,500 $m^3$ (15,000 $yd^3$), which could be obtained from excess unaffected soil removed from the silo berms.

The site preparation activities would also include the installation of roadways, site fencing, site lighting, process water piping, sewer lines, power poles, and the extension of site power to the processing elements requiring service.

Processing elements to be constructed include the work platform with an underlying foundation (used during removal of the material), a material processing facility for vitrification, and the above-grade disposal vault.

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The material removal work platform would be a reusable, rail-mounted, 54-m (180-ft) structure truss bridge that would span the silos (Figure 4-1). The placement of the rail system would require the removal of part of the berms. The work platform would support the hydraulic mining device and allow the placement of the mining device into each of the four perimeter manways and the center manway in each silo. The work platform would be built between Silos 3 and 4 rather than directly over either Silos 1 or 2 to minimize the risk of a construction accident impacting a silo dome. Following the removal of Silo 1 contents, the platform will be moved to Silo 2.

The processing facility would be a preengineered metal building structure built approximately 75 m (250 ft) east of the silos and measuring 36 m by 36 m by 9 m (120 ft by 120 feet by 30 ft). The processing facility would house all material treatment and material product sampling activities, and equipment and administrative activities relating to material processing and equipment maintenance. The administrative areas would be shielded from the material processing areas. Negative pressure and a separate ventilation system would be used. See Figure 4-2 for a depiction of the site layout.

Removal

A slurry pump with a jetting ring could be used to dislodge and transport the materials, in slurry form, to the processing facility. The slurry pump jetting ring would be introduced through the silo and tank manways and would be remotely operated from a shielded control station adjacent to the work platform. As the contents are removed from the silos, the berm material opposite the silo wall would be removed to ensure the forces are balanced. Both the silo contents and the berm material would be removed in equal layers. Because of the removal-by-layer method and the configuration of the silo, silo contents may not be accessible to the slurry pump jetting ring through a single manway. The removal device could be moved from manway to manway or through enlarged manways, until all of the contents have been removed evenly.

During normal operations, personnel would be required to reposition the slurry pump jetting ring on the silo domes once a week for approximately two hours. Other than this weekly activity and required monitoring activities, personnel would not work above the silo domes. Material removal operations would take place eight hours/day, seven days/week, and three weeks/month. The fourth week of every month would be used for equipment maintenance and repairs. An estimated 18 months would be required to remove the Silo 1 contents, 16 months to remove the Silo 2 contents, and one week to remove the decant sump tank sludge.

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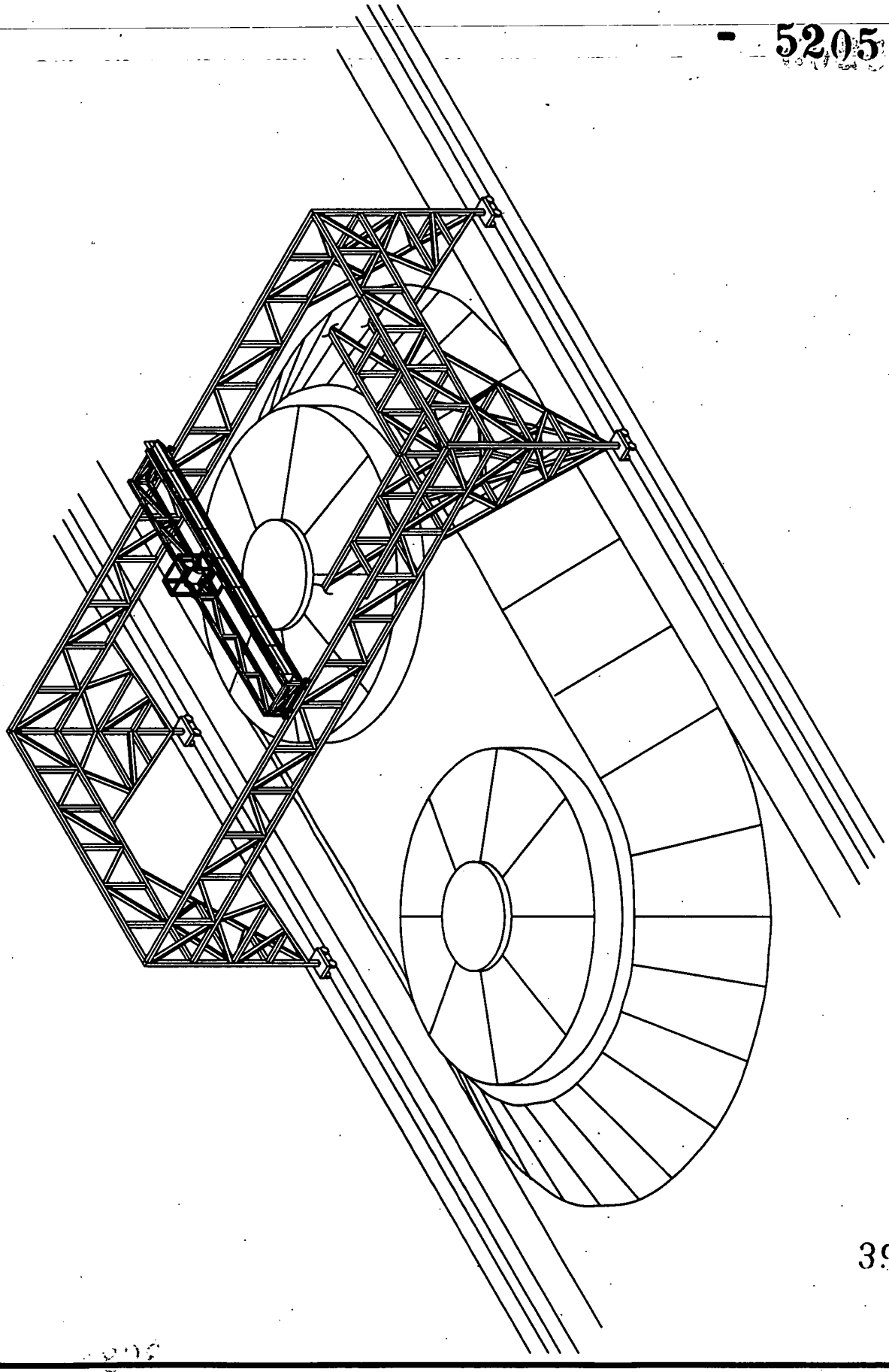

FIGURE 4-1 SILO MATERIAL REMOVAL WORK PLATFORM

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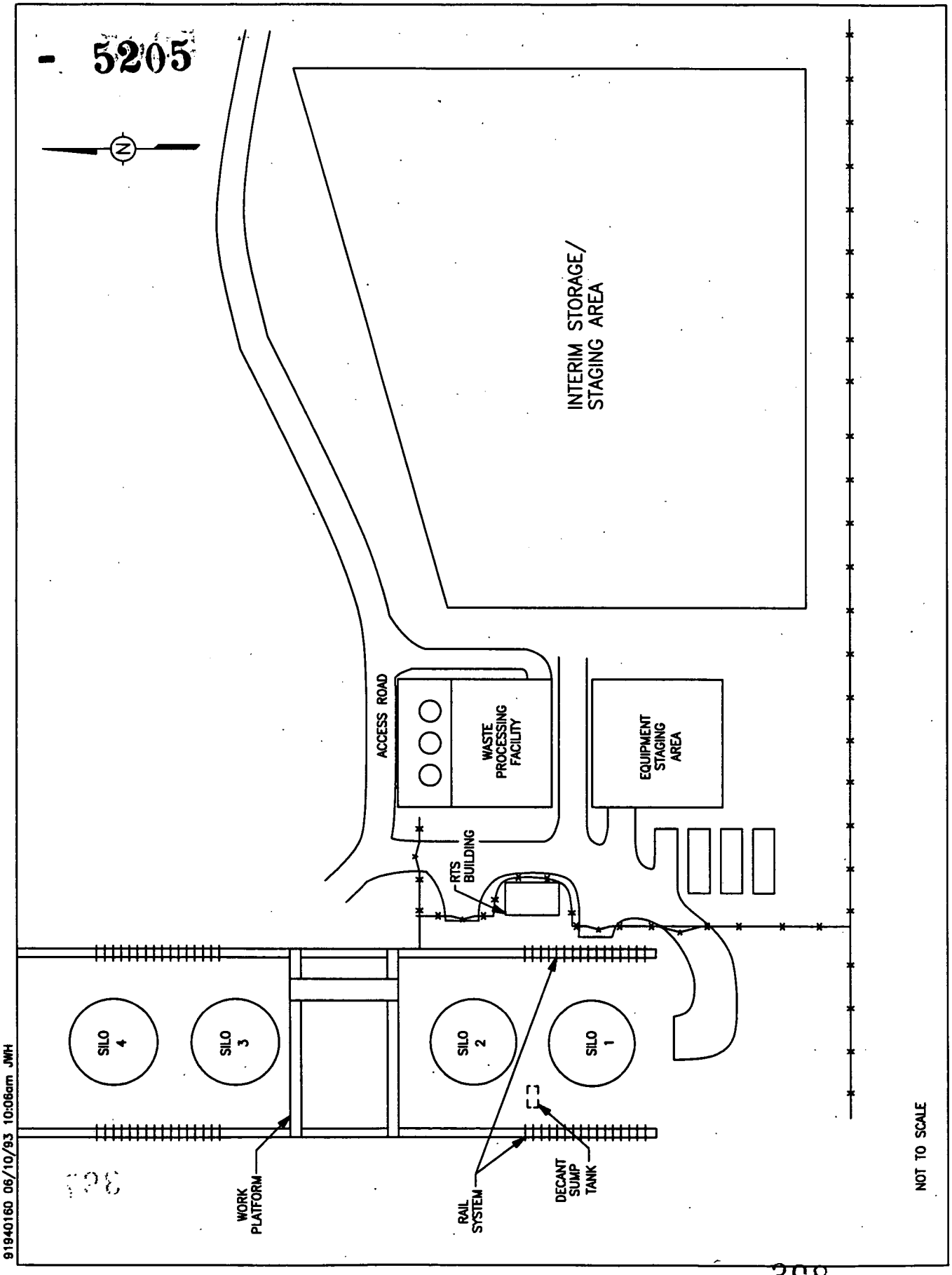


FIGURE 4-2 SITE LAYOUT-ALT. 2A-3A.1

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The silos and decant sump tank would have a recirculating RTS that would maintain the silo atmosphere in a state of negative pressure (see Figure 4-3). The RTS would be operational during material removal and before personnel are sent over the silo domes to reposition the slurry pump jetting ring and conduct repairs or maintenance. The system and procedures would be designed to minimize exposure to personnel over the work areas and to prevent the escape of radon and radioactive particulates from the silos and the decant sump tank. The RTS would use calcium sulfate dehumidification media, carbon absorbers, and HEPA filters. The RTS would be housed in a building adjacent to the silos.

A glove bag would be used at the slurry pump jetting ring/manway interface to function as a part of the containment along with the vessel. The setup, along with procedural compliance and an operational RTS, would be designed to prevent the release of radon or radioactive particulates.

Material Processing

The silo contents and decant sump tank sludge would be removed as a slurry with a water content of 80 percent. The slurry would be pumped through double-walled piping to the processing facility. The slurry transfer piping would be contained in an enclosed concrete trench placed just below grade. After the slurry enters the processing facility, it would be dewatered with a horizontal belt filter to reduce its water content to the level required for vitrification. The filtrate would pass to a filtrate recycle tank and be pumped back to the vessels for reuse in the hydraulic removal operations. The dewatered residues and sludge would then pass to a surge tank, which is required because material removal operations would occur eight hours/day and material processing would occur 24 hours/day. The surge tank would be continuously emptied by the material processing operations and filled during the removal operations.

For the vitrification process (Figure 4-4), the dewatered slurry would be mixed with the glass-forming agents, sodium carbonate and carbon, and melted in a joule-heated melter. The molten glass would be poured directly into DOT specification 7A Type A containers designed to withstand the temperatures of the molten glass without compromising container integrity. The containers would then be placed in the storage room until the form has cooled and been sampled.

The design of the vitrification process is based upon a one-day cooling period for a monolithic waste form. This length of time has been determined to be adequate to allow for sufficient reduction in temperature to permit movement of the container, without jeopardizing the eventual quality of the

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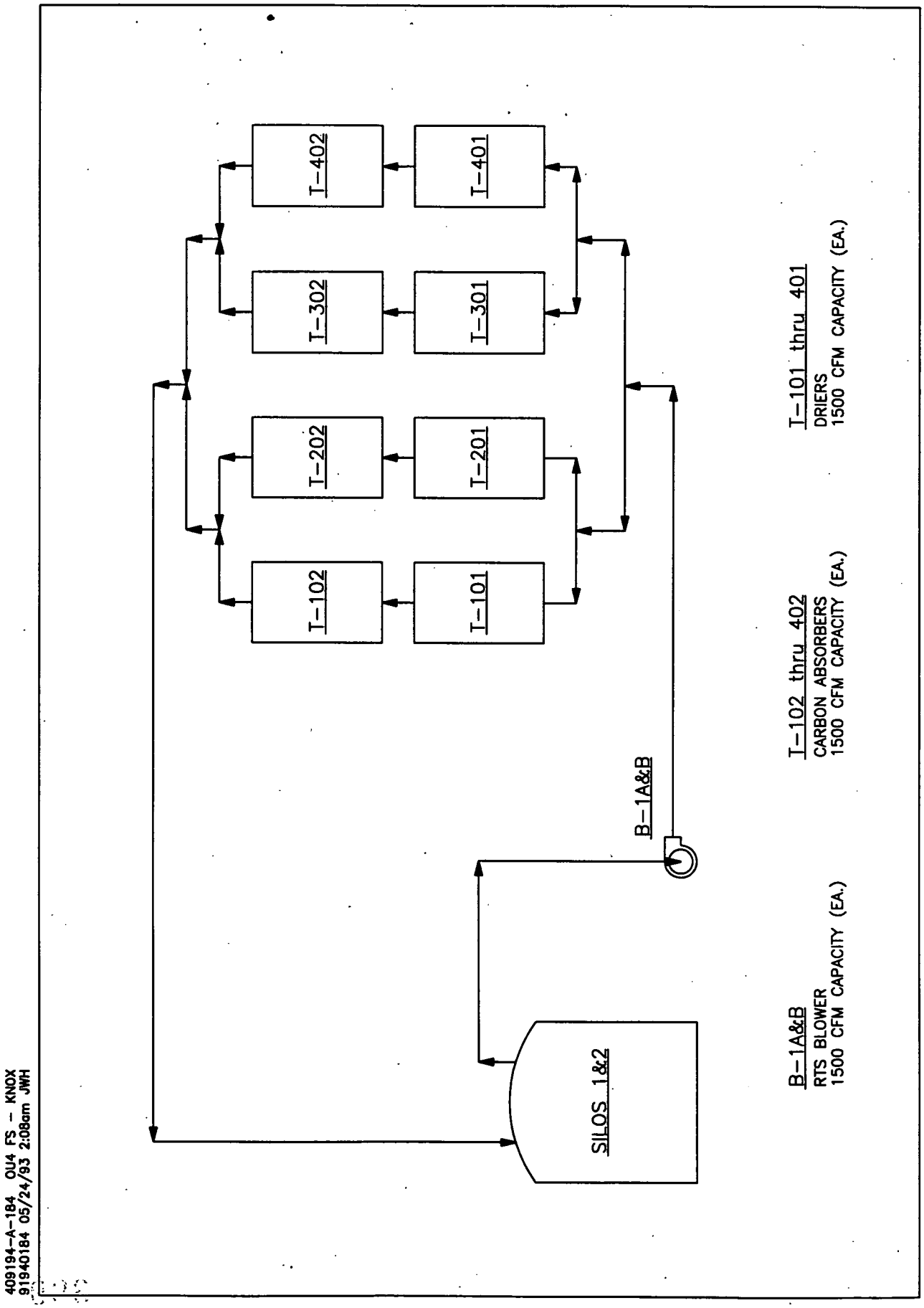


FIGURE 4-3 RADON TREATMENT SYSTEM



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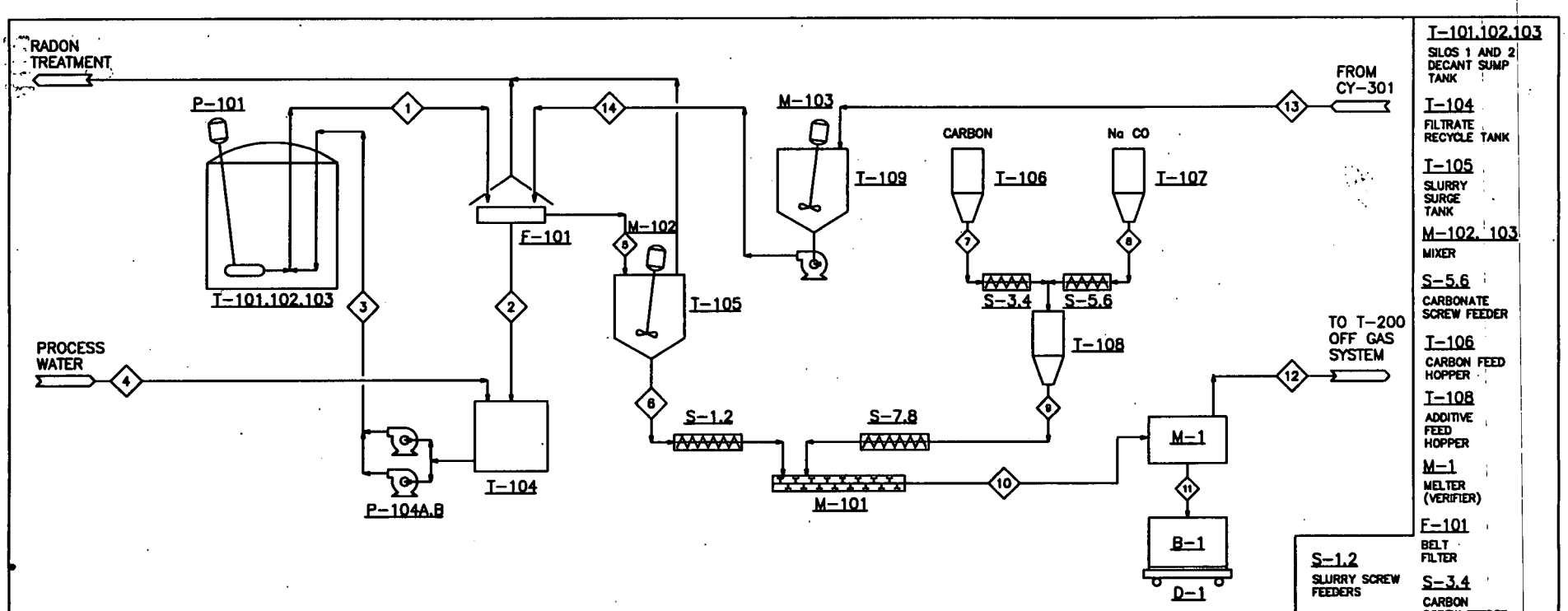


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| STREAM NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MASS FLOW (lb/HR) | 14930 | 10149 | 11944 | 1795 | 6335 | 2230 | 2.4 | 240 | 242 | 2644 | 1378 | 1268 | 836 | 2524 |
| SOLIDS (lb/HR) | 2988 | | | | 3340 | 1153 | 2.4 | 240 | 242 | 1637 | 1066 | | 118 | 354 |
| WATER (lb/HR) | 11944 | 10149 | 11944 | 1795 | 2990 | 1077 | - | - | - | 1007 | 1378 | | 718 | 2878 |
| CARBON (lb/HR) | | | | | | | 2.4 | | 2.4 | 2.4 | | | | |
| SODIUM CARBONATE (lb/HR) | | | | | | | | 240 | 240 | 240 | | | | |
| GLASS | | | | | | | | | | | | | | |
| % SOLIDS | 20 | | | | 49 | 49 | 100 | 100 | 100 | 65 | 100 | | 0.2 | |
| FLOW (gpm) | | | 24 | 3.2 | | | | | | | | | 103 | |
| HOURS/DAY | 8 | 8 | 8 | 8 | 8 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 8 |
| DAYS/WEEK | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

ALTERNATIVES 2A/VIT, 3A.1/VIT
VITRIFICATION
PROCESS FLOW DIAGRAM
FIGURE 4-4

5205

glass product.

Sampling of the vitrified waste form would be limited to measurement of dose rate. Rigorous sampling during the optimization and pilot plant programs has and would define radon emanation rates and leaching potential. Statistically based, periodic sampling of the waste form (radon and leaching) would ensure that the glass product achieves waste disposal acceptance criteria requirements. The sampling procedures and protocols would be developed and presented in the Operable Unit 4 Remedial Design/Remedial Action Work Plan.

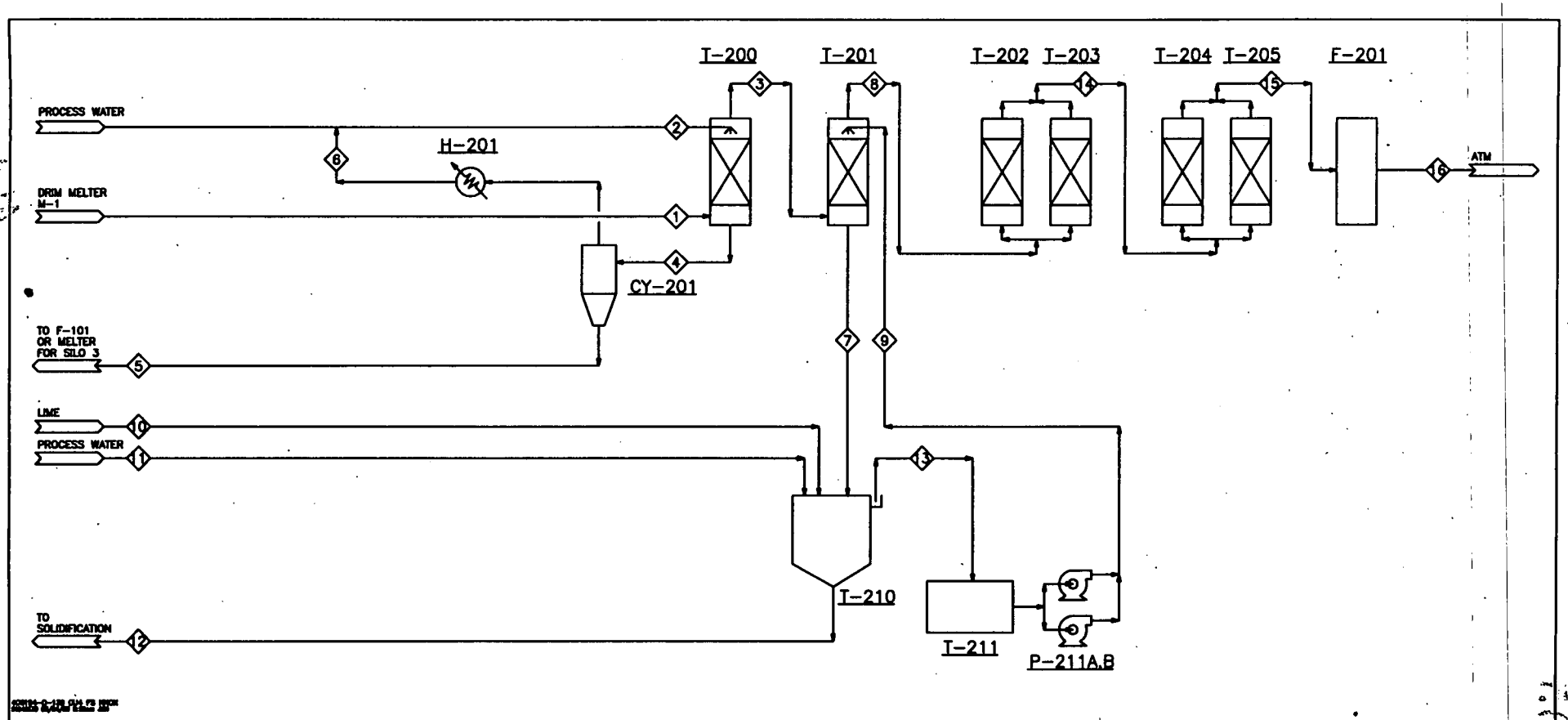
It should be noted for purposes of this FS that current planning focuses upon a monolith as the preferred final product form. The final waste form will continue to be optimized in the pilot plant phase. At present, there are understood to be several advantages in a final monolithic waste form, the most significant of these being the low radon emanation rate. Because of the increased surface area associated with smaller waste forms, i.e., marbles, the radon emanation rate is large for the waste form. A final decision regarding the final waste form will be reached during the pilot plant treatability studies.

Due to the high temperatures required for vitrification [1350°C (2460°F)], significant quantities of superheated steam and volatilized matter would be produced. This off-gas would contain water, radon, lead, radium, and other materials. An off-gas treatment system (Figure 4-5) would use scrubbers to treat the gases for lead, radium, and other miscellaneous nongaseous material; carbon adsorbers would be used to treat the gases for radon, and HEPA filters would be used for the remaining airborne particulates. Because the potential exists for emissions of radionuclides to the ambient air to exceed 40 CFR § 61, Subpart H and DOE Order requirements, there would be continuous radionuclide emission monitoring of both the off-gas treatment system and the RTS.

All process vessels containing the slurry would be vented to an RTS separate from that used for the silos and decant sump tank. The process piping/vessels design, the process vessel headspace RTS, and operational procedures would be designed to minimize emissions.

Treatment Residuals Handling

Treatment residuals from the scrubber would be handled through the AWWT. Specific details of waste treatment should be left for the Remedial Design stage of the process, since discussions at this level of detail may change with refinement of the treatment process. An example from this was the




| STREAM NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MASS FLOW (lb/HR) | 1268 | 50,500 | 550 | 51,336 | 836 | 50,500 | 2516 | 484 | 2500 | 19.7 | 46 | 66 | 2500 | 484 | 484 | 484 |
| SOLIDS (lb/HR) | | | | 118 | 118 | 19.7 | 16 | | 19.7 | 19.7 | | 19.7 | 19.7 | | | |
| WATER (lb/HR) | | 50,500 | | 51,218 | 718 | 50,500 | 2500 | | 2500 | | 46 | 46 | 2500 | | | |
| GAS (lb/HR) | 1268 | | 550 | | | | | 484 | | | | | | 484 | 484 | 484 |
| FLOW (cfm) | 1593 | | 129 | | | | | 113 | | | | | | 113 | 113 | 113 |
| FLOW (gpm) | | 101 | | 103 | | 101 | 5.3 | | 5 | | | | 5 | | | |
| % SOLIDS | 0 | 0 | 0 | .2 | 15 | | | | | | | 30 | | | | |
| HOURS/DAY | 24 | 24 | 24 | 24 | 24 | | | | | | | | | | | |
| DAYS/WEEK | 7 | 7 | 7 | 7 | 7 | | | | | | | | | | | |

**T-200** PRIMARY QUENCH SCRUBBER

**H-201** QUENCH COOLER

**T-210** CALCIUM SULPHATE SEPERATOR

**P-211A,B** RECYCLE PUMPS

**T-204,205** OFF-GAS RADON ABSORBERS

**CY-201** QUENCH SOLIDS CYCLONE

**T-201** SECONDARY SCRUBBER

**T-211** SECONDARY SCRUBBER LIQUID RECYCLE TANK

**T-202,203** OFF-GAS DRYERS

**F-201** HEPA FILTER

ALTERNATIVES 2A/VIT, 3A.1/VIT
OFF-GAS TREATMENT SYSTEM
PROCESS FLOW DIAGRAM
FIGURE 4-5



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previous plans to dispose of the charcoal from the charcoal canister by vitrifying it. Recent information developed in the Glass Optimization Study indicates that this would cause reduction (of metal) problems within the melter. Therefore, at present, this approach is not advocated. Current intentions are to reduce the carbon to ash (utilizing the same off gas treatment control as the vitrifier) and then dispose of the ash in the melter. This same concept may be extended to the HEPA filters. Scrubber residuals are intended to be managed by utilizing the AWWT System.

Decontamination and Decommissioning

All facilities and equipment installed and used by this alternative would be disassembled, decontaminated (if necessary), characterized, and appropriately disposed as part of Subunit C.

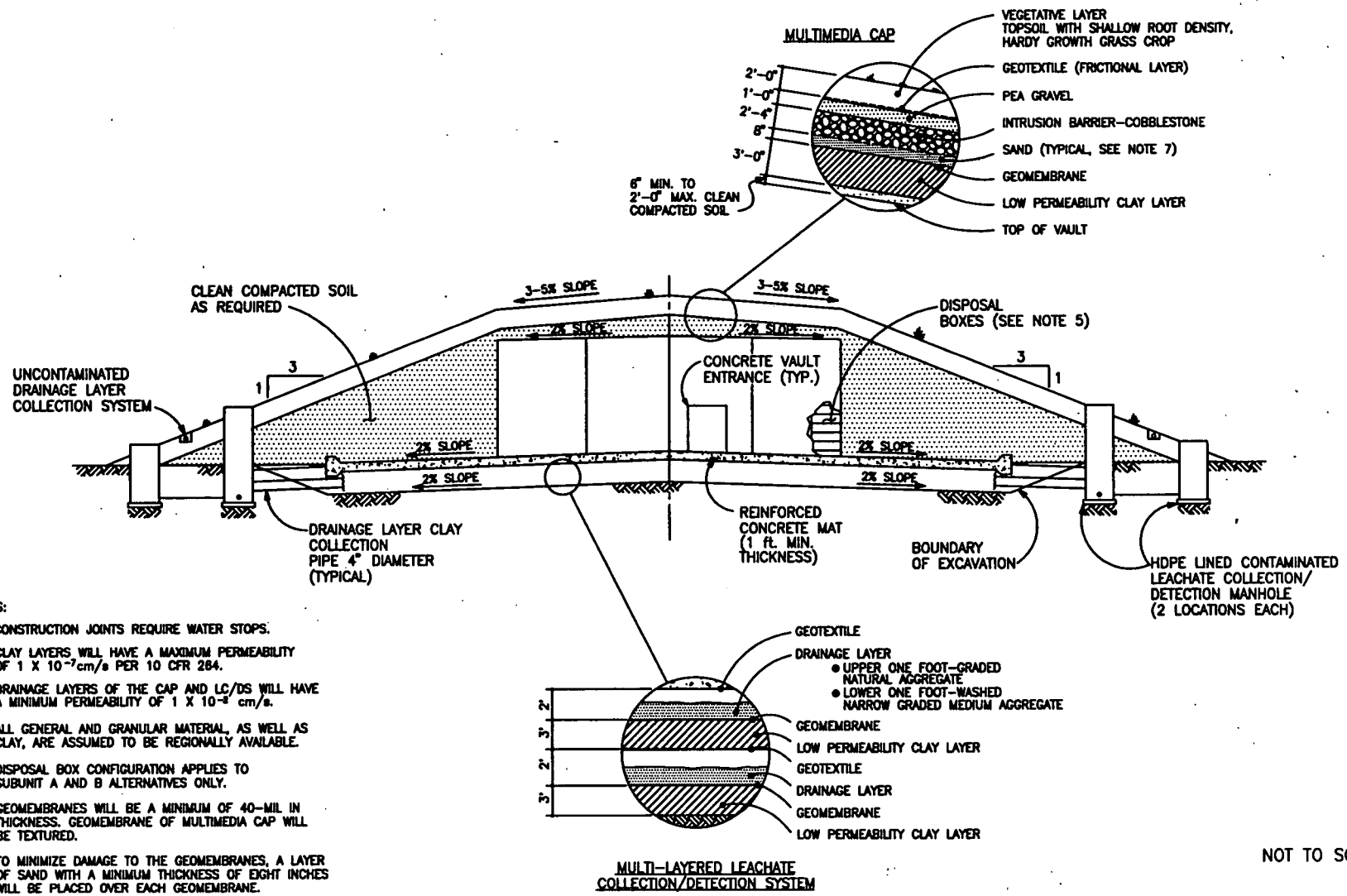
On-Property Disposal

The vitrified product would be disposed in an above-grade disposal vault. Figure 4-6 provides a typical conceptual cross-sectional view of the vault and the underlying multimedia LC/DS. Final closure would be completed by the construction of a multimedia cap over the vault. Figure 4-7 depicts the plan view of the conceptual disposal vault with institutional controls. The final location of the vault will be determined in accordance with the OU5 ROD.

The concrete vault would have a service opening to allow access for the placement of DOT specification 7A Type A containers. The floor of the vault would have a minimum slope of two percent to facilitate any leachate collection and monitoring. The roof of the vault would also have a minimum slope of two percent to allow storm water runoff. As each vault is filled to capacity, all equipment and temporary utilities would be removed and the vault sealed before the multimedia cap is installed.

The vault would be constructed on a reinforced concrete mat with a minimum thickness of 0.3 m (1 ft). The perimeter of the mat would be bounded by a curb with embedded pipes that are connected to the manholes of the underlying multimedia LC/DS to facilitate the collection of any contaminated leachate after final closure. The LC/DS would be composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the groundwater and the underlying Great Miami Aquifer.

The soil of the composite liners would be constructed of a natural, compacted clay with a maximum permeability of $1 \times 10^{-7}$ cm/s. The layers would be a minimum of 0.9 m (3 ft) thick. To improve




NOTES:

1. CONSTRUCTION JOINTS REQUIRE WATER STOPS.
2. CLAY LAYERS WILL HAVE A MAXIMUM PERMEABILITY OF 1 X $10^{-7}$cm/s PER 10 CFR 264.
3. DRAINAGE LAYERS OF THE CAP AND LC/DS WILL HAVE A MINIMUM PERMEABILITY OF 1 X $10^{-3}$ cm/s.
4. ALL GENERAL AND GRANULAR MATERIAL, AS WELL AS CLAY, ARE ASSUMED TO BE REGIONALLY AVAILABLE.
5. DISPOSAL BOX CONFIGURATION APPLIES TO SUBUNIT A AND B ALTERNATIVES ONLY.
6. GEOMEMBRANES WILL BE A MINIMUM OF 40–MIL IN THICKNESS. GEOMEMBRANE OF MULTIMEDIA CAP WILL BE TEXTURED.
7. TO MINIMIZE DAMAGE TO THE GEOMEMBRANES, A LAYER OF SAND WITH A MINIMUM THICKNESS OF EIGHT INCHES WILL BE PLACED OVER EACH GEOMEMBRANE.

FIGURE 4–6 ABOVE GRADE DISPOSAL VAULTS



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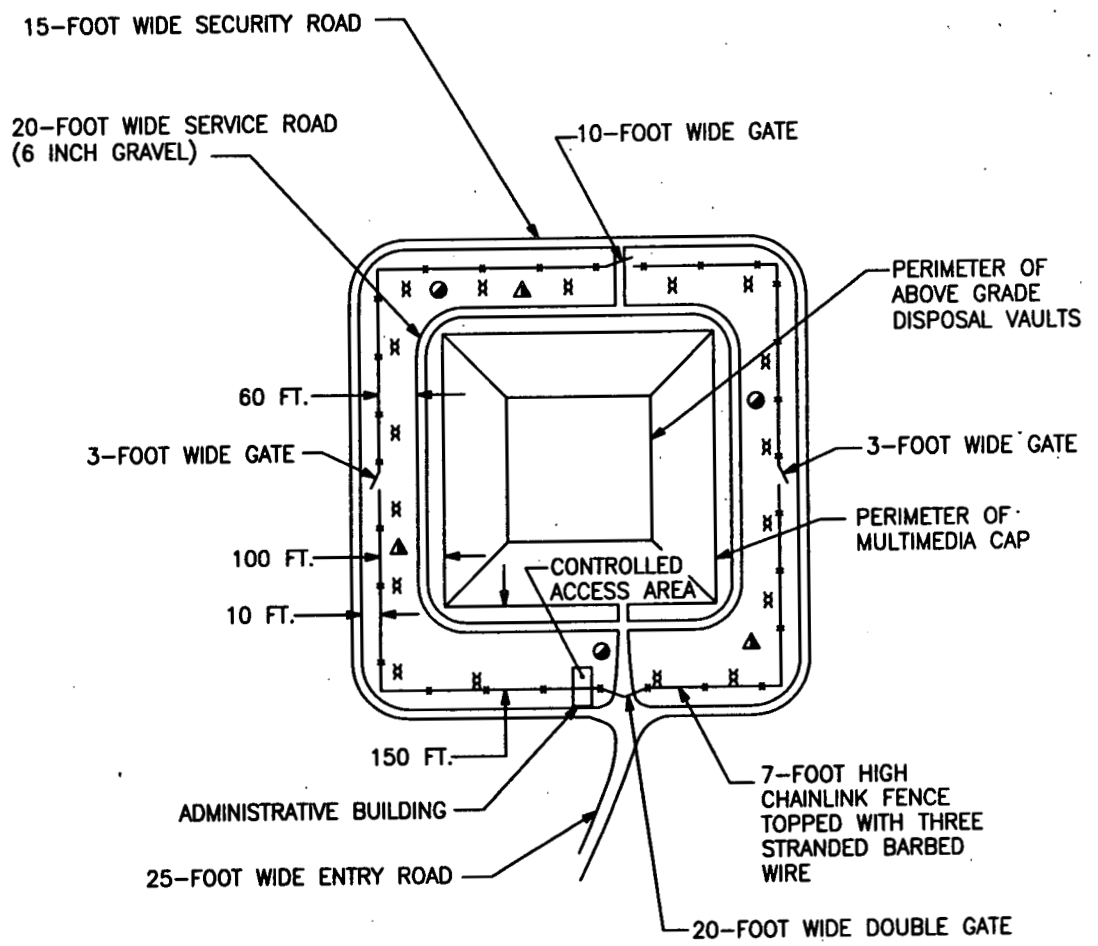
- 5205
FEMP-OU4FS-6-FINAL
February 1994

NOTES:

1. PERIMETER OF INSTITUTIONAL ACTIONS: VARIABLE BASED UPON CHOSEN ALTERNATIVE.
2. ACTUAL MONITORING WELL LOCATIONS ARE DEPENDENT ON FINAL REGIONAL GROUNDWATER FLOW DIRECTIONS
3. SEE FIGURE 4-8 FOR DETAILS OF ABOVE GRADE DISPOSAL VAULTS.




LEGEND:

- DEEP MONITORING WELL
- SHALLOW MONITORING WELL
- 20-FOOT HIGH 150 W SODIUM VAPOR MAST MOUNTED LIGHTS 3 PHASE ON WOODEN POLES

NOT TO SCALE

FIGURE 4-7
PLAN VIEW OF ABOVE GRADE DISPOSAL VAULTS WITH INSTITUTIONAL ACTIONS

the performance of the clay, a geomembrane of at least 40 mil in thickness would be placed over the surface of the clay, which has been smooth-rolled to ensure good hydraulic contact. To minimize damage to the geomembranes during construction, a sand layer with a minimum thickness of 20 cm (8 in.) would be placed over the geomembranes of the LC/DS.

Between the composite soil liners, drainage layers would be installed to intercept any leachate that may be generated. The drainage layers would be a minimum of 0.6 m (2 ft) each in thickness. The upper 0.3 m (1 ft) of each layer would be a graded natural aggregate and the lower 0.3 m (1 ft) would be a narrow-graded medium aggregate to provide a minimum permeability of 1 x $10^{-2}$ cm/s. A geotextile membrane would be placed on the upper surface of each drainage layer to prevent the migration of fines from overlying material.

During placement of the aggregate, 10 cm (4 in.) diameter pipes would be installed within the aggregate to collect and direct any leachate to a series of manholes lined with high density polyethylene (HDPE). The leachate would then be removed from the manholes by vacuum truck for treatment at the FEMP site AWWT facility.

For purposes of this FS, it has been assumed that active maintenance of the leachate collection system would continue for a period of 30 years. The 30-year time period was adopted since it is considered to best represent the time required to achieve site-wide remedial action objectives for the five FEMP operable units. It is anticipated, however, that active maintenance of the leachate collection system would not be required for the entire 30-year timeframe due to the design of the capping system (i.e., infiltration barriers). In the unlikely event that active maintenance of the leachate collection system is required beyond the end of active on-site remedial activities (i.e., 30 years), active maintenance would be continued until such time as deemed unnecessary by DOE and EPA to ensure protection of human health or the environment.

A multimedia cap constructed of five distinct layers of media would provide final closure of the vault. The upper layer of the cap would be a vegetative layer consisting of topsoil with a hardy, shallow-root grass cover. This layer would be noncompacted and have a minimum thickness of 0.6 m (2 ft) to support plant growth. The vegetative layer would inhibit erosion and allow runoff during storm events. A drainage layer would be beneath the vegetative layer to intercept infiltrating precipitation. Within the layer would be 0.3 m (1 ft) of pea gravel that would provide a minimum permeability of 1 x $10^{-2}$ cm/s. A geotextile membrane would be placed between the vegetative layer and the top surface

of the drainage layer to prevent the migration of granular fines from the vegetative layer to the drainage layer.

A layer of cobblestone with a minimum thickness of 0.7 m (2.3 ft) would be beneath the peagravel to serve as an inadvertent intrusion barrier and would also serve as part of the drainage layer. Beneath the cobblestone would be a composite soil liner to impede downward moisture movement from the drainage layer. The soil of this layer would be natural, compacted clay with a maximum permeability of 1 x $10^{-7}$ cm/s. The layer would be 0.9 m (3 ft) thick to ensure the isolation of the disposal containers (Subunits A and B only). A geomembrane at least 40 mil in thickness would be placed over the surface of the clay, which is smooth-rolled to ensure good hydraulic contact, thus improving the performance of the clay. To minimize slippage of the overlying layers due to interfacial shearing characteristics, the geomembrane would be textured. Similar to the composite soil liners of the LC/DS, a layer of sand would be placed over the geomembrane to minimize damage during construction. The foundation of the multimedia cap would be clean, compacted soil. This layer would be a minimum of 15 cm (6 in.) to a maximum of 0.6 m (2 ft) in thickness above the vault. All general and granular material, as well as clay, are assumed to be regionally available.

Upon completion of the multimedia cap, fencing, permanent markers and deed restrictions would be instituted. To provide assurance against inadvertent intrusion into the wastes, this alternative also provides for continued federal ownership of the FEMP property. Under continued federal ownership, the government is assumed to discontinue active access controls and site maintenance following completion of remedial activities and attainment of site-wide remedial action objectives. While the federal government would not maintain a continued site presence after completion of site cleanup, the government would continue to exercise its rights of ownership to preclude site development. Monitoring of the site would continue, as necessary, to support CERCLA five-year reviews. The monitoring network would include wells appropriately located to indicate the effectiveness of the above-grade disposal facility in ensuring the continued protection of human health and the environment. The on-property above-grade disposal vault would cover approximately 2.8 ha (6.9 acres).

4.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2A/Vit meets the remedial action objectives for Subunit A. Implementation of this alternative would prevent direct access to waste materials and would mitigate the migration of contaminants to the air, soil, and groundwater. Exposure to direct radiation above protective levels

also would be prevented. Three primary actions would be used to meet the remedial action objectives, thereby providing adequate protection to human health and the environment. These actions are treatment through vitrification, containment in above-grade disposal vault, and implementation of institutional control measures.

Treatment of Subunit A materials through vitrification would reduce contaminant toxicity, mobility, and volume. The leaching rate of the treated waste would be reduced, enhancing the protection of the underlying Great Miami Aquifer. Treatment of the material prior to disposal would provide additional protection in the event that the disposal vault begins to degrade, allowing increased infiltration and subsequent leachate formation. However, beyond the 1,000 year expected design life of the disposal vault, continued protection becomes less certain as a result of possible degradation of the vitrified material and subsequent increased leachability. As demonstrated by treatability studies, the leaching rate of the treated material is much slower than untreated material.

Containment of the treated material in an on-property, capped above-grade disposal vault would provide additional control of contaminant migration to human and environmental receptors. The disposal vault would also prevent direct radiation from the treated waste material and radon (minor contribution). The vault design would include an intruder barrier and permanent markings to inhibit purposeful or inadvertent human intrusion of the facility's engineered protective features. The vault would be designed for a life of 1,000 years. The vault would be designed to preclude the need for long-term active maintenance. The design features of the vault, including the infiltration barriers, are anticipated to eliminate the need for the active operation, maintenance, and monitoring of the leachate collection system.

The leachate system would be monitored with collected waters pumped (if necessary) during the active operational phase of site remedial actions (i.e., approximately 30 years). It is anticipated that such operations and maintenance of the leachate collection would not be warranted (i.e., due to lack of flow) beyond that timeframe. As discussed above, continued long-term effectiveness of the vault cap and leachate collection system is uncertain, and eventual degradation could lead to an increased rate of infiltration, leachate formation, and release. Fate and transport modeling using conservative assumptions supports the conclusion that long-term protection of human health and the environment would still be achieved, based on the slow rate of deterioration of the disposal vault.

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Institutional control measures would be employed to supplement the treatment and containment actions to provide additional assurance that overall protection would be maintained as engineered components degrade. Institutional controls include the adoption of long-term federal government ownership of the FEMP site. Continued federal ownership of the site would preclude future on-property residential and farming land uses which could result in direct exposure to the waste materials through intrusive actions or facility degradation. The use of institutional controls is also consistent with an ARAR for the on-property disposal vault. To comply with ORC 3734.02(H), hazardous and solid waste disposal facilities must include a protective covenant to restrict future mining, drilling, and residential uses of the active disposal areas in any conveyance deeds. In accordance with this requirement, a deed restriction would be placed on the FEMP site property detailing these restrictions. The uncertainty associated with very long-term institutional control periods includes a possible loss of federal ownership and the loss of administration of the property records containing the deed restrictions.

Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the vitrified material by future human and ecological receptors. Exposures to receptors through these pathways (groundwater, air, etc.,) in the event of disposal vault failure would be expected to be minimal due to the positive attributes of the treated wastes. Direct radiation exposure could be significant in the event the disposal vault is breached, due to the presence of significant activity concentrations of the long-lived gamma emitting radionuclides. For example, the primary radionuclide of concern in the K-65 material is radium (Ra-226). It has a half-life of more than 1,600 years. Consistent with the standard health physics concept of radioactive decay, it is generally recognized that only after a period of seven half-lives, a material would present negligible risk or be considered "safe." If this concept is applied to Ra-226, 11,000 years would have to pass before Ra-226 becomes "safe." Similarly, the half-life of thorium-230 (Th-230) is 80,000 years; the seven half-life period for this radionuclide would be on the order of a half million years.

Ultimately, the risks from complete failure of the alternative could approach baseline risk conditions. However, both engineering controls and institutional controls would have to fail before unacceptable risks to human health and the environment would occur.

There are no unacceptable short-term risks from Alternative 2A/Vit. There are increased worker risks over the no-action alternative due to radiation exposure during removal, treatment, and

packaging. However, through the use of remote removal, shielding, and implementation of a worker health and safety plan in compliance with 29 CFR § 1910.120, these exposures would be kept to ALARA levels and would comply with DOE Orders.

4.2.2.2 Compliance with ARARs

Alternative 2A/Vit would comply with all pertinent ARAR/TBC requirements identified and discussed in Tables F.2-1 of Appendix F. Compliance or noncompliance with the key chemical-, location-, and action-specific ARARs/TBCs presented in these tables is discussed below. Detailed documentation of compliance with ARARs/TBCs for Alternative 2A/Vit is presented in Table F.2-2 of Appendix F and in the detailed risk assessment presented in Appendix D.

Chemical-Specific ARAR/TBCs

A set of the identified ARAR/TBCs provides chemical-specific and dose-based requirements for the protection of groundwater. SDWA regulations provide prescriptive chemical-specific limitations including the MCLs defined in 40 CFR §§ 141.11, 141.15, 141.16, 141.15, 141.61, and 141.62 for inorganics and organics. These concentration-based limits are presented in numerical form in Table F-2.1a, and would be met in the groundwater below the disposal site. A recent SDWA rule-making by EPA in 40 CFR § 141 has proposed concentration-based limitations for certain previously unregulated radionuclides, including uranium at 20 ug/l. These proposed limitations are more restrictive than existing promulgated standards; therefore, they have been adopted as TBC requirements. These TBCs would also be met in the groundwater below the disposal facility.

Additionally, dose-based requirements for the protection of potential public receptors using affected groundwaters are defined in SDWA and RCRA solid waste requirements of 40 CFR § 141.16 and OAC 3745-27-10(D) respectively. As specified in 40 CFR § 141.16, the annual effective dose equivalent is limited to 4 mrem, assuming the consumption of two liters per day of potable groundwater. DOE Order 5400.5 limits the allowable annual effective dose equivalent from exceeding 100 mrem to any member of the public from all pathways including groundwater. Under this alternative, these dose limits would not be exceeded.

Groundwater compliance is typically demonstrated by fate and transport modeling. Guidance is provided in 40 CFR § 257.3-4 and 40 CFR § 264 Subpart F as to the point of compliance for demonstrating whether the groundwater protection requirements for inorganic and organic contaminants would be attained. The most restrictive groundwater requirements for these constituents

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appear in 40 CFR § 264.94, which requires the disposal vault to meet the concentration-based limits in the uppermost aquifer underlying the waste management area at the point of compliance, which is a vertical surface located at the hydraulically down-gradient limit of the waste management area (pending the specific establishment of an alternative boundary). The uppermost aquifer is the Great Miami Aquifer. The point of compliance for the conceptual vault would be adjacent to the berm and inside the fenced security area for the unit.

The specified 1,000-year fate and transport modeling of uranium, the principal groundwater constituent of concern, indicates the uranium concentration would not exceed the proposed MCL at the point of compliance (see Appendix D for a description and results of this modeling and the discussion of the Long-Term Effectiveness in Section 4.2.2.3). The concentrations in the Great Miami Aquifer modeled for releases of the other contaminants of concern would also be within the concentration- and dose-based regulatory limits.

Airborne emissions, soil-related exposures, and penetrating radiation associated with the disposal vault would be controlled with engineered features. The most critical chemical-specific ARAR/TBC for airborne releases for this alternative relates to radon. The CAA NESHAP program established a radon flux rate standard for radium bearing material. The maximum permissible surface release rate of radon-222, as specified in 40 CFR § 61 Subpart Q, is 20 pCi/m$^2$/s, surface averaged. This requirement is supplemented by the Uranium Mill Tailings Radiation Control Act (UMTRCA) radon release standards in 40 CFR § 192.02(b), which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 pCi/L. Similar TBC requirements are contained in DOE Order 5400.5, Chapters III and IV.

Requirements for other radionuclides are established in the CAA NESHAP program under 40 CFR § 61 Subpart H and DOE Order 5400.5, Chapter III. The NESHAP standard sets a maximum annual dose rate of 10 mrem to any member of the public, measured as an effective dose equivalent. The atmospheric release of radionuclides (including radon) from the surface of the disposal vault would be essentially eliminated due to the treated non-porous (vitrified) waste form, the concrete disposal vault liner [over 3 m (9 ft) thick], and the multi-media engineered cover [at least 3 m (9 ft) thick].

On the basis of available treatability data (further discussed under Reduction of Toxicity, Mobility, and Volume), the vitrification of the Subunit A materials decreases the radon flux rate from the untreated waste to below the required or emission rate limits. The application of the multi-media

capping system to the above-grade disposal vault would further reduce, or essentially eliminate, any potential above background releases of radon and other airborne contaminants from the waste disposed in the unit. Given these multiple barriers to the release of radionuclides, the 40 CFR § 61 Subpart Q release rate and the other identified chemical-specific public dose and airborne concentration limits would be met.

All surface water releases (originating from the vault LC/DS) would be directed to the FEMP site AWWT facility for treatment prior to release. Since the AWWT facility would be subject to the NPDES permit issued by the State of Ohio, any contaminants in this waste stream would be removed or treated to acceptable levels prior to discharge. The Ohio Water Quality Standards for a receiving surface water (OAC 3745-1-07) for a warm water aquatic life habitat would also be attained by this treatment. Restrictions on uncontrolled discharges to surface water bodies would be met through designed engineered controls, and procedures such as Best Management Practices (BMPs).

Location-Specific ARAR/TBCs

Location-specific requirements associated with this alternative relate to the protection of four principal natural features or resources: floodplains, wetlands, endangered species, and the sole-source aquifer underlying the FEMP site. Restrictions on activities conducted in floodplain areas are specified in 10 CFR § 1022. Compliance with these requirements would be met through appropriate planning, siting, design, and operational procedures. Restrictions on activities conducted in wetland areas are presented in 40 CFR § 258.12, 10 CFR § 1022, and OAC 3745-27-07. In accordance with these requirements, steps would be taken to avoid wetland impacts to the maximum extent practicable. If avoidance is not practicable, based on the setback requirements and geomorphology, steps would be taken to minimize wetland impacts. Compensatory mitigation of wetland impacts would be determined using the 404(b)(1) guidelines of the Clean Water Act in consultation with COE, USEPA, and OEPA. Impacts to wetlands will be considered when making a final remedy decision.

Protection of endangered species is mandated by 50 CFR § 402. Studies have been conducted to determine if any potential endangered species or habitat exist in the Operable Unit 4 area. Studies are also being conducted to determine the extent of potential habitat of federally- and state-listed animal and plant species as well as any areas of archeological significance in relation to the location of the disposal facility. If any habitat or cultural artifacts or remains are found, appropriate mitigative measures would be taken. Alternative 2A/Vit would, therefore, comply with these identified location-specific ARAR/TBC requirements.

The State of Ohio solid waste disposal design criteria considerations are found at OAC 3745-27-07. Embodied within these requirements are restrictions pertinent to the location of the on-property disposal vault at the FEMP (Table 4-2). Through the definition of a corrective action management unit (CAMU), these OAC requirements would be considered relevant and appropriate to the implementation of this alternative. The CAMU for Operable Unit 4 includes the area encompassing the Operable Unit boundary and any proposed on-property treatment and disposal areas. To meet the state requirements, the final location of the disposal vault (as determined in accordance with the OU5 ROD) would meet the specific set-back requirements as defined in the citation, including the distance from the property line and the disposal vault to the nearest domicile or water supply well, and the 4.5 m (15 ft) isolation distance between the bottom of the liner system and the top of the uppermost aquifer underlying the disposal vault.

OAC 3745-27-07 (B)(5) specifically prohibits solid waste disposal facilities from being constructed over sole-source aquifers. Exemptions have been granted to this requirement on the basis of technical considerations which are defined in "Guidance on Solid Waste Siting Criteria: Sole Source Aquifer (Guidance No. GD0202.101, May 6, 1991)." These technical considerations include the following:

- There is a significant thickness of low permeability material between the disposal vault liner and the aquifer.
- There is no significant interconnection between the aquifer and any significant saturated zones that exist above the aquifer.
- No adverse impact to human health or safety or the environment would occur as a result of granting the exemption.

In order to meet the technical criteria for exception from this part of the state siting requirements, hydrogeologic data would have to be collected from the actual site of the disposal vault (once determined in accordance with the OU5 ROD), and must demonstrate through modeling, that any future releases to groundwater would not pose an unacceptable risk. It is believed an acceptable site location exists to meet this requirement.

For example, the conceptual location of the disposal vault would meet the technical considerations used to grant exemptions to the location requirements: approximately 30 feet of low permeability glacial till lies beneath the proposed liner, saturated zones in the glacial till have no significant hydraulic connections with the underlying aquifer, and fate and transport modeling predicts that potential future releases to the aquifer from the facility would not exceed MCLs or lead to an ILCR

TABLE 4-2

## SUMMARY OF SOLID WASTE LANDFILL SITING REQUIREMENTS IN OAC 3745-27-07(B)

(1) The sanitary landfill facility is not located in a sand or gravel pit.

(2) The sanitary landfill facility is not located in a limestone quarry or sandstone quarry.

(3) The limits of solid waste placement are not located in any of the following areas, in existence on the date of receipt of the permit to install application by Ohio EPA:

- (a) National park or recreation area; or
- (b) Candidate area for potential inclusion in the national park system; or
- (c) State park or established state park purchase area; or
- (d) Any property that lies within the boundaries of a national park or recreation area but that has not been acquired or is not administered by the secretary of the United States Department of the Interior.

(4) The sanitary landfill facility is not located within the surface and subsurface area surrounding a public water supply well through which contaminants may move toward and may reach the public water supply well within a period of five years.

(5) The sanitary landfill facility is not located above an aquifer declared by the federal government under the "Safe Drinking Water Act" to be a sole source aquifer prior to the date of receipt of the permit to install application by the Ohio EPA.

(6) The limits of solid waste placement are not located within 1000 feet of the following:

- (a) Areas designated by the Ohio Department of Natural Resources as either a state nature preserve, a state wildlife area, or a state scenic river; or
- (b) Areas designated, owned, and managed by the Ohio historical society as a nature preserve; or
- (c) Areas designated by the United States Department of the Interior as either a national wildlife refuge or a national scenic river; or
- (d) Areas designated by the United States forest service as either a special interest area or a research natural area in the Wayne National Forest; or
- (e) Stream segments designated by Ohio EPA as either a state resource water, a coldwater habitat, or an exceptional warmwater habitat.

(7) The limits of solid waste placement and the leachate management system are not located within two hundred feet of a fault that had been displacement in Holocene time.

(8) The sanitary landfill facility is not located within an area of potential subsidence due to an underground mine.

(9) The sanitary landfill facility is not located above an unconsolidated aquifer capable of sustaining a yield of one hundred gallons per minute for a twenty-four-hour period to a water supply well located within one thousand feet of the limits of solid waste placement.

(10) The limits of solid waste placement and the leachate management system are not located in a regulatory floodplain.

(11) The limits of solid waste placement are not located within one thousand feet of a water supply well or a developed spring.

(12) The limits of solid waste placement are not located within three hundred feet of the sanitary landfill facility's property line.

(13) The limits of solid waste placement are not located within one thousand feet of a domicile.

(14) The limits of solid waste placement are not located within two hundred feet of a stream, lake, or natural wetland.

(15) The isolation distance between the uppermost aquifer system and the bottom of the recompacted soil liner of a sanitary landfill facility is not less than fifteen feet of in situ or added geologic material.

greater than $1x10^{-6}$. However, this type of information would be collected and demonstrated for the final disposal location in order to demonstrate compliance with this requirement.

Fate and transport modeling for the specified 1,000-year time frame predicts that no adverse impact to human health or the environment would occur for Alternative 2A/Vit (groundwater fate and transport model results are presented in Appendix D). The ILCR is less than $1x10^{-6}$ for all receptors and all land use scenarios. Predicted concentrations in the Great Miami Aquifer at the point of compliance for the disposal facility are all less than the MCLs, proposed MCLs, non-zero MCLGs, and dose limits that have been identified as ARARs and TBCs for Alternative 2A/Vit.

In consideration of the hydrogeologic factors, design, and impact prevention and mitigation capabilities, an exemption to allow the construction of a disposal vault over the sole-source aquifer at a suitable location at the FEMP site could be technically justified, and the location requirements of OAC 3745-27-07 relating to the sole-source aquifer would be met for Alternative 2A/Vit.

Action-Specific ARAR/TBCs

Alternative 2A/Vit would comply with all pertinent action-specific ARARs identified in Appendix F. The above-grade disposal vault system incorporates the design requirements for the disposal of uranium mill tailings (40 CFR § 192), hazardous waste under RCRA (i.e., the TSDF requirements for land disposal facilities under 40 CFR § 264), and the intruder protection requirements under 10 CFR § 61. The following features would be incorporated into the overall design for Alternative 2A/Vit: (a) waste treatment through vitrification; (b) an engineered concrete vault with intrusion barrier; (c) a multi-layer LC/DS; and (d) a 3 m (10 ft) thick multi-media cap. The technical elements of this design are described in Section 4.2.2. A NEPA evaluation as required by 10 CFR § 1021.2 would be performed prior to implementing specific remedial actions.

Pursuant to Section 3734.02 (H) of the Ohio Revised Code, construction activities are prohibited over land areas where hazardous or solid waste facilities were operated, without the prior approval of the Director of the Ohio EPA. Additionally, requirements under 40 CFR § 264.310 provide that all disposal vault systems be protected and benchmarks be used to mark the location of waste cells. Compliance with these ARARs would be achieved through design and the implementation of institutional controls at the disposal vault. These controls would be maintained through the use of fences, sign posting, deed restrictions, and continued federal ownership of the FEMP site.

As a result of the elevated direct penetrating radiation associated with the vitrified residues, the prescriptive intruder protection requirements established in 10 CFR § 61.7 have been adopted for the on-property disposal of the residues. These requirements include a minimum cover thickness of 4.5 m (15 feet) above the wastes or the use of specially designed intruder barriers to preclude inadvertent intrusion for at least 500 years. These requirements have been incorporated into the disposal vault conceptual design and would be adopted as a remedial design requirement for Alternative 2A/Vit.

In addition, the Alternative 2A/Vit disposal system has been evaluated and would satisfy the 100 mrem/yr public dose limit for radiation exposure from all pathways as established by DOE Order 5400.5 Chapter II (see Appendix D for the presentation of the analysis). The total exposure to radiation from all potential pathways associated with this alternative would be less than 1 mrem/yr.

The design of the on-property disposal vault also would include engineered features that satisfy the requirements of the Clean Water Act (CWA) for BMPs (40 CFR §§ 125.100 and .104) and 40 CFR § 122.26 for discharge of storm water runoff. Engineering design and controls would also be used to attain compliance with the Ohio Water Quality Standards (OAC 3745-1-07) and RCRA Subtitle C for hazardous waste facilities. Construction and operational requirements for disposal facilities, such as those specified in 40 CFR § 241 Subpart B, and 40 CFR § 264 Subparts B, C, and D would also be complied with through design, planning, and the implementation of appropriate procedures. 40 CFR § 264 Subpart F requirements mandate groundwater detection monitoring and a program to initiate corrective action, if necessary. 40 CFR § 264 Subpart G requires facility closure in a manner that minimizes the release of hazardous constituents. Compliance with these RCRA requirements is met with the incorporation of the appropriate design features. Remediation waste generated during cleanup operations would be managed in accordance with RCRA storage requirements for containers (40 CFR § 264 Subpart I) and tank systems (40 CFR § 264 Subpart J).

Furthermore, remediation wastes would be managed in a CAMU pursuant to implementing remedial action requirements. Use of a CAMU at a RCRA TSDF for remedial activities is allowed by the EPA under 40 CFR § 264 Subpart S. The provisions of the CAMU regulation are designed to facilitate management of remediation wastes. Remediation wastes include both solid and hazardous wastes, as well as media and debris which may be contaminated with a hazardous waste. Residues from the silos, contaminated media and debris, and any hazardous or solid wastes generated during the remediation of Operable Unit 4 may be managed in the CAMU, or moved between CAMUs

without triggering the applicability of the LDRs, or the minimum technology requirements (MTRs) normally required of land based units.

The designation of CAMUs must meet seven specific criteria. These criteria, along with the rationale for designation of CAMUs under this alternative, is as follows:

Criterion #1 - The CAMU must facilitate the implementation of a reliable, effective, protective, and cost-effective remedy. The CAMUs would allow implementation of an alternative which would have been determined through the CERCLA process to be reliable, effective, protective, and cost-effective for the management of the waste in accordance with acceptable risks and all identified ARARs.

Criterion #2 - Management under a CAMU must not create unacceptable risks to human health or the environment. Management of Operable Unit 4 waste material under a CAMU would not create unacceptable risks to human health or the environment since the risks associated with this alternative would have to be acceptable to the agencies and the public before the alternative could be accepted. Identified risks were evaluated for this alternative, assuming remediation wastes would be managed in the CAMU as described under this alternative.

Criterion #3 - Inclusion of any land area that is uncontaminated into a CAMU is allowed only if the waste management in that area will be more protective of human health and the environment than management of such wastes at more contaminated areas of the facility. Although the land area eventually designated for the on-site disposal facility may be less contaminated than the Operable Unit 4 area where the wastes are presently located, inclusion of this area into a CAMU for the on-site disposal alternative would be more protective than management of the wastes either under in situ alternatives at the Operable Unit 4 location, or in disposal facilities located in other operable units or areas of the facility that are more contaminated. On-site disposal in the Operable Unit 4 area, or within other operable unit boundaries would be less protective, and additional contaminants in those areas could contribute additional long term risks.

Criterion #4 - Areas within a CAMU where wastes remain in place after "closure" of the CAMU are to be managed and contained to minimize future releases. Once the material is removed from the silos and treated, the silos and the land area within the CAMU, which includes the Operable Unit 4 boundary and the treatment facility, would be remediated to acceptable risk levels under an alternative for Subunit C that would remove or contain residuals to the greatest extent practicable or otherwise

act to minimize future releases. The substantive RCRA closure and groundwater monitoring requirements would be potential ARARs for any alternative involving treatment or disposal units, including the disposal vault. Any residual wastes that exceed risk or regulatory thresholds would undergo additional remediation.

Criterion #5 - The CAMU must expedite the implementation of the remedy, which would be achieved by removing the administrative and technical requirements of the LDRs and MTRs that otherwise might be triggered upon managing the remedial waste in a land based unit.

Criterion #6 - Wastes that will remain in place after "closure" of the CAMU are required to be treated to enhance the long-term effectiveness of the remediation by reducing their toxicity, mobility, and volume, using innovative technologies wherever possible. This alternative would meet this criterion by removing material from the silos, treating the material using vitrification, and managing the treated waste in an on-site disposal vault.

Criterion #7 - Use of the CAMU will minimize the land area of the facility upon which wastes will remain in place after closure. Use of the CAMUs would meet this criterion after completion of this portion of Operable Unit 4 remediation by allowing consolidation by treatment, followed by managing the treated material in an on-site disposal vault. This would contain the material for long-term management and reduce the potential for release and migration of untreated material.

For remediation of Silos 1 and 2 material under this alternative, the designation of two CAMUs would be appropriate. The first would encompass the delineated boundary of Operable Unit 4, and extend to include the adjacent area to the east of Silos 1 and 2, which would be designated for construction of the treatment facility. The second would encompass the area to be designated for the on-site disposal facility. Since this waste material presents significant risks to human health and the environment, management of the remediation wastes would be in accordance with the pertinent ARARs and TBCs, including compliance with the substantive hazardous waste landfill closure requirements and the closure performance standard of 40 CFR § 264.111. Although the RCRA LDRs are not required to be a potential ARAR for this alternative, treatment of the silo material would consequently meet the technical requirements of the LDRs by reducing the leachability of the heavy metals to below RCRA regulatory levels. In summary, management of the remediation waste in the CAMU would be protective of human health and the environment and would abide by other requirements regulating cleanup goals and remedy selection.

The provisions of 40 CFR § 264 Subpart S also allow for the use of temporary units (TUs) for the treatment or storage of remediation waste to provide additional flexibility during the process of remediation. Designated TUs would be either tanks or containers, and would be operated under this provision for a one year time period (subject to a one year extension). The physical and chemical characteristics of the wastes, along with an estimate of volume of remediation waste to be managed in the TUs, would be specifically described in the Remedial Design/Remedial Action (RD/RA) Work Plan for Operable Unit 4 following selection of the alternative. In addition, the RD/RA Work Plan would assess the potential for releases from the unit, the hydrogeological or other relevant environmental conditions at the facility which may influence the migration of any potential releases, and the potential for exposure of humans and environmental receptors if releases were to occur from the TUs. Management of the remediation wastes in TUs would be in accordance with all pertinent ARARs and TBCs, including compliance with the substantive RCRA requirements for hazardous waste tanks and containers (40 CFR § 264 Subparts I and J) as necessary to ensure protection of human health and the environment.

During implementation of the remedial action (including facility construction and waste treatment), appropriate engineered features and procedures would be implemented to comply with the State of Ohio requirements for fugitive dust control (OAC 3745-17-08), the control of emissions of particulates (OAC-3745-17-07 and OAC-3745-17-11), and the prevention of air pollution nuisance (OAC-3745-15-07).

An action-specific ARAR/TBC requirement particular to on-property disposal of Subunit A material at the FEMP site is 40 CFR § 191 (Standards for the Management and Disposal of Spent Nuclear Fuel, High Level, and Transuranic Radioactive Wastes). In October 1990, EPA directed DOE to consider 40 CFR § 191 Subpart A (dealing with the storage and management of waste) as relevant and appropriate to the on-site portions of remedial activities involving the K-65 residues, and to consider 40 CFR § 191 Subpart B (pertaining to waste disposal) as a TBC requirement for the on-site Subunit A disposal alternatives. This direction resulted primarily from EPA's concerns about the potential for inadvertent intrusion into the disposed residues due to conditions present at the FEMP site.

40 CFR § 191 Subpart A specifies a public dose limit during waste storage and remedial operations. This requirement would be met through the use of engineered features that would prevent exposures, or the uncontrolled release of radioactive waste material. Estimates of the dose to the public

calculated for the short-term risk assessment indicate that exposures would be less than 1 mrem/yr (see Appendix D), which is well below the dose rate standard.

40 CFR § 191 Subpart B includes in § 191.13 certain containment requirements which are TBC during design to provide a reasonable expectation that specified cumulative radionuclide-specific release limits will not be exceeded for 10,000 years. More specifically, the disposal system must limit releases such that there is less than one chance in 10 of exceeding the following quantities of activity (based on Table 4-3 of the RI Report for Operable Unit 4, November 1993) over 10,000 years as the result of man-made and natural events (or less than one chance in 1,000 of exceeding 10 times these quantities):

- Ra-226 - 0.450 Ci
- Th-232 - 0.045 Ci
- U-235 - 0.450 Ci
- Th-230 - 0.045 Ci
- U-234 - 0.450 Ci
- U-238 - 0.450 Ci

In order to demonstrate compliance with this requirement, a probabilistic assessment of all events that could result in a release of waste material from the disposal vault would need to be undertaken, along with an assessment of the impact each identified release would have on the accessible environment (i.e., the Great Miami Aquifer). These results would then need to be appropriately summed according to their relative likelihood. The application of such probabilistic modeling techniques is beyond the scope of a CERCLA FS. In a January 21, 1991 letter, EPA questioned the application of these release limits to the on-site disposal alternatives, but reiterated their concern about the need to provide for the long-term protection of inadvertent intruders for 10,000 years.

In order to demonstrate compliance with these limitations, it would require that no more than 1374 kg (3000 pounds) of uranium-238 or 0.45 grams (1/1000th of a pound) of radium-226 would be released from the disposal vault over the 10,000 year period. In the case of uranium, this corresponds to an average of 137 grams (4.8 ounces) released per year. For radium, the quantity is $4.5 \times 10^{-5}$ grams ($1 \times 10^{-7}$ pound) per year. An ability to confidently demonstrate that such minute quantities of material would not be released over so long a period of time is well beyond current modeling abilities. On this basis, the likely compliance or noncompliance of Alternative 2A/Vit to the cumulative release limits of this TBC requirement could not be assessed. However, in response to EPA's letter and the reasonable expectation that the required CERCLA risk goals would be attained for the 1,000-year

modeling horizon, the uncertainty as to compliance with the aforementioned limits was not used as a basis for screening the alternative from further evaluation.

40 CFR § 191 Subpart B also contains requirements that are equivalent or similar to those contained in other ARARs for this alternative that have already been discussed. These include 10 CFR § 61 (Low-Level Radioactive Waste); 40 CFR § 192 (Uranium Mill Tailings); 40 CFR § 61 Subpart Q (Radon Standard); and 40 CFR § 141.16 (Safe Drinking Water Standards). Additional consideration of the adequacy and reliability of the engineering controls to provide for the long-term protection of the inadvertent intruder is discussed as a part of the evaluation of the long-term effectiveness of this alternative. All other provisions of 40 CFR § 191 would be attained by Alternative 2A/Vit.

#### 4.2.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2A/Vit reduces the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Figure 4-8 is a conceptual site model for the various action alternatives considered. It is presented to illustrate the potential long-term exposure pathways. These pathways represent the realm of potential exposures which could occur after remediation is completed. Some of the pathways can only occur with failure of the engineered or institutional controls (indicated with a dashed line). Some of the pathways would occur to some extent as part of the alternative (indicated by a solid line). Residual risk would only be through completed pathways. The basis of the risk evaluation is presented in Appendix D. Each of these concerns is addressed through the primary components of Alternative 2A/Vit: treatment, isolation in an disposal vault, and the application of institutional controls.

Vitrification significantly reduces the mobility of the COCs and the radon emanation rate. While the direct radiation fields remain unchanged after vitrification, the disposal vault design supplemented by institutional controls precludes contact to or direct radiation exposure from the treated waste by an expanded trespasser. The disposal vault also contributes to a significant reduction in leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude access to the waste material by an on-property resident.

Because 2A/Vit includes the on-property disposal of treated residues, the five-year CERCLA review process to ensure continued performance of the disposal system would be part of this alternative.

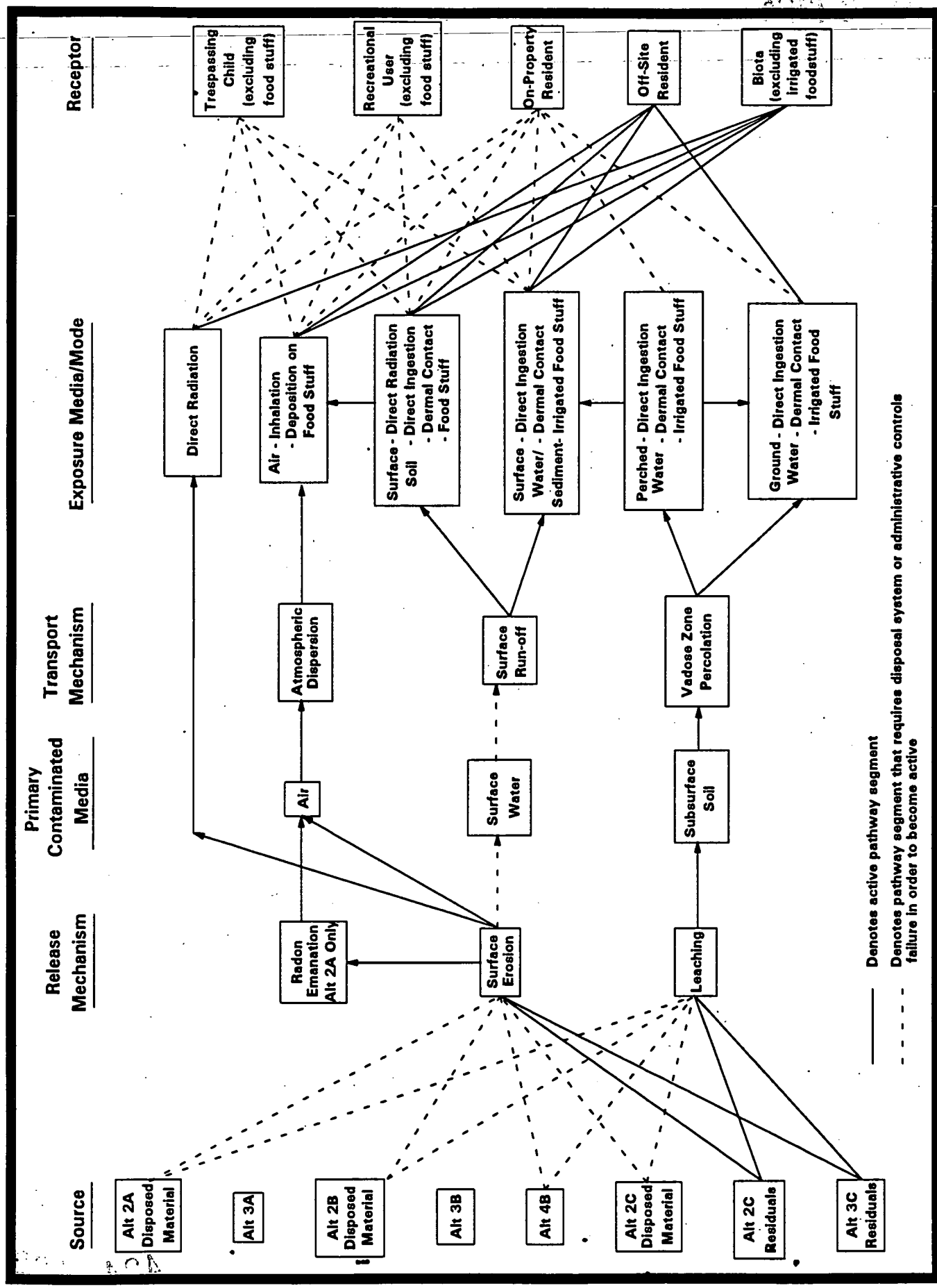


FIGURE 4-8 LONG-TERM RISK CONCEPTUAL SITE MODEL

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Adequacy and Reliability of Controls

As previously indicated, the projected residual excess cancer risk to viable receptors, which is attributable to Alternative 2A/Vit, is less than $10^{-6}$. The on-property disposal unit uses proven construction technologies and materials. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low-level radioactive waste under both DOE and NRC programs, and uranium mill tailings under the DOE UMTRCA and the Formerly Utilized Sites Remedial Action Program (FUSRAP). Fate and transport modeling to assess the most likely release mechanism under degradation of the facility (leaching) is completed. The results were based on the assumption that components of the system slightly degrade over 1,000 years and that infiltration rates (and consequently exfiltration rates) increase to 1.3 cm/yr [based on the Hydrologic Evaluation of Landfill Performance (HELP) model]. Also, the leachability of the treated material was assumed to be the same as that indicated in the treatability study results. Under these assumptions, the leaching of contaminants would not pose a risk to off-site receptors. Even if these input parameters were increased to 15 cm/yr (highest possible with no infiltration barrier) and the leachability of the untreated material were used, the overall result would not change. The leaching of the contaminants would result in a risk to off-site receptors of approximately $10^{-6}$.

Vitrification is a proven technology which has not been previously applied to the stabilization of waste materials at the scale contemplated under Alternative 2A/Vit. From 1989 to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of the vitrification technology on K-65 residues. The tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics (see Appendix C). An ongoing glass optimization program underway for the K-65 residues has identified a relatively wide envelope of operating parameters (temperature, additive rate, and waste composition) under which the vitrification system could perform to produce an acceptable product. Additionally, the use of vitrification provides added operational flexibility to recycle glass product not meeting performance based requirements through the glass melter. On this basis, there is a high probability that the vitrification treatment system would attain the required glass product performance requirements.

As a result of the significant direct radiation field associated with the treated K-65 residues and to the long half-life gamma emitting radionuclides present, there is concern for ensuring the long-term protection of the inadvertent intruder or on-property resident (in the event of institutional control failure). The potential dose rate to an individual from intruding into the disposal vault has been

approximated by the Baseline Risk Assessment's calculation of potential dose rates above the untreated silo contents. The baseline risk assessment calculated the potential dose rate to a trespasser on the silo dome to be 3.5 mrem/hr. To address direct intrusion onto the top of the wastes, the baseline calculation were modified to eliminate shielding and distance between the source and receptor. The source was also conservatively assumed as an infinite slab with 20 meter (60 ft) depth. The resultant dose rate was found to be approximately 550 mrem/hr at the point of contact of the waste surface. The density of the vitrified waste would be more than that of the untreated waste. This would offset the contribution to the dose rate from increase in radionuclide concentrations in the vitrified waste. Therefore the approximated dose rate presented here is adequate for risk discussion purposes, especially when there are other unknown parameters such as design details of waste disposal facility and concentrations of radionuclides in the vitrified waste. The location and physical site conditions associated with the FEMP produce significant uncertainties as to the ability to maintain appropriate long term controls to mitigate potential exposures to potential intruders.

Consistent with DOE Order 5400.5, 40 CFR § 264.114 Subparts F and G, and 40 CFR § 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required five-year CERCLA review. As a result of the findings of the review, there is a potential that the disposal system may require maintenance, modification, or replacement. The risks associated with maintenance activities would be generally limited to direct radiation to on-property workers. Consistent with 10 CFR § 835, these potential exposures would be kept ALARA and within regulatory limits.

Long-Term Environmental Impacts

The following paragraphs discuss the long-term impacts of the Alternative 2A/Vit on the environment. Section 4.7 provides a discussion of the irreversible and irretrievable commitment of resources associated with Alternative 2A/Vit.

Soil and Geology

Construction of the disposal vault would result in the permanent disruption of 2.8 ha (6.9 acres) of land. The disposal vault configuration would prevent erosion of waste material that could result in surface soil contamination and would prevent leaching that would contaminate subsurface soil. Uncontaminated soil would be used as fill. Borrow pit soil for construction would be obtained from clearing and grubbing and clean berm soil.

The regional geology of the FEMP site and surrounding area would not be affected by implementation of Alternative 2A/Vit. Geological conditions are important in terms of site suitability for construction of an on-property disposal vault . Because the Subunit A material would be vitrified and the appropriate design factors (e.g., depth of cover material) would be incorporated into the disposal vault, the proposed on-property location would be suitable from a geologic standpoint. The design would also incorporate appropriate protection against seismic damage. A review of local conditions suggests the soil beneath the potential disposal areas on-site are not susceptible to liquefaction or seismically induced settling.

Water Quality and Hydrology

A system to monitor long-term water quality would be implemented by installing monitoring wells around the perimeter of the disposal vault . No significant long-term hydrological impacts to the surrounding area are expected to result from changes to the site. However, after 1,000 years, some degradation could occur. Run-on and runoff controls would be used at the disposal vault and the remaining areas of the site would be regraded to the surrounding grade and surface water would be directed by engineered controls to existing on-property drainageways for proper treatment prior to release.

Final grading would ensure that the site is well drained to minimize any potential impacts to the above-grade disposal vault. The above-grade disposal vault would be actively monitored and maintained for a period of 30 years; however, as previously discussed, the disposal vault was designed for a life of 1,000 years with no active maintenance. To support CERCLA five-year reviews, monitoring of nearby surface water and groundwater would continue as necessary; periodic site inspections would be carried out to identify any damage to the disposal vault or other areas of the site from the erosive forces of heavy rains and wind, biointrusion, or severe natural phenomena (e.g., earthquake or tornado).

Air Quality

Following implementation of Alternative 2A/Vit, the air quality at the FEMP site would be similar to current conditions. There would be no long-term impacts on air quality because the depth and material of the cap on the disposal vault and the non-porous nature of the vitrified waste would limit radon emissions. Disturbed areas would be revegetated, which would minimize release of fugitive dust and other particulates.

Biotic Resources

Long-term impacts may include the destruction of potential habitat for federally- or state-listed plant species or individuals from these species. Potential habitat for threatened or endangered species has been tentatively identified in areas to be impacted by Alternative 2A/Vit activities. Additional studies are being conducted in 1994 to confirm the presence of habitat and individual specie representatives. Federally endangered running buffalo clover (Trifolium stoloniferum) has not been found in spot checks in the grassland areas on the property but has been found in Miami Whitewater forest in similar habitat. Additionally, the state-endangered mountain bindweed (Polygonum cilinode), mentioned as rare in the riparian and pine plantations in 1986 by Facemire et. al, 1990, is found in forested openings. However, the Ohio Department of Natural Resources (ODNR) reports that the only other locations for this species are found in northern Ohio.

Several state-listed migratory birds have been sighted in the northern part of the site (Facemire et al., 1990); however, they do not nest in this area and should not be impacted by the installation of the disposal vault. Implementing 2A/Vit would result in the loss of 2.8 ha (6.9 acres) of potential habitat or individuals. Following completion of construction and excavation activities, disturbed areas would be backfilled, regraded, and revegetated with native grass species. If destruction of habitat or individuals of the Federal- or State-listed plants occurs, appropriate mitigative measures would be taken.

Wetlands and Floodplains

A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and received COE approval in August 1993. The delineation identified approximately 12 ha (29 acres) of jurisdictional wetlands in the northern part of the site. Efforts would be made to site the disposal vault in areas not containing jurisdictional wetlands. However, for the purposes of this NEPA impact analysis, it was assumed that disposal vaults would be sited in the northern and eastern portions of the site. Therefore, the siting of the facility for Alternative 2A/Vit could result in the loss of approximately 5.0 ha (12.4 acres) of forested wetlands. A wetlands assessment pursuant to the requirements of 10 CFR § 1022 has been prepared (Appendix J) for the representative alternative (i.e., leading alternative) and other alternatives evaluated.

The 100- and 500-yr Paddys Run floodplain is located near Silos 1 and 2 and the support facilities. However, these areas would not be permanently altered as a result of implementing Alternative 2A/Vit.

Socioeconomics and Land Use

The area of the disposal vault is estimated at less than 0.1 percent of the site. However, the presence of the on-property disposal vault would result in future land use limitations for the site. No change would be expected in the local population growth, nearby industrial and commercial operations, or noise level. The net long-term impact of Alternative 2A/Vit on these socioeconomics is expected to be positive because the silo contents and sludge would be isolated and controlled. However, aesthetic perceptions to a visitor or passerby could be altered due to the access controls required for the disposal vault. A fenced area topped with barbed wire would be used for restricting access to the material disposal area. These controls could result in noticeable attention drawn to the disposal area.

Cultural Resources

An archaeological survey would be performed for non-controlled areas, not previously disturbed, to be impacted by Alternative 2A/Vit. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of National Historic Preservation Act (NHPA), Ohio Historic Preservation Office (OHPO), American Indian Religious Freedom Act (AIRFA), and Native American Graves Protection and Repatriation Act (NAGPRA). Because any encountered cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2A/Vit uses vitrification to treat all of the wastes making up the contents of Silos 1 and 2 and the sludge in the decant sump tank. A remedy selection treatability study was conducted with Operable Unit 4 materials to compare the performance of vitrification to other remediation technologies. The criteria upon which this comparison was based were the leachability of the waste form, the material volume reduction achieved, and the reduction in radon emanation from the material (Appendix C, Section C.3.0).

The chemical and physical properties of Subunit A wastes were determined and used in developing glass formulas for the bench-scale treatability study tests (Appendix C, Tables C.3-1 to C.3-10). Data from the study revealed that the radon emanation rate from the vitrified K-65 material ranged from 0.01 to 0.06 pCi/m$^2$/s, more than two orders of magnitude less than the EPA limit of 20 pCi/m$^2$/s for radon emanation from uranium mill tailings. Based on an emanation rate ranging from 1,985 to 7,314 pCi/m$^2$/s for the untreated K-65 material, a reduction of radon emanation by a factor of approximately 500,000 was obtained in the bench-scale vitrification tests (Appendix C, Figure C.3-

1). The measured radon emanation rate from the treated waste form is approximately equal to the emanation rate from natural building materials such as brick and concrete, even though the radium content of the waste glass is $10^3$ to $10^6$ times greater than that of natural building materials.

Data from the treatability study revealed that significant volume reductions could be achieved through vitrification. As shown in Table C.3-13, the reduction in volume of material ranged from 50 to 68 percent. Thus, the final volume was approximately 41 percent of the untreated material volume. This result corresponds to a total estimated treated volume of 2770 $m^3$ (3645 $yd^3$).

The results from TCLP testing showed that the vitrified residue material would not exceed RCRA regulatory limits for metals. Thus, the comparison of the TCLP test results (through the leachate concentration) for the treated to the untreated residues demonstrated the effectiveness of vitrification as a treatment process for Subunit A residues. Previous TCLP testing conducted during the RI for Operable Unit 4 indicated that untreated K-65 material exceeded RCRA toxicity characteristic thresholds for lead. Leachate concentrations were below RCRA regulatory limits for all of the glasses produced in these tests Appendix C, Table C.3-14. Lead concentrations in the leachate from the treated material were reduced by a factor of about 500 relative to the untreated K-65 material. Table C.3-18 presents a comparison of the leachate activity from the untreated wastes to the leachate activity from the vitrified wastes.

A wide variation in leaching of the various radionuclides achieved through vitrification was observed. While leaching of Ac-227 from the untreated waste is reduced by a factor of thousands through vitrification, the leachability of some radionuclides such as Ra-226, Ra-228, Th-228, Th-230, and Th-232 was unchanged. The low ratios observed of the activity in the leachate from the untreated waste to the activity in the leachate from the vitrified waste do not necessarily indicate that radionuclides are immobilized; rather, the ratios show that some radionuclides are not leached as readily as others from the untreated waste. For example, while nearly nine percent of the Pb-210 in the K-65 material is leached from the untreated waste, only 0.45 percent of the Ra-226 and 0.01 percent of the Th-230 are leached. Such variations can arise because of differences in solubility among the elements for the conditions encountered in the leachate. Some radionuclides, particularly Ra-226, were found to leach from the treated material samples at the same rate as the major glass constituents, indicating the absence of selective leaching of radionuclides.

A measure of the stability of the vitrified K-65 material is to compare it to leach rate standards which have been developed for high-level vitrified materials. The normalized leach rates observed during the treatability study indicated that all glass formulas exhibited exceptional durability comparable to glasses developed from vitrified high-level wastes. The normalized leach rates were an order of magnitude less than the Defense Waste Processing Environmental Assessment (EA) glass rates and are comparable to those measured for simulated high-level waste glasses. The EA glass is designed to be a standard representing the maximum acceptable leach rate for high-level waste glasses; therefore, the K-65 glasses are substantially more durable than the minimum standard for high-level waste glasses.

Another observation of the treatability tests was that the TCLP will leach the glass more aggressively than the Product Consistency Test (PCT). The PCT is a seven-day static leach test developed for the high-level waste vitrification program. The test uses deionized water at 90°C (194°F) to leach a glass sample which has been crushed and sieved to a size fraction of -100/+200 mesh. The TCLP employs weak acid rather than water to leach the vitrified material. The PCT leach testing demonstrated a high degree of durability for the vitrified K-65 materials.

The viscosity and electrical conductivity of the vitrified materials were measured as a function of temperature. The viscosity data show the glass from various tests (Sequences A, C, and D) had reasonable viscosities for processing within the temperature range reported, but the glass from Sequence B was too viscous in this temperature range. The higher viscosity for Sequence B glass resulted from the high alumina content in the BentoGrout® mixed with the residues, and can be brought to within acceptable levels by increasing the fluxing additives or reducing the BentoGrout® content of the mixture. The conductivity values for all glasses were close to typical ranges for glass processing. Therefore, the results show that the K-65 material can be made into glasses with reasonable conductivity and viscosity by processing in a joule-heated ceramic melter; however, it is also evident that further development for optimization of glass formulas is needed.

The operating temperature considered for the vitrification design [1350°C (2460°F)] would destroy any organic compounds present in the residues and fix metals into the nonleachable stabilized melt. Hazardous inorganic constituents actually become part of the chemical structure of the glass matrix, and not merely encapsulated. Treatability tests demonstrate that the vitrified product effectively immobilizes the RCRA constituents and reduces their leachability to levels below the regulatory limits. Additional remedial design treatability studies would be conducted to further determine the

factors that affect the destruction and removal efficiencies for the contaminants during vitrification and the extent of partitioning of undestroyed contaminants between the vitrified material and the off-gas treatment system. The results of these studies would be used to develop appropriate glass formulations, provide data necessary for sizing and design of the full-scale continuous melter system, and to determine the configuration of the final off-gas treatment system for removal of radon.

Literature data on the leachability of the vitrified product from a variety of waste types indicate similar leach resistance; all vitrified material tested to date have passed the RCRA TCLP test. Contaminant release from a vitrified product is controlled by diffusion and is governed by the same factors that affect release from a chemically stabilized/solidified product. The leachability of the vitrified product could be impacted by the development of immiscible phases in the melt because of the variable chemical composition of the feed stream; however, the short residence time in the melter would minimize the potential for immiscible phase development.

The weathering behavior of volcanic glass (a natural analog to the vitrified product) can provide some measure of the long-term stability and durability of the vitrified product. Only very thin weathering rinds develop on volcanic glass over a period of several million years. The slowness in the overall degradation of a glass grain suggests that the diffusion coefficient or leachability index would remain relatively unchanged over time. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates. On the basis of the longevity of volcanic glass and diffusion calculations, the vitrified product would be expected to withstand environmental exposure for thousands of years.

Treatment residual of the vitrification process would be produced from the off-gas treatment system. Off-gases containing particulate and other pollutants would be captured and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary for an adequate design to reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the vitrification process until all the residual waste is contained in the glass matrix. Furthermore, the effects of vitrification as a treatment are essentially irreversible.

4.2.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls and access controls, Alternative 2A/Vit would be protective of the community during implementation. Figure 4-9 illustrates that radon release during material removal and close proximity to direct emissions of untreated material are the release mechanisms that could potentially impact the community during remediation activities. Potential radon exposures would be minimized through the use of engineering controls. The silo headspace would be kept under negative pressure to prevent the release of radon during removal of material. Additionally, the installation of a RTS would capture released radon and remove it from the air stream. Gas collection and treatment systems operated during vitrification of the material would also minimize radon and other gaseous contaminant releases. It has been estimated that during implementation of Alternative 2A/Vit, fenceline radon exposure levels for the off-site public would be indistinguishable from background levels, less than 0.5 pCi/L.

There is the potential for dust created during berm excavation and disposal vault construction to be slightly contaminated. To control migration of the dust off site, a variety of dust suppression methods would be considered during the design. Controlling the dust would provide protection to the community.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to direct radiation from the residues along with radon, gases, or dust. In addition to the engineering controls that would be implemented to limit the release of contaminants, access controls would also be used during remediation. Through the use of fences and guards, access to the materials by the public would be limited. Access controls are effective, especially in the short term. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 2A/Vit is effective in protecting the community in the short term.

Protection of Workers During Remedial Action

There are no unacceptable risks to workers as a result of implementation of Alternative 2A/Vit. This alternative involves the handling of the waste materials; therefore, there are several potential exposure pathways for workers. Both the release of radon and exposure to direct radiation from the residues could create a risk to workers. It has been estimated that with appropriate protection, the removal and treatment of materials would result in an excess cancer risk level to remediation workers of

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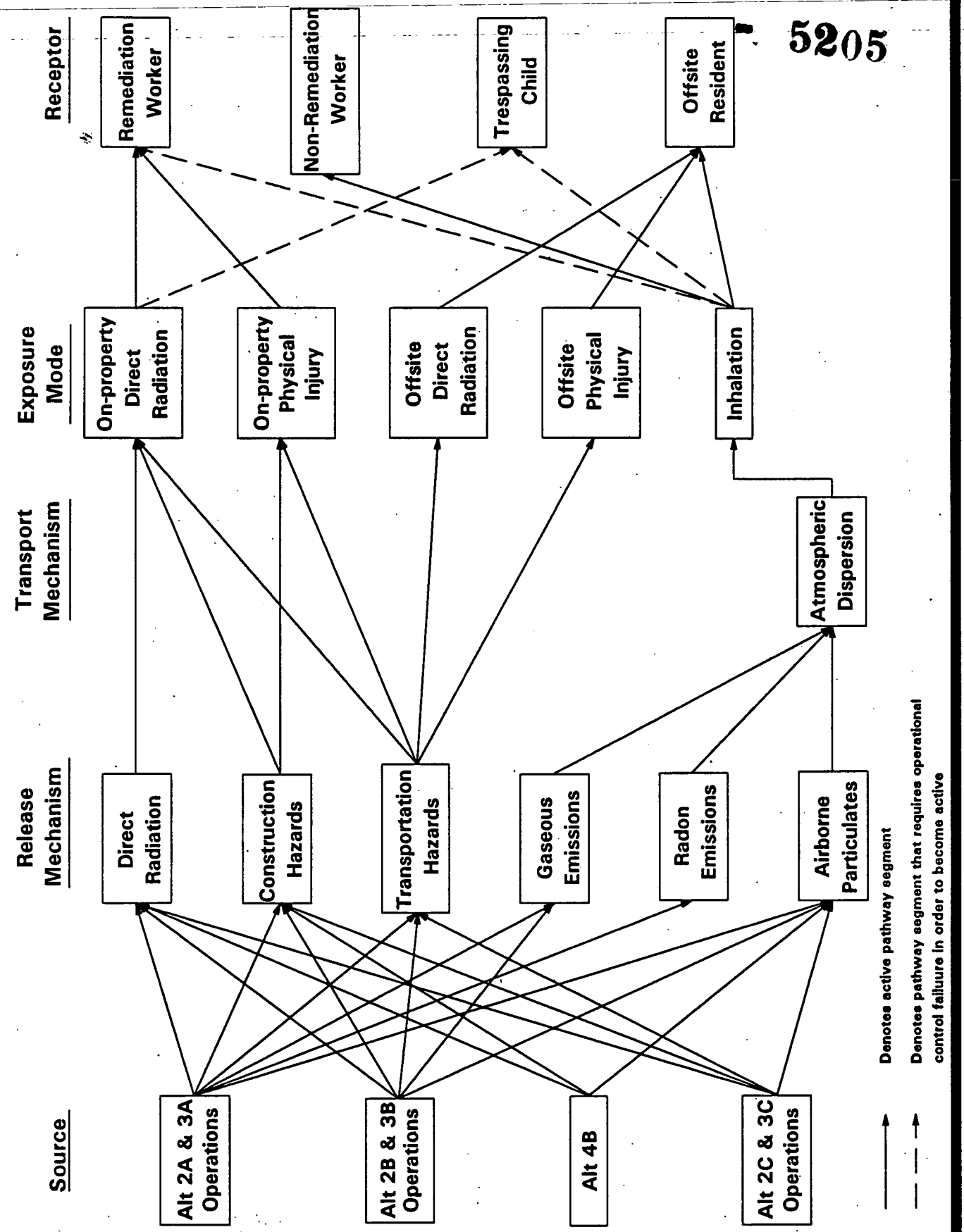


FIGURE 4-9 SHORT-TERM RISK CONCEPTUAL SITE MODEL

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$4x10^{-4}$ (see Appendix D), well within the occupational standards required by DOE Orders. Most of this risk would occur during handling of the untreated residues. As appropriate, workers would wear protective clothing. Shielding would also be used, along with remote activities where needed.

With the negative headspace pressure in the silos and the RTS, it is estimated that there would be no additional risk from radon to remediation or non-remediation workers. However, there may be some additional risk to non-remediation workers who are assumed to not be in protective equipment from dust particles released during berm excavation. Although below occupational limits, the non-remediation worker could experience an ILCR level of $9.6x10^{-7}$ from dust and radon inhalation. This estimate is very conservative and assumes that dust is always present. Dust control would significantly reduce this risk.

There are safety issues associated with the removal and vitrification process. The high temperatures and power of vitrification results in an unquantifiable added risk over cement stabilization. There are also safety issues with constructing the on-property disposal vault. There may be accidents bringing the material on site or heavy equipment accidents. Without considering the nature of the activity, it has been estimated, based solely on labor hours, that the removal, treatment, and on-property disposal of Alternative 2A/Vit could have 7.7 injuries and 0.13 deaths during remediation. All remediation activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR § 1910.120(b)(4). Training and procedures would assure that worker exposure would be ALARA.

Short-Term Environmental Impacts

Soil and Geology

Soil disturbance during implementation of Alternative 2A/Vit would result primarily from preparation of disposal vault location and construction of access roads, a treatment/packaging area, a staging area, and support facilities. Construction and excavation activities could disturb a total of approximately 4.3 ha (10.6 acres) of the site. [Note: These acreages could increase up to 2.8 ha (7 acres) to accommodate interim storage needs due to delays in transportation or disposal.] These same activities could also result in the erosion of exposed soil areas. Erosion controls such as straw bales and berm would be used to minimize potential erosion. Measures for reducing fugitive dust generation such as surface wetting or using dust suppressants would be used in exposed soil areas as appropriate. Following completion of all construction and excavation activities, disturbed areas would be filled with clean backfill and topsoil and revegetated with native grasses.

Water Quality and Hydrology

Through erosion control and dust suppression, contaminants disturbed during remediation would not be transported to adjacent surface water bodies. These measures include: surface grading; using berms and silt fences; covering surfaces with straw, mulch, riprap, or geotextile membranes; and using revegetation mats in areas with high water velocity. Surface water near the site would be monitored during remediation in accordance with the existing water discharge permit to assess potential impacts to the water from remediation.

Operation of the treatment facility would result in the generation of filtrate water, dewatered residues, and sludge. These waste streams would be recycled and utilized during processing operations (i.e., vitrification) to minimize wastes generated. However, the operation of the vitrification process would result in the generation of a limited amount of wastewater, which would require treatment by the FEMP AWWT prior to discharge.

Remediation would not increase the release of contaminants to the groundwater since the material would always be contained. Groundwater concerns in the short term would be addressed by implementing source control actions (i.e., removing the sources of groundwater contamination and monitoring to ensure initiation of a timely response) if needed. A monitoring well network is currently in place at the FEMP. Existing monitoring wells would be sampled to provide information on groundwater quality to: (1) establish baseline conditions, (2) monitor groundwater elevations and concentrations during source removal, and (3) evaluate the effect that remedial activities have on groundwater.

The monitoring frequency is expected to be location specific, depending on the amount of material to be excavated, the level of contamination, and the characteristics of the overburden at each source area. As part of the final monitoring design, Paddys Run and other drainageways would be monitored to assess changes in water quality during source removal activity.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are three potential sources of air emissions: 1) dust from construction and earth-moving activities, 2) radon and gas releases during removal and treatment, and 3) heavy equipment exhaust. Dust would be controlled as discussed in the soil section. With the appropriate dust suppression,

excavation activities are not expected to negatively impact the air quality. The exhaust emissions from heavy equipment are not expected to impact air quality.

Silo headspace would be kept under negative pressure to prevent the release of radon, and a RTS would be installed to remove any released radon from the air stream. Radon and other gaseous emissions would be controlled through collection and treatment during both removal and waste treatment. Therefore, fenceline radon exposure concentrations for the off-site public are expected to be consistent with background levels (less than 0.5 pCi/L).

Biotic Resources

The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 2A/Vit would result primarily from activities associated with 1) construction of the on-property disposal vault and other facilities, 2) excavation of berm soils, and 3) installation of electric power lines, transformers, process water and sewer lines, and material slurry transfer lines. Approximately 4.3 ha (10.6 acres) of local biota (wildlife and wildlife habitat) would be temporarily displaced along with potential threatened and endangered species habitat due to increased noise and vehicular activity.

There also is the potential for impact to biota from contaminant releases such as through erosion, dust emissions, and radon and gas releases. The releases would be minimized through engineering controls such as erosion control, dust suppression, radon and gas collection and treatment, and shielding of waste materials. There should be no negative exposure impact on biota during implementation of Alternative 2A/Vit. Accidental spills of petroleum products (e.g., diesel fuel and oil) or excavated materials could result in the exposure of site contaminants to local biota and water quality degradation. Response actions would be in place for responding to accidental spills to minimize any potential impacts.

Wetlands and Floodplains

A site-wide wetlands delineation has identified several areas of wetlands in or adjacent to areas that could be impacted by the implementation of Alternative 2A/Vit. Wetlands north and south of the treatment facilities are not expected to be affected; however, there could be a disturbance of wetlands during the construction of the on-property disposal vault. Approximately 5.0 ha (12.4 acres) of forested wetlands could be affected in the northern part of the site. Engineering controls through the site activities, such as silt fences and straw bales, would be used to minimize the migration of eroded soil to wetland areas.

The 100- and 500-year Paddys Run floodplains are located immediately west of Silos 1 and 2. Alternative 2A/Vit activities are not planned to occur within the floodplains, and contaminant migration during remediation would be controlled through engineered erosion controls to minimize impacts on the floodplains.

Socioeconomics and Land Use

Short-term impacts to socioeconomics and land use would be minor. Employment needed to implement Alternative 2A/Vit would require 180 workers and approximately 19 one-way truck trips per working day. It is assumed for this analysis that many of the workers needed for the remedial activities already work at the site; consequently, the relocation of additional workers to the area would not have a significant impact on public facilities within the CMSA.

The implementation of this alternative would require the acquisition of resources such as steel and concrete. These resources are readily available in the region around the FEMP site. In addition, it is expected that most of the resources such as sand and soil would be available from excavated areas within the site boundary. Implementation of this alternative would not result in the consumption of large quantities of geological resources. However, due to the requirements for high temperatures associated with the vitrification process, the implementation of Alternative 2A/Vit would require approximately 18,500,000 kilowatt-hours of electricity.

To better assess economic impacts, it is assumed for this analysis that all resources needed for remedial activities would be purchased within the CMSA. Rather than addressing each individual county and the resources they are capable of supplying, a total budget figure for all counties has been derived from each county's operating budget for the fiscal year 1992 to 1993. The total operating budget for the CMSA 1992-1993 was approximately $805,000,000. The collective revenue for the CMSA would increase by 4.7 percent. The additional expenditures would be spent over approximately six years of implementation. Therefore, only minor economic impacts are expected for the CMSA as a result of implementing Alternative 2A/Vit.

The land adjacent to the FEMP site is primarily devoted to open land use such as agriculture and recreation. Only 87 people reside within a one mile radius of the FEMP Site. A total 1,281 people reside within a two mile radius of the site (U.S. DOE 1993b). Commercial activity is generally restricted to the village of Ross, Ohio, approximately 3.2 km (2 miles) northeast of the FEMP site, and along State Route 128, just south of the village. More than 160 ha (400 acres) of the open land

on the FEMP site are leased to a nearby dairy farmer, who allows livestock to graze on the property. Pine plantations are located to the northeast and southwest of the former Production Area. Because the area had been extensively used for agricultural purposes prior to the establishment of the FEMP site, there is no land on or in the vicinity of the site where a predevelopment natural environment remains intact. The land closest to this description is the recreated prairie lands on the Miami Whitewater Forest property, located several miles south of the site.

Cultural Resources

The NHPA (36 CFR § 800, Section 106) requires federal agencies to protect properties on or eligible for inclusion on the NRHP. This list includes undiscovered resources, districts, sites, buildings, structures, or objects that may be eligible for inclusion on the NRHP. There are currently no areas identified at the FEMP site that are eligible for inclusion on the National Register.

To avoid impacts on undiscovered cultural resources, an archeological survey would be performed by a professional firm approved and managed by DOE for all non-controlled areas not previously disturbed. An ethnographic survey would be conducted by a professional anthropologist to determine the presence of Indian sacred sites and burial grounds. These cultural resources, if present, would be protected in accordance with the AIRFA and the NAGPRA. If possible, impact area boundaries should be designated to avoid cultural resources; however, if this is not feasible and cultural resources are affected, they would be evaluated to determine the appropriate treatment. In situ cultural resources would be preserved through agreement with the OHPO and other interested parties. Should it be agreed that cultural resources are to be removed, the following steps would be followed; 1) archaeological excavation, 2) laboratory treatment of cultural resources recovered at the site, and 3) curation of any recovered artifacts. If final in situ preservation of on-property artifact(s) is chosen (the artifacts remain in place), the plan for preservation would have to be compatible with remedial alternatives selected for the area in which the artifact(s) is located (Luce 1987).

Duration of Remedial Activities

Remedial action activities under Alternative 2A/Vit are expected to be completed in approximately six years. Construction, testing, and startup of the material processing could require at least three years, with the possibility of a longer period depending on the difficulties encountered. Material removal activities would require approximately three years, assuming eight hours/day, seven days/week, and three weeks/month. The treatment would operate concurrently with removal for three years assuming that operations would be conducted 24 hours/day, seven days/week, and three weeks/month. The

time to implement the treatment component of this alternative could be prolonged if pilot-scale testing and full-scale testing of the vitrification resulted in scale-up and operational difficulties because of the innovative nature of this treatment technology. Physical, substantial, and continuous on-property activities would be initiated within 15 months after the ROD is approved by the EPA.

4.2.2.6 Implementability

Technical Feasibility

Technical feasibility, construction, and operation of the material removal component of Alternative 2A/Vit would be reliable. Hydraulic removal is a standard technology that is normally reliable and readily available. Although hydraulic removal has not been used before on this type of material, it has been used to remove material of similar consistency. Because the silo domes have questionable structural integrity, extreme caution must be exercised when removing the silo contents. In case of silo dome failure and the subsequent implementation of the emergency response plan, all silo contents removal would stop until an assessment of the failure and any impacts is complete. Upon completion of the assessment, the steps required to continue removal of the silo contents would be determined.

Construction and operation of the disposal component of this alternative would be reliable. Components of the design have been used at numerous other sites. Readily available resources and standard procedures would be used for the construction and operation of the above-grade disposal vault. About 2.8 ha (6.9 acres) would be required for the above-grade disposal vault. If disposal volumes are greater than anticipated, the above-grade disposal vault would be increased to accommodate the additional capacity.

The technical feasibility of the vitrification facility construction is expected to be moderately straightforward, but a full-scale facility for the vitrification of materials similar to those in Silos 1 and 2 and the decant sump tank has never been built. However, remedial design treatability studies (bench- and pilot-scale) would be performed to address specific remedial design requirements for Subunit A materials. The necessary equipment would be modified from available equipment used in the glass making industry. An electrical substation also would be built in the vicinity to supply the power required for vitrification.

The vitrification technology for Alternative 2A/Vit would require engineering scale-up to be implemented full scale. Pilot testing, detailed design, fabrication, installation, and full scale operation

would be needed to optimize the treatment process. The construction of a vitrification facility is expected to be relatively straightforward, but a full scale facility for the vitrification of hazardous or radioactive waste similar to that at the FEMP site has not yet been constructed elsewhere. The necessary equipment could be modified from available equipment used in the glass-making industry. Construction of a vitrification facility on site would include construction of an electrical substation. Operation of the vitrification facility would be somewhat difficult. The vitrification system consists of three basic circuits: a feed preparation circuit, a melter circuit, and an off-gas treatment system. The feed preparation circuit would be used to remove water from the slurry material prior to vitrification. The equipment needed for this circuit is readily available because this component of the process is widely used in industry. Joule-heated ceramic melters have been used to vitrify liquid high-level radioactive material, radioactively contaminated soil, and waste contaminated with heavy metals in quantities ranging from 4.5 to 410 metric tons per day [5 to 450 tons per day (tpd)]. The conceptual design for the Operable Unit 4 treatment system specifies a 13 tpd melter with a slurry feed.

A trained process engineer would be needed to operate both the physical pretreatment and melting circuits of the ceramic melter and to act as supervisor of the melter circuit. Operators and maintenance personnel, laborers, laboratory technicians, and administrative personnel would also be needed. Industrial work experience would be required for the system operators and maintenance personnel. The number of operators and maintenance personnel with previous experience in the vitrification of hazardous waste is limited, but these personnel could be drawn from the commercial glass-making industry or the high-level radioactive waste vitrification industry. The melter system could be designed to operate largely by computer, with a combination of human and computerized oversight. Start-up of the vitrification would require at least four months; however, because the melter system has not been previously used at the scale required for the site, operational problems might develop during start-up that could impact the processing schedule and costs.

Potential operational problems in the melter circuit include temperature variation, incomplete melting, immiscible phase development, and thermocouple or heat sensor failure. Refractory failure is not anticipated to be a problem because the design life of the melter operation is less than the design life of the refractory at anticipated operating temperatures. Temperature variation and improper control could result in the incomplete melting of feed material. Temperature fluctuations could also cause phase immiscibility. The use of electricity allows for almost immediate control over melt temperatures and, thus, would aid in controlling temperatures continuously monitored by thermocouples and heat detectors. These thermocouples could be prone to failure at the high

operating temperatures, necessitating the placement of redundant thermocouples at critical locations in the system and routine replacement and repair as part of maintenance activities. Any product from the vitrification system that was incompletely melted or contained immiscible phases would be returned to the system until an acceptable product was produced.

The reliability of the melter system for waste treatment is not well established because this system has not yet been implemented at full scale or continuous operation. Similar melting systems used in commercial glass-making report a 90 percent continuous operation efficiency.

The off-gas treatment system would use standard air pollution treatment and control devices. Although the capabilities of the individual off-gas treatment devices are known and well demonstrated, the effects are less known with regard to linking multiple treatment devices together to treat the off-gas stream expected from vitrification of the Silos 1 and 2 contents and decant sludge at full scale. The off-gas treatment system would use standard components, but the selected devices and their configuration will have to be explicitly defined, tested, and optimized through bench-scale and pilot-scale testing.

The limited experience in developing the required off-gas treatment system could result in schedule delays or cost increases because more time and personnel might be needed to bring the system on-line. Operators and repair personnel would probably be drawn from the incineration industry because of their experience in operating and maintaining off-gas treatment systems. The likelihood of operational problems would increase as the complexity of the off-gas treatment system increased. It is possible that a complex linkage of treatment devices could lead to operational difficulties with individual devices. The potential for effects from failure of individual devices could be exacerbated in downstream devices and result in an overall problem with system operations and collection and removal efficiencies. If the off-gas emissions exceeded applicable requirements, delays could result. Failure of monitoring devices or inadequate test results from a full-scale off-gas system could also cause delays until corrective actions were completed. Additional conceptual design and testing would be required to identify and resolve the potential difficulties in designing and operating an off-gas treatment system for a vitrification system.

Operational problems that could develop in the off-gas treatment circuit include production of large amounts of particulate that require secondary handling, added treatment requirements for the scrub solution prior to disposal, monitoring device calibration, maintenance requirements, and exacerbation

of operational problems in downstream control devices resulting from failure of an upstream device. The off-gas treatment system would require testing and optimization to resolve these potential problems.

The effectiveness of the main components of the treatment process for Alternative 2A/Vit would be regularly monitored. The off-gas treatment system effluent would be monitored to determine the off-gas composition and ensure compliance with applicable requirements. The effectiveness of the vitrification process would be monitored by regular testing of the treated material. If a sample fails the determined leachability criteria, additional samples would be collected; these samples would be tested and analyzed to determine the cause of the problem. The failed treated material would be revitrified if necessary, and the process modification would be instituted.

Any leachate generated from the treated material placed in the above-grade disposal vault would be captured by the LC/DS. A radon monitoring system would be used to detect any radon emissions to verify the integrity and effectiveness of the multimedia cap. Groundwater monitoring wells would be installed to detect changes in groundwater quality. The monitoring system associated with the above-grade disposal vault would provide the information needed to determine if corrective action should be taken to prevent the migration of materials into the environment.

The implementation of Alternative 2A/Vit would not adversely impact the performance of additional remedial actions at the FEMP site. For example, the presence of the above-grade disposal vault would not affect the ability to remediate groundwater beneath the vault. Migration and exposure pathways would be addressed through active sampling and analysis during on-property activities.

Administrative Feasibility

No permits or licenses would be required, but permit information summary packages may be necessary. The substantive technical requirements of air emissions permits would also need to be demonstrated and may include calculating estimated emissions, providing air emissions controls, developing a sampling and analysis plan to monitor air emissions, and air sampling. Coordination with OEPA would be necessary to ensure that the substantive technical requirements for location of the above-grade disposal vault would be met.

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Availability of Services and Materials

Although it is technically feasible to design, construct, and operate a vitrification facility, a full-scale facility for the vitrification of materials similar to those within Operable Unit 4 has never been built. Remedy-selection treatability studies have been completed and remedial design treatability studies (bench- and pilot-scale) would be performed to address site-specific design requirements. Necessary equipment would be modified from available equipment in the glass-making industry. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel would be trained as required. There would be sufficient disposal capacity for the vitrified materials.

The activities involved in Alternative 2A/Vit include: construction of the rail system for the work platform, the work platform and hydraulic mining device, clearing and grubbing of areas around the silos and at the location of the material processing facility, construction of access roads, fencing, lighting, water, sewer, and electrical services, construction of an above-grade disposal vault, construction of a new RTS, construction of a materials processing facility including a belt filter and vitrification unit, and construction of a multimedia cap.

The construction of the rail system, a work platform, and hydraulic mining device would involve the purchase of materials and services which are standard in the construction industry.

The clearing and grubbing, and construction of roads, fencing, lighting, sewers, and electrical services would involve the use of standard construction equipment and trades, the use of a fence installation contractor, and the purchase of appropriate materials. These are all readily available.

The construction of an above-grade disposal vault would require the use of standard construction equipment and trades. Materials needed to construct the vault would be purchased. These services and materials are available locally.

The construction of a materials processing facility would involve the purchase of a pre-engineered building, the process equipment, the process chemicals/materials, electrical transformers and transmission lines, and the instrumentation and controls. It would also involve the use of standard construction equipment and services. Some engineering would be required during construction, start-up, and debugging of the process equipment. Qualified personnel would be needed to operate and maintain the facility. Of these, only the operators may be difficult to retain.

The construction of the multimedia cap would require the acquisition of material for a geotextile liner, a clay layer with a permeability of $1x10^{-7}$ cm/s, a 40-mil textured geomembrane, and clean soil for the foundation. As shown in a survey, these materials would be readily available. Standard construction equipment, operators, and trades personnel would be required. The installation of membranes and liners would require specialized equipment and personnel to lay the material and seal the seams.

Finally, it would be necessary to ensure that EPA, OEPA, and the local community are fully involved in the development of RD/RA work plans. Close coordination with the regulatory agencies and the community prior to and during remedial activities would be essential for successful implementation.

4.2.2.7 Cost

The total present worth cost of Alternative 2A/Vit is $43.6 Million. A detailed breakdown of the cost is provided in Table 4-3.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and hydraulic removal/transfer system for transfer of the residues, purchase of vitrification equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-3. More detailed information is provided in Appendix E.

The largest component of the capital cost is the construction of the hydraulic removal/transfer system. This represents approximately 40 percent of the total capital costs. Most of the expense of this component is due to construction of the steel superstructure that supports the hydraulic system. The second largest element of the capital costs (13 percent) is the purchase of vitrification equipment.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, packaging pad for the removed berm material, material slurry transfer trench, utilities, roads, and equipment staging areas. The basis of estimate includes the following assumptions:

TABLE 4–3

COST ESTIMATE FOR ALTERNATIVE 2A/VIT

| ALTERNATIVE 2A: REMOVAL, STABILIZATION W/VITRIFICATION, ON–PROPERTY DISPOSAL | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $768,600 | $660,000 | $1,428,600 |
| WASTE PROCESSING | $1,008,500 | $1,065,000 | $2,073,500 |
| VITRIFICATION | $2,935,500 | $1,703,600 | $4,639,100 |
| HYDRAULIC REMOVAL/TRANSFER SYSTEM | $6,655,400 | $7,797,800 | $14,453,200 |
| DISPOSAL VAULT | $937,100 | $1,595,500 | $2,532,600 |
| PACKAGING (2,412 PKGS. @ $955/PKG.) | $636,800 | $1,666,700 | $2,303,500 |
| TOTAL CAPITAL | $12,941,900 | $14,488,600 | $27,430,500 |
| RISK BUDGET (11.0%) | $1,423,600 | $1,593,700 | $3,017,300 |
| SUBTOTAL | $14,365,500 | $16,082,300 | $30,447,800 |
| CONTINGENCY (20.0%) | $2,873,100 | $3,216,500 | $6,089,600 |
| TOTAL ESTIMATED INSTALLED COST | $17,238,600 | $19,298,800 | $36,537,400 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $11,692,500 |
| POST–REMEDIATION | | | $3,425,400 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $43,601,900 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during remediation (years): 3
Post–remediation O&M (years): 30

- An area of approximately 2.8 ha (6.9 acres) would be cleared and grubbed.

- Filling would be performed where necessary. The volume of fill was estimated to be 11,500 $m^3$ (15,000 $yd^3$). It was assumed that this soil could be obtained from excess on-property soil.

- New fencing would be added across the southern end of the remediation area, around the interim storage area, and between the proposed parking area and the equipment staging area. Fencing would be 2 m (7 ft) high, barbed wire topped chain link fence. Approximately 550 linear meters (1,800 linear ft) would be required. It is assumed that seven gates would be required, each 4.5 m (15 ft) wide and 2 m (7 ft) high, and topped with barbed wire.

- An equipment staging area would be added to the north end of the remediation site. This area would consist of 15 cm (6 in.) of crushed stone [2.54 cm (1 in) maximum diameter] applied over an area 45 m (150 ft) by 60 m (200 ft) [2700 $m^3$ (30,000 $ft^2$)].

- Approximately 450 m (1,500 ft) of 6 m (20 ft) wide roads would be constructed in the remediation area. The roads would be constructed of 15 cm (6 in.) deep crushed stone [2.54 cm (1 in.) maximum diameter].

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the RTS. Costs were estimated based on the following assumptions:

- The waste processing facility would be a modified, two-story, pre-engineered building built on slab. The first floor would provide approximately 1350 $m^2$ (14,400 $ft^2$) and the second floor would have 50 $m^2$ (500 $ft^2$). The waste facility would be fully insulated and would have a 10-year design life span.

- The walls of the processing rooms and the storage room would be shielded with 0.6 m (2 ft) thick concrete.

- Approximate dimensions of the various areas of the building were estimated to be as follows: processing area - 820 $m^2$ (8,800 $ft^2$), administrative/personnel area - 300 $m^2$ (3,200 $ft^2$), miscellaneous equipment area - 450 $m^2$ (4,800 $ft^2$), and storage area - 220 $m^2$ (2,400 $ft^2$).

- The ventilation system for the general process area would operate continuously and would either recirculate or exhaust to atmosphere. This system would not be designed to remove radon.

- The general process area ventilation would provide seven air changes per hour. The system would include a 1135 $m^3$/min (40,000 cfm) blower and HEPA filter, and 91 m (300 ft) of 1.5 m (5 ft) diameter ductwork with dampers and fittings. A second redundant train would be installed.

- A separate ventilation train would be used in the event radon is detected in the process area. The general process area ventilation system would shut down if radon is detected in the general process area.

- The radon treatment system for process air would consist of a 30 $m^3$/min (1,000 cfm) blower, a calcium sulfate media dehumidification vessel, a carbon adsorption canister, a HEPA filter, and approximately 61 m (200 ft) of 25 cm (10 in) diameter ductwork (with dampers and fittings). This system would be rated for 30 $m^3$/min (1,000 cfm), and the system would exhaust to atmosphere. A second redundant train would be installed.

Vitrification

This cost item includes the cost of the vitrification equipment, RTS, and off-gas system, and is estimated based on the following:

- The vitrification equipment would operate 24 hours/day and would be designed to treat 11,800 kg/day (13 tons/day) of material.

- Vitrification equipment includes a horizontal belt filter for sludge dewatering, filtrate recycle tank, surge tank, sodium carbonate and carbon storage/feed facilities, process piping, pumps, mixers, and a joule-heated melter.

- The off-gas treatment system would be rated at 4 $m^3$/min (150 cfm). It would consist of blowers, scrubbers, carbon adsorbers, and HEPA filters.

- A RTS for the headspace for Silos 1 and 2 and the decant sump tank would be provided.

- The RTSs would each be rated at 40 $m^3$/min (1,500 cfm). Each would consist of a blower, carbon adsorbers, and driers.

Hydraulic Removal/Transfer System

This cost component includes the support superstructure and work platform, rail trolleys, an enclosure for the hydraulic equipment, a concrete material transfer pit, RTS and building for the silo structures, and the hydraulic removal equipment. Assumptions used for the cost estimate include:

- The work platform would be a rail-mounted, 54 m (180 ft) structure truss that would span the silos.

- A 2.4 m (8 ft) wide by 2.4 m (8 ft) long by 9 m (30 ft) high, 1.3 cm (0.5 in) thick plexiglass enclosure would be provided for the drive unit of the hydraulic removal equipment.

- The silo RTS would be as described for the vitrification system RTS for the silo headspace. The RTS equipment building would be 6 m (20 ft) long by 9 m (30 ft) wide by 3 m (10 ft) high, with 0.3 m (1 ft) thick concrete walls.

- The hydraulic removal equipment would consist of a slurry pump.

- A 60 m (200 ft) long, below-grade concrete pit with a removable concrete lid would be constructed between the silo and the waste processing facility. This pit would contain the double-walled material transfer piping and serve as a secondary containment for the piping.

Disposal Vault

The cost of the disposal vault was estimated as follows:

- Cost for the on-property, above-grade disposal vault was estimated at a unit cost of $939/m^3$ ($718/yd^3$).

- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 $m^3$ (120,000 $ft^3$) of material. As additional disposal volume space is required, additional modular cells were added for cost estimating purposes. Cell numbers were estimated by rounding up to the nearest whole number.

- The size of the disposal vault was based on the number of packages noted below, assuming each package occupies 1.81 $m^3$ (64 $ft^3$) of space, and was estimated as 4372 $m^3$ (154,368 $ft^3$). Assuming a cell size of 3400 $m^3$ (120,000 $ft^3$), two cells would be required [1394 $m^2$ (15,000 $ft^2$) vault footprint area].

- The design of the vault includes a multimedia cap, liner, intruder barrier, and LC/DS.

- The vault would cover approximately 2.8 ha (6.9 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation. Estimated cost is based on the following:

- Packages would be DOT specification 7A-Type A containers with exterior dimensions of 1.2 m (4 ft) width by 1.2 m (4 ft) length by 1.2 m (4 ft) depth. Interior dimensions would be 1.1 m (3.5 ft) width by 1.1 m (3.5 ft) length by 1.1 m (3.5 ft) depth, providing 1.22 $m^3$ (43 $ft^3$) of storage per package.

- Total weight of each individual filled container would not exceed 3628 kg (8000 lbs) to facilitate handling. The weight of material in each container would not exceed 3300 kg (7260 lbs) per package and the density would be less than 2698 $kg/m^3$ (168 $lb/ft^3$).

- Total volume that would be packaged was based on 3636 $m^3$ (4,756 $yd^3$) and 3158 $m^3$ (4,130 $yd^3$) of untreated Silos 1 and 2 material, respectively. Final packaging volume, assuming a 59 percent volume reduction due to the vitrification process and 2859 $kg/m^3$ (178 $lb/ft^3$), was 2770 $m^3$ (3,643 $yd^3$).

- Packages would not be full, but would be based upon maximum density of 2698 $kg/m^3$ (168 $lb/ft^3$) since the density of vitrified material is greater than this.

- Packaging and disposal of materials generated during D&D operations are not included in this cost, but are included in the costs for Subunit C.
- Total packaging cost was estimated assuming 2,412 containers.
- A unit cost of $955 per container was determined based on a material cost of $650 per unit and a labor cost of 16 man-hours per unit for handling, filling, and documentation.

O&M Cost

Short-term O&M costs incurred during remediation and long-term O&M costs are $11.7 Million and $3.4 Million, respectively (not considering present worth). Long-term O&M costs include the maintenance and monitoring which would be conducted until FEMP site-wide remedial action objectives are attained, i.e., for a period of approximately 30 years. The monitoring would support the required CERCLA five-year reviews.

4.2.2.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 2A/Vit. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.2.2.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 2A/Vit. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.2.3 Analysis of Alternative 2A/Cementation

This alternative is identical to Alternative 2A/Vit with the exception of the stabilization process option (Figure 4-10). Alternative 2A/Cem would use the same site preparation/construction, material removal, and on-property above-grade disposal vault process options as Alternative 2A/Vit (Section 4.2.2); however, Alternative 2A/Cem would use cement stabilization in place of vitrification as the treatment process option. Also, because cement stabilization results in a greater quantity of treated material than vitrification, the on-property above-grade disposal vault for the treated material is estimated at 4.3 ha (10.6 acres).

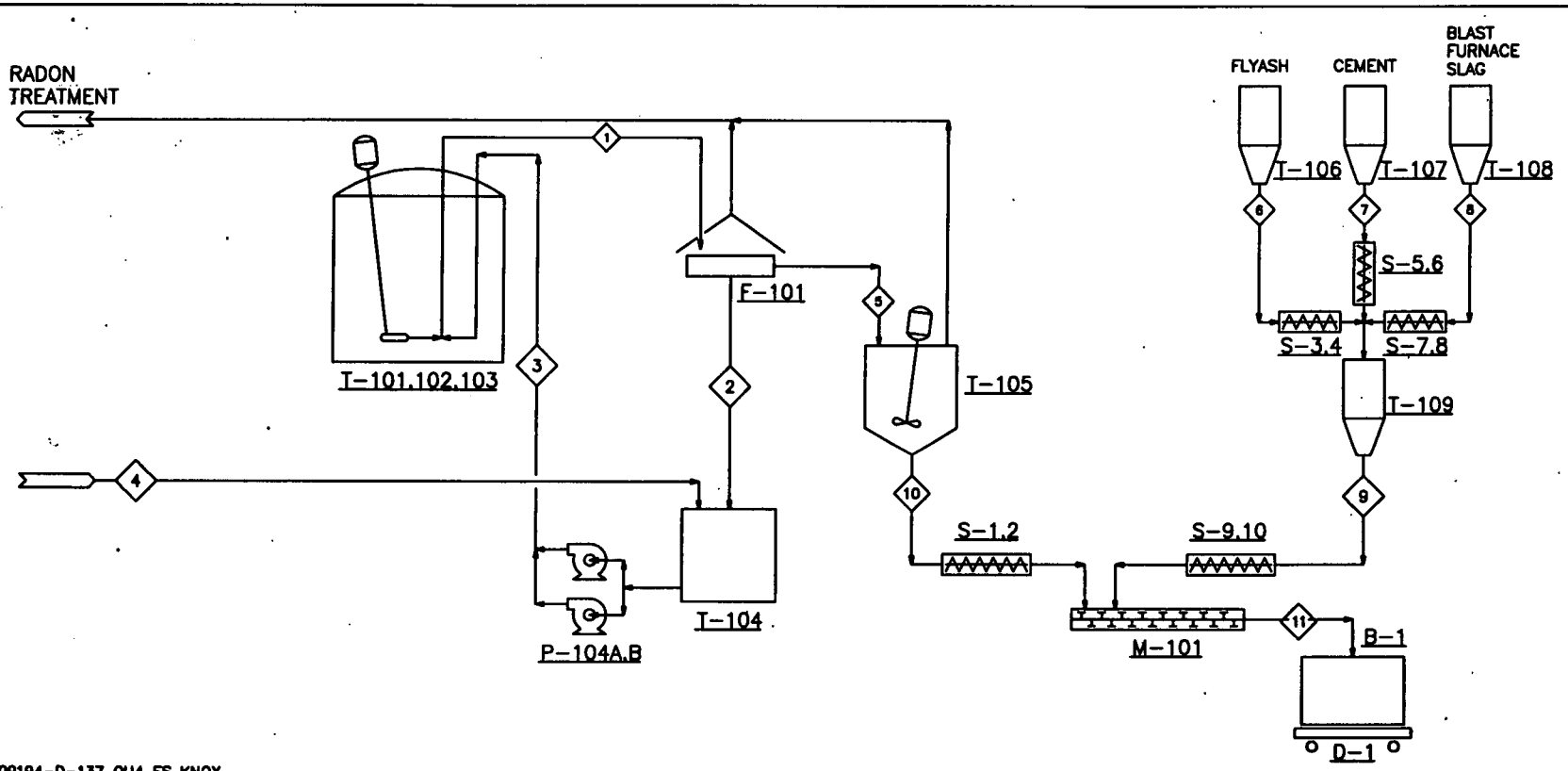
Material Processing

The Subunit A material would be removed as described in Alternative 2A/Vit (Section 4.2.2). Cement stabilization involves pumping the slurried silo contents and decant sump tank sludge from the slurry surge tank through a screw feeder to a stabilization mixer, to which the additives (flyash, cement, and blast furnace slag) are added with the appropriate amount of water. After the contents are thoroughly mixed with the additives, the mixture would be pumped directly into DOT specification 7A Type A containers and transported to a nearby curing area. After the treated material has cured, it would be tested and transported to the above-grade disposal vault (see Figure 4-6).

4.2.3.1 Overall Protection of Human Health and the Environment

Alternative 2A/Cem meets the remedial action objectives for Subunit A. As with Alternative 2A/Vit, Alternative 2A/Cem meets the objectives through treatment, containment in an on-property above-grade disposal vault, and implementation of institutional control measures. The difference between the two alternatives is the treatment method used.

Treatment of Subunit A material through cement stabilization would reduce contaminant mobility but would increase the volume of contaminated material. The leaching rate of the treated waste form would be reduced, enhancing the protection of the underlying Great Miami Aquifer. As with Alternative 2A/Vit, treatment of the material prior to disposal would also provide additional protection in the event that the vault begins to degrade. Similar to Alternative 2A/Vit, continued protection by Alternative 2A/Cem is uncertain as a result of the possible degradation of the stabilized material and subsequent increased leachability.




| STREAM NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MASS FLOW (lb/HR) | 14930 | 7963 | 11944 | 3981 | 6967 | 221 | 774 | 369 | 1364 | 2322 | 3686 |
| SOLIDS (lb/HR) | 3098 | 110 | 110 | | 2986 | 221 | 774 | 369 | 1364 | 995 | 2359 |
| WATER (lb/HR) | 11944 | 7963 | 11944 | 3981 | 3981 | | | | | 1327 | 1327 |
| FLYASH (lb/HR) | | | | | | 221 | | | 221 | | |
| CEMENT (lb/HR) | | | | | | | 774 | | 774 | | |
| BFS (lb/HR) | | | | | | | | 369 | 369 | | |
| % SOLIDS | 20 | 0 | 0 | 0 | 43 | 100 | 100 | 100 | 100 | | |
| FLOW (gpm) | | 15.9 | 24 | 8 | | | | | | | |
| HOURS/DAY | 8 | 8 | 8 | 8 | 8 | 24 | 24 | 24 | 24 | 24 | 24 |
| DAYS/WEEK | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

S-3,4 FLY ASH SCREW FEEDER

T-107 CEMENT HOPPER

S-1,2 SLURRY SCREW FEEDERS

T-105 SLURRY SURGE TANK

T-104 FILTRATE RECYCLE TANK

S-9,10 ADDITIVE SCREW FEEDER

T-101,102,103 SILOS 1 & 2 DECANT SUMP TANK

D-1 WASTE TRANSFER DOLLY

F-101 BELT FILTER

T-106 FLY ASH HOPPER

B-1 DISPOSAL BOX

T-109 STABILIZATION FEED HOPPER

S-7,8 BLAST FURNACE SLAG SCREW CONVEYOR

M-101 STABILIZATION MIXER

P-104A,B FILTRATE RECYCLE PUMPS

S-5,6 CEMENT SCREW FEEDER

T-108 BLAST FURNACE SLAG HOPPER

ALTERNATIVES 2A/CEM, 3A.1/CEM
CEMENT SOLIDIFICATION
PROCESS FLOW DIAGRAM
FIGURE 4-10

The containment features of Alternative 2A/Cem include the above-grade disposal vault and provide additional control of contaminant migration along with prevention of direct access to the waste. Uncertainties exist in long-term reliability of the vault although fate and transport modeling results show Alternative 2A/Cem to be protective even with slight degradation of the disposal vault.

Both 2A alternatives use institutional controls to provide protection to human health in the event of failure of the engineering controls and to provide an added measure of protection against destruction of the vault. Additionally, under ORC 3734.02, a restrictive covenant limiting site use is required for any disposal vault. As with the other components of these two alternatives, the long-term reliability of institutional controls is uncertain.

Exposures to receptors from pathways resulting from the vault failure would be expected to be minimal due to the positive attributes of the treated material. However, direct radiation exposure could be significant. Eventually, failure of both the engineered controls and the institutional controls could result in human health and environmental risks approaching baseline conditions.

Short-term risks for Alternative 2A/Cem would be almost the same as for Alternative 2A/Vit. While the difference in hazards between the two treatment process options is not quantifiable, cement stabilization probably poses slightly lower risks because it does not employ the high voltages and temperatures that vitrification does.

4.2.3.2 Compliance with ARARs

Alternative 2A/Cem is identical to Alternative 2A/Vit with the exception of the process option used to treat the Subunit A materials. In this alternative, cement stabilization would be used in place of vitrification. Because cement stabilization results in a greater quantity of treated material than vitrification, the on-property disposal vault for Alternative 2A/Cem would be proportionately larger than the disposal vault required under Alternative 2A/Vit. This difference is insignificant for compliance with potential ARAR/TBC requirements (see Table F.2-1 in Appendix F). Compliance of this alternative would be substantially identical to that of Alternative 2A/Vit presented in Section 4.2.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 2A/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a). Included would be those standards associated with meeting drinking water MCLs

and MCLGs requirements, the RCRA solid and hazardous waste groundwater protection requirements, UMTRCA and the CAA NESHAPS requirements for radionuclides other than radon, and other radionuclide public dose release limits for water and air in DOE Order 5400.5. Although radon-222 emission rates from cement stabilized waste, as determined following treatability studies on Subunit A material, exceeded the CAA 40 CFR § 61 Subpart Q flux rate standard of 20 $pCi/m^2 \cdot s$, the attenuation expected to be provided by the 3m (9 ft) thick multimedia cover for the disposal facility would sufficiently reduce the radon-222 release rate to comply with this ARAR. Appendix D contains the description and results of the analyses supporting these assessments for Alternative 2A/Cem. Additional documentation of compliance of Alternative 2A/Cem with the identified ARARs is presented in Appendix F (Table F.2-2).

Location-Specific ARAR/TBCs

Alternative 2A/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b). Included would be those requirements associated with the protection of floodplains, wetlands, endangered species and habitat, and the sole-source aquifer underlying the FEMP site. Despite the larger footprint of the on-property disposal vault associated with this alternative, the final location of the Alternative 2A/Cem disposal vault would have adequate setbacks to comply with these distance requirements. As was noted, under Alternative 2A/Vit, compliance with the OAC 3745-27-07 prohibition on the location of a solid waste disposal facility over a sole-source aquifer would be based on demonstrating the substantive technical requirements for an exemption to this requirement as discussed in Section 4.2.2.2. Since the design and location of the disposal vault would be the same as for Alternative 2A/Vit, the discussion of the technical demonstration to meet the exemption would be identical.

Action-Specific ARAR/TBCs

Alternative 2A/Cem would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c). Included would be those standards associated with the design of the multi-barrier above-grade disposal vault system and design and operational requirements identified under RCRA, UMTRCA, and the NRC. As was discussed for Alternative 2A/Vit, Alternative 2A/Cem would comply with 40 CFR § 191 Subpart A (a relevant and appropriate requirement) and would comply with most of the requirements in 40 CFR § 191 Subpart B (identified as TBC requirements).

In addition, Alternative 2A/Cem would comply with ARARs associated with the NEPA (environmental documentation), the CAA (for radon and other radionuclides), and the CWA (for

storm water runoff, surface water quality of the receiving waters, BMPs, and dredge and fill activities. As for Alternative 2A/Vit, this alternative would comply with the substantive design and groundwater monitoring requirements for RCRA solid and hazardous waste disposal facilities, as well as the RCRA closure requirements for tanks, containers, and land disposal facilities.

This alternative would comply with the annual average public dose requirement of 100 mrem from all pathways found in DOE Order 5400.5. Additional supporting documentation to justify that Alternative 2A/Cem would comply with the identified ARARs is presented in Appendices D and F (Table F.2-2).

4.2.3.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2A/Cem reduces the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Since the only difference between Alternatives 2A/Cem and 2A/Vit is the treatment technology applied and since the magnitude of the residual risk under an effective alternative does not depend in this case on the type of treatment technology, the residual risk from both alternatives would be the same.

Adequacy and Reliability of Controls

The projected residual excess cancer risk attributable to Alternative 2A/Cem for viable receptors is less than $10^{-6}$. The on-property disposal unit is the same as that for Alternative 2A/Vit and, therefore, has the same adequacy of controls and the same degree of reliability. Fate and transport modeling of the leaching pathway is completed. The assumptions were the same as for Alternative 2A/Vit except that the leachability of the treated material was assumed to be that of the treatability results for cement stabilization. The results were the same as for Alternative 2A/Vit; leaching of contaminants would not pose an unacceptable risk to off-site receptors.

Cement stabilization is a proven technology that has been previously applied to the stabilization of similar waste materials as those contemplated under Alternative 2A/Cem. Additionally, over the period of 1989 to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of the cement stabilization technology on K-65 residues. The tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics

(see Appendix C). On this basis, there is a high probability that the cement stabilization treatment system would attain the required product performance requirements.

Consistent with DOE Order 5400.5, 40 CFR § 264.114, and 40 CFR § 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required five-year CERCLA review.

Long-Term Environmental Impacts

With the exception of the area disturbed and energy requirements, Alternative 2A/Cem has essentially the same long-term environmental impacts as Alternative 2A/Vit. Alternative 2A/Cem would permanently disturb 4.3 ha (10.6 acres) of land as a result of construction of an on-property disposal vault.

4.2.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2A/Cem uses cement stabilization to treat the contents of Silos 1 and 2 and the sludge in the decant sump tank. Cement stabilization reduces the mobility of contaminants by binding them into a cement mixture. As a result of the additives used in the process, the volume increases. A remedy selection treatability study was conducted with Operable Unit 4 materials to compare vitrification and cement stabilization. The criteria for the comparison included leachability of the treated waste form, the material volume reduction achieved, and the reduction in radon emanation from the material (Appendix C Section C1.0 and Appendix H).

The chemical and physical properties of Subunit A residues were determined and used in developing the bench-scale treatability studies. Data from the study revealed that the radon emanation rates from the treated K-65 material did not pass the 20 pCi/m$^2$/s criteria established for DOE in 40 CFR § 61. The rates exceeded 200 pCi/m$^2$/s. The cementation process is effective in reducing radon emanation by an average of 78 to 87 percent; however, significant levels of radon continue to be emitted after cement stabilization.

The amount of volume increase caused by the addition of cementatious material varied greatly. For Subunit A material, the increase varied from 136 to 216 percent as a result of the heterogeneity of the residue. Assuming an average increase of 169 percent, there would be a total estimated treated material volume of 18,166 m$^3$ (23,903 yd$^3$) for Alternative 2A/Cem.

The results from the TCLP tests showed that the cement stabilized material did not exceed RCRA regulatory levels for metals. Thus, the comparison of the TCLP test results (through the leachate concentration) of the treated waste to the untreated residues are the basis for the demonstration of the effectiveness of cement stabilization as a treatment process for Subunit A waste. A formulation including blast furnace slag, cement, and flyash was the most effective even though reductions in contaminant concentrations in the leachate were not achieved for all parameters. The percent reduction for lead in leachate was typically above 99 percent. High percent reductions for uranium were demonstrated while Ra-228 exhibited mean reductions from 48 to 57 percent. The mean reduction of Ra-226 ranged from 53 to 84 percent.

Durability was measured by freeze-thaw and wet-dry testing and comparison to ASTM standards (30 percent weight loss) and EPA guidance of 15 percent weight loss. No average weight losses for Subunit A material exceeded 15 percent. Durability was also measured using the unconfined compressive strength (UCS) test on the durability samples. The comparison of the UCS results is used to indicate how the physical properties of the stabilized material changes as a result of the simulated climatic stress. None of the Subunit A treated residues degraded to the extent that it had no resistance to compressive stress. However, degradation and leachability results for some contaminants indicate that cement stabilization is not an irreversible treatment process.

Residuals from the stabilization process would be generated from the off-gas treatment system. Off-gases containing particles and other pollutants would be removed and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary to adequately reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the stabilization process until all were contained in a cementatious form.

4.2.3.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Alternative 2A/Cem provides the same degree of short-term protection of the community as Alternative 2A/Vit (Section 4.2.2.5) using the same engineering and access controls.

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Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and non-remediation workers are the same for Alternatives 2A/Vit and 2A/Cem. Although cement stabilization is inherently less dangerous than vitrification, the increase in labor hours results in an estimate of 9.9 injuries and 0.15 deaths during remediation activities.

Short-Term Environmental Impacts

The short-term impacts associated with Alternative 2A/Cem are essentially the same as those for Alternative 2A/Vit. Short-term disturbances would involve 5.8 ha (14.3 acres) of land at the FEMP site; however, the energy requirements for 2A/Cem (approximately 11,500,000 kilowatt-hours) would not be as great as the energy needed for 2A//Vit. In addition, 230 workers and approximately 26 one-way truck trips per working day would be required to implement remedial activities. For this analysis, it is assumed that all expenditures would take place within the CMSA, in which case the implementation of Alternative 2A/Cem would increase revenues by 6.7 percent over a six-year period.

Duration of Remedial Activities

The duration of Alternative 2A/Cem is the same as Alternative 2A/Vit.

4.2.3.6 Implementability

Technical Feasibility

The technical implementability, construction, and operation of Alternative 2A/Cem would be reliable and straightforward and, except for the treatment component, the same as Alternative 2A/Vit.

The cement stabilization facility would be reliable and straightforward to construct and operate. All of the necessary equipment would be readily available because the process is widely used in the construction and mining industries. It is also used frequently in hazardous material treatment applications. The treatment system would consist of a standard configuration of industrial equipment. The cement stabilization process would require a supervisor and general laborers with industrial work experience, as well as maintenance personnel. After remedial design treatability studies further defined and optimized the reagent to material blend, the plant supervisor would be able to respond to operational problems that could arise during processing. Continual testing of treatment batches during

operation would determine required modifications to the standard blend to optimize product and immobilization of contaminants.

The benefits of cement stabilization technology are the moderate processing costs, the compatibility with a wide variety of disposal options, and the ability to meet stringent processing and performance requirements. The associated increase in volume caused by adding dry materials could be minimized through encapsulation of the solids and evaporation of associated water. However, water evaporation increases the complexity and cost of the treatment.

Administrative Feasibility

The administrative feasibility for Alternative 2A/Cem is the same as for 2A/Vit.

Availability of Services and Materials

Alternative 2A/Cem would involve the same activities as Alternative 2A/Vit, with the exception of cement stabilization being utilized in place of vitrification. Since cement stabilization is a commonly utilized technology, the availability of vendors to provide service and materials would be adequate.

The construction of a cement stabilization facility involves the same steps as described in Section 4.2.2 with the substitution of cement stabilization equipment and materials for vitrification equipment and materials.

4.2.3.7 Cost

The total present worth cost of Alternative 2A/Cem is $74 Million. A detailed breakdown of the cost is provided in Table 4-4.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and hydraulic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-4. More detailed information is provided in Appendix E.

The largest component of the capital cost is the disposal vault, which represents approximately 30 percent of the total capital cost. This is due to the increase in volume of the cement-stabilized

TABLE 4–4

COST ESTIMATE FOR ALTERNATIVE 2A/CEM

| ALTERNATIVE 2A: REMOVAL, CEMENT STABILIZATION, ON–PROPERTY DISPOSAL | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $768,600 | $660,000 | $1,428,600 |
| WASTE PROCESSING | $1,008,500 | $1,065,000 | $2,073,500 |
| CEMENT STABILIZATION | $2,590,500 | $2,843,300 | $5,433,800 |
| HYDRAULIC REMOVAL/TRANSFER SYSTEM | $6,655,400 | $7,797,800 | $14,453,200 |
| DISPOSAL VAULT | $5,831,000 | $9,928,500 | $15,759,500 |
| PACKAGING (15,009 PKGS. @ $955/PKG.) | $3,962,400 | $10,371,200 | $14,333,600 |
| TOTAL CAPITAL | $20,816,400 | $32,665,800 | $53,482,200 |
| RISK BUDGET (11.0%) | $2,289,800 | $3,593,200 | $5,883,000 |
| SUBTOTAL | $23,106,200 | $36,259,000 | $59,365,200 |
| CONTINGENCY (20.0%) | $4,621,200 | $7,251,800 | $11,873,000 |
| TOTAL ESTIMATED INSTALLED COST | $27,727,400 | $43,510,800 | $71,238,200 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $11,715,700 |
| POST–REMEDIATION | | | $3,582,000 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $74,038,600 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during remediation (years): 3
Post–remediation O&M (years): 30

material over that of the untreated material. Construction of the hydraulic removal/transfer system and packaging are the next largest components of the costs, each representing approximately 27 percent of the total capital cost.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2A/Vit.

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the RTS. Costs were estimated based on the same assumptions as for Alternative 2A/Vit.

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the following:

- The cement stabilization equipment would operate 24 hours/day and would be designed to treat 11,800 kg/day (13 tons/day) of waste material.
- Cement stabilization equipment includes a surge tank, screw feeder, stabilization mixers, flyash, cement, and blast furnace slag storage/feed facilities, process piping, pumps, and mixers.

Hydraulic Removal/Transfer System

This cost component includes the support superstructure and work platform, rail trolleys, an enclosure for the hydraulic equipment, a concrete material transfer pit, RTS and building for the silo structures, and the hydraulic removal equipment. System components and cost are the same as for Alternative 2A/Vit.

Disposal Vault

Assumptions used to estimate the disposal vault cost are the same as those described for Alternative 2A/Vit, except for the following:

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- The size of the disposal vault was based on the number of packages noted below, assuming each package occupies 1.81 $m^3$ (64 $ft^3$) of space, and was estimated as 27,204 $m^3$ (960,576 $ft^3$). Assuming a vault size of 3400 $m^3$ (120,000 $ft^3$), nine cells would be required [ 6270 $m^2$ (67,500 $ft^2$) vault footprint area].

- The vault would cover approximately 4.3 ha (10.6 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation, and was estimated as described for Alternative 2A/Vit, with the following differences:

- Total volume that would be packaged was based on 3636 $m^3$ (4,756 $yd^3$) and 3158 $m^3$ (4,130 $yd^3$) of untreated Silos 1 and 2 material, respectively. Final packaging volume, assuming a 169 percent volume increase due to the cement stabilization process, was 18,274 $m^3$ (23,903 $yd^3$).

- Packages would be filled since the density of cement stabilized material is approximately 1735 $kg/m^3$ (108 $lb/ft^3$), which is below the maximum load limit.

- Total packaging cost was estimated assuming 15,009 containers.

O&M Cost

Short-term O&M costs incurred during remediation and long-term O&M costs are $11.7 Million and $3.6 Million, respectively, not considering present worth. Long-term O&M costs include maintenance and monitoring until all FEMP site-wide remedial action objectives are attained, i.e., in an estimated 30 years. The monitoring would support the required CERCLA five-year reviews.

4.2.3.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 2A/Cem. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.2.3.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 2A/Cem. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

### 4.2.4 Analysis of Alternative 3A.1/Vitrification

Alternative 3A.1/Vit would use the same site preparation, construction, removal, material processing, as Alternative 2A/Vit (Section 4.2.2). The difference between these two alternatives is that Alternative 3A.1/Vit would dispose of the treated material off site at NTS.

Off-site disposal for this alternative involves the packaging, loading, and shipping of the treated material to the Low-Level Radioactive Disposal Site at NTS. Shipping of the treated material to NTS would involve rail transportation from the FEMP site through East St. Louis on the CSX rail lines. From St. Louis, Missouri, the treated material would be transported on the Union Pacific (UP) rail lines through North Platte, Nebraska, and Salt Lake City, Utah. Currently, there are no direct rail lines to NTS. Presently, the treated material would be transported to either a point near Las Vegas, Nevada, or one of the areas north of Las Vegas. From either location, the containers carrying the treated material would be transferred to trucks for transportation over roads to NTS. If a direct rail line to NTS becomes available before this alternative is implemented, it should be used in lieu of shipping the treated material by truck on the last leg of its trip. Treated material may be staged and/or placed into interim storage, as required, in response to interruptions in the availability of disposal capacity.

#### 4.2.4.1 Overall Protection of Human Health and the Environment

Alternative 3A.1/Vit meets the remedial action objectives for Subunit A. As with Alternative 2A/Vit, Alternative 3A.1/Vit prevents direct access with residues and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Similar to Alternative 2A/Vit, treatment of the Subunit A materials through vitrification would reduce contaminant toxicity, mobility, and volume. Treatment through vitrification will enable the treated waste form to meet acceptance criteria at NTS. This is due to the fact that the vitrified material does not exceed the RCRA toxicity characteristic limits. In addition, the treatment of the material prior to disposal would provide additional long-term protection in the event the off-site containment system were to degrade.

The removal of the contaminants and their disposal off site provides the final element of protectiveness for Alternative 3A.1/Vit. The off-site disposal facility would provide protection by eliminating access to the residues and preventing migration of contaminants out of the waste similar to

the on-site disposal vault under Alternative 2A/Vit. The off-site NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant release, migration, and direct contact with contaminants. The long-term effectiveness of the necessary institutional controls at the NTS disposal facility is believed to be very reliable.

Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. Further, the climatic (low average annual precipitation) and hydrogeologic [depths to groundwater ranging from 157 - 600 m (515 - 2000 ft) below ground surface] characteristics would tend to mitigate impacts to human health and the environment in the event that engineering and institutional controls fail.

There are no unacceptable short-term risks from Alternative 3A.1/Vit which, for removal and treatment processes, pose the same risks as Alternative 2A/Vit. Additional risk is associated with transportation accidents. Radiation exposure to workers and the public as a result of the transportation is expected to be minimal.

4.2.4.2 Compliance with ARARs

Issues related to ARAR compliance for Alternative 3A.1/Vit are similar to Alternative 2A/Vit with the exception of the disposal of Subunit A treated material at a DOE-owned off-site facility. Alternative 3A.1/Vit meets all ARARs identified for this alternative. Only applicable requirements pertain to off-site portions of alternatives selected. In cases where relevant and appropriate requirements or TBC criteria are identified for activities under this alternative, the referenced citation pertains only to that portion of the activity conducted on site. Because Alternative 3A.1/Vit consists of off-site disposal of the treated material, the State of Ohio location criteria in OAC 3745-27-07 for disposal facilities would no longer be relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3A.1/Vit pertain to waste management and treatment and are similar to the ARARs for Alternative 2A/Vit (see Table F.2-1 in Appendix F). Consequently, the discussion of compliance for those common ARARs would be identical to that presented in Section 4.2.2.2, which is summarized below. Additional documentation of compliance of Alternative 3A.1/Vit with the identified ARARs is presented in Appendix F (Table F.2-2).

Chemical-Specific ARAR/TBCs

Alternative 3A.1/Vit would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those requirements associated with meeting

Ohio surface water quality standards; control of radon-222 airborne releases under the CAA; and control of other radionuclide releases to air and water, and their resulting doses to the public under DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting exposure assessments for Alternative 3A.1/Vit. Compliance with MCLs and MCLGs for underground drinking water supplies would be ensured by removal of the source term off site.

Location-Specific ARAR/TBCs

Alternative 3A.1/Vit would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, and endangered species and their habitat during the on-property treatment of the residues. As noted above, disposal vault location criteria and disposal requirements would no longer be relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARAR/TBCs

Alternative 3A.1/Vit would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. As was discussed for Alternative 2A/Vit, Alternative 3A.1/Vit would comply with 40 CFR § 191 Subpart A (a relevant and appropriate requirement), as well as ARARs associated with NEPA (for environmental documentation), the CAA (for release of dust and non-radioactive particulates) and the CWA (for storm water runoff, BMPs, and dredge and fill activities). This alternative would comply with the substantive RCRA closure requirements for tanks and containers used in the treatment process. This alternative would also comply with the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity.

As described in Alternative 2A, residues from the silos, contaminated media and debris, and any hazardous or solid wastes generated during the remediation of Operable Unit 4 may be managed in a designated CAMU under 40 CFR § 264 Subpart S, either while undergoing treatment, or during on-site disposal of the material. Management of the remediation wastes would be in accordance with all pertinent ARARs and TBCs, including compliance with the substantive hazardous waste landfill closure requirements and the closure performance standard of 40 CFR § 264.111.

TUs, as provided in 40 CFR § 264 Subpart S, and/or containment buildings as provided in 40 CFR § Subpart DD, might also be used under this alternative for the treatment or storage of remediation

waste, including media and debris which may be contaminated with a hazardous waste. These units would comply with all pertinent ARARs, including closure of the units in accordance with the pertinent closure requirements of 40 CFR § 264 as necessary to ensure protection of human health and the environment from operation of these units.

Off-site disposition would require shipment of materials. Hazardous material transport requirements would be complied with by following the pertinent regulations under 40 CFR §§ 262 and 263, and the appropriate DOT shipping requirements under 49 CFR §§ 172 and 173.

4.2.4.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementability of Alternative 3A.1/Vit would reduce the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Because all of the material is removed from the site, there is no residual risk from Subunit A residues at the FEMP site. Residual risk at NTS is limited by the facility institutional controls, the characteristics of the vitrified materials, and the arid environment.

Adequacy and Reliability of Controls

The reliability of the vitrification of Subunit A material for Alternative 3A.1/Vit is the same as that for Alternative 2A/Vit (Section 4.2.2.3). Off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate maintenance are likely to be reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrogeologic conditions, and characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct human contact in the event of disposal containment failure.

Long-Term Environmental Impacts

The long-term environmental impacts of removal and treatment actions of Alternative 3A.1/Vit are the same as for Alternative 2A/Vit (Section 4.2.2.3) with the exception of land for disposal. The discussion below focuses on impacts to the NTS site.

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Soil and Geology

Approximately 5.0 ha (12.4 acres) of soil at NTS would be permanently disturbed for the disposal of the Subunit A materials. Borrow material from NTS may be required to accommodate disposal at the NTS . The geology of NTS has been determined to be suitable for disposal of low level radioactive waste (LLRW) (DOE 1991). NTS is characterized by great depths to the groundwater table. As stated previously, depths to groundwater beneath NTS vary from about 155 m (515 ft) to more than 600 m (2000 ft) (DOE 1991). Groundwater movement in the saturated and unsaturated zones is very slow and there is an extremely low potential for transport of contaminants to off-site areas. These parameters make the geology of NTS very suitable for long-term disposal activities.

Water Quality and Hydrology

The disposal of treated material at NTS under this alternative is not expected to have significant impacts on water quality or hydrology. There are no continuously flowing streams on NTS. Stream beds carry water only during unusually intense or persistent rains. Rainfall [which averages 1 cm (0.4 in) per year] infiltrates quickly into moisture deficient soil. These parameters, coupled with very suitable geology, would help minimize long-term impacts to water quality. Engineered controls (capping) and ongoing monitoring activities would also be used to control and minimize water quality impacts.

Air Quality

Following implementation of Alternative 3A.1/Vit, the air quality at the NTS site would be similar to current conditions. There would be no long-term impacts on air because the cover system on the disposal facility would prevent radon emissions and because disturbed areas would be revegetated.

Biotic Resources

Most of NTS is vegetated by various desert shrubs. There are 711 types of vascular plants within or near the boundaries of NTS (DOE 1991). Several mammal species on NTS (e.g., feral horses, burros, kit foxes) have been placed on the protected classification list by the State of Nevada. The desert tortoise (Gopherus agassizii) is federally-listed as a threatened species and is present in some of the areas of NTS. The disposal activities at NTS related to Alternative 3A.1/Vit are not expected to impact the habitat of the desert tortoise or displace any other species at NTS.

Wetlands and Floodplains

No wetland areas have been delineated at NTS (DOE 1991). In addition, no floodplain areas are located near the disposal areas of NTS.

Socioeconomics and Land Use

NTS encompasses about 3500 $km^2$ (1350 $mi^2$), an area larger than the State of Rhode Island. Since 1951, primary land use on NTS is nuclear weapons testing and low-level radioactive waste disposal for on-site and off-site DOE-affiliated generators. NTS is surrounded on the east, north, and west sides by public access exclusion zones (e.g., Nellis Air Force Base Bombing and Gunnery Range). This area provides a buffer zone between the test areas and public lands of 24 to 105 km (15 to 65 mi). The population density within a 150-km (93-mi) radius of NTS is about 2.8 persons per $km^2$ (7.2 per $mi^2$). In comparison, the 48 contiguous states (1990 census) had a population density of approximately 29 persons per $km^2$ (75 per $mi^2$). The off-site areas adjacent to NTS are predominantly rural; hence, aesthetic impacts would not be expected to change. Hence, treated material disposal activities (associated with this alternative) would not impact socioeconomics or land use at NTS.

Cultural Resources

A site-wide archaeological survey would be performed for the areas to be impacted by Alternative 3A.1/Vit. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, SHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site. Archaeological sites have been surveyed and inventoried at NTS and currently, disposal activities are avoided in those areas.

4.2.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reductions in constituent toxicity, mobility, or volume would be the same for Alternative 3A.1/Vit as for Alternative 2A/Vit, based on application of the same treatment technology (Section 4.2.2.4).

4.2.4.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Alternative 3A.1/Vit provides the same level of short-term protection of the community during removal and treatment as does Alternative 2A/Vit (Section 4.2.2.5). There is added risk to the public through transporting the treated material off site. The estimate of public radiation exposure;

expressed in terms of ILCR, along the route to NTS is $8.3 \times 10^{-10}$, far below the target risk range of $10^{-4}$ to $10^{-6}$. It is estimated that 0.16 injuries and 0.039 deaths may occur due to transportation accidents. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 3A.1/Vit is effective in protecting the community in the short term. The basis for these estimates is provided in Appendix D.

The disposal of FEMP materials at NTS would not be expected to exceed protective levels for the community around NTS over the short term. The vitrified materials would meet NTS waste acceptance criteria and, therefore, would be managed within the bounds of the NTS facility's protectiveness criteria. The area required for the disposal of low-level waste at NTS represents only a small fraction of the site. Surveillance systems operated around NTS showed no radiological exposures that could be attributed to site operations in 1991. A hypothetical resident living 73 km (45 mi) west of NTS would be exposed to a maximum calculated dose of $8.6 \times 10^{-3}$mrem. In addition, the collective dose equivalent to the approximately 21,752 residents living within 80 km (50 mi) in 1991 from NTS airborne sources was $4.2 \times 10^{-2}$ person-rem. All of the dose estimates calculated are much less than one percent of the most restrictive standard (DOE 1991). The waste volumes from Alternative 3A/Vit would require only five acres of the 1350 square miles at NTS. Therefore, the disposal of FEMP waste is not expected to result in increased exposures to the public.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal and treatment are the same for Alternatives 3A.1/Vit as for 2A/Vit. There are additional radiation exposure risks to the worker resulting from transporting the material to NTS. The excess ILCR is estimated at $2.8 \times 10^{-6}$, near EPA's target risk level of $10^{-6}$. The estimate of the occurrence of injuries during remediation activities is 2.0 and indicates the incidence of deaths is 0.029. The risk to workers due to radiological exposures during off-loading activities at NTS is conservatively assumed to be below the estimated ILCR risk level of $4.0 \times 10^{-6}$ during treatment/construction activities at the FEMP site because the waste would already be packaged and stabilized upon receipt. There is uncertainty for some additional risk due to exposure to wastes already present at NTS in the vicinity of off-loading operations for FEMP materials.

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal and treatment of materials under Alternative 3A.1/Vit are the same as those for Alternative 2A/Vit (Section 4.2.2.5). The total area

disturbed at the FEMP site for Alternative 3A.1/Vit is 1.5 ha (3.0 acres). Since Alternative 3A.1/Vit involves off-site disposal of the treated materials at NTS, short-term environmental impacts for that facility are summarized below. Relevant information on NTS environmental impacts is also provided under Section 4.2.4.3, Long-Term Effectiveness and Permanence.

Soil and Geology

Soils at NTS would be disturbed during disposal activities. Appropriate mitigative controls (e.g., cover and grading) would be used at NTS to control erosion, the off-site transport of waste material, and radon release. Groundwater at NTS would not be impacted in the short term by disposal of Subunit A material due to the treated waste form, disposal under a cover system, and depth to groundwater. Ongoing monitoring would identify any unacceptable releases, with maintenance occurring to minimize the potential for release.

Water Quality and Hydrology

The implementation of 3A.1/Vit is expected to have minor impacts on the surface water hydrology at NTS. The NTS lies in an arid region with little rainfall. There are no continuously flowing streams on NTS.

Air Quality

Shipping treated material for disposal would result in minor increases in emissions related to vehicle exhaust. Short-term impacts would be negligible.

Biotic Resources

Disposal activities would disturb portions of NTS. However, habitat at NTS in the disposal area is limited (DOE 1991), and little displacement of species would occur.

Wetlands and Floodplains

No wetland or floodplain areas exist at NTS (DOE 1991).

Socioeconomics and Land Use

Short-term disposal activities for this alternative would not impact socioeconomics at NTS.

The implementation of Alternative 3A.1/Vit would have minimal short-term impacts on socioeconomic and land use at and around the FEMP site. Remedial activities would require

workers and approximately three one-way truck trips per day. Relocation of workers and their families are not expected to impact public facilities.

Synonymous with the other alternatives, it is assumed for this analysis that all resources needed for remedial work would be purchased within the CMSA. This would increase the collective revenue of the CMSA by 4.8 percent over six years. This would have a minimal economic impact on the thirteen surrounding counties. Furthermore, the removal of the Subunit A material would help eliminate any impacts on future population and economic growth in the area.

Transportation

The implementation of Alternative 3A.1/Vit would result in minor increases in traffic flow (3.0 truck trips per working day) on and around the FEMP site. Temporary increases in deliveries and workers to the FEMP site are not expected to result in any significant impact to traffic patterns or roadways. It was determined that an additional 300 to 400 vehicles a day would be required to impact traffic patterns. The implementation of Alternative 3A.1/Vit would result in an increase of only a fraction of those numbers. Due to the fewer worker hours associated with this alternative, fewer worker injuries should occur compared to Alternative 2A/Vit.

Treated material could be transported first by rail, and then transferred to trucks for transport to NTS. Environmental impacts from shipping and disposing of treated material are expected to be minimal from normal transportation because all procedures would be in compliance with applicable DOT requirements and DOE Orders. However, added risk to the public from transportation off site would increase public radiation exposure along the route to NTS to $8.3 \times 10^{-10}$, still far below the target range. More information on the risk to workers and the public associated with the transportation of treated material is addressed in Appendix D and Section 4.2.2.5.

Duration of Remedial Activities

The duration of remedial activities is assumed to be the same as for Alternative 2A/Vit. There is more uncertainty in the remedial activity schedule estimate since transportation or waste acceptance problems could cause delays in the shipping schedule.

4.2.4.6 Implementability

Technical Feasibility

The technical feasibility of implementing the removal and treatment components of Alternative 3A.1/Vit would be the same as described for Alternative 2A/Vit (Section 4.2.2.6). The technical feasibility of implementing the disposal component of Alternative 3A.1/Vit depends on the implementability of both transport of the treated material to NTS and disposal at that site. Off-site transport of the treated material to NTS would consist of rail transport from the FEMP site to within 483 km (300 mi) of NTS. Currently, NTS is not accessible by rail; therefore, the treated material would be transferred to trucks and transported to NTS. Equipment, facilities, and the required personnel for truck and rail transport would be readily available. The treated material would be placed in appropriate containers that meet all transportation and disposal requirements.

Administrative Feasibility

NTS is a DOE-owned facility; thus, no special permits would be required. However, an addendum to the current "FEMP Application to Ship Waste to the Nevada Test Site" would be required to be approved by NTS because this waste stream is a new stream not covered by current application.

This alternative would require agency approvals and coordination for the interstate shipment of the material. Many states require advance notification or permitting for shipments of radioactive material entering their state. All material shipments would be required to meet applicable federal and state regulations. The public and regulatory agencies from the states located within the transportation route from FEMP site to NTS are likely to oppose transport; thus, some coordination work would be required to obtain these approvals.

Availability of Services and Materials

The availability of services and materials for Alternative 3A.1/Vit is the same as for Alternative 2A/Vit, with the exception of the disposal vault. NTS currently accepts low-level waste and has adequate facilities to accept the Alternative 3A.1/Vit treated material. Transfer areas, storage areas, decontamination facilities, and a laboratory are available at NTS. The treated material form would be tested to ensure that it complies with NTS waste acceptance criteria.

4.2.4.7 Cost

The total present worth cost of Alternative 3A.1/Vit is $43.7 Million. A detailed breakdown of the cost is provided in Table 4-5.

TABLE 4–5

COST ESTIMATE FOR ALTERNATIVE 3A.1/VIT

| ALTERNATIVE 3A.1: REMOVAL, STABILIZATION W/VITRIFICATION, OFF–SITE DISPOSAL AT NTS | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| SITE PREPARATION | $768,600 | $660,000 | $1,428,600 |
| WASTE PROCESSING | $1,695,800 | $1,427,700 | $3,123,500 |
| VITRIFICATION | $2,935,500 | $1,703,600 | $4,639,100 |
| HYDRAULIC REMOVAL/TRANSFER SYSTEM | $6,655,400 | $7,797,800 | $14,453,200 |
| TRANSPORTATION | $1,268,100 | | $1,268,100 |
| DISPOSAL | $1,541,100 | | $1,541,100 |
| PACKAGING (2,412 PKGS. @ $955/PKG.) | $636,800 | $1,666,700 | $2,303,500 |
| TOTAL CAPITAL | $15,501,300 | $13,255,800 | $28,757,100 |
| RISK BUDGET (11.0%) | $1,705,100 | $1,458,100 | $3,163,300 |
| SUBTOTAL | $17,206,400 | $14,713,900 | $31,920,400 |
| CONTINGENCY (20.0%) | $3,441,300 | $2,942,800 | $6,384,100 |
| TOTAL ESTIMATED INSTALLED COST | $20,647,700 | $17,656,700 | $38,304,500 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $11,692,500 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $43,730,700 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on following time periods:
Construction (years): 3
O&M during remediation (years): 3
Post–remediation O&M (years): 0

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing and hydraulic removal/transfer system for transfer of the residues, purchase of vitrification equipment, packaging of material for disposal, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-5. More detailed information is provided in Appendix E.

This alternative includes identical cost components as Alternative 2A/Vit (Section 4.2.2.7), except off-site transportation and disposal replace the on-property vault that was included in Alternative 2A/Vit. As with Alternative 2A/Vit, the largest component of the capital cost is the construction of the hydraulic removal/transfer system, representing approximately 50 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2A/Vit (Section 4.2.2.7).

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the RTS. Costs were estimated based on the same assumptions as for Alternative 2A/Vit (Section 4.2.2.7). In addition, a staging facility would be provided for the temporary staging of material prior to off-site transportation and disposal.

Vitrification

This cost item includes the cost of the vitrification equipment, RTS, and off-gas system, and is estimated based on the same assumptions discussed for Alternative 2A/Vit.

Hydraulic Removal/Transfer System

System components and cost are the same as for Alternative 2A/Vit (Section 4.2.2.7).

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2A/Vit Section 4.2.2.7). The same number of containers (2,412) required for Alternative 2A/Vit are required for Alternative 3A.1/Vit.

Transportation

This cost item includes transportation of the packaged material, and is based on the following assumptions:

- Packages would be transported by rail to within 483 km (300 mi) of the disposal facility (NTS) and then transported by truck the remainder of the distance.
- Rail costs were estimated using a unit rate of $3.97 per railcar per mile. Railcars were assumed to weigh 8165 kg (180,000 lb) each.
- Truck costs were estimated using a unit rate of $0.53 per kg ($0.24 per pound) [for the total 483 km (300-mile) trip].

Disposal

- Treated material would be disposed at NTS.
- Unit disposal cost was estimated as $353/m$^3$ ($10/ft$^3$).

O&M Cost

Short-term O&M costs incurred during remediation are the same as for Alternative 2A/Vit ($11.7 Million, not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at the FEMP site.

4.2.4.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 3A.1/Vit. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.2.4.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 3A.1/Vit. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for public

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review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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### 4.2.5 Analysis of Alternative 3A.1/Cementation

This alternative will use the same site preparation, construction, removal, and D&D process options as Alternative 2A/Vit (Section 4.2.2). The treatment process option for this alternative is cement stabilization and would be the same as described for Alternative 2A/Cem (Section 4.2.3). The off-site disposal at NTS would use the same transportation route as discussed in Alternative 3A.1/Vit (Section 4.2.4). The volume of cement stabilized material to be disposed would be more than for the vitrification alternative.

#### 4.2.5.1 Overall Protection of Human Health and the Environment

Alternative 3A.1/Cem meets the remedial action objectives for Subunit A. As with Alternative 3A.1/Vit, Alternative 3A.1/Cem prevents direct access to residues and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Treatment of the Subunit A materials through cement stabilization would reduce contaminant mobility. The volume of contaminated material would increase due to additives used in the stabilization process. Treatment through cement stabilization would enable the treated material to meet the acceptance criteria for disposal at the NTS. This is due to the fact that the cement stabilized material does not exceed the RCRA toxicity characteristic limits. In addition, the treatment of the material prior to disposal would provide protection in the event the off-site containment system were to degrade.

The removal of the contaminants and their disposal off site provides the final element of protection for Alternative 3A.1/Cem and is the same disposal option as Alternative 3A.1/Vit. The off-site disposal facility would provide protection by eliminating access to the residues and preventing migration of contaminants from the residues. As previously discussed in Section 4.2.4.1, the uncertainties associated with institutional controls at this DOE facility are very low. The NTS environmental and demographic characteristics help to ensure long-term protectiveness in the event of institutional control failure. There are no unacceptable short-term risks from Alternative 3A.1/Cem.

#### 4.2.5.2 Compliance with ARARs

Issues related to ARAR compliance for Alternative 3A.1/Cem are similar to Alternative 2A/Cem with the exception of the Subunit A treated material final disposition being at a DOE-owned off-site facility. Alternative 3A.1/Cem meets all ARARs identified for this alternative. Because Alternative 3A.1/Cem involves off-site disposal of the treated material, the location criteria in OAC 3745-27-07

for disposal facilities would no longer be relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3A.1/Cem focus on waste handling and treatment and are similar to the ARARs for Alternative 2A/Cem (see Table F.2-1 in Appendix F). Consequently, the discussion of compliance for those common ARARs would be identical to that presented in Section 4.2.3.2, which is summarized below. Additional documentation of compliance of Alternative 3A.1/Cem with the identified ARARs is presented in Appendix F (Table F.2-2).

Chemical-Specific ARAR/TBCs

Alternative 3A.1/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those requirements associated with the protection of Ohio surface water quality; the control of radon-222 airborne releases under the CAA; and the control of other radionuclide releases to air and water, and their resulting doses to the public during remedial operations at the FEMP under DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting exposure assessments for Alternative 3A.1/Cem.

Location-Specific ARAR/TBCs

Alternative 3A.1/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, and endangered species and their habitat during the on-property treatment of the material. As noted above, disposal vault location criteria and disposal requirements would no longer be relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARAR/TBCs

Alternative 3A.1/Cem would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. As was discussed for Alternative 2A/Cem, Alternative 3A.1/Cem would comply with 40 CFR § 191 Subpart A (a relevant and appropriate requirement), as well as ARARs associated with NEPA (for environmental documentation), the CAA (for releases of dust and non-radioactive particulates), and the CWA (for storm water runoff, BMPs, and dredge and fill activities). This alternative would comply with the substantive RCRA closure requirements for tanks and containers used in the treatment process. This alternative would comply with the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity.

As described in Alternative 2A, residues from the silos, contaminated media and debris, and any hazardous or solid wastes generated during the remediation of Operable Unit 4 may be managed in a designated CAMU under 40 CFR § 264 Subpart S, either while undergoing treatment or during on-site disposal of the material. Management of the remediation wastes would be in accordance with all pertinent ARARs and TBCs, including compliance with the substantive hazardous waste landfill closure requirements and the closure performance standard of 40 CFR § 264.111.

TUs, as provided in 40 CFR § 264 Subpart S, and/or containment buildings as provided in 40 CFR § Subpart DD, might also be used under this alternative for the treatment or storage of remediation waste, including media and debris which may be contaminated with a hazardous waste. These units would comply with all pertinent ARARs, including closure of the units in accordance with the pertinent closure requirements of 40 CFR § 264 as necessary, to ensure protection of human health and the environment from operation of these units. Off-site disposition will require shipment of materials. Hazardous material transport requirements would be complied with by following the regulations under 40 CFR §§ 262 and 263 and the appropriate DOT shipping standards under 49 CFR §§ 172 and 173.

#### 4.2.5.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 3A.1/Cem would reduce the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Because all of the material is removed from the site, there is no residual risk from Subunit A residues at the FEMP site. Residual risk at NTS is limited by the disposal facility institutional controls, the characteristics of the cement stabilized materials, and the environment.

Adequacy and Reliability of Controls

The reliability of cement stabilization for Alternative 3A.1/Cem is the same as for Alternative 2A/Cem (Section 4.2.3.3). Off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be reliable at NTS. Additionally, if there is a release at NTS, the climate hydrologic and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct contact with released materials.

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Long-Term Environmental Impacts

The long-term environmental impacts to the FEMP site from the removal and treatment actions of Alternative 3A.1/Cem are the same as for Alternative 2A/Vit (Section 4.2.2.3). Impacts to NTS are the same as for Alternative 3A.1/Vit, except that the volume of cement stabilized material would require additional disposal space. The overall impact due to the increased volume is not significant.

4.2.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The reduction in contaminant toxicity, mobility, or volume would be the same for Alternative 3A.1/Cem as for Alternative 2A/Cem (Section 4.2.3.4).

4.2.5.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Protection of the community during removal and treatment operations is estimated to be the same for Alternative 3A.1/Cem as for Alternative 2A/Vit (Section 4.2.2.5). The potential for injury and deaths due to the treated material transportation is 0.98 injuries and 0.25 deaths, respectively. The estimate of public radiation exposure, expressed in terms of ILCR, along the route to NTS is 4.3 x $10^{-10}$, far below the target risk range of $10^{-4}$ to $10^{-6}$.

Protection of Workers During Remedial Actions

Protection of workers during implementation of Alternative 3A.1/Cem is the same as for Alternative 3A.1/Vit (Section 4.2.4.5). Both alternatives protect workers during remediation by using personal protective equipment, remote operating procedures, and shielding.

Short-Term Environmental Impacts

The short-term impacts of Alternative 3A.1/Cem are the same as the impacts discussed for Alternative 3A.1/Vit (Section 4.2.4.5) with the exception of the number of workers, trucks, and procurement of resources needed to complete the remedial activities. One hundred workers and approximately two one-way truck trips per day are required. For this analysis, it is assumed that all resources would be obtained within the area in which cause the collective revenue for the CMSA would increase by 7.4 percent over a period of six years. Minor positive economic impacts to the CMSA would result from the implementation of Alternative 3A.1/Cem.

Duration of Remedial Activities

The removal and treatment components of Alternative 3A.1/Cem would require the same amount of time (six years) for implementation as the other action alternatives. As with Alternative 3A.1/Vit, there is a chance for the schedule to be delayed as a result of transportation or disposal delays.

4.2.5.6 Implementability

Technical Feasibility

The technical feasibility of implementing the removal and treatment components of Alternative 3A.1/Cem would be the same as described for Alternative 2A/Cem (Section 4.2.3.6). The technical feasibility of implementing the disposal component of Alternative 3A.1/Cem would be the same as described for Alternative 3A.1/Vit (Section 4.2.4.6).

Administrative Feasibility

The administrative feasibility of Alternative 3A.1/Cem is the same as for Alternative 3A.1/Vit (Section 4.2.4.6).

Availability of Services and Materials

Cement stabilization includes the use of readily available equipment and materials. This is a demonstrated technology with commercial services available. This alternative would have the same availability of services and materials as those for Alternative 2A/Cem (Section 4.2.3.6).

4.2.5.7 Cost

The total present worth cost of Alternative 3A.1/Cem is $73.1 Million. A detailed breakdown of the cost is provided in Table 4-6.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and hydraulic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, packaging of material for disposal, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-6. More detailed information is provided in Appendix E.

TABLE 4–6

COST ESTIMATE FOR ALTERNATIVE 3A.1/CEM

| ALTERNATIVE 3A.1: REMOVAL, CEMENT STABILIZATION, DISPOSAL AT NTS | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $768,600 | $660,000 | $1,428,600 |
| WASTE PROCESSING | $1,695,800 | $1,427,700 | $3,123,500 |
| CEMENT STABILIZATION | $2,590,500 | $2,843,300 | $5,433,800 |
| HYDRAULIC REMOVAL/TRANSFER SYSTEM | $6,655,400 | $7,797,800 | $14,453,200 |
| TRANSPORTATION | $5,574,000 | | $5,574,000 |
| DISPOSAL | $9,589,700 | | $9,589,700 |
| PACKAGING (15,009 PKGS. @ $955/PKG.) | $3,962,400 | $10,371,200 | $14,333,600 |
| TOTAL CAPITAL | **$30,836,400** | **$23,100,000** | **$53,936,400** |
| RISK BUDGET (11.0%) | $3,392,000 | $2,541,000 | $5,933,000 |
| SUBTOTAL | $34,228,400 | $25,641,000 | $59,869,400 |
| CONTINGENCY (20.0%) | $6,845,700 | $5,128,200 | $11,973,900 |
| TOTAL ESTIMATED INSTALLED COST | **$41,074,100** | **$30,769,200** | **$71,843,300** |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $11,715,700 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | **$73,086,300** |

NOTES:

Costs are order of magnitude costs (−30% to +50% accuracy).
Present worth cost calculated based on following time periods:
Construction (years): 3
O&M during remediation (years): 3
Post−remediation O&M (years): 0

The alternative includes identical cost components as Alternative 2A/Cem (Section 4.2.3.7), except off-site transportation and disposal replace the on-property vault that was included in Alternative 2A/Cem. As with Alternative 2A/Cem, the largest component of the capital cost is the construction of the hydraulic removal/transfer system, representing approximately 27 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

The basis of estimate is the same as that discussed for Alternative 2A/Vit (Section 4.2.2.7).

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the RTS. Costs were estimated based on the same assumptions as for Alternative 2A/Cem (Section 4.2.3.7).

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the same assumptions provided for Alternative 2A/Cem (Section 4.2.3.7).

Hydraulic Removal/Transfer System

System components and cost are the same as for Alternative 2A/Cem (Section 4.2.3.7).

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2A/Cem (Section 4.2.3.7). The total quantity of containers required for packaging 2A/Cem materials were estimated to be 15,009 containers.

Transportation

This cost item includes transportation of the packaged material and has the same basis of estimate as Alternative 3A.1/Vit (Section 4.2.4.7). However, the final cost for this alternative was greater than Alternative 3A.1/Vit due to the increased volume of cement-stabilized material.

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Disposal

This cost is estimated as described for Alternative 3A.1/Vit (Section 4.2.4.7), but it adjusted for the disposal of a greater number of containers for the cement-stabilized material.

O&M Cost

Short-term O&M costs incurred during remediation are the same as for Alternative 2A/Cem ($11.7 Million, not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at the FEMP site.

4.2.5.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 3A.1/Cem. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.2.5.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 3A.1/Cem. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

## 4.3 SUBUNIT B

### Source Term Description

It was identified that Subunit B (Silo 3 contents) contains 3890 $m^3$ (5088 $yd^3$) of residues. As part of the RI for Operable Unit 4, Subunit B was sampled for a full range of analyses including radionuclides and organic and inorganic chemicals. Present within the silo residues is approximately 450 Ci of Th-230, 26 Ci of Ra-226, and nearly 40 metric tons (44 tons) of uranium. Due to the physical characteristics (i.e., dry powder) and the significant concentrations of long-lived alpha emitting radionuclides, the Silo 3 residues present a significant inhalation and ingestion hazard to exposed populations.

Of the 23 inorganic constituents detected, those which represent the highest relative hazard include arsenic, chromium, and selenium at levels exceeding RCRA limits. However, based on the generation process of the residues, they are classified as by-product material as defined in Section 11(e)2 of the AEA and, therefore, are excluded from regulation under RCRA.

Because of the process by which the Silo 3 residues were produced, first dried then calcined at temperatures near 820°C (1500°F), all organics present in the metal oxides were either combusted or volatized prior to residue transfer to Silo 3. This hypothesis is supported by the analytical results presented in the RI Report for Operable Unit 4.

### Principal Threats

The NCP describes principal threats as those involving liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.

Consistent with the NCP, the RI Report for Operable Unit 4 provided a detailed characterization of the source term within Silo 3 and identified those contaminants which contributed to an ILCR value greater than $1 \times 10^{-6}$ and a hazard quotient greater than 1.0. The RI Report for Operable Unit 4 identified that the principal threats to human health and the environment posed by the Silo 3 contents in its current configuration are from the following contaminant/transport pathways:

### Direct Radiation

- Direct exposure to Silo 3 residues under the future source term scenario assuming structural collapse of the silo.

Air Emissions

- Dispersion of Silo 3 contents under the future source term scenario assuming structural collapse of the silo.

Surface Water Runoff

- Erosion of released Silo 3 contents under the future source term scenario assuming structural collapse of the silo.

Potential remedial alternatives for Subunit B were developed in order to mitigate both the short-term and long-term exposure and associated risks from gamma radiation, eliminate potential of air dispersion from silo collapse and eliminate potential for contaminated surface water runoff resulting from release Silo 3 contents under the future source term scenario (assuming structural collapse of the silo).

### 4.3.1 Analysis of Alternative 0B - No Action

The No-Action Alternative is retained throughout the FS process as required by the NCP (40 CFR § 300.430[e][6]). As with Alternative 0A, Alternative 0B provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action would be taken. In the No-Action Alternative, the materials are considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. The contents of Silo 3 would remain in place. Alternative 0B does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and Alternative 0B does not provide for passive or active administrative controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

#### 4.3.1.1 Overall Protection of Human Health and the Environment

The no-action alternative does not meet the remedial action objectives for Subunit B. It is not protective of human health and the environment in the long term based on a comparison defined in EPA criteria. With no maintenance of Silo 3, the silo dome may collapse, releasing contaminants to the groundwater. Use of the groundwater by an off-site resident or by an on-property resident (potential receptor under no action) would result in unacceptable risks (ILCR exceeding $1x10^{-4}$ to $1x10^{-6}$ range). Exposure to the site soils and residues following silo collapse would also result in unacceptable risks to humans and biota. Additionally, migration of contaminated groundwater towards and into Paddys Run could result in further human health risk and adverse environmental impacts to the stream and to aquatic biota.

#### 4.3.1.2 Compliance with ARARs

Potential regulatory requirements that might be ARARs or TBCs to the final remedial alternatives for Subunit B are identified and evaluated in Appendix F. With no further action, certain ARARs would not be met. Without further maintenance or proper closure of Silo 3, eventual failure would result in release of material from the silo that would violate state water quality standards for surface receiving waters under the CWA and exposure limits to the public from radionuclides established under DOE Order 5400.5. Drinking water MCLs and MCLGs under the SDWA would most likely be exceeded if the released material were to migrate into the groundwater of the Great Miami Aquifer. Since the Silo 3 material is in powder form, airborne releases of radionuclides following silo structural failure would exceed the allowable NESHAPs dose rate under the CAA. Failure of the unit would also lead

to violation of Ohio regulations for control of fugitive dust (OAC 3745-17-08) and prohibition of air pollution nuisance (OAC 3745-15-07).

Design standards for long-term protection from radiation hazards associated with radioactive waste disposal would not be a part of this alternative. Proper closure of the silo would not be conducted, which would not meet the relevant and appropriate closure performance standard under 40 CFR § 264 Subpart G of RCRA. With unrestricted site access (e.g., no access controls), the DOE Order 5400.5 standards for general radiation exposure of the public and levels of residuals remaining at the site established in 40 CFR § 192 would also not be met.

CERCLA Section 121 cleanup standards, including compliance with ARARs, apply only to remedial actions EPA determines should be taken under CERCLA Sections 104 and 106 authority. A no-action decision can only be made when it is determined that no remedial action is necessary to reduce, control, or mitigate exposure because the site is already protective of human health and the environment. If the alternative passes the protectiveness threshold criterion, then compliance with ARARs is not pertinent to the selection of Alternative 0B.

#### 4.3.1.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Contaminant levels in surrounding media and habitats would increase as a result of transport and deposition of airborne residues or contaminants leaching from the residue under Alternative 0B. New habitats could become contaminated, especially along Paddys Run. Human health risks that may occur if no action is taken are discussed in Appendix D of this FS. The no-action alternative assumes eventual silo dome failure, and the risks from no action are unacceptable. Excess cancer risks could reach unity from ingestion of the perched water beneath the silos (Pb-210 is the primary risk driver), external radiation (Ra-226), food ingestion (arsenic), and inhalation (Th-230). The scenario also has the potential for significant noncarcinogenic affects (HI of 500 for adult and 2000 for child) driven by arsenic through food ingestion. Under the no-action alternative with silo failure, the risk to the off-site farmer is also unacceptable (excess cancer risk of $2 \times 10^{-4}$). Until the silo collapses, there is no projected unacceptable risk to the public from Silo 3 contents.

Because this alternative leaves the silo contents on the property, a review of silo conditions and contaminant release would be conducted at least every five years to ensure protectiveness in accordance with CERCLA Section 121 (c).

Adequacy and Reliability of Controls

The no-action alternative only remains protective as long as the silo is intact. Because the silo collapse over the long-term is imminent, the condition has been included in the no-action alternative rendering it unprotective. Under the silo collapse scenario, Silo 3 material cancer risks are estimated to be noticeably higher than Silos 1 and 2 because Silo 3 has no protective bentonite layer.

Long-Term Environmental Impacts

Alternative 0B would not be protective of human health and the environment in the long term because it does not prevent exposure to residues and the possibility of silo collapse. Silo collapse and subsequent loss of containment could lead to increased contamination levels in the perched ground water zone, surface water and sediment in Paddys Run, and the 0.36 ha (0.76 acre) wetland south of Silos 1 and 2. For the long-term risks associated with Alternative 0B, refer to Section 4.3.1.3, "Magnitude of Residual Risk."

4.3.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

No treatment of the silo contents would be involved in Alternative 0B; therefore, reduction of toxicity, mobility, or volume through treatment would not result.

4.3.1.5 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation of the remedial action. Under the no-action alternative, no remedial action would be taken. There would be no increase in short-term risks and no short-term environmental impacts.

4.3.1.6 Implementability

Technical Feasibility

Under the no-action alternative there would not be any difficulties or uncertainties associated with implementation. The no-action alternative is included in the detailed analysis of alternatives for a baseline comparison.

Administrative Feasibility

No permits or licenses would be required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials

Under the no-action alternative, there would be no services or materials required.

4.3.1.7 Cost

There are no costs associated with Alternative 0B-No Action.

4.3.1.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 0B. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.3.1.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 0B. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

### 4.3.2 Analysis of Alternative 2B/Vitrification

This alternative requires the removal of cold metal oxides from Silo 3, stabilization of the material by vitrification, and on-property disposal of the stabilized material. The cold metal oxides would be removed by a pneumatic removal system introduced through the silo dome. This equipment would be supported by a work platform that would span the silo. This platform is similar to that used in Alternative 2A. The cold metal oxides would be pneumatically transferred to a processing facility for vitrification and packaging, and then would be disposed in an on-property above-grade disposal vault. Treated wastes may be staged or placed into interim storage, as required, as a contingency for operational difficulties. This alternative would include the placement of markers to define waste disposal areas, the use of deed restrictions, and the provision of continued federal ownership of the property to preclude drilling or residential development for the site.

#### Site Preparation/Construction

The site preparation activities would begin with the clearing and grubbing of vegetated areas in the vicinity of the silo. These activities are in preparation for the construction of cold metal oxides processing facility, the transfer trench, and the construction of roads and equipment staging areas. Approximately 2 ha (5 acres) would require clearing and grubbing. The site preparation activities would also consist of the installation of roadways, site fencing, site lighting, process water piping, sewer lines, power poles, and the extension of site power to the areas requiring service.

Other facilities to be constructed include the pneumatic removal work platform with underlying tracks and foundation, a processing facility with equipment for vitrification, and an above-grade disposal vault for the disposal of the stabilized cold metal oxides.

#### Removal

A pneumatic removal device consisting of a cutterhead and a negative pressure (vacuum) would be used to remove the dry, powdery contents of Silo 3. The pneumatic removal equipment would be supported by a work platform identical in design, construction, and purpose to that used for the removal alternatives in Subunit A. If removal alternatives are selected for both Subunits A and B, the rail system for the work platform used for Alternative 2A/Vit (Section 4.2.2) would be used for Subunit B. Because all of the cold metal oxides are not accessible to the pneumatic removal system through a single manway, the equipment would be rotated from manway to manway until all of the cold metal oxides have been removed. During normal operations, personnel would be required to work over the dome once every week for approximately two hours to reposition the pneumatic

removal equipment. Other than this weekly activity and required monitoring activities, personnel would not be required to work above the silo dome. Cold metal oxides removal would be conducted eight hours/day, seven days/week, for three weeks/month. The fourth week of every month would be for equipment maintenance and repairs. It is estimated to take approximately 12 months to remove the Silo 3 contents.

The air entrained in the cold metal oxides, suctioned from the silo, would be separated in a filter/receiver adjacent to the work platform. The cold metal oxides would then be pneumatically "pushed" to the cold metal oxides processing facility for treatment.

The glove box would be used at the interface of the pneumatic removal system and silo dome and would function as secondary containment in conjunction with the silo dome. This setup, along with procedural compliance, is designed to prevent a release to the atmosphere during normal operations in the event of a breach in the primary containment.

Material Processing

Cold metal oxides would be treated through vitrification. This vitrification treatment option is identical to the vitrification option used for Alternative 2A/Vit with the exception that the cold metal oxides would be mixed with silica, alumina, and borate. The molten glass would be poured into DOT specification 7A Type A containers designed to withstand the temperatures of the molten glass without compromising container integrity. The containers would then be stored in the facility until the glassified blocks have cooled and been sampled. Similar to Alternative 2A/Vit, the design of the 2B/Vit vitrification process is based upon a one-day cooling period for a monolithic waste form. Likewise, as discussed in Section 4.2.2, sampling methods and final waste form decisions are being investigated and optimized as part of ongoing pilot plant studies.

Due to the very high temperatures required for vitrification [1350°C (2462°F)], superheated steam and volatilized matter would be produced. This off-gas would contain a number of constituents that must be treated before discharge. An off-gas treatment system, similar to that used for Subunit A alternatives, would treat this stream with scrubbers and HEPA filters and then would exhaust to the atmosphere. Because the potential exists for emissions of radionuclides to the ambient air in excess of 40 CFR § 61, Subpart H and Subpart Q, there would be continuous radionuclide emissions monitoring of the off-gas treatment system and the RTS.

The cold metal oxides processing facility would use shielding and radiation control zones to minimize exposure to workers. Highly radioactive components and piping would be shielded or contained in restricted access rooms.

On-Property Disposal

For the on-property disposal alternatives, the containerized glassified block would be transported to an above-grade disposal vault for disposal. Figure 4-6 provides a cross-sectional view of the adopted representative disposal concept. The need for and actual configuration of the components of the disposal vault (i.e., vaults, intruder barriers, etc.,) would be established through the remedial design process. As depicted on the figure, the concrete vault would have a service opening to allow access for the placement of DOT specification 7A Type A containers. The floor of the vault would have a minimum slope of two percent to facilitate any leachate collection and monitoring. The roof of the vault would also have a minimum slope of two percent to allow storm water runoff. As each vault is filled to capacity, all equipment and temporary utilities would be removed and the vault sealed before the multimedia cap is installed.

The vault would be constructed on a reinforced concrete mat with a minimum thickness of 0.3 m (1 ft). The perimeter of the mat would be bounded by a curb with embedded pipes that are connected to the manholes of the underlying multimedia LC/DS to facilitate the collection of any contaminated leachate after final closure. The LC/DS would be composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the groundwater and the underlying Great Miami Aquifer.

The soil of the composite liners would be constructed of a natural, compacted clay with a maximum permeability of $1 \times 10^{-7}$ cm/s. The layers would be a minimum of 0.9-m (3-ft) thick. To improve the performance of the clay layers, geomembranes of at least 40 mil in thickness would be placed over the surface of the clay, which has been smooth-rolled to ensure good hydraulic contact. To minimize damage to the geomembranes during construction, a sand layer with a minimum thickness of 20 cm (8 in.) would be placed over the geomembranes of the LC/DS.

Between the composite soil liners, drainage layers would be installed to intercept any leachate that may be generated. The drainage layers would be a minimum of 0.6 m (2 ft) each in thickness. The upper 0.3 m (1 ft) of each layer would be a graded natural aggregate, and the lower 0.3 m (1 ft) would be a narrow-graded medium aggregate to provide a minimum permeability of $1 \times 10^{-2}$ cm/s. A

geotextile membrane would be placed on the upper surface of each drainage layer to prevent the migration of fines from the overlying material.

During placement of the aggregate, 10-cm (4-in.) diameter pipes would be installed within the aggregate to collect and direct any leachate to a series of manholes lined with HDPE. The leachate would then be removed from the manholes for treatment at the FEMP AWWT facility. For purposes of this FS, it has been assumed that active maintenance of the leachate collection system would continue for a period of 30 years. The thirty-year time period was adopted since it is considered to best represent the time required to achieve site-wide remedial action objectives for the five FEMP operable units. It is anticipated, however, that active maintenance of the leachate collection system would not be required for the entire 30-year timeframe due to the design of the capping system (i.e., infiltration barriers). In the unlikely event that active maintenance of the leachate collection system is required beyond the end of active on-site remedial activities (i.e., 30 years) to ensure protection of human health and the environment, such active maintenance would be continued until such time as deemed unnecessary by DOE and EPA.

A multimedia cap constructed of five distinct layers of media would provide final closure of the vault. The upper layer of the cap would be a vegetative layer consisting of topsoil with a hardy, shallow root grass cover. This layer would be noncompacted and have a minimum thickness of 0.6 m (2 ft) to support plant growth. The vegetative layer would inhibit erosion and allow runoff during storm events. A drainage layer would be beneath the vegetative layer to intercept infiltrating precipitation. Within the layer would be 0.3 m (1 ft) of pea gravel that would provide a minimum permeability of 1 x $10^{-2}$ cm/s. A geotextile membrane would be placed between the vegetative layer and the top surface of the drainage layer to prevent the migration of fines from the vegetative layer to the drainage layer.

A layer of cobblestone with a minimum thickness of 0.7 m (2.3 ft) may be installed beneath the peagravel to serve as an inadvertent intrusion barrier and would also serve as part of the drainage layer. The need for such a barrier would be established during final remedial design. Beneath the cobblestone would be a composite soil liner to impede downward moisture movement from the drainage layer. The soil of this layer would be natural, compacted clay with a maximum permeability of 1 x $10^{-7}$ cm/s. The layer would be 0.9 m (3 ft) thick to ensure the isolation of the disposal containers (Subunits A and B only). A geomembrane at least 40 mil in thickness would be placed over the surface of the clay, which is smooth-rolled to ensure good hydraulic contact, thus improving the performance of the clay. To minimize slippage of the overlying layers due to interfacial shearing

characteristics, the geomembrane would be textured. A layer of sand, similar to the composite soil liners of the LC/DS, would be placed over the geomembrane to minimize damage during construction.

The foundation of the multimedia cap would be clean, compacted soil. This layer would be a minimum of 15 cm (6 in.) to a maximum of 0.6 m (2 ft) in thickness above the vault. All general and granular material, as well as clay, are regionally available. Upon completion of the multimedia cap, institutional controls including permanent markers, deed restrictions, and continued federal ownership of the FEMP site would be provided to comply with identified ARARs and minimize the potential for future exposures. Under continued federal ownership, the government is assumed to discontinue active access controls and site maintenance following completion of remedial activities and attainment of site-wide remedial action objectives. While the federal government would not maintain a continued site presence after completion of site cleanup, the government would continue to exercise its rights of ownership to preclude future site development. Monitoring of the site would continue, as necessary, to support CERCLA five-year reviews. The monitoring network would include wells located appropriately to evaluate the effectiveness of the above-grade disposal facility and to ensure the continued protection of human health and the environment. With buffer zones and fences, 2.4 ha (6 acres) would be required for the disposal vault for Alternative 2B/Vit.

4.3.2.1 Overall Protection of Human Health and the Environment

Alternative 2B/Vit meets the remedial action objectives for Subunit B. Implementation of this alternative would prevent direct access to the residues and would mitigate the migration of contaminants to the air, soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. Three primary actions would be used to meet the remedial action objectives, thereby providing adequate protection to human health and the environment. These actions are treatment through vitrification, containment in an on-property above-grade disposal vault, and implementation of institutional control measures.

Treatment of Subunit B materials through vitrification would reduce contaminant toxicity, mobility, and volume. The leaching rate of the treated waste form would be reduced, enhancing the protection of the underlying Great Miami Aquifer. Treatment of the material prior to disposal would also provide additional protection in the event that the disposal vault begins to degrade, allowing increased infiltration and subsequent leachate formation. However, beyond the 1,000 year expected design life of the disposal vault, continued protection becomes less certain as a result of possible degradation of

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the vitrified material and subsequent increased leachability. As demonstrated by treatability studies, the leaching rate of the treated material is much lower than the untreated form.

Containment of the treated waste form in an on-property, capped, above-grade disposal vault would provide additional control of contaminant migration to human and environmental receptors. The disposal vault would also prevent direct radiation from the treated residues and radon (considered a minor contribution to dose based risks for Subunit B). The vault design would include an intruder barrier and permanent markings to inhibit purposeful or inadvertent human entrance or destruction of the facility's engineered protective features. The vault would be designed for a life of 1,000 years. The vault would be designed to preclude the need for long-term active maintenance. The design features of the vault, including the infiltration barriers, are anticipated to eliminate the need for the active operation, maintenance, and monitoring of the leachate collection system. The leachate system would be actively monitored, with collected waters pumped (if necessary) during the active operational phase of site remedial actions (i.e., approximately 30 years). It is anticipated that such operations and maintenance of the leachate collection would not be warranted (i.e., due to lack of flow) beyond that timeframe. As discussed above, continued long-term effectiveness of the vault cap and leachate collection system is uncertain and eventual degradation could lead to an increased rate of infiltration, leachate formation, and release. Fate and transport modeling using conservative assumptions supports the conclusion that long-term protection of human health and the environment would still be achieved based on the low rate of degradation of the disposal vault.

Institutional control measures would be employed to supplement the treatment and containment actions in order to provide additional assurance that overall protection would be maintained as engineered components degrade. Institutional controls would include the adoption of long-term federal government ownership of the FEMP site. This ownership of the site would preclude future on-property residential and farming land uses, which could result in direct exposure to the residues through intrusive actions or facility degradation. The use of institutional controls is also consistent with an ARAR for the on-property above-grade disposal vault. To comply with ORC 3734.02, hazardous and solid waste disposal facilities must include a protective covenant to restrict future mining, drilling, and residential uses. In accordance with this requirement, a deed restriction would be placed on the FEMP site property detailing these restrictions. The uncertainty associated with very long institutional control periods includes a possible loss of federal ownership and the loss of or lack of administration of the property records containing the deed restrictions.

Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the vitrified material by future human and biota receptors. Exposures to receptors through these pathways (i.e., groundwater, air, etc.,) in the event of disposal vault failure would be expected to be minimal due to the positive attributes of the treated wastes. However, direct radiation exposure could be significant in the event of failure due to the presence of significant activity concentrations of long-lived gamma emitting radionuclides. Eventually, the risks from complete failure in the future could approach baseline risk conditions. However, both engineering and institutional controls would have to fail before unacceptable risks to human health would occur.

There are no unacceptable short-term risks from Alternative 2B/Vit. There are worker risks from radiation exposure during removal, treatment, and packaging. However, through the use of remote removal, shielding, and implementation of a worker health and safety plan in compliance with 29 CFR § 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE Orders.

4.3.2.2 Compliance with ARARs

The implementation of Alternative 2B/Vit would comply with all pertinent ARARs identified for this alternative. With two exceptions, the identification of ARAR/TBC requirements for 2B/Vit is basically identical to Alternative 2A/Vit. The exceptions involve the deletion of disposal requirements established in the AEA under 40 CFR § 191 and 10 CFR § 61, with a greater emphasis placed on disposal requirements established under the UMTRCA in 40 CFR § 192. The reason for this change is because the Subunit B material poses less hazard than the Subunit A material; therefore, a higher level of protection is not necessary. As a result, the requirements under 40 CFR § 192 would offer adequate protection of human health and the environment for the disposal of Subunit B material. With the exception of compliance issues presented for 40 CFR §§ 191 and 192, the discussion of the compliance of this alternative with identified ARARs/TBCs would be identical to that for Alternative 2A/Vit presented in Section 4.2.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 2B/Vit would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those standards associated with meeting the SDWA drinking water MCLs and MCLGs; the RCRA solid and hazardous waste groundwater protection requirements; UMTRCA and CAA radon-222 airborne release requirements; and other

radionuclide release limits for water and air and their resulting doses to the public under the CAA and DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 2B/Vit. Additional documentation of compliance of Alternative 2B/Vit with the identified ARARs is presented in Appendix F (Table F.2-3).

Location-Specific ARAR/TBCs

Alternative 2B/Vit would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b). Included would be those requirements associated with the protection of floodplains, wetlands, endangered species and their habitat, and the sole-source aquifer underlying the FEMP site. As was noted, compliance with the OAC 3745-27-07 prohibition on the location of a solid waste disposal facility over a sole-source aquifer would be based on demonstrating attainment of the substantive technical requirements for an exemption to this requirement as discussed in Section 4.2.2.2. Since the final location of the disposal vault would be similar to that for Alternative 2A/Vit, the information regarding the technical demonstration to meet the exemption would also be similar to that alternative.

Action-Specific ARARs

Alternative 2B/Vit would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. Included would be those standards associated with the design and operation of the multi-barrier above-grade disposal vault system under RCRA and UMTRCA. 40 CFR § 192, Subpart A requires that the disposal system be designed to "be effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years...". This design criterion is standard for all DOE UMTRCA sites, including sites having an environmental setting similar to the FEMP site. Such UMTRCA disposal cover designs have been modeled with the Corps of Engineers' HELP computer code and shown to maintain their integrity for at least 1,000 years. Although not specifically identified as an ARAR for Subunit B, 40 CFR § 192 Subpart B requires that average surface concentrations of radium-226 residuals left in soil not exceed background by more than: "5 pCi/g, averaged over the first 15 cm (6 in.) of soil below the surface...." This requirement would be met by covering all the treated Subunit B residues in the vault with a 3 m (10 ft) thick multimedia cover.

As described in Alternative 2A/Vit, residues from the silos, contaminated media and debris, and any hazardous or solid wastes generated during the remediation of Operable Unit 4 may be managed in a designated CAMU under 40 CFR § 264 Subpart S, either while undergoing treatment or during on-

site disposal of the material. Management of the remediation wastes in a CAMU would be in accordance with all pertinent ARARs and TBCs, including compliance with the substantive hazardous waste landfill closure requirements and the closure performance standard of 40 CFR § 264.111.

TUs, as provided in 40 CFR § 264 Subpart S, and/or containment buildings, as provided in 40 CFR § Subpart DD, might also be used under this alternative for the treatment or storage of remediation waste, including media and debris which may be contaminated with a hazardous waste. These units would comply with all pertinent ARARs, including closure of the units in accordance with the pertinent closure requirements of 40 CFR § 264 as necessary, to ensure protection of human health and the environment from operation of these units.

As for Alternative 2A/Vit, this alternative would comply with the substantive groundwater monitoring requirements for RCRA solid and hazardous waste disposal facilities, as well as the RCRA closure requirements for tanks, containers, and land disposal facilities. This alternative would also comply with NEPA (for environmental documentation), and with the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity. Compliance with requirements under the CAA, CWA, and RCRA would be met by incorporating sound engineering features and BMPs into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 2B/Vit would comply with the identified ARARs is presented in Appendices D and F (Table F.2-3).

#### 4.3.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 2B/Vit would reduce the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Figure 4-8 was presented as a conceptual site model for the various action alternatives considered. Residual risk would only be through completed pathways. The basis of the risk evaluation is presented in Appendix D. Each of these potential concerns would be addressed through the primary remedial action components of Alternative 2B/Vit: treatment, isolation in an above-grade disposal vault, and the application of institutional controls.

Vitrification would significantly reduce the mobility of the COCs and the radon emanation rate, while the direct radiation fields would remain unchanged after vitrification. The disposal vault design, supplemented by institutional controls, would preclude contact with or direct radiation

exposure from the treated waste by a expanded trespasser. The disposal vault also would contribute to a significant reduction in leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude access to the residues by an on-property resident.

Because 2B/Vit includes the on-property disposal of treated residues, the five-year CERCLA review process to ensure continued performance of the disposal system would be part of this alternative.

Adequacy and Reliability of Controls

As previously stated, the projected residual excess cancer risk attributable to Alternative 2B/Vit to viable receptors is less than $10^{-6}$. The on-property disposal vault uses proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low-level radioactive waste under both DOE and NRC programs, and uranium mill tailings under the UMTRCA and the FUSRAP.

Fate and transport modeling to assess the most likely release mechanism, leaching under degradation of the facility, was completed. The results were based on the assumption that components of the system slightly degrade over 1,000 years and that infiltration rates (and consequently exfiltration rates) increase to 1.3 cm/yr (based on the HELP model). Also, the leachability of the treated material was assumed to be that measured during treatability tests. Under these assumptions, the leaching of contaminants would not pose a risk to off-site receptors. Uranium-238 is the only contaminant predicted by modeling to reach the Great Miami Aquifer. Even if these input parameters were increased to 15 cm/yr (highest possible with no infiltration barrier) and the leachability of the untreated material were used, the overall result would not change.

Treatability data for the vitrification process option (Table C.3-18) indicated that the ratio of the activity of Uranium-238 in the leachate from the untreated Silo 3 waste to the activity in the leachate from vitrified Silo 3 material was one. The leaching of the contaminants using these conservative assumptions would result in a risk to off-site receptors of about $10^{-6}$.

Vitrification is an innovative technology that has not been previously applied to the stabilization of waste materials at the same scale as contemplated under Alternative 2B/Vit. Over the period 1989 to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of vitrification technology on Silo 3 residues. The tests have repeatedly demonstrated consistent reductions in the leachability of both radionuclides and inorganic constituents (see Appendix

C). An ongoing glass optimization program underway for the Subunit A residues has identified a relatively wide envelope of operating parameters (temperature, additive rate, and waste composition) under which the vitrification system could perform to produce an acceptable product. These conclusions can be extrapolated to Subunit B material. Additionally, the use of vitrification provides added operational flexibility to recycle glass product not meeting performance based requirements through the glass melter. On this basis, there is a high probability that the vitrification treatment system would retain the required glass product performance requirements for Subunit B residues.

The disposal vault would be designed to preclude the need for long-term management. Operation and maintenance functions would occur until long-term protectiveness was attained at the time when the FEMP site-wide remedial action objectives would be met.

Consistent with DOE Order 5400.5, 40 CFR § 264.114, and 40 CFR § 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required five-year CERCLA review.

Long-Term Environmental Impacts

The environmental impacts resulting from the implementation of Alternative 2B/Vit after remedial activities are completed would be essentially the same as for Alternative 2A/Vit. Refer to Alternative 2A/Vit (Section 4.2.2.3) for detailed information; this section only contains a summary. For irreversible and irretrievable commitment of resources, refer to Section 4.7. The following paragraphs summarize the long-term effects of Alternative 2B/Vit on the environment.

Soil and Geology

Construction of the disposal vault would result in the permanent disruption of 2.4 ha (6.0 acres) of land. The disposal configuration would prevent erosion of residues that could result in surface soil contamination and would prevent leaching that would contaminate subsurface soil. Uncontaminated soil would be used as fill. Borrow pit soil for construction would be obtained from clearing and grubbing.

The regional geology of the FEMP site and surrounding area would not be affected by implementation of Alternative 2B/Vit. Geological conditions are important in terms of site suitability for construction of an on-property disposal vault. The material would be vitrified and the facility would incorporate appropriate protection against leaching to the aquifer and seismic damage.

Water Quality and Hydrology

A system to monitor long-term water quality would be implemented by installing monitoring wells around the perimeter of the disposal vault. No significant long-term hydrological impacts to the surrounding area are expected to result from changes to the site. However, after 1,000 years, some degradation could occur. Run-on and runoff controls would be used at the disposal vault, and the remaining areas of the site would be regraded to the surrounding grade and would discharge surface runoff to existing on-property drainageways.

Air Quality

Following implementation of Alternative 2B/Vit, the air quality at the FEMP site would be similar to current conditions. There would be no long-term impacts on air quality because the disturbed areas would be revegetated.

Biotic Resources

Long-term impacts may include displacement of potential threatened and endangered species habitat. No critical habitat for threatened and endangered species has been identified in areas to be impacted by Alternative 2B/Vit activities. Implementing Alternative 2B/Vit would result in the loss of 2.4 ha (6.0 acres) of potential habitat. Following completion of construction and excavation activities, disturbed areas would be backfilled, regraded, and revegetated with native grass species. For detailed information on the biotic impacts, refer to Alternative 2A/Vit (Section 4.2.2.3).

Wetlands and Floodplains

A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and received COE approval in August 1993 . The delineation identified approximately 12 ha (29 acres) of jurisdictional wetlands in the northern part of the site. Efforts would be made to site the disposal vault in areas not containing jurisdictional wetlands. However, for NEPA purposes it was assumed that the siting of the facility for Alternative 2B/Vit would result in the loss of approximately 5 ha (12.5 acres) of forested wetlands. A wetlands assessment pursuant to the requirements of 10 CFR § 1022 has been prepared (Appendix J) for the representative alternative and other alternatives evaluated.

The 100- and 500-yr floodplains of Paddys Run are located near Silo 3 and the support facilities. However, these areas would not be permanently altered as a result of implementing Alternative 2B/Vit.

Socioeconomics and Land Use

The area of the disposal vault is estimated at less than 0.1 percent of the FEMP site area. However, the presence of the permanent disposal vault would result in future limitations for use of the site. No change would be expected in the local population growth, nearby industrial and commercial operations, or noise level. The net long-term impact of Alternative 2B/Vit on these socioeconomics is expected to be positive because the silo contents and sludge would be isolated and controlled. However, aesthetic perceptions to a visitor or passerby could be altered due to the controls required for the disposal vault. A fenced area topped with barbed wire would be used for material disposal. These controls could result in a noticeable attention drawn to the disposal area.

Cultural Resources

An archaeological survey would be performed for the non-controlled areas not previously disturbed that could be impacted by Alternative 2B/Vit. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

In Alternative 2B/Vit, vitrification would be used to treat all the Silo 3 contents. This process would reduce contaminant toxicity, mobility, and volume. The vitrified material would undergo up to a 62 percent decrease in volume as a result of treatment. This result corresponds to a total treated volume of 1471 $m^3$ (1935 $yd^3$). The reduction in volume of Silo 3 waste is based on the chemical thermal destruction of sulfates, phosphates, nitrates, and carbonates. There is also a reduction in volume due to a closer packing arrangement of the inorganics, including radionuclides material in a glass matrix, as opposed to the "particle-void-particle" arrangement of the waste in its present form. The toxicity of radionuclides in the silo waste would not be reduced.

A remedy-selection treatability study was conducted with Operable Unit 4 materials, including the contents of Silo 3. This treatability study demonstrated the effectiveness of vitrification as a treatment alternative (see Appendix C). Additional remedial design treatability studies would be conducted to further determine the factors that affect the destruction and removal efficiencies for the contaminants during vitrification and the extent of partitioning of undestroyed contaminants between the vitrified material and the off-gas treatment system. The results of these studies would be used to develop appropriate glass formulations, provide data necessary for sizing and design of the full-scale

continuous melter system, and determine the configuration of the final off-gas treatment system for removal of radon.

The chemical and physical properties of Subunit B material were determined and used in developing glass formulas for the bench-scale treatability study tests (Appendix C, Tables C.3-1 to C.3-10). Data from the study revealed that the radon emanation rate from the vitrified Silo 3 material was below detection limits, far less than the EPA limit of 20 pCi/m$^2$/s for radon emanation from uranium mill tailings. The measured radon emanation rate from the treated material is approximately equal to the emanation rate from natural building materials such as brick and concrete, though the radium content is 1x10$^3$ to 1x10$^6$ times greater than that of natural building materials.

Data from the treatability study revealed that significant volume reductions could be achieved through vitrification. As shown in Table C.3-13 (Appendix C) for tests CO.1 and CC.1 (applicable to Subunit B materials), the reduction in volume of material was 62 percent. Thus, the final volume was approximately 38 percent of the untreated material volume. This result corresponds to a total estimated treated volume of 1471 m$^3$ (1935 yd$^3$).

The results from TCLP testing showed that the vitrified residue material did not exceed RCRA regulatory limits for metal. Thus, the comparison of TCLP test results (through the leachate concentration) for the treated residues to the untreated residues demonstrated the effectiveness of vitrification as a treatment process for Subunit B residues. Leachate concentrations were below RCRA TC regulatory limits for all the glass produced in these tests (Appendix C, Table C.3-14). Table C.3-18 presents a comparison of the leachate activity from the untreated wastes to the leachate activity from the vitrified wastes.

For Silo 3 material, the ratio of activity in the leachate of the untreated waste to that in the vitrified waste was less than that of Silos 1 and 2 material. A wide variation in leaching of the various radionuclides achieved through vitrification was observed. The low ratios of the activity observed in the leachate from the untreated residue compared to the activity in the leachate from the vitrified residue do not necessarily indicate that radionuclides are immobilized. Instead, the ratios show that some radionuclides are not leached as readily as others from the untreated residue. For example, while nearly 0.87 percent of the Ra-226 in the Silo 3 material is leached from the untreated residue, only 0.0003 percent of the Th-230 is leached. Such differences can arise because of differences in solubility among the various elements at the conditions encountered in the leachate.

The normalized leach rates indicated that all glass formulas exhibited exceptional durability, comparable to glasses developed from vitrified high-level wastes. For discussion purposes only, the normalized leach rates were compared to the Defense Waste Processing Facility EA (a standard representing the maximum acceptable leach rate for high-level waste glasses) (Jantzen et al. 1992) and were found to be an order of magnitude less. Also, the rates are comparable to those measured for simulated high-level waste glasses (Piepel et al. 1989).

Another observation of the treatability tests was that the TCLP appears to leach constituents from the glass more aggressively than the PCT. The difference between the acid conditions of the TCLP and the neutral conditions of the PCT are likely the cause of the great differences in the leaching behavior. Nevertheless, the PCT leach testing demonstrated a high degree of durability for the vitrified Operable Unit 4 residues.

The viscosity and electrical conductivity of the vitrified residues were measured as a function of temperature. The viscosity data shows the glass from various Silo 3 material tests (Sequence C) had reasonable viscosities for processing within the temperature range reported. The conductivity values for all glasses are close to typical ranges for glass processing. Therefore, the results show that the Silo 3 material can be made into glasses with reasonable conductivity and viscosity for processing in a joule-heated ceramic melter.

Treatability tests demonstrate that the vitrified product effectively immobilizes the RCRA constituents and reduces their release to levels less than the regulatory limits. Additional remedial design treatability studies would be conducted to further determine the factors that affect the destruction and removal efficiencies for the contaminants during vitrification and the extent of partitioning of undestroyed contaminants between the vitrified material and the off-gas treatment system. The results of these studies would be used to develop appropriate glass formulations, provide data necessary for sizing and design of the full-scale continuous melter system, and determine the configuration of the final off-gas treatment system for removal of radon.

The operating temperatures considered for the vitrification design [1350°C (2460°F)] would destroy any organic compounds present in the residues and fix metals into the nonleachable stabilized melt. Since hazardous inorganic constituents actually become part of the chemical structure of the glass matrix and not merely encapsulated, the process is essentially irreversible.

Literature data on the leachability of the vitrified product from a variety of waste types indicate similar leach resistance; all vitrified material tested to date has passed the RCRA TCLP test. Contaminant release from a vitrified product is controlled by diffusion and is governed by the same factors that affect release from a chemically stabilized/solidified product. The leachability of the vitrified product could be impacted by the development of immiscible phases in the melt because of the variable chemical composition of the residues; however, the short residence time in the melter would minimize the potential for immiscible phase development.

The weathering behavior of volcanic glass (a natural analog to the vitrified product) can provide some measure of the long-term stability and durability of the vitrified product. Only very thin weathering rinds develop on volcanic glass over a period of several million years. The slowness in the overall degradation of a glass grain suggests that the diffusion coefficient or leachability index would remain unchanged over time. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates. On the basis of the longevity of volcanic glass and diffusion calculations, the vitrified product would be expected to withstand environmental exposure for thousands of years.

Treatment residuals of the vitrification process would be produced from the off-gas treatment system. Off-gases containing particulates and other pollutants would be removed and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary to adequately reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the vitrification process until all the residuals are contained in the glass matrix. Furthermore, the effects of vitrification as a treatment are essentially irreversible.

4.3.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls and access controls, Alternative 2B/Vit would be protective of the community during implementation. Figure 4-9 illustrates that direct emissions from being near the untreated material and gas emissions during treatment are the release mechanisms that could potentially impact the community during remediation activities. Gas collection and treatment systems operated during vitrification of the material would control gaseous contaminant releases. It

has been estimated that during implementation of Alternative 2B/Vit, fenceline radon exposure levels for the off-site public would be indistinguishable from background levels, less than 0.5 pCi/L.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to direct radiation from the residues along with radon, gases, or dust. In addition to the engineering controls that would be implemented to limit the release of contaminants, access controls during remediation would be used. Fences and security forces would limit access of the public to the materials. Access controls are effective, especially in the short term. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 2B/Vit is effective in protecting the community in the short term.

Protection of Workers During Remedial Action

There are no unacceptable risks to workers as a result of implementation of Alternative 2B/Vit. This alternative involves the handling of the residues and, therefore, there are several potential exposure pathways for workers. Both the release of gases and exposure to direct radiation from the residue could cause a risk to workers. It has been estimated that, with appropriate protection, the removal and treatment of materials would result in an excess cancer risk level to remediation workers of $4.1 \times 10^{-5}$ (see Appendix D), well within the occupational standards required by DOE Orders. Most of this risk would occur during handling of the untreated residue. As appropriate, workers would wear protective clothing. Shielding would also be used, along with remote operations where needed.

There are safety issues associated with the removal and vitrification process. The high temperatures and power requirements of vitrification results in potential risk. There are also physical injury risks associated with constructing the on-property disposal vault. There may be accidents transporting the construction material on property or operating heavy equipment. Without considering the nature of the activity, it has been estimated, based solely on labor hours, that the removal, treatment, and on-property disposal actions of Alternative 2B/Vit could result in 4.5 injuries and 0.07 deaths during remediation. All remediation activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR § 1910.120(b)(4). Training and procedures would assure that worker exposure would be ALARA.

Short-Term Environmental Impacts

The short-term impacts resulting from the implementation of Alternative 2B/Vit during remedial activities are basically the same as those identified for Alternative 2A/Vit, Section 4.2.2.5; therefore, the following discussion is a summary.

Soil and Geology

Soil disturbance during implementation of Alternative 2B/Vit would primarily result from preparation of the disposal vault location and construction of access roads, a treatment/packaging area, a staging area, and support facilities. Construction and excavation activities could disturb a total of approximately 3.6 ha (9 acres) of the site. These same activities could also result in the erosion of exposed soil areas. Erosion controls such as straw bales and berm would be used to minimize potential erosion. Measures for reducing fugitive dust generation such as wetting surface or using dust suppressants would be used in exposed soil areas as appropriate. Following completion of all construction and excavation activities, disturbed areas would be filled with clean backfill and topsoil and revegetated with native grasses.

Water Quality and Hydrology

Through erosion control and dust suppression, contaminants disturbed during remediation would not be transported to adjacent surface water bodies. Surface water near the site would be monitored during remediation in accordance with the existing water discharge permit to assess potential impacts to the water from remediation.

Remediation would not increase the release of contaminants to the groundwater since the material would always be contained. However, selected existing groundwater wells on the FEMP site would be monitored during source removal.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are three potential sources of air emissions: 1) dust from construction and earth-moving activities, 2) gas releases during treatment, and 3) heavy equipment exhaust. The exhaust emissions from heavy equipment are not expected to impact air quality.

Dust would be controlled as discussed in the soil section. With the appropriate dust suppression, excavation activities are not expected to negatively impact the air quality. Gas emissions would be

controlled through both collection and treatment during residue treatment. Therefore, no significant releases into the environment are expected to occur.

Biotic Resources

The short-term disturbance of 3.9 ha (9.0 acres) of on-property vegetation and wildlife habitat under Alternative 2B/Vit would primarily result from activities associated with construction of the on-property disposal vault and other facilities and installation of electric power lines, transformers, process water and sewer lines, and material slurry transfer lines. Local biota (wildlife and wildlife habitat) would be temporarily displaced along with potential threatened and endangered species habitat. However, these impacts would be temporary, and permanent habitat losses are expected to be minor.

There also is the potential for impact to biota from contaminant releases such as through erosion, dust emissions, gas releases, and direct radiation. As discussed in previous short-term effectiveness discussions, the releases would be minimized through engineering controls such as erosion control, dust suppression, gas collection and treatment, and shielding of residues. There should be no negative exposure impact on biota during implementation of Alternative 2B/Vit.

Wetlands and Floodplains

A site-wide wetlands delineation has identified several areas of wetlands in or adjacent to areas that could be impacted by the implementation of Alternative 2B/Vit. Wetlands north and south of the material treatment facility would not be expected to be affected; however, for NEPA purposes it was assumed that there would be disturbance of wetlands during the construction of the on-property disposal vault. Approximately 2.2 ha (5.5 acres) could be affected. Engineering controls through the site activities such as silt fences and straw bales would be used to control the migration of eroded soil to wetland areas.

The 100- and 500-year Paddys Run floodplains are located immediately west of Silos 1 and 2. Alternative 2B/Vit activities are not planned to occur within the floodplains, and contaminant migration during remediation would be controlled through engineered erosion controls to minimize impacts on the floodplains.

Socioeconomics and Land Use

For this analysis, it is assumed that all of the resources needed to complete remedial activities could be obtained within the local area. Consequently, the collective revenue for the CMSA would increase by 3.3 percent over a period of four years. With the implementation of Alternative 2B/Vit, the increase in revenues for the CMSA would have limited impact on surrounding communities. The implementation of Alternative 2B/Vit would require approximately 18,500,000 kilowatt-hours of electricity.

Cultural Resources

Any areas determined to be of significance resulting from a cultural resource review would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA (Luce 1987). A more detailed discussion of management procedure is provided in the short-term effectiveness evaluation for Alternative 2A/Vit.

Duration of Remedial Activities

Remedial action activities under Alternative 2B/Vit are expected to be completed in about four years. Construction, testing, and startup of the material processing facility could require at least three years, with the possibility of a longer period depending on the difficulties encountered. Material removal activities would require about three years, assuming eight hours/day, seven days/week, for three weeks/month. The treatment facility would operate concurrently with removal for three years assuming that operations would be conducted 24 hours/day, seven days/week, for three weeks/month. The time to implement the treatment component of this alternative could be prolonged if pilot-scale testing and full-scale testing of the vitrification facility resulted in scale-up and operational difficulties because of the innovative nature of this treatment technology. Physical, substantial, and continuous on-property activities would be initiated within 15 months after the ROD is approved by the EPA.

4.3.2.6 Implementability

Technical Feasibility

Construction and operation of the removal component of Alternative 2B/Vit would be readily implementable. Pneumatic removal is a standard technology that is normally reliable and readily available. Although pneumatic removal has not been used before on the Silo 3 cold metal oxides, it has been used to remove material of similar consistency. Because the structural integrity of Silo 3 is questionable, extreme caution would need to be exercised during removal of silo contents. In case of

silo dome failure and the subsequent implementation of an emergency response plan, all removal operations would cease until an assessment of the failure and its impacts is complete. Upon completion of the assessment, the steps required to complete the remedial action would be determined. Construction and operation of the disposal components of this alternative would be reliable. Components of the design have been used at numerous other sites. If disposal volumes were greater than anticipated, the disposal vault footprint could be easily increased.

The technical feasibility of the vitrification facility construction is expected to be moderately straightforward, but a full-scale system for similar materials has never been built. The vitrification technology would require engineering scale-up to be implemented full-scale at Operable Unit 4. Pilot testing, detailed design, fabrication, installation, and three to six months of full-scale operation would be needed to optimize the treatment process. The necessary equipment would be modified from available equipment used in the glass-making industry. Construction of the vitrification facility at the FEMP site would include construction of an electric substation.

Operation of the vitrification facility would be somewhat difficult. The vitrification system consists of three basic circuits: a feed preparation circuit, a melter circuit, and an off-gas treatment system. Joule-heated ceramic melters have been used to vitrify liquid high-level radioactive material, radioactively contaminated soil, and waste contaminated with heavy metals in quantities ranging from 4.5 to 410 metric tons/day (5 to 450 tons/day). Several vendors have been identified for the electrically based (joule-heated ceramic melters or plasma arc torch) and in situ vitrification technologies.

A trained process engineer would be needed to operate both the physical pretreatment and melting circuits of the electrically based ceramic melter and to act as supervisor of the melter circuit. Operators and maintenance personnel, laborers, laboratory technicians, and administrative personnel would also be needed. Industrial work experience would be required for the system operators and maintenance personnel. The number of operators and maintenance personnel with previous experience in the vitrification of hazardous waste is limited, but these personnel could be drawn from the commercial glass-making industry or the high-level radioactive waste vitrification industry. The melter system could be designed to operate largely by computer, with a combination of human and computerized oversight. Start-up of the vitrification facility would require at least four months; however, because the melter system has not been previously used at the scale required for the site,

operational problems might develop during start-up that could impact the processing schedule and costs.

Potential operational problems in the melter circuit include temperature variation, incomplete melting, immiscible phase development, and thermocouple or heat sensor failure. Refractory failure would not be anticipated to be a problem because the design life of the melter operation is less than the design life of the refractory at anticipated operating temperatures. Temperature variation and improper control could result in the incomplete melting of feed material. Temperature fluctuations could also cause phase immiscibility. The use of electricity allows for almost immediate control over melt temperatures and thus would aid in controlling variability in melt viscosity and phase immiscibility.

Temperatures within the system would be continuously monitored by thermocouples and heat detectors. These thermocouples would probably be prone to failure at the high operating temperatures, necessitating the placement of redundant thermocouples at critical locations in the system and routine replacement and repair as part of maintenance activities. Any product from the vitrification system that was incompletely melted or contained immiscible phases would be returned to the facility until an acceptable product was produced.

The reliability of the melter system for waste treatment is not well established because this system has not yet been implemented at full scale or continuous operation. Similar melting systems used in commercial glass-making report a 90 percent continuous operation efficiency.

The off-gas treatment system would use standard air pollution treatment and control devices. Although the capability of the individual off-gas treatment devices are known and well demonstrated, the effects are less well known with regard to linking multiple treatment devices together to treat the off-gas expected from vitrification of the Silo 3 contents. The off-gas treatment system would use standard components, but the selected devices and their configuration would have to be explicitly defined, tested, and optimized through bench-scale and pilot-scale testing.

The limited experience in developing the required off-gas treatment system could result in schedule delays or cost increases because more time and personnel might be needed to bring the system on-line. Operators and repair personnel would probably be drawn from the incineration industry because of their experience in operating and maintaining off-gas treatment systems. The likelihood of operational problems would increase as the complexity of the off-gas treatment system increased. It

is possible that a complex linkage of treatment devices could lead to operational difficulties with individual devices. The potential for effects from failure of individual devices could be exacerbated in downstream devices and result in an overall problem with system operations and collection and removal efficiencies. If the off-gas emissions exceeded applicable requirements, delays would result; failure of monitoring devices or inadequate test results from a full-scale off-gas system could also cause delays until corrections could be implemented. Additional conceptual design and testing would be required to identify and resolve the potential difficulties in designing and operating an off-gas treatment system for a vitrification system.

Operational problems that could develop in the off-gas treatment circuit include production of large amounts of particulates that require secondary handling; added treatment requirements for the scrub solution prior to disposal; monitoring device calibration; maintenance requirements; and exacerbation of operational problems in downstream control devices resulting from failure of an upstream device. The off-gas treatment system would require testing and optimization to resolve these potential problems.

The effectiveness of the main components of the treatment process for Alternative 2B/Vit would be regularly monitored. The off-gas treatment system effluent would be monitored to determine the off-gas composition and ensure compliance with applicable requirements. The effectiveness of the vitrification process would be monitored by regular testing of the treated product. If a sample fails the leachability criteria, additional samples would be collected, tested, and analyzed to determine the cause of the problem. The failed treated material could be revitrified, if necessary, and a process modification instituted.

About 2.4 ha (6 acres) would be required for the above-grade disposal vault, with a capacity of approximately 3402 $m^3$ (4450 $yd^3$).

The effectiveness of the above-grade disposal vault would be monitored through several systems to meet the requirements of the CERCLA five-year review. Groundwater monitoring wells would be located to detect changes in groundwater quality. The monitoring system associated with the disposal vault would provide the information needed to determine if additional corrective action should be taken to prevent the migration of contaminants into the environment.

The implementation of Alternative 2B/Vit would not adversely impact the performance of additional remedial actions at the FEMP site. For example, the presence of the above-grade disposal vault would not affect the ability to remediate groundwater at the site.

Administrative Feasibility

No permits or licenses would be required, but permit information summary packages may be necessary. The substantive technical requirements of air emissions permits would also need to be demonstrated. This may include calculating estimated emissions, providing air emissions controls, developing a sampling and analysis plan to monitor air emissions, and air sampling. Coordination with OEPA would be necessary to ensure that the substantive technical requirements for siting the above-grade disposal vault would be met.

Availability of Services and Materials

Although it is technically feasible to design, construct, and operate a vitrification facility, a full-scale facility for the vitrification of materials similar to those within Operable Unit 4 has never been built.

Remedy-selection treatability studies have been completed and remedial design treatability studies (bench- and pilot-scale) would be performed to address site-specific design requirements. Necessary equipment would be modified from available equipment in the glass-making industry. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel would be trained as required. There would be sufficient disposal capacity for the vitrified residue.

The construction activities involved in Alternative 2B/Vit include: construction of the rail system for the work platform, the work platform and hydraulic mining device; clearing and grubbing of areas around the silos and at the location of the material processing facility; construction of access roads, fencing, lighting, water, sewer, and electrical services; construction of an above-grade disposal vault; construction of a materials processing facility and a vitrification unit; and construction of a multimedia cap.

The construction of the rail system, a work platform, and pneumatic mining device would involve the purchase of materials and services which are standard in the construction industry.

The clearing and grubbing, and construction of roads, fencing, lighting, sewers, and electrical services would involve the use of standard construction equipment and trades, the use of a fence installation contractor, and the purchase of appropriate materials. These would all be readily available.

The construction of an above-grade disposal vault would require the use of standard construction equipment and trades. Materials needed to construct a reinforced concrete vault would be purchased. These services and materials would be available locally.

The construction of a materials processing facility would involve the purchase of a pre-engineered building, the process equipment, the process chemicals/materials, electrical transformers and transmission lines, and the instrumentation and controls. It would also involve the use of standard construction equipment and services. Some engineering would be required during construction, start-up, and debugging of the process equipment. Qualified personnel would be needed to operate and maintain the facility. Of these, only the operator may be difficult to retain.

Although it is technically feasible to design, construct, and operate a vitrification facility, a full-scale facility for the vitrification of hazardous materials similar to those within Operable Unit 4 has never been built. Remedy-selection treatability studies have been completed and remedial design treatability studies (bench-and pilot-scale) would be performed to address site-specific design requirements. There would be sufficient disposal capacity for the vitrified residue.

The construction of the multimedia cap would require the acquisition of material for a geotextile liner, a clay layer with a permeability of $1x10^{-7}$cm/s, a 40 mil textured geomembrane, and clean soil for the foundation. As shown in a materials survey, these materials would be readily available. Standard construction equipment, operators, and trades personnel would be required. The installation of membranes and liners would require specialized equipment and personnel to lay the material and seal seams.

In summary, the resources and materials would be readily available. It would be necessary to ensure that EPA, OEPA, and the local community are fully involved in the development of RD/RA work plans. Close coordination with the regulatory agencies and the community prior to and during remedial activities would be essential for successful implementation.

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4.3.2.7 Cost

The total present worth cost of Alternative 2B/Vit is $28 Million. A detailed breakdown of the cost is provided in Table 4-7.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, purchase of vitrification equipment, construction of the above-grade disposal vault, and packaging of material for disposal. A breakdown of direct and indirect costs for each major component of this alternative is provided in Table 4-7. More detailed information is provided in Appendix E.

The largest component of the capital cost is the construction of the pneumatic removal/transfer system. This represents approximately 50 percent of the total capital costs. Most of the expense of this component is due to construction of the steel superstructure that supports the pneumatic system. The second largest element of the capital costs (21 percent) is the purchase of vitrification equipment.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and the equipment staging areas. The basis of estimate includes the following assumptions:

- An area of approximately 2.4 ha (6 acres) would be cleared and grubbed.
- Filling would be performed where necessary. The volume of fill was estimated to be 11,500 $m^3$ (15,000 $yd^3$). It was assumed that this soil could be obtained from excess on-property soil.
- New fencing would be added across the southern end of the remediation area and between the proposed parking area and the equipment staging area. Fencing would be 2 m (7 ft) high, barbed-wire topped chain link fence. Approximately 550 linear meters (1,800 linear ft) would be required. It is assumed that seven gates would be required, each 4.5 m (15 ft) wide and 2 m (7 ft) high, and topped with barbed wire.
- An equipment staging area would be added to the north end of the remediation site. This area would consist of 15 cm (6 in.) of crushed stone [2.5 cm (1 in.) maximum diameter)

TABLE 4–7

COST ESTIMATE FOR ALTERNATIVE 2B/VIT

| ALTERNATIVE 2B: REMOVAL, STABILIZATION W/VITRIFICATION, ON–PROPERTY DISPOSAL | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $579,500 | $528,700 | $1,108,200 |
| WASTE PROCESSING | $915,300 | $971,000 | $1,886,300 |
| VITRIFICATION | $2,593,400 | $1,460,700 | $4,054,100 |
| PNEUMATIC REMOVAL/TRANSFER SYSTEM | $4,571,600 | $4,744,400 | $9,316,000 |
| DISPOSAL VAULT | $498,100 | $848,000 | $1,346,100 |
| PACKAGING (1,282 PKGS. @ $955/PKG.) | $338,400 | $885,900 | $1,224,300 |
| TOTAL CAPITAL | $9,496,300 | $9,438,700 | $18,935,000 |
| RISK BUDGET (11.0%) | $1,044,600 | $1,038,300 | $2,082,900 |
| SUBTOTAL | $10,540,900 | $10,477,000 | $21,017,900 |
| CONTINGENCY (20.0%) | $2,108,200 | $2,095,400 | $4,203,600 |
| TOTAL ESTIMATED INSTALLED COST | $12,649,100 | $12,572,400 | $25,221,500 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $4,923,000 |
| POST–REMEDIATION | | | $3,162,000 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $27,971,300 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during remediation (years): 1
Post–remediation O&M (years): 30

applied over an area 45 m (150 ft) by 60 m (200 ft) (30,000 $ft^2$).

- Approximately 450 m (1,500 ft) of 6 m (20 ft) wide roads would be constructed in the remediation area. The roads would be constructed of 15 cm (6 in.) deep crushed stone [2.5 cm (1 in.) maximum diameter].

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and an off-gas treatment system. Costs were estimated based on the following assumptions:

- The waste processing facility would be a modified two-story pre-engineered building built on slab. The first floor would provide approximately 1350 $m^2$ (14,400 $ft^2$), and the second floor would have 50 $m^2$ (500 $ft^2$). The processing facility would be fully insulated and would have a 10-year design life span.

- The walls of the processing rooms and the storage room will be shielded with 0.6 m (2 ft) thick concrete.

- Approximate dimensions of the various areas of the building were estimated to be as follows: processing area - 820 $m^2$ (8,800 $ft^2$), administrative/personnel area - 300 $m^2$ (3,200 $ft^2$), miscellaneous equipment area - 450 $m^2$ (4,800 $ft^2$), and storage area - 220 $m^2$ (2,400 $ft^2$).

- The ventilation system for the general process area would operate continuously and would either recirculate or exhaust to atmosphere. This system would not be designed to remove radon.

- The general process area ventilation would provide seven air changes per hour. The system would include a 1135 $m^3$/min (40,000-cfm) blower and HEPA filter, and 91 m (300 ft) of 1.5 m (5 ft) diameter ductwork with dampers and fittings. A second redundant train would be installed.

- A separate ventilation train would be used in the event radon is detected in the process area. The general process area ventilation system would shut down if radon is detected in the general process area.

- The RTS for process air would consist of a 30 $m^3$/min (1,000 cfm) blower, a calcium sulfate media dehumidification vessel, a carbon adsorption canister, a HEPA filter, and approximately 61 m (200 ft) of 25 cm (10 in) diameter ductwork (with dampers and fittings). This system would be rated for 30 $m^3$/min (1,000 cfm), and the system would exhaust to atmosphere. A second redundant train would be installed.

Vitrification

This cost item includes the cost of the vitrification equipment and off-gas system, and is estimated based on the following:

- The vitrification equipment would operate 24 hours/day and would be designed to treat 11,800 kg/day (13 tons/day) of material.
- Vitrification equipment includes a surge tank, silica, alumina, and borate storage/feed facilities, process piping, pumps, mixers, and a joule-heated melter.
- The off-gas treatment system would be rated at 4 $m^3$/min (150 cfm). It would consist of blowers, scrubbers, carbon adsorbers, and HEPA filters.

Pneumatic Removal/Transfer System

This cost component includes the support superstructure and work platform, rail system, filter/receiver, glove box, and the pneumatic removal equipment. Assumptions used for the cost estimate include:

- The work platform would be a rail-mounted, 54-m (180-ft) structure truss that would span the silos.
- A glove box would be used at the interface of the pneumatic removal system and the silo dome.
- The air suctioned from the silo would be separated in a filter/receiver adjacent to the work platform.
- The pneumatic removal equipment would consist of a cutterhead, vacuum, and pump.

Disposal Vault

The cost of the disposal vault was estimated as follows:

- Cost for the on-property, above-grade disposal vault was estimated at a unit cost of \$939/$m^3$ (\$718/$yd^3$).
- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 $m^3$ (120,000 $ft^3$) of material. As additional disposal volume space is required, additional modular cells were added for cost estimating purposes. Cell numbers were established by rounding up to the nearest whole number.
- The size of the disposal vault was estimated based on the number of packages noted below, assuming each container occupies 1.81 $m^3$ (64 $ft^3$) of space, and was estimated at 2324 $m^3$ (82,048 $ft^3$). Assuming a cell size of 3400 $m^3$ (120,000 $ft^3$), one cell would be required [697 $m^3$ (7,500 $ft^3$) vault footprint area].

- The design of the vault includes a multimedia cap, liner, intruder barrier, and LC/DS.
- The vault would cover approximately 2.4 ha (6 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation. Estimated cost is based on the following:

- Packages would be DOT specification 7A Type A containers with exterior dimensions of 1.2 m (4 ft) width by 1.2 m (4 ft) length by 1.2 m (4 ft) depth. Interior dimensions would be 1.1 m (3.5 ft) width by 1.1 m (3.5 ft) length by 1.1 m (3.5 ft) depth, providing 1.22 $m^3$ (43 $ft^3$) of storage per container.
- Total weight of each individual filled container would not exceed 3628 kg (8000 lbs) to facilitate handling. The weight of material in each container would not exceed 3300 kg (7260 lbs) per package and the density would be less than 2698 $kg/m^3$ (168 $lb/ft^3$).
- Total volume that would be packaged was based on 3895 $m^3$ (5,093 $yd^3$) of untreated Silo 3 material. Final packaging volume, assuming a 62 percent volume reduction due to the vitrification process and 2859 $kg/m^3$ (178 $lb/ft^3$) material density, was 1471 $m^3$ (1,935 $yd^3$).
- Packages would not be full but would be based upon maximum density of 2698 $kg/m^3$ (168 $lb/ft^3$) since the density of vitrified material is greater than this.
- Packaging and disposal of materials generated during D&D operations are not included in this cost, but are included in the costs for Subunit C.
- Total packaging cost was estimated assuming 1,282 containers.
- A unit cost of $955 per container was determined based on a material cost of $650 per unit and a labor cost of 16 man-hours per unit for handling, filling, and documentation.

O&M Cost

Short-term O&M costs incurred during remediation, and long-term O&M costs are $4.9 Million and $3.2 Million, respectively (not considering present worth). Long-term O&M costs include the maintenance and monitoring, which would be conducted until FEMP site-wide remedial action objectives are attained, i.e., for a period of approximately 30 years. The monitoring would support the required CERCLA five-year reviews.

4.3.2.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 2B/Vit. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this

modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.3.2.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 2B/Vit. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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### 4.3.3 Analysis of Alternative 2B/Cementation

This alternative is identical to Alternative 2B/Vit except that cement stabilization is used as the stabilization process option instead of vitrification. Also, as a result of the increased bulking of the stabilized material form (58 percent volume increase for cement stabilization versus 68 percent volume decrease for vitrification), the on-property above-grade disposal vault would require an area of 3 ha (7.5 acres) instead of the 2.4 ha (6 acres) required for the Alternative 2B/Vit. The site preparation/construction, material removal, and features of the above-grade disposal vault will be essentially the same as for Alternative 2B/Vit.

The cement stabilization process is identical to that described for Alternative 2A/Cem (Section 4.2.3) with the exception that ferrous chloride is also added to the cold metal oxides following removal. Ferrous chloride is a reducing agent for the hexavalent chromium present in Silo 3 residues. Because the cold metals oxides and removal process is dry, water must be added.

#### 4.3.3.1 Overall Protection of Human Health and the Environment

Alternative 2B/Cem meets the remedial action objectives for Subunit B. As with Alternative 2B/Vit 4.3.2.1, Alternative 2B/Cem meets the objectives through treatment, containment in an on-property above-grade disposal vault, and implementation of institutional control measures. The difference between the two alternatives is the treatment method used.

Treatment of Subunit B material through cement stabilization would reduce contaminant mobility but would increase the volume of contaminated material. The leaching rate of the treated residue form would be reduced resulting in protection of the underlying Great Miami Aquifer. As with Alternative 2B/Vit, treatment of the material prior to disposal would provide additional protection in the event that the vault begins to degrade. Similar to Alternative 2B/Vit, there is uncertainty associated with continued long-term protection for Alternative 2B/Cem due to the possible degradation of the stabilized material and subsequent increased leachability.

The containment features of Alternative 2B/Cem include the above-grade vault and provide additional control of contaminant migration along with prevention of direct access to the treated residue. Uncertainties exist in long-term reliability of the vault although fate and transport modeling results show it to be protective.

Both 2B alternatives use institutional controls to provide protection to human health in the event of failure of the engineering controls and to provide an added measure of protection against destruction of the vault. Additionally, under ORC 3734.02, a restrictive covenant limiting site use is required for any disposal facility. As with the other components of these two alternatives, the long-term reliability of institutional controls is uncertain.

Eventually, complete failure of the engineered controls and the institutional controls could result in human health and environmental risk conditions approaching baseline risk conditions.

Short-term risks for Alternative 2B/Cem would be almost the same as for Alternative 2B/Vit. While the difference in hazards between the two treatment process options is not quantifiable, cement stabilization poses slightly lower risks because it does not employ the high voltages and temperatures that vitrification does.

4.3.3.2 Compliance with ARARs

Alternative 2B/Cem is identical to Alternative 2B/Vit with the exception of the process option used to treat the Subunit B residues (see Table F.2-1 in Appendix F). Compliance of this alternative would also be identical to that of Alternative 2B/Vit presented in Section 4.3.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 2B/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those standards associated with meeting the SDWA drinking water MCLs and MCLGs; the RCRA solid and hazardous waste groundwater protection requirements; the UMTRCA and CAA radon-222 airborne release requirements; and other radionuclide release limits for water and air and their resulting doses to the public under the CAA and DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 2B/Cem. Additional documentation of compliance of Alternative 2B/Cem with the identified ARARs is presented in Appendix F (Table F.2-3).

Location-Specific ARAR/TBCs

Alternative 2B/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b). Included would be those requirements associated with the protection of floodplains, wetlands, endangered species and their habitat, and the sole-source aquifer underlying the FEMP site.

Despite the larger footprint of the on-property disposal facility associated with this alternative, the Alternative 2B/Cem disposal facility would have adequate setbacks to comply with the location requirements of OAC 3745-27-07. As was noted, compliance with the prohibition in this regulation on the location of a solid waste disposal facility over a sole-source aquifer would be based on demonstrating attainment of the substantive technical requirements for an exemption to this requirement as discussed in Section 4.2.2.2. Since the final location of the disposal vault would be similar to that for Alternative 2A/Vit, the information regarding the technical demonstration to meet the exemption would also be similar to that alternative.

Action-Specific ARAR/TBCs

Alternative 2B/Cem would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. Included would be those standards associated with the design and operation of the multi-barrier above-grade disposal vault system under RCRA and UMTRCA. As was discussed for Alternative 2B/Vit, Alternative 2B/Cem would comply with the requirements of 40 CFR § 192 Subparts A and B.

This alternative would also comply with the requirements for designation and use of CAMUs and TUs. As for Alternative 2B/Vit, this alternative would comply with the substantive groundwater monitoring requirements for RCRA solid and hazardous waste disposal facilities, as well as the RCRA closure requirements for tanks, containers, and land disposal facilities. This alternative would also comply with NEPA requirements and with the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity. Compliance with requirements under the CAA, CWA, and RCRA would be met by incorporating sound engineering features and BMPs into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 2B/Cem would comply with the identified ARARs is presented in Appendices D and F (Table F.2-3).

4.3.3.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2B/Cem reduces the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Since the only difference between Alternatives 2B/Cem and 2B/Vit is the treatment technology applied and since the magnitude of the residual risk under an

effective alternative does not depend in this case on the type of treatment technology, the residual risk from both alternatives would be the same.

Adequacy and Reliability of Controls

The projected residual excess cancer risk attributable to Alternative 2B/Cem to viable receptors is less than $10^{-6}$. The on-property disposal unit is the same as that for Alternative 2B/Vit and, therefore, has the same adequacy of controls and the same degree of reliability. Fate and transport modeling of the leaching pathway was completed. The assumptions were the same as for Alternative 2B/Vit except that the leachability of the treated material was assumed to be that of the treatability results for cement stabilization. The results were the same as for Alternative 2B/Vit; leaching of contaminants would not pose an unacceptable risk to off-site receptors.

Cement stabilization is a proven technology that has been previously applied to the stabilization of similar waste materials as those contemplated under Alternative 2B/Cem. Additionally, over the period 1989 to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of the cement stabilization technology on Subunit B materials. The tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics (see Appendix C). On this basis, there is a high probability that the cement stabilization treatment system would obtain the required product performance requirements.

Consistent with DOE Order 5400.5, 40 CFR § 264.114, and 40 CFR § 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required five-year CERCLA review.

Long-Term Environmental Impacts

With the exception of the area disturbed, Alternative 2B/Cem has the same long-term environmental impacts as Alternative 2B/Vit (Section 4.3.2.3). Alternative 2B/Cem would permanently disturb 1.8 ha (4.5 acres) of land.

4.3.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2B/Cem uses cement stabilization to treat the contents of Silo 3. Cement stabilization reduces the mobility of contaminants by binding them into a cement mixture. As a result of the additives used in the process, the volume increases. There is no reduction in toxicity. A remedy selection treatability study was conducted with Operable Unit 4 materials to compare vitrification and

cement stabilization. The criteria for the comparison included leachability of the treated residue form, the material volume reduction achieved, and the reduction in radon emanation from the material (Appendix C, Section C1.0 and Appendix H).

The chemical and physical properties of Subunit B residues were determined and used in developing the bench-scale treatability studies. The treated material is effective in reducing radon emanation by an average of 45 percent; however, the lower radon quantities emitted by Subunit B material mean that acceptable levels are emitted after cement stabilization. Data from the study revealed that the radon emanation rates from the treated Silo 3 material were less than the 20 $pCi/m^2/s$ criteria established for DOE in 40 CFR § 61. The rates averaged between 13 to 17 $pCi/m^2/s$.

The amount of volume increase caused by the addition of cementatious material varied from 50.3 to 63 percent as a result of the heterogeneity of the Subunit B material. Consequently, there would be a total treated material volume of 5999 $m^3$ (7894 $yd^3$).

The results from the TCLP tests showed that the cement stabilized material did not exceed RCRA toxicity characteristic limits. Thus, the comparison of the TCLP test results (through the leachate concentration) of the treated residue to the untreated residues are the basis for the demonstration of the effectiveness of cement stabilization as a treatment process for Subunit B residue. A formulation including blast furnace slag, cement, and flyash was the most effective with virtually all chemical and radionuclide constituents having reductions in contaminant concentrations in the leachate. The percent reduction for lead in leachate was typically above 95 percent. The mean reduction of Ra-226 was 83 percent.

Durability was measured by freeze-thaw and wet-dry testing and comparison to ASTM standard (30 percent weight loss) and EPA guidance of 15 percent weight loss. The average weight losses for Subunit B material exceeded 15 percent with one average above 30 percent weight loss. Durability was also measured using the UCS test on the durability samples. The comparison of the UCS results are used to indicate how the physical properties of the stabilized material change as a result of the simulated climatic stress. Many of the Subunit B samples degraded to the extent that they had no resistance to compressive stress after the wet/dry test, although Subunit B samples responded comparably to Subunit A samples after the freeze-thaw test. Some wet/dry samples crumbled before the test was run. The degradation and leachability results for some contaminants indicate that cement stabilization is not an irreversible treatment process.

Residuals from the stabilization process would be generated from the off-gas treatment system. Off-gases containing particulates and other pollutants would be removed and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary to adequately reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the stabilization process until all of them were contained in a cement form.

4.3.3.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Alternative 2B/Cem provides the same degree of short-term protection of the community as Alternative 2B/Vit (Section 4.3.2.5), using the same engineering and access controls.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers are the same for Alternatives 2B/Vit and 2B/Cem. Although cement stabilization is inherently less dangerous than vitrification, the increase in labor hours results in an estimate of 5.1 injuries and 0.077 deaths during remediation activities.

Short-Term Environmental Impacts

The short-term impacts associated with Alternative 2B/Cem are essentially the same as those for Alternative 2B/Vit, with the exception of workers, trucks, and resources needed to implement remedial activities and the area required for disposal. Approximately 20 one-way truck trips per working day would have a minor impact on nearby communities. For this analysis, it is assumed that all expenditures would take place within the CMSA; in which case, the implementation of Alternative 2B/Cem would increase revenues by 3.9 percent over a six-year period. The temporary disturbance of 4.5 ha (11.1 acres) would result from remedial action. In addition, implementation of 2B/Cem would require approximately 11,000,000 kilowatt-hours of electricity.

Duration of Remedial Activities

The duration of Alternative 2B/Cem is the same as Alternative 2B/Vit.

#### 4.3.3.6 Implementability



Technical Feasibility

The technical implementability, construction, and operation of the removal component of Alternative 2B/Cem would be straightforward and, except for the treatment component, would be the same as Alternative 2B/Vit (Section 4.3.2.6).

The cement stabilization facility would be reliable and straightforward to construct and operate. All of the necessary equipment would be readily available because the process is widely used in the construction and mining industries. It is also used frequently in hazardous material treatment applications. The treatment system would consist of a standard configuration of industrial equipment. The cement stabilization facility would require a supervisor and general laborers with industrial work experience, as well as maintenance personnel. After remedial design testing has further defined and optimized the reagent to cold metal oxide blend, the plant supervisor would be able to respond to operational problems that could arise during processing. Continual testing of treatment batches during operation would determine required modifications to the standard blend to optimize product and immobilization of contaminants.

A significant temperature rise was noted during the treatability testing for the Silo 3 contents. This heat rise needs to be better controlled for Silo 3 stabilization. Optimization of reagent addition over time or use of an inert reagent that could act as a heat sink should be investigated, although this could increase the bulking factor for the treated material.

The benefits of cement stabilization technology are the moderate processing costs, the compatibility with a wide variety of disposal options, and the ability to meet stringent processing and performance requirements. The associated increase in volume caused by adding dry materials could be minimized through encapsulation of the solids and evaporation of the associated water. However, water evaporation increases the complexity and cost of the treatment.

Administrative Feasibility

The administrative feasibility of Alternative 2B/Cem would be the same as 2B/Vit.

Availability of Services and Materials

Alternative 2B/Cem would involve the same activities as Alternative 2B/Vit, with the exception of cement stabilization being utilized in place of vitrification. Because cement stabilization is a commonly used technology, the availability of vendors to provide service and materials would be adequate.

4.3.3.7 Cost

The total present worth cost of Alternative 2B/Cem is $37.4 Million. A detailed breakdown of the cost is provided in Table 4-8.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-8. More detailed information is provided in Appendix E.

The largest component of the capital cost is the construction of the pneumatic removal/transfer system which represents approximately 35 percent of the total capital cost. The disposal vault and packaging are the next largest components of the costs, each representing approximately 20 percent of the total capital cost.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2B/Vit.

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the RTS. Costs were estimated based on the same

TABLE 4–8

COST ESTIMATE FOR ALTERNATIVE 2B/CEM

| ALTERNATIVE 2B: REMOVAL, CEMENT STABILIZATION, ON–PROPERTY DISPOSAL | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $579,500 | $528,700 | $1,108,200 |
| WASTE PROCESSING | $915,300 | $971,000 | $1,886,300 |
| CEMENT STABILIZATION | $2,253,700 | $2,473,400 | $4,727,100 |
| PNEUMATIC REMOVAL/TRANSFER SYSTEM | $4,571,600 | $4,744,400 | $9,316,000 |
| DISPOSAL VAULT | $1,925,800 | $3,279,100 | $5,204,900 |
| PACKAGING (4,957 PKGS. @ $955/PKG.) | $1,308,600 | $3,425,300 | $4,733,900 |
| TOTAL CAPITAL | $11,554,500 | $15,421,900 | $26,976,400 |
| RISK BUDGET (11.0%) | $1,271,000 | $1,696,400 | $2,967,400 |
| SUBTOTAL | $12,825,500 | $17,118,300 | $29,943,800 |
| CONTINGENCY (20.0%) | $2,565,100 | $3,423,700 | $5,988,800 |
| TOTAL ESTIMATED INSTALLED COST | $15,390,600 | $20,542,000 | $35,932,600 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $4,923,000 |
| POST–REMEDIATION | | | $3,207,000 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $37,358,600 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during remediation (years): 1
Post–remediation O&M (years): 30

assumptions as for Alternative 2B/Vit.

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the following:

- The cement stabilization equipment would operate 24 hours/day and would be designed to treat 11,800 kg/day (13 tons/day) of material.

- Cement stabilization equipment includes a surge tank, screw feeder, stabilization mixers, flyash, cement, and blast furnace slag storage/feed facilities, process piping, pumps, and mixers.

Pneumatic Removal/Transfer System

System components and cost are the same as for Alternative 2B/Vit.

Disposal Vault

Assumptions used to estimate the disposal vault cost are the same as those described for Alternative 2B/Vit, except for the following:

- The size of the disposal vault was based on the number of packages noted below, assuming each package occupies 1.81 $m^3$ (64 $ft^3$) of space, and was estimated as 8984 $m^3$ (317,248 $ft^3$.) Assuming a cell size of 3400 $m^3$ (120,000 $ft^3$), three cells would be required [2090 $m^2$ (22,500 $ft^2$) vault footprint area].

- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 $m^3$ (120,000 $ft^3$) of material. As additional disposal volume space is required, additional modular cells are added for cost estimating purposes. Cell numbers were estimated by rounding up to the nearest whole number.

- The vault would cover approximately 3 ha (7.5 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation, and was estimated as described for Alternative 2B/Vit, with the following differences:

- Total volume that would be packaged was based on 3895 $m^3$ (5,093 $yd^3$) of untreated Silo 3 material. Final packaging volume, assuming a 55 percent volume increase due to the cement stabilization process and 1.22 $m^3$ (43 $ft^3$) of storage space per container, was 5999 $m^3$ (7,894 $yd^3$).

- Packages would be filled since the density of cement-stabilized material is approximately 1735 kg (108 $lb/ft^3$), which is below the maximum allowable loading limit.

- Total packaging cost was estimated assuming 4,957 containers.

O&M Cost

Short-term O&M costs incurred during remediation and long-term O&M costs are $4.9 Million and $3.2 Million, respectively, not considering present worth. Long-term O&M costs include maintenance and monitoring until all FEMP site-wide remedial action objectives are attained, i.e., in an estimated 30 years. The monitoring would support the required CERCLA five-year reviews.

4.3.3.8 State Acceptance

The criterion addresses the comments made by the OEPA on Alternative 2B/Cem. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.3.3.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 2B/Cem. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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#### 4.3.4 Analysis of Alternative 3B.1/Vitrification

This alternative is identical to Alternative 2B/Vit except that the final disposal location of the stabilized cold metal oxide forms would be at the Low-Level Radioactive Waste Disposal Facility at NTS. The site preparation, construction, cold metal oxide removal, and processing of the oxides by vitrification would be the same as for Alternative 2B/Vit.

The off-site disposal option for this alternative involves the packaging, loading, and shipping of the stabilized cold metal oxide forms to the low-level radioactive waste disposal site at NTS. A possible route for transport of the stabilized forms to NTS will involve rail transportation from the FEMP site through East St. Louis on the CSX rail line. From St. Louis, Missouri the stabilized forms will be transported on the UP rail line through North Platte, Nebraska and Salt Lake City, Utah. Currently, there is no direct rail line to the NTS disposal site. At present, the stabilized forms will be transported by UP to either a point near Las Vegas, Nevada or an area north of Las Vegas. From either location, the containers carrying the stabilized forms will be transferred to trucks and transported by road to NTS. If a direct rail to NTS becomes available before this alternative is implemented, it should be used in lieu of trucking. Treated waste may be staged or placed into interim storage at the FEMP site as required to accommodate interruptions in the availability of transportation or disposal capacity.

##### 4.3.4.1 Overall Protection of Human Health and the Environment

Alternative 3B.1/Vit meets the remedial action objectives for Subunit B. As with Alternative 2B/Vit, Alternative 3B.1/Vit prevents direct contact with waste residue and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Similar to Alternative 2B/Vit, treatment of the Subunit B materials through vitrification would reduce contaminant toxicity, mobility, and volume. Much like Alternative 2B/Vit, the treatment of the material prior to disposal would provide additional protection in the event the off-site disposal facility were to degrade. The added benefit of treatment for Subunit B is less than for Subunit A because the material has been previously calcined, and the leachability from the material is less.

The removal of the contaminants and their disposal off site provides the final element of protectiveness for Alternative 3B.1/Vit. The off-site disposal facility would provide protection by eliminating access to the residue and preventing migration of contaminants out of the residue as much

as the on-property disposal facility would under Alternative 2B/Vit. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant release, migration, and direct contact with contaminants. The long-term effectiveness of the necessary institutional controls at the NTS disposal facility is believed to be very reliable.

Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. Further, the climatic (low average annual precipitation) and hydrologic [depths to groundwater ranging from 157 - 600 m (515 - 2000 ft) below ground surface] characteristics would tend to mitigate impacts to human health and the environment in the event that engineering and institutional controls fail.

There are no unacceptable short-term risks from Alternative 3B.1/Vit for which removal and treatment options pose the same risks as Alternative 2B/Vit. Additional risk is associated with transportation accidents. Radiation exposure to workers and the public as a result of the transportation is expected to be minimal.

4.3.4.2 Compliance with ARARs

ARAR compliance for Alternative 3B.1/Vit would be similar to Alternative 2B/Vit with the exception of the Subunit B treated material, final disposition being at a DOE-owned off-site facility. Alternative 3B.1/Vit meets all ARARs identified for this alternative. Only applicable requirements pertain to off-site portions of alternatives selected. In cases where relevant and appropriate requirements, or TBC criteria are identified for activities under this alternative, the referenced citation pertains only to that portion of the activity conducted on site. Because Alternative 3B.1/Vit involves off-site disposal of the treated residue, the State of Ohio location criteria in OAC 3745-27-07 for disposal facilities would no longer be relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3B.1/Vit focus on residue handling and treatment, and are similar to the ARARs for Alternative 2B/Vit (see Table F.2-1 in Appendix F). Consequently, the discussion of the compliance of those common ARARs would be identical to that presented in Section 4.3.2.2, which is summarized below. Additional documentation of compliance of Alternative 3B.1/Vit with the identified ARARs is presented in Appendix F (Table F.2-3).

Chemical-Specific ARAR/TBCs

Alternative 3B.1/Vit would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those CWA requirements associated with the

Ohio water quality standards; the control of radon-222 airborne releases under UMTRCA and the CAA; and the control of other radionuclide releases to air and water and their resulting doses to the public as required under DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting exposure assessments for Alternative 3B.1/Vit. It should be noted that standards associated with meeting the SDWA drinking water MCLs and MCLGs would not be ARARs for this alternative since the source of the waste would be removed.

Location-Specific ARAR/TBCs

Alternative 3B.1/Vit would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, and endangered species and their habitat during the on-property treatment of the material. As noted above, the State of Ohio location criteria in OAC 3745-27-07 for solid waste disposal facilities would no longer be relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARAR/TBCs

Alternative 3B.1/Vit would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. Included would be those standards associated with on-property requirements under the CAA (for releases of dust and non-radioactive particulates) and the CWA (for storm water runoff, BMPs and dredge and fill activities). As for Alternative 2B/Vit, this alternative would comply with the substantive RCRA closure requirements for tanks and containers used in the treatment process, and with the CAMU and TU requirements. This alternative would also comply with NEPA (for environmental documentation), the annual average dose requirement of 100 mrem in DOE order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity, and with the UMTRCA guidance for control and cleanup of residual radioactive material. These requirements would be met by incorporating sound engineering features, BMPs, and ALARA principles into the remediation operations of the unit.

Off-site disposal would require shipment of materials. Hazardous material transport requirements would be complied with by following the pertinent regulations under 40 CFR §§ 262 and 263, and the appropriate DOT shipping requirements under 49 CFR §§ 172 and 173.

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#### 4.3.4.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 3B.1/Vit would reduce the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Because all of the material is removed from the site, there is no residual risk at the FEMP site. Residual risk at NTS is limited by the facility institutional controls, the characteristics of the vitrified materials, and the arid climate.

Adequacy and Reliability of Controls

The reliability of vitrification for Alternative 3B.1/Vit is the same as for Alternative 2B/Vit (Section 4.3.2.3). Off-site disposal at NTS has enhanced reliability because the facility is currently utilized by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrologic conditions, and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct contact in the advent of disposal facility failure.

Long-Term Environmental Impacts

The long-term environmental impacts from removal and treatment actions of Alternative 3B.1/Vit are the same as for Alternative 2B/Vit (Section 4.3.2.3) with the exception of land committed at the FEMP site for waste disposal. Long-term environmental impacts associated with off-site disposal of the treated material at NTS are the same as those presented for Alternative 3A.1/Vit in Section 4.2.4.3.

#### 4.3.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reduction in constituent toxicity, mobility, or volume would be the same for Alternative 3B.1/Vit as for Alternative 2B/Vit based on application of the same treatment technology (Section 4.3.2.4).

#### 4.3.4.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Alternative 3B.1/Vit provides the same level of short-term protection of the community during removal and treatment as does Alternative 2B/Vit (Section 4.3.2.5). There is added risk to the public through transporting the treated material off site. The estimate of public radiation exposure,

expressed in terms of ILCR, along the route to NTS is $1.7 \times 10^{-11}$, far below the target risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. It is estimated that 0.08 injuries and 0.02 deaths may occur due to transportation accidents. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 3B.1/Vit is effective in protecting the community in the short term. The basis for these estimates is provided in Appendix D.

The disposal of FEMP materials at NTS would not be expected to exceed protective levels for the community around NTS over the short term. The vitrified materials would meet NTS waste acceptance criteria and, therefore, would be managed within the bounds of the NTS facility's protectiveness criteria. Additional discussion is provided in Section 4.2.4.5 (Alternative 3A.1/Vit).

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal and treatment are the same for Alternatives 3B.1/Vit as for 2B/Vit. There are additional radiation exposure risks to the worker resulting from transporting the material to NTS. The excess ILCR is estimated at $1.1 \times 10^{-7}$, below EPA's target risk level of $10^{-6}$. The estimate of injuries during remediation activities is 1.3 injuries and 0.019 deaths.

The risk to workers due to radiological exposures during off-loading activities at NTS is assumed to be below the estimated ILCR risk level of $4.1 \times 10^{-5}$ during treatment/construction activities at the FEMP site because the waste would already be packaged and in a stabilized form. There is uncertainty for some additional risk due to exposure to wastes already present at NTS in the vicinity of off-loading operations for FEMP materials.

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal and treatment of materials under Alternative 3B.1/Vit are the same as those for Alternative 2B/Vit (Section 4.3.2.5) with the exception that less land is disturbed for this alternative because there is no on-property disposal vault. The total area disturbed at the FEMP site for Alternative 3B.1/Vit is 1.2 ha (3.0 acres). This alternative would require two one-way truck trips per working day. Alternative 3B.1/Vit involves off-site disposal of the treated residue form at NTS. Short-term environmental impacts for that facility would be the same as for Alternative 3A.1/Vit. Reference is made to Section 4.2.4.5 for a discussion of these impacts.

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Duration of Remedial Activities

The duration of remedial activities is assumed to be the same as for Alternative 2B/Vit. There is more uncertainty in the time estimate since transportation or waste acceptance problems could easily add time to the estimate.

4.3.4.6 Implementability

Technical Feasibility

The technical feasibility of Alternative 3B.1/Vit, with the exception of the disposal activities, is the same as that of Alternative 2B/Vit (Section 4.3.2.6). The technical feasibility of off-site transport and disposal at NTS is straightforward and reliable. Off-site transport of the treated material to NTS would consist of rail transport from the FEMP site to within 483 km (300 mi) of NTS. Currently, NTS is not accessible by rail; therefore, the treated material would be transferred to trucks and transported to NTS. The treated material would be placed in appropriate containers that meet transportation and disposal requirements.

Administrative Feasibility

NTS is a DOE-owned facility; thus, no special permits would be required. However, an addendum to the current FEMP site's waste shipping application would be required for this new waste stream. This alternative would require agency approvals and coordination for the interstate shipment of the material. Many states require advance notification or permitting for shipments of radioactive material entering their state. All material shipments would be required to meet applicable federal and state regulations. The public and regulatory agencies from the states located within the transportation route from FEMP to NTS would likely oppose transport; thus, some coordination would be required to obtain these approvals.

Availability of Services and Materials

With the exception of the disposal components, the availability of services and materials for Alternative 3B.1/Vit are similar to those of Alternative 2B/Vit. NTS currently accepts low-level waste, and it has adequate facilities to accept the Alternative 3B.1/Vit treated material. Transfer areas, storage areas, decontamination facilities, and a laboratory are available on the site. The treated material would be tested to ensure that it complies with NTS waste acceptance criteria.

4.3.4.7 Cost

The total present worth cost of Alternative 3B.1/Vit is $28 Million. A detailed breakdown of the cost is provided in Table 4-9.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, purchase of vitrification equipment, packaging of material for disposal, transportation, and disposal. Breakdown of the direct and indirect costs for each major component of this alternative are provided in Table 4-9. More detailed information is provided in Appendix E.

This alternative includes identical cost components as Alternative 2B/Vit (Section 4.3.2.7), except off-site transportation and disposal replace the on-property vault component that was included in Alternative 2B/Vit. As with Alternative 2B/Vit, the largest component of the capital cost is the construction of the pneumatic removal/transfer system, representing approximately 46 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2B/Vit.

Waste Processing

Components of the 3B.1/Vit waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the same assumptions as for Alternative 2B/Vit. In addition, a staging facility would be provided for temporary staging of materials prior to off-site transportation and disposal.

Vitrification

This cost item includes the cost of the 3B.1/Vit vitrification equipment, RTS, and off-gas system, and is estimated based on the same assumptions discussed for Alternative 2B/Vit.

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TABLE 4–9

COST ESTIMATE FOR ALTERNATIVE 3B.1/VIT

| ALTERNATIVE 3B.1: REMOVAL, STABILIZATION W/VITRIFICATION, OFF–SITE DISPOSAL AT NTS | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $579,500 | $528,700 | $1,108,200 |
| WASTE PROCESSING | $1,602,600 | $1,333,700 | $2,936,300 |
| VITRIFICATION | $2,593,400 | $1,460,700 | $4,054,100 |
| PNEUMATIC REMOVAL/TRANSFER SYSTEM | $4,571,600 | $4,744,400 | $9,316,000 |
| TRANSPORTATION | $646,900 | | $646,900 |
| DISPOSAL | $819,100 | | $819,100 |
| PACKAGING (1,282 PKGS. @ $955/PKG.) | $338,400 | $885,900 | $1,224,300 |
| TOTAL CAPITAL | **$11,151,500** | **$8,953,400** | **$20,104,900** |
| RISK BUDGET (11.0%) | $1,226,700 | $984,900 | $2,211,600 |
| SUBTOTAL | $12,378,200 | $9,938,300 | $22,316,500 |
| CONTINGENCY (20.0%) | $2,475,600 | $1,987,700 | $4,463,300 |
| TOTAL ESTIMATED INSTALLED COST | **$14,853,800** | **$11,926,000** | **$26,779,800** |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $4,923,000 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | **$28,026,400** |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during remediation (years): 1
Post–remediation O&M (years): 0

Pneumatic Removal/Transfer System

The 3B.1/Vit pneumatic removal/transfer system components and cost are the same as for Alternative 2B/Vit.

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2B/Vit. The same number of containers required for Alternative 2B/Vit are required for Alternative 3B.1/Vit.

Transportation

This cost item includes transportation of the packaged material, and is based on the following assumptions:

- Packages would be transported by rail to within 483 km (300 mi) of the disposal facility (NTS) and then transported by truck the remainder of the distance.
- Rail costs were estimated using a unit rate of $2.47 per railcar per km ($3.97 per railcar per mile). Railcars were assumed to weigh 8165 kg (180,000 lbs) each.
- Truck costs were estimated using a unit rate of $0.53/kg ($0.24 per pound) [for the total 483 km (300 mi) trip].

Disposal

- Treated material would be disposed at NTS.
- Unit disposal cost was estimated as $353 $m^3$ ($10/$ft^3$).

O&M Cost

Short-term O&M costs incurred during remediation are the same as for Alternative 2B/Vit ($4.9 Million, not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at Subunit B.

4.3.4.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 3B.1/Vit. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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#### 4.3.4.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 3B.1/Vit. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.3.5 Analysis of Alternative 3B.1/Cementation

This alternative is identical to Alternative 2B/Cem except that the final disposal location of the stabilized cold metal oxide material would be the Low-Level Radioactive Disposal Facility at NTS. The site preparation, construction, material removal, and processing would be the same as for Alternative 2B/Cem (Section 4.3.3).

Off-Site Disposal

The route and method of transportation for this alternative will be the same as for Alternative 3B.1/Vit (Section 4.3.4).

4.3.5.1 Overall Protection of Human Health and the Environment

Alternative 3B.1/Cem meets the remedial action objectives for Subunit B. As with Alternative 3B.1/Vit, Alternative 3B.1/Cem prevents direct access to the treated residues and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Treatment of the Subunit B materials through cement stabilization would reduce contaminant mobility. Cement stabilization would increase the volume of contaminated material due to additives used in the stabilization process. Treatment of the material prior to disposal would provide additional protection in the event the off-site disposal facility were to degrade.

The removal of the contaminants and their off-site disposal provides the final element of protection for Alternative 3B.1/Cem and is the same disposal option as Alternative 3B.1/Vit. The off-site disposal facility would provide protection by eliminating access to the residue and preventing migration of contaminants from the residue. As previously discussed in Section 4.2.4.1, the uncertainties associated with institutional controls at this DOE facility are very low. The NTS environmental and demographic characteristics help to ensure long-term protectiveness in the event of institutional control failure. There are no unacceptable short-term risks from Alternative 3B.1/Cem.

4.3.5.2 Compliance with ARARs

ARAR compliance for Alternative 3B.1/Cem would be similar to Alternative 2B/Cem with the exception of the Subunit B treated residues final disposition being at a DOE-owned off-site facility. Alternative 3B.1/Cem meets all pertinent ARARs identified for this alternative. Because Alternative 3B.1/Cem involves off-site disposal of the treated residue, the State of Ohio location siting criteria in

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OAC 3745-27-07 for disposal facilities would no longer be relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3B.1/Cem focus on residue handling and treatment, and are similar to the ARARs for Alternative 2B/Cem (see Table F.2-1 in Appendix F). Consequently, the discussion of compliance for those common ARARs would be identical to that presented in Section 4.3.2.2, which is summarized below. Additional documentation of compliance of Alternative 3B.1/Cem with the identified ARARs is presented in Appendix F (Table F.2-3).

Chemical-Specific ARAR/TBCs

Alternative 3B.1/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those CWA requirements associated with the Ohio water quality standards; the control of radon-222 airborne releases under UMTRCA and the CAA; and the control of other radionuclide releases to air and water and their resulting doses to the public during remedial operations at the FEMP site as required under DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting exposure assessments for Alternative 3B.1/Cem. Compliance with SDWA MCLs and MCLGs would be ensured by removal of the source of waste off site.

Location-Specific ARAR/TBCs

Alternative 3B.1/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, and endangered species and their habitat during the on-property treatment of the material. As noted above, the State of Ohio location criteria in OAC 3745-27-07 for solid waste disposal facilities criteria would not be relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARAR/TBCs

Alternative 3B.1/Cem would comply with all pertinent action-specific ARARs identified in Appendix F Table F.2-1c) for this alternative. Included would be those standards associated with on-property activities under the CAA (for releases of dust and non-radioactive particulates) and the CWA (for storm water runoff, BMPs and dredge and fill activities). As for Alternative 2B/Cem, this alternative would comply with the substantive RCRA closure requirements for tanks and containers used in the treatment process, and with the requirements for use of CAMUs and TUs. This alternative would also comply with NEPA (for environmental documentation), the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of

exposure to radioactivity, and with the UMTRCA guidance for control and cleanup for residual radioactive material. These requirements would be met by incorporating sound engineering features, BMPs and ALARA principles into the remediation operations of the unit.

Off-site disposal would require shipment of materials. Hazardous material transport requirements would be complied with by following the pertinent regulations under 40 CFR § 262 and § 263, and the appropriate DOT shipping requirements under 49 CFR § 172 and § 173.

#### 4.3.5.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 3B.1/Cem would reduce the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $1x10^{-6}$. Because all of the material is removed from the site, there is no residual risk from Subunit B residues at the FEMP site. Residual risk at NTS is limited by the disposal facility institutional controls, the characteristics of the cement stabilized materials, and the arid environment.

Adequacy and Reliability of Controls

The reliability of cement stabilization for Alternative 3B.1/Cem is the same as for Alternative 2B/Cem (Section 4.3.3.3). Off-site disposal at NTS has enhanced reliability because the facility is currently owned and used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be more reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrologic, and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density of the area surrounding NTS would also reduce the potential for direct contact with released materials.

Long-Term Environmental Impacts

The long-term environmental impacts to the FEMP site and surrounding area for removal and treatment actions of Alternative 3B.1/Cem are the same as for Alternative 2B/Cem (Section 4.3.2.3) with the exception of land committed at the FEMP site for disposal. Impacts to NTS are the same as for Alternative 3B.1/Vit, except that the volume of cement-stabilized material would require additional disposal space. The overall impact of the increased volume is not significant.

4.3.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reduction in constituent toxicity, mobility, or volume would be the same for Alternative 3B.1/Cem as for Alternative 2B/Cem.

4.3.5.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Protection of the community during removal and treatment operations is estimated to be the same for Alternative 3B.1/Cem as for Alternative 2B/Vit (Section 4.3.2.5). The potential injury and deaths due to treated material transportation is 0.33 injuries and 0.08 deaths for this alternative. Estimates of excess cancer risk to the community from transporting the material are $1.9 \times 10^{-11}$.

Protection of Workers During Remedial Actions

Protection of workers during implementation of Alternative 3B.1/Cem is the same as Alternative 3B.1/Vit (Section 4.3.4.5). Both alternatives protect workers during remediation by using personal protective equipment, remote operating-procedures, and shielding.

Short-Term Environmental Impacts

The short-term impacts associated with Alternative 3B.1/Cem are essentially the same as those found with Alternative 3B.1/Vit (Section 4.3.4.2). Eighty workers and approximately two one-way truck trips per working day would be required to complete remedial activities. It is assumed for this analysis that all resources needed for Alternative 3B.1/Cem would be purchased within the area; in which case, the collective revenue for the CMSA would increase by 3.4 percent over a five-year period. Minor impacts are expected as a result of remedial activities associated with Alternative 3B.1/Cem.

Duration of Remedial Activities

The removal and treatment components of Alternative 3B.1/Cem would require the same amount of time (four years) for implementation as the other action alternatives. As with Alternative 3B.1/Vit, there is a chance for the schedule to be delayed as a result of transportation or disposal delays.

4.3.5.6 Implementability

The implementability for removal and treatment components of Alternative 3B.1/Cem would be the same as that of Alternative 2B/Cem (Section 4.3.3.6). The implementability of disposal for Alternative 3B.1/Cem is the same as that of Alternative 3B.1/Vit (Section 4.3.4.6).

4.3.5.7 Cost

The total present worth cost of Alternative 3B.1/Cem is $36 Million. A detailed breakdown of the cost is provided in Table 4-10.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, packaging of material, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-10. More detailed information is provided in Appendix E.

The alternative includes identical cost components as Alternative 2B/Cem (Section 4.3.3.7), except off-site transportation and disposal replace the on-property vault that was included in Alternative 2B/Cem. As with Alternative 2B/Cem, the largest component of the capital cost is the construction of the pneumatic removal/transfer system, representing approximately 34 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

The basis of estimate is the same as that discussed for Alternative 2B/Vit (Section 4.3.2.7).

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the RTS. Costs were estimated based on the same assumptions as for Alternative 2B/Cem (Section 4.3.3.7).

TABLE 4–10

COST ESTIMATE FOR ALTERNATIVE 3B.1/CEM

| ALTERNATIVE 3B.1: REMOVAL, CEMENT STABILIZATION, OFF–SITE DISPOSAL AT NTS | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $579,500 | $528,700 | $1,108,200 |
| WASTE PROCESSING | $1,602,600 | $1,333,700 | $2,936,300 |
| CEMENT STABILIZATION | $2,253,700 | $2,473,400 | $4,727,100 |
| PNEUMATIC REMOVAL/TRANSFER SYSTEM | $4,571,600 | $4,744,400 | $9,316,000 |
| TRANSPORTATION | $1,625,600 | | $1,625,600 |
| DISPOSAL | $3,167,200 | | $3,167,200 |
| PACKAGING (4,957 PKGS. @ $955/PKG.) | $1,308,600 | $3,425,300 | $4,733,900 |
| TOTAL CAPITAL | $15,108,800 | $12,505,500 | $27,614,300 |
| RISK BUDGET (11.0%) | $1,662,000 | $1,375,600 | $3,037,600 |
| SUBTOTAL | $16,770,800 | $13,881,100 | $30,651,900 |
| CONTINGENCY (20.0%) | $3,354,200 | $2,776,200 | $6,130,400 |
| TOTAL ESTIMATED INSTALLED COST | $20,125,000 | $16,657,300 | $36,782,300 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $4,056,000 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $35,964,600 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during remediation (years): 1
Post–remediation O&M (years): 0

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the same assumptions provided for Alternative 2B/Cem (Section 4.3.3.7).

Pneumatic Removal/Transfer System

System components and cost are the same as for Alternative 2B/Vit (Section 4.3.2.7).

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2B/Cem (Section 4.3.3.7).

Transportation

This cost item includes transportation of the packaged material and has the same basis of estimate as Alternative 3B.1/Vit (Section 4.3.4.7); however, it was adjusted for the greater quantity of containers of cement-stabilized material.

Disposal

This cost is estimated as described for Alternative 3B.1/Vit (Section 4.3.4.7).

O&M Cost

Short-term O&M costs incurred during remediation are $4 Million (not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at Subunit B.

4.3.5.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 3B.1/Cem. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.3.5.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 3B.1/Cem. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for public

review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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### 4.3.6 Analysis of Alternative 4B

This alternative requires the removal of cold metal oxides from Silo 3, packaging of the cold metal oxides, and on-property disposal of the packaged cold metal oxides without treatment. The cold metal oxides would be removed by a pneumatic removal system introduced through the silo dome. This equipment would be supported by a work platform that would span the silo. The cold metal oxides would be pneumatically transferred to a processing facility for packaging, and would then be disposed in an on-property above-grade disposal vault. The alternative would include the placement of permanent markers to define disposal areas, the use of deed restrictions, and the provision of continued federal ownership of the property to preclude drilling into the disposal cell or residential development in the area used for waste disposal. The components of this alternative (e.g., site preparation/construction, material removal, and features of the above-grade disposal vault) are essentially the same as for Alternative 2B/Vit, with the exception that treatment is not included. Also, because there is no reduction in volume of material due to treatment, the number of packages and the size of the vault are larger for this alternative than for Alternative 2B/Vit.

#### 4.3.6.1 Overall Protection of Human Health and the Environment

Alternative 4B meets the remedial action objectives for Subunit B. Implementation of this alternative would prevent direct access to materials and would mitigate the migration of contaminants to the air, soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. Two primary actions would be used to meet the remedial action objectives, thereby providing protection to human health and the environment. These actions are containment of material in packages placed in an on-property engineered disposal vault and implementation of institutional control measures.

Since no treatment of Subunit B materials would be performed, this alternative would not reduce contaminant toxicity, mobility, and volume. The leaching characteristics of the untreated waste form would be unchanged. Containment of the untreated waste form in an on-property, capped, disposal vault would provide control of contaminant migration to human and environmental receptors. The disposal vault would also prevent direct radiation from the residue and any significant release of radon (minor contribution). The vault design would include an intrusion barrier and permanent markings to inhibit purposeful or inadvertent human intrusion through the facility's engineered protective features. The disposal vault would be designed for a life of 1,000 years.

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The vault would be designed to preclude the need for long-term active maintenance. The design features of the vault, including the infiltration barriers, are anticipated to eliminate the need for the active operation, maintenance, and monitoring of the leachate collection system. The leachate system would be monitored, and any collected waters would be pumped (if necessary) during the active operational phase of site remedial actions (i.e., approximately 30 years). It is anticipated that such operations and maintenance of the leachate collection would not be warranted (i.e., due to lack of significant leaching) beyond the 30-year time frame.

Beyond the 1,000 year expected design life of the disposal vault, continued protection becomes less certain as a result of possible degradation of the disposal vault, which could lead to an increased rate of infiltration, leachate formation, and release. Fate and transport modeling using conservative assumptions supports the conclusion that long-term protection of human health and the environment would still be achieved based on the slow rate of degradation of the disposal vault.

Institutional control measures would be employed to supplement the containment action in order to provide additional assurance that overall protection would be maintained as engineered components degrade. Institutional controls would include the adoption of long-term federal government ownership and control of the FEMP site. This ownership of the site would preclude future on-property residential and farming land uses, which could result in direct exposure to the residues through intrusive actions or facility degradation.

The use of institutional controls is also consistent with an ARAR for the on-property disposal vault. To comply with ORC 3734.02, hazardous and solid waste disposal facilities must include a protective covenant to restrict future mining, drilling, and residential uses of the disposal location. In accordance with this requirement, a deed restriction would be placed on the FEMP site property detailing these restrictions into perpetuity. The uncertainty associated with very long institutional control periods includes a possible loss of federal ownership and the loss of or lack of administration of the property records containing the deed restrictions.

Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the untreated material by future human and ecological receptors. Exposures to receptors through these pathways (i.e., groundwater, air, etc.,) in the event of disposal vault failure would be expected to be significant due to the lack of treatment of the residues. In addition, direct radiation exposure could be significant

in the event of failure due to the presence of significant activity of long-lived gamma emitting radionuclides. Eventually, the risks from complete failure of the disposal facility in the future could approach baseline risk conditions. However, both engineering and institutional controls would have to fail before unacceptable risks to human health would occur.

There are no unacceptable short-term risks from Alternative 4B. There are worker risks from radiation exposure during removal and packaging. However, through the use of remote removal, shielding, and implementation of a worker health and safety plan in compliance with 29 CFR § 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE Orders.

4.3.6.2 Compliance with ARARs

The implementation of Alternative 4B would comply with all pertinent ARARs identified in Appendix F for this alternative. The identification of ARAR/TBC requirements for 4B is similar to Alternative 2B/Vit with the exception that the residues under Alternative 4B would not undergo any treatment prior to disposal. Thus, the discussion of the compliance of this alternative with associated ARARs would be similar to that for Alternative 2B/Vit presented in Section 4.3.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 4B would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those standards associated with meeting the SDWA drinking water MCLs and MCLGs; the RCRA solid and hazardous waste groundwater protection requirements; the UMTRCA and CAA radon-222 airborne release requirements; and other radionuclide release limits for water and air and their resulting doses to the public under the CAA and DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 4B. Additional documentation of compliance of Alternative 4B with the identified ARARs is presented in Appendix F (Table F.2-3).

Location-Specific ARAR/TBCs

Alternative 4B would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, endangered species and their habitat, and the sole-source aquifer underlying the FEMP site. As was indicated in the discussion of Alternative 2A/Vit (Section

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4.2.2.2), compliance with the OAC 3745-27-07 prohibition on the location of a solid waste disposal facility over a sole-source aquifer would be based on demonstrating attainment of the substantive technical requirements for an exemption to this requirement. Since the final location of the disposal vault would be similar to that for Alternative 2A/Vit, the information regarding the technical demonstration to meet the exemption would also be similar to that alternative.

Action-Specific ARARs

Alternative 4B would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. Included would be those standards associated with the design and operation of multi-barrier above-grade disposal vault system under RCRA and UMTRCA. 40 CFR § 192 Subpart A requires that the disposal system be designed to "be effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years...." This design criterion is standard for all DOE UMTRCA sites, including sites having an environmental setting similar to the FEMP site. Such UMTRCA disposal cover designs have been modeled with the Corps of Engineers' HELP computer code and shown to maintain their integrity for at least 1,000 years.

Although not specifically identified as an ARAR for silo material, 40 CFR § 192 Subpart B requires that average surface concentrations of radium-226 residuals left in soil not exceed background by more than: "5 pCi/g, averaged over the first 15 cm (6 in.) of soil below the surface...." This requirement would be met by covering all the Subunit B residue in the vault with a 3 m (10 ft) thick multimedia cover.

This alternative would comply with requirements of the CAA (for releases of dust and non-radioactive particulates) and the CWA (for storm water runoff, BMPs, and dredge and fill activities). This alternative would comply with the groundwater monitoring requirements for a RCRA solid and hazardous waste disposal facility, the substantive RCRA closure requirements for a land disposal facility, and the requirements for designation and use of a CAMU.

This alternative would also comply with NEPA (for environmental documentation), the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity, and with the UMTRCA guidance for control and cleanup for residual radioactive material. Compliance with requirements under the CAA, CWA, and RCRA would be met by incorporating sound engineering features, BMPs, and ALARA principles into the remediation and operation of the unit. Additional supporting documentation to justify that

Alternative 4B would comply with the identified ARARs is presented in Appendices D and F (Table F.2-3).

Under 40 CFR § 264, Subpart S, remediation wastes can be managed in an area of the property designated as a CAMU. Management of wastes, including disposal of remediation wastes, in a CAMU does not constitute land disposal and does not create a waste management unit subject to the MTRs. Although CAMUs are required to allow the appropriate use of treatment technologies, treatment is not a requirement for this alternative. Thus, disposal of untreated material in an on-site vault is in compliance with CAMU regulations. "Closure" of the CAMU would be in accordance with 40 CFR § 264 Subpart S, and other ARARs to ensure long-term protection of human health and the environment under this alternative.

#### 4.3.6.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 4B would reduce the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$. Figure 4-8 was presented as a conceptual site model for the various action alternatives considered. Residual risk would only be through completed pathways. The basis of the risk evaluation is presented in Appendix D. Each of these potential concerns would be addressed through the primary remedial action components of Alternative 4B: removal, packaging, isolation in an above-grade disposal vault, and the application of institutional controls.

The disposal vault design, supplemented by institutional controls, would preclude contact with or direct radiation exposure from the untreated waste by an expanded trespasser. The disposal vault also would contribute to a significant reduction in leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude access to the residues by an on-property resident.

Because Alternative 4B includes the on-property disposal of the untreated residues, the five-year CERCLA review process to ensure continued performance of the disposal system would be part of this alternative.

Adequacy and Reliability of Controls

As previously stated, the projected residual excess cancer risk attributable to Alternative 4B to viable receptors is less than $10^{-6}$. The on-property disposal vault uses proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low-level radioactive waste under both DOE and NRC programs, and uranium mill tailings under UMTRCA and FUSRAP.

Fate and transport modeling to assess the most likely release mechanism, leaching under degradation of the facility, was completed. The results were based on the assumption that components of the system slightly degrade over 1,000 years and that infiltration rates (and consequently exfiltration rates) increase to 1.3 cm/yr (based on the HELP model). Under these assumptions, the leaching of contaminants from untreated material would not pose a risk to off-site receptors. Uranium-238 is the only contaminant predicted to reach the aquifer. Even if these input parameters were increased to 15 cm/yr (highest possible with no infiltration barrier), the overall result would not change.

Treatability data for the vitrification process option (Table C.3-18) indicated that the ratio of the activity of uranium-238 in the leachate from the untreated Silo 3 residue to the activity in the leachate from vitrified Silo 3 material was one. The leaching of the contaminants from the untreated material using these assumptions would result in a risk to off-site receptors of about $10^{-6}$.

The disposal vault would be designed to preclude the need for long-term management. Operation and maintenance functions would occur until long-term protectiveness was attained at the time when the FEMP site-wide remedial action objectives would be met.

Consistent with DOE Order 5400.5, 40 CFR § 264.117, 40 CFR § 191.14, and § 191.15, active monitoring would assess the performance of the disposal system. This monitoring supports the required five-year CERCLA review.

Long-Term Environmental Impacts

The environmental impacts resulting from the implementation of Alternative 4B after remedial activities are completed would be essentially the same as for Alternative 2B/Vit, except for the waste being in an untreated form. Refer to Alternative 2A/Vit (Section 4.2.2.3) for detailed information since this section only contains a summary. For irreversible and irretrievable commitment of

resources, refer to Section 4.7. The following paragraphs summarize the long-term effects of Alternative 4B on the environment.

Soil and Geology

Construction of the disposal vault would result in the permanent disruption of 2.8 ha (6.9 acres) of land. The disposal configuration would prevent erosion of residues that could result in surface soil contamination and would prevent leaching that would contaminate subsurface soil. Uncontaminated soil would be used as fill. Borrow pit soil for construction would be obtained from clearing and grubbing.

The regional geology of the FEMP site and surrounding area would not be affected by implementation of Alternative 4B. Geological conditions are important in terms of site suitability for construction of an on-property disposal vault. Appropriate design factors (thickness and performance of cover material and liner) would be incorporated into the facility. The facility would also incorporate appropriate protection against seismic damage.

Water Quality and Hydrology

A system to monitor long-term water quality would be implemented by installing monitoring wells around the perimeter of the disposal vault. No significant long-term hydrological impacts to the surrounding area are expected to result from changes to the site. However, after 1,000 years, some degradation could occur. Run-on and runoff controls would be used at the disposal vault, and the remaining areas of the site would be regraded to the surrounding grade and would discharge surface runoff to existing on-property drainageways.

Air Quality

Following implementation of Alternative 4B, the air quality at the FEMP site would be similar to current conditions. There would be minimal long-term impacts on air quality because the disturbed areas would be revegetated, which would help control releases of fugitive dust. In addition, the disposal vault design would minimize impacts to air quality associated with long-term disposal.

Biotic Resources

Long-term impacts may include displacement of potential threatened and endangered species habitat. No critical habitat for threatened and endangered species has been identified in areas to be impacted

by Alternative 4B activities. However, a potential habitat for threatened and endangered species may exist in the disposal area.

Potential state threatened and endangered species observed in or near the disposal location include: Running buffalo clover (Trifolium stoloniferum), Mountain bindweed (Polygonum cilinode), the Northern junco (Junco hyemalis), Northern harrier (Circus cyaneus), Red-shouldered hawk (Beuto lineatus), and the Mountain bindweed (Polygonum cilinode). Suitable habitat also exists for the Sharp-shinned hawk and the Northern waterthrush. It is important to note that none of the bird species listed above were observed nesting. These species are only present during migratory stops. Implementing Alternative 4B would result in the loss of 2.8 ha (6.9 acres) of potential habitat for the above species. Following completion of construction and excavation activities, disturbed areas would be backfilled, regraded, and revegetated with native grass species. For detailed information on the biotic impacts refer to Alternative 2A/Vit (Section 4.2.2.3).

Wetlands and Floodplains

A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and received COE approval in August 1993. The delineation identified approximately 12 ha (29 acres) of jurisdictional wetlands in the northern part of the site. Efforts would be made to site the disposal vault in areas not containing jurisdictional wetlands. However, for NEPA purposes it was assumed that the siting of the facility for Alternative 4B would result in the loss of approximately 6 ha (12.4 acres) of forested wetlands. A wetlands assessment pursuant to the requirements of 10 CFR § 1022 has been prepared (Appendix J) for the representative alternative and other alternatives evaluated.

The 100- and 500-yr Paddys Run floodplains are located near Silo 3 and the support facilities. However, these areas would not be permanently altered as a result of implementing Alternative 4B.

Socioeconomics and Land Use

The area of the disposal vault is estimated at less than 0.1 percent of the FEMP site area. Other impacts of Alternative 4B on socioeconomics and land use are the same as described for Alternative 2A/Vit (Section 4.2.2.3).

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Cultural Resources

An archaeological survey would be performed for the non-controlled areas not previously disturbed to be impacted by Alternative 4B. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site.

4.3.6.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Although migration of contaminants would be reduced by the disposal vault and run-on/runoff controls, the waste material would not be treated; therefore, there is no reduction of contaminant, toxicity, or volume.

4.3.6.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls and access controls, Alternative 4B would be protective of the community during implementation. Figure 4-9 illustrates that close proximity to direct emissions of untreated material (and gas emissions during treatment, for those alternatives that include treatment) is the release mechanism that could potentially impact the community during remediation activities for Alternative 4B. It has been estimated that during implementation of Alternative 4B, fenceline radon exposure levels for the off-site public would be indistinguishable from background levels, less than 0.5 pCi/L.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to direct radiation from the residues along with radon, gases, or dust. In addition to the engineering controls that would be implemented to limit the release of contaminants, access controls during remediation would be used. Fences and security forces would limit access of the public to the materials. Access controls are effective, especially in the short term. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 4B is effective in protecting the community in the short term.

Protection of Workers During Remedial Action

There are no unacceptable risks to workers as a result of implementation of Alternative 4B. This alternative involves the handling of the residues and, therefore, there are several potential exposure

pathways for workers. Both the release of gases and exposure to direct radiation from the residue could cause a risk to workers. It has been estimated that with appropriate protection, the removal and packaging of materials would result in an excess cancer risk level to remediation workers of $4.5 \times 10^{-6}$ (see Appendix D), well within the occupational standards required by DOE Orders. Most of this risk would occur during handling of the untreated residue. As appropriate, workers would wear protective clothing. Shielding would also be used, along with remote operations where needed.

There are safety issues associated with the removal process. There are physical injury risks associated with constructing the on-property disposal vault. There may be accidents bringing the material on property or operating heavy equipment. Without considering the nature of the activity, it has been estimated based solely on labor hours that the removal, packaging, and on-property disposal actions of Alternative 4B could result in 4.5 injuries and 0.07 deaths during remediation. All remediation activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR § 1910.120(b)(4). Training and procedures would assure that worker exposure would be ALARA.

Short-Term Environmental Impacts

The short-term impacts resulting from the implementation of Alternative 4B during remedial activities are basically the same as those identified for Alternative 2A/Vit, Section 4.2.2.5; therefore, the following discussion is a summary.

Soil and Geology

Soil disturbance during implementation of Alternative 4B would result primarily from preparation of the disposal vault location and construction of access roads, a packaging area, a staging area, and support facilities. Construction and excavation activities could disturb a total of approximately 4.3 ha (10.6 acres) of the site. These same activities could also result in the erosion of exposed soil areas. Erosion controls such as straw bales and berm would be used to minimize potential erosion. Measures for reducing fugitive dust generation such as wetting surface or using dust suppressants would be used in exposed soil areas as appropriate. Following completion of all construction and excavation activities, disturbed areas would be filled with clean backfill and topsoil and revegetated with native grasses.

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Water Quality and Hydrology

Through erosion control and dust suppression, contaminants disturbed during remediation would not be transported to adjacent surface water bodies. Surface water near the site would be monitored during remediation in accordance with the existing water discharge permit to assess potential impacts to the water from remediation.

Remediation would not increase the release of contaminants to the groundwater since the material would always be contained. However, selected existing groundwater wells on the FEMP site would be monitored during source removal.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are three potential sources of air emissions: 1) dust from construction and earth-moving activities, 2) gas releases during removal and packaging, and 3) heavy equipment exhaust. The exhaust emissions from heavy equipment are not expected to impact air quality.

Dust would be controlled as discussed in the soil section. With the appropriate dust suppression, excavation activities are not expected to negatively impact the air quality. Gas and particulate emissions would be monitored through collection and treatment during waste removal. Therefore, no significant releases into the environment are expected to occur.

Biotic Resources

The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 4B would result primarily from activities associated with construction of the on-property disposal vault and other facilities and installation of electric power lines, transformers, process water and sewer lines, and material slurry transfer lines. Local biota (wildlife and wildlife habitat) would be temporarily displaced along with potential threatened and endangered species habitat.

There also is the potential for impact to biota from contaminant releases such as through erosion, dust emissions, gas releases, and direct radiation. As discussed in previous short-term effectiveness discussions, the releases would be minimized through engineering controls such as erosion control, dust suppression, off-gas collection and treatment, and shielding of residues. There should be no negative exposure impact on biota during implementation of Alternative 4B.

Wetlands and Floodplains

A site-wide wetlands delineation has identified several areas of wetlands in or adjacent to areas that could be impacted by the implementation of Alternative 4B. Wetlands north and south of the material treatment facility are not expected to be affected; however, for NEPA purposes it was assumed that there would be disturbance of wetlands during the construction of the on-property disposal vault. Approximately 5.0 ha (12.4 acres) could be affected. Engineering controls through the site activities such as silt fences and straw bales would be used to control the migration of eroded soil to wetland areas. Alternative 4B activities are not planned to occur within the floodplains, and contaminant migration during remediation would be controlled through engineered erosion controls to minimize impacts on the floodplains.

Socioeconomics and Land Use

For this analysis, it is assumed that all of the resources needed to complete remedial activities could be obtained within the local area. Consequently, the collective revenue for the CMSA would increase by a maximum of 2.8 percent over a period of two years. With the implementation of Alternative 4B, the increase in revenues for the CMSA would have limited impact on surrounding communities.

Cultural Resources

Any areas determined to be of significance resulting from a cultural resource review would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA (Luce 1987). A more detailed discussion of management procedure is provided in the short-term effectiveness evaluation for Alternative 2A/Vit.

Duration of Remedial Activities

Remedial action activities under Alternative 4B are expected to be completed in about two years. Material removal activities would require about one year, assuming eight hours/day, seven days/week, for three weeks/month. Physical, substantial, and continuous on-property activities would be initiated within 12 months after the ROD is approved by the EPA.

4.3.6.6 Implementability

Technical Feasibility

Construction and operation of the removal component of Alternative 4B would be readily implementable, as discussed for Alternative 2B/Vit (Section 4.3.2.6).

Administrative Feasibility

DOE would need to initiate designation of the Operable Unit 4 waste management area as a CAMU. EPA concurrence of the CAMU designation would be required. The substantive technical requirements of air emissions permits would also need to be demonstrated. This may include calculating estimated emissions, providing air emissions controls, developing a sampling and analysis plan to monitor air emissions, and air sampling. Coordination with OEPA would be necessary to ensure that the substantive technical requirements for siting the above-grade disposal vault would be met.

Availability of Services and Materials

The availability of services and materials for Alternative 4B would be the same as described for the removal and disposal vault components of Alternative 2B/Vit (Section 4.3.2.6).

4.3.6.7 Cost

The total present worth cost of Alternative 4B is $22 Million. A detailed breakdown of the cost is provided in Table 4-11.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-11. More detailed information is provided in Appendix E.

This alternative includes identical cost components as Alternative 2B/Vit (Section 4.3.2.7), except that treatment is not included in Alternative 4B. As with Alternative 2B/Vit, the largest component of the capital cost is the construction of the pneumatic removal/transfer system, representing approximately 57 percent of the total capital costs. Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

The basis of estimate is the same as that discussed for Alternative 2B/Vit.

TABLE 4–11

COST ESTIMATE FOR ALTERNATIVE 4B

| ALTERNATIVE 4B: REMOVAL AND ON–PROPERTY DISPOSAL | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| SITE PREPARATION | $579,500 | $528,700 | $1,108,200 |
| WASTE PROCESSING | $183,100 | $194,200 | $377,300 |
| PNEUMATIC REMOVAL/TRANSFER SYSTEM | $4,571,600 | $4,744,400 | $9,316,000 |
| DISPOSAL VAULT | $937,100 | $1,595,500 | $2,532,600 |
| PACKAGING (3,195 PKGS. @ $955/PKG.) | $843,500 | $2,207,700 | $3,051,200 |
| TOTAL CAPITAL | $7,114,800 | $9,270,500 | $16,385,300 |
| RISK BUDGET (11.0%) | $782,600 | $1,019,800 | $1,802,400 |
| SUBTOTAL | $7,897,400 | $10,290,300 | $18,187,700 |
| CONTINGENCY (20.0%) | $1,579,500 | $2,058,100 | $3,637,600 |
| TOTAL ESTIMATED INSTALLED COST | $9,476,900 | $12,348,400 | $21,825,300 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| DURING REMEDIATION | | | $1,094,000 |
| POST–REMEDIATION | | | $3,207,000 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $22,045,600 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on following time periods:
Construction (years): 2
O&M during remediation (years): 2
Post–remediation O&M (years): 30

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Waste Processing

Components of the waste processing cost include construction of the waste processing facility and the process area general ventilation system. Costs were estimated based on the following assumptions:

- The waste processing facility would be a pre-engineered building built on slab and would provide approximately 470 $m^2$ (5,000 $ft^2$) of space. The waste facility would be fully insulated and would have a 10-year design life span.
- The walls of the processing rooms and the storage room will be shielded with 0.6 m (2 ft) thick concrete.
- The ventilation system for the general process area would operate continuously and would either recirculate or exhaust to atmosphere. This system would not be designed to remove radon.

Pneumatic Removal/Transfer System

The pneumatic removal/transfer system components and cost are the same as for Alternative 2B/Vit.

Disposal Vault

The cost of the disposal vault was estimated as described for Alternative 2B/Vit (Section 4.3.2.7). The size of the disposal vault was estimated to include two 3400 $m^3$ (120,000-$ft^3$) cells.

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2B/Vit. The number of containers required for Alternative 4B were estimated to be 3,195 containers.

4.3.6.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 4B. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.3.6.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 4B. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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## 4.4 SUBUNIT C

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### Source Term Description

The RI for Operable Unit 4 identifies that the surface soils, berm soils, and subsurface soils have been sampled and analyzed for radiological, inorganic, and organic constituents during the CIS, the Waste Pit Area Runoff Control Removal Action, and the RI for Operable Unit 4.

### Surface Soil

In general, the results of the studies are consistent with one another and show that surface soils across Operable Unit 4 are contaminated with U-238 and, to a lesser extent, Ra-226 and Th-230. Concentrations decrease rapidly with depth, to background levels below 6-inches. The results of these samples show no direct link between surface soil contamination and the silo contents. Instead, the data show uniform distribution of low-level radiological surface contamination throughout the Operable Unit 4 Study Area consistent with air deposition of contaminants from the Waste Pit Area and/or the former Production Area.

### Subsurface Soils

In general, subsurface soils contained concentrations of uranium and progeny at levels less than 4 pCi/g. The data indicate that soil contamination in Operable Unit 4, outside of the areas immediately adjacent to and under Silos 1 and 2, is limited primarily to the surface. There appears to be no contamination from the surface through the vadose zone except in samples collected from trenches located west of the silos. Above background uranium concentrations at depths up to 15 ft below the surface indicate that this area may be contaminated with construction debris.

### Berm Soils

Characterization of the berm soils included 23 samples for radiological analyses, 12 samples for inorganic analyses, 12 samples for HSL organics, and 4 samples for TCLP analysis. With the exception of two locations, sample results revealed only background concentrations of all constituents. Section 7.3.2 of the RI Report for Operable Unit 4 discusses the potential causes for contamination at these two locations, attributing their existence to the spillage during silo filling operations, leakage of the silo to surface soils prior to berm installation, or seepage of the silo underdrains to near subsurface soils immediately adjacent to the silos.

In general, with the exception of the few localized contaminated areas, the berm soils are contaminant free.

Principal Threats

The NCP describes principal threats as those involving liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials. Consistent with the NCP, the RI Report for Operable Unit 4 identified the nature and extent of contamination within the Operable Unit 4 boundary, characterizing and identifying those contaminants which contributed to ILCR values greater than $1 \times 10^{-6}$ and a hazard quotient greater than 1.0. The RI Report for Operable Unit 4 identified that the principal threats to human health and the environment posed by the Subunit C structures, soil and debris are from the following contaminant/transport pathways:

Direct Radiation

- Direct exposure to gamma radiation from radioactive constituents in surface soil.

Air Emissions

- Dispersion of volatile organic compounds and fugitive dust generated from soil.

Surface Water Runoff

- Erosion of contaminated soils into Paddys Run form the vicinity of the silos.

Potential remedial alternatives for Subunit C were developed in order to mitigate the short-term and long-term exposure and associated risks from gamma radiation from radioactive constituents in the surface soils, eliminate the dispersion of fugitive dust generated from the soil, elimination of contaminate surface water, runoff from contaminated soils into Paddys Run from Operable Unit 4.

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4.4.1 Analysis of Alternative 0C - No Action

The no-action alternative is retained throughout the FS process as required by the NCP (40 CFR § 300.430[e][6]). This alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action would be taken. In the no-action alternative, the materials are considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. All existing equipment, soils, and structures included in Subunit C would remain in place. Alternative 0C does not provide for the monitoring of soil, groundwater, or radon emissions, and Alternative 0C does not provide for active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

4.4.1.1 Overall Protection of Human Health and the Environment

Alternative 0C does not meet the remedial action objectives for Subunit C and therefore is not protective of human health and the environment. The no-action alternative does not contain, remove, or treat the sources of contamination. In the absence of remedial action, risks to on-property workers would exceed the EPA target range of $10^{-4}$ to $10^{-6}$. The Baseline Risk Assessment calculated a value exceeding the $10^{-4}$ excess cancer risk for a viable receptor (groundskeeper). Under the no-action alternative, Silos 1, 2, and 3 would be expected to deteriorate to the point of collapse, resulting in additional release of COCs to the air, soil, surface water, and groundwater pathways. It should also be noted that Silos 1, 2, and 3 may be empty under Alternative 0C. That is, the contents of each silo may be removed as part of the selected remedial alternatives for Subunits A and B. Collapse of these silos, if they were empty, would present less risk than if they were full.

In the event institutional controls were lost, an on-property residence could be established. The on-property resident would be exposed to unacceptable levels of contamination through ingestion of food grown in the Operable Unit 4 soil and by direct radiation.

Erosion of contaminated soil into Paddys Run or leaching to groundwater with subsequent migration to Paddys Run would threaten environmental receptors such as aquatic biota. In addition to radiological and chemical risks, physical hazards associated with the abandoned silos would remain to threaten the safety of both a resident and an expanded trespasser.

4.4.1.2 Compliance with ARARs

Alternative 0C would not comply with all pertinent chemical-specific ARARs identified for this alternative. Contaminated material would be left exposed to the environment, available for immediate

transport via the air, groundwater, surface water (due to storm water runoff), and residual soil pathways. Fate and transport modeling indicates that the safe drinking water limits (MCLs in 40 CFR § 141) would be exceeded for uranium and gross beta radiation. Air releases might violate the CAA dose limits on radioactive particulates (40 CFR § 61 Subpart H), and the State of Ohio fugitive dust and air pollution mixture regulations. Releases to surface waters might violate the Ohio Water Quality standards for receiving waters established under the CWA. This alternative would not meet the RCRA closure performance standard or attain the standards for control of residual radioactive materials established under the UMTRCA. Localized "hot spots" would exceed levels established for radium residuals in surface soils (40 CFR § 192.12). Releases via all pathways could exceed DOE radionuclide release limits or the annual effective dose equivalent limit for the unrestricted public under this alternative. Detailed documentation of compliance with ARARs for Alternative 0C is presented in Appendix F.

#### 4.4.1.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Alternative 0C would not be effective because this alternative does not protect against exposure to contaminated soils or the silos. Erosion of the soils would contaminate Paddys Run. Leaching of contaminants from the soil into the groundwater would continue to contaminate the groundwater. This alternative provides no protection against silo failure and the associated physical dangers.

Risks to the general public are unacceptable if no action is taken as presented in Appendix D of this FS. Risks from exposure to soil only (assumes silo material removed or contained) for a trespassing child and a groundskeeper are above the acceptable range (ILCR of $5 \times 10^{-3}$). In addition, risks to an on-property farmer from the soils in the event institutional controls are lost are an ILCR of $1 \times 10^{-1}$ and a HI of 20 (100 for the child). The no-action alternative does not mitigate these risks. The no-action alternative also does not mitigate risk to humans and terrestrial biota from the silo physical dangers.

Because this alternative leaves Subunit C hazardous materials on property, a five-year review would have to be conducted to ensure that the no-action remedy provides adequate protection of human health and the environment.

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Adequacy and Reliability of Controls

The no-action alternative is not protective under future, unrestricted release conditions. There are no controls over this future risk and as a result, the alternative is not adequate.

Long-Term Environmental Impacts

Alternative 0C would not be protective of human health and the environment in the long-term because it does not protect against the exposure to contaminated surface soil and the runoff to surface waters. Runoff of contaminated soil could lead to increased contamination levels in the perched groundwater zone, surface water and sediment in Paddys Run, and the 0.36 ha (0.76 acre) wetland south of Silos 1 and 2. In addition, the potential exists for contaminated particulates from the soil to become resuspended in the air. For the long-term risks associated with Alternative 0C, refer to Section 4.4.1.3, "Magnitude of Residual Risk."

4.4.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment is not involved in Alternative 0C; therefore, no reduction in toxicity, mobility, or volume would occur.

4.4.1.5 Short-Term Effectiveness

This evaluation criteria addresses the effects of the alternative during the construction and implementation of the remedial action. Under the Alternative 0C, no remedial action would be taken; therefore, there would be no increase in short-term risks.

4.4.1.6 Implementability

Technical Feasibility

Since no remedial action would be taken, there would not be any difficulties or uncertainties associated with construction. The no-action alternative is included in the detailed analysis of alternatives for a baseline comparison.

Administrative Feasibility

No permits or licenses would be required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials

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For Alternative 0C, there would not be any services or materials required.

4.4.1.7 Cost

There are no costs associated with Alternative 0C-No Action.

4.4.1.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 0C. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.4.1.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 0C. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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### 4.4.2 Analysis of Alternative 2C

This alternative involves the decontamination, if required, and demolition of Silos 1, 2, 3, and 4. Contamination may include either radiologic surface or volumetric contamination, which results in increased activity levels, or chemical contaminants, which adhere to the surface or have migrated into the concrete. In some cases, the residual contamination may cause the material to exhibit a hazardous waste characteristic (e.g., heavy metal toxicity), which would require management as a hazardous waste. Figure 4-11 depicts the proposed Alternative 2C site plan.

The contaminated material generated in this alternative includes concrete rubble, the existing RTS of Silos 1 and 2, surface and subsurface soils, the decant sump tank, process piping, and the process piping trenches. The concrete slab of the Drum Handling Building and concrete foundation of the sump lift station would also be removed. Additionally, used equipment, contact waste, rubble, and debris generated consequential to the implementation of remedial actions for Subunits A and B would be dispositioned under this alternative. This material and debris includes demolition debris from the Subunit A and B treatment processes. Once the contaminated soil and debris has been collected and is ready for disposition, there are two options to be considered: 1) interim storage of the materials to facilitate integration with other operable unit's treatment programs, 2) on-property disposal in an above-grade disposal vault.

It should be recognized that the volume of contaminated soils and rubble being addressed under Subunit C is less than one percent of the volumes of similar contaminated materials anticipated to be generated and handled on a site-wide basis under the five FEMP operable units. In the development of all remedial alternatives for Subunit C materials, this FS has considered the integration of several treatment programs currently under development, which potentially can offer waste minimization opportunities in the near future. Operable Unit 3 is currently developing pilot plant programs which focus upon the treatment of rubble and debris prior to disposal. Likewise, Operable Unit 5 is currently evaluating technologies and alternatives which have the potential to treat the Operable Unit 4 contaminated soils.

To ensure the proper integration of site-wide cleanup strategies, activities, and the responsible expenditure of available resources, interim storage of Operable Unit 4 generated soils, rubble, and debris may be necessary for a period of time. Interim storage would be provided to enable full utilization of projected treatment systems (e.g., Operable Unit 5 soil washing) and to provide for consistency in FEMP waste management strategies. Interim storage facilities and practices would be

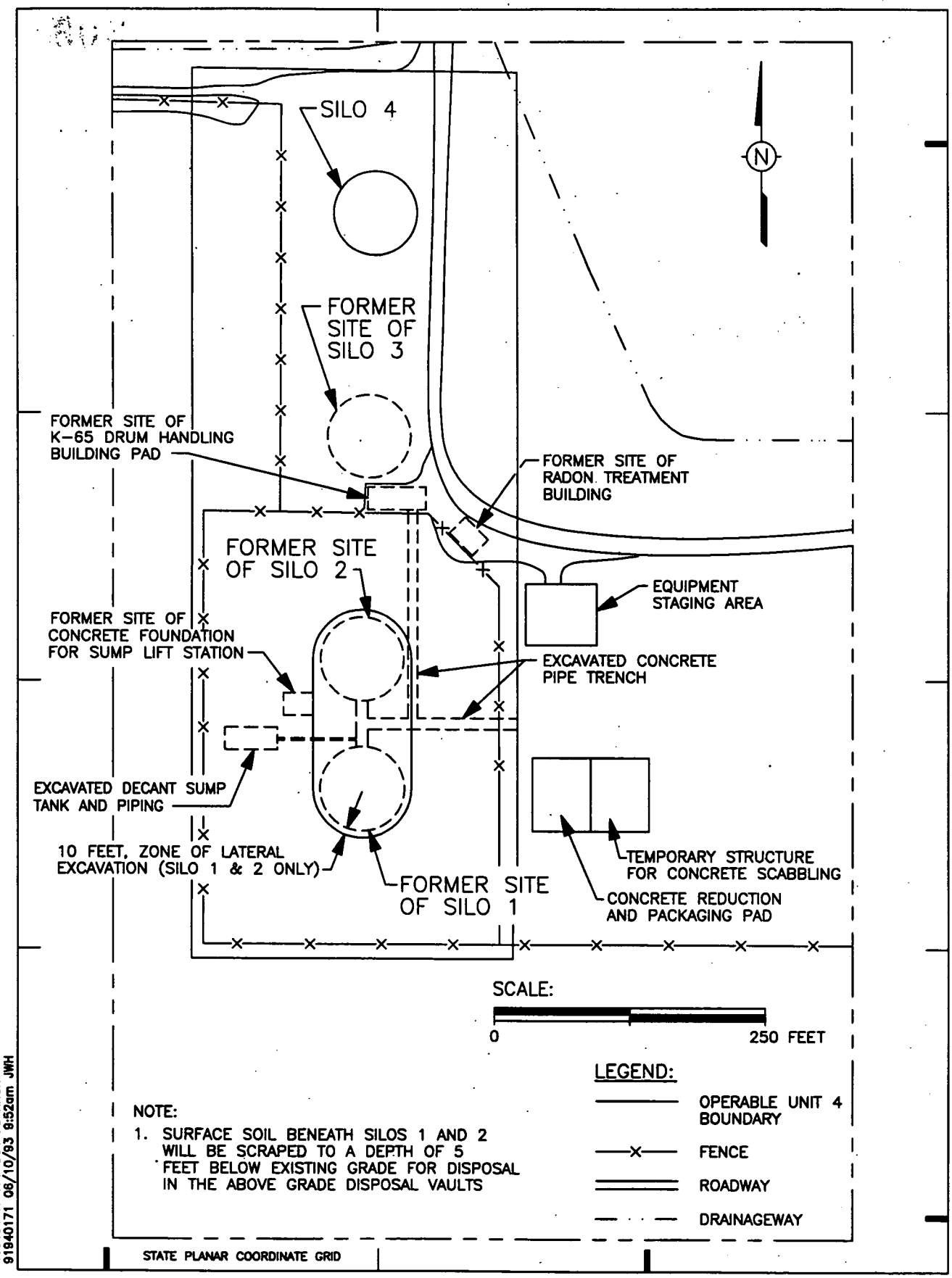



FIGURE 4-11 ALTERNATIVE 2C SITE PLAN

consistent with approved removal action procedures, identified ARARs, and other direction provided by EPA. In addition, the management of the Operable Unit 4 contaminated soil and debris during interim storage would include measures consistent with the work plan for Removal Action 17 - Improved Storage of Soil and Debris to ensure future identification and retrievability of these wastes for final disposition.

As part of Alternative 2C, on-property disposal has been considered as part of this alternative as the final disposition of the waste. Contaminated materials would be placed directly (without packaging) into an above-grade disposal vault located on property. As stated in Section 3.2.2.1, the final location of the on-site disposal facility will be determined in accordance with the OU5 ROD.

Soil and Debris Waste Management Integration

Because Subunit C involves the handling of Operable Unit 4 soil and debris volumes, which compared on a FEMP site-wide scale are relatively small, DOE believes that the final disposition of the materials should take full advantage of waste minimization opportunities offered by the integration of remedial activities with other FEMP operable units.

Currently, two other FEMP site operable units are in the process of evaluating remedial alternatives for contaminated soils and debris. By definition, Operable Unit 5 will develop, evaluate, and propose a final remedial alternative to address contaminated environmental media including soils on a site-wide basis. Similarly, Operable Unit 3 will propose a final remedial alternative for the debris, including structural concrete, steel, and process piping, which will result from the decontamination and dismantling of the former Production Area facilities.

Operable Unit 5 has already initiated pilot-scale soil washing operations on the basis of earlier bench-scale tests which yielded promising results for this technology. The soil washing process involves treating contaminated soils with a reagent (e.g., acid) which extracts soil contaminants in solution and reduces contaminant concentration in the soils. The extract is recovered and reduced in volume for appropriate disposal. Based on the efficiency of the process, the washed soils (which represent the largest fraction of the treated material) may be suitable for disposal in a less restrictive manner, based on estimated residual risk. The approach is designed to minimize the volume of waste eventually requiring more restrictive and expensive containment or disposal. The total volume of soil which might be treated by Operable Unit 5 is estimated to be several million cubic yards. A large-scale soil

washing facility is currently in the preliminary design stage. Based on current schedules for remedial actions for Operable Unit 5, this facility could be operational by mid-1996.

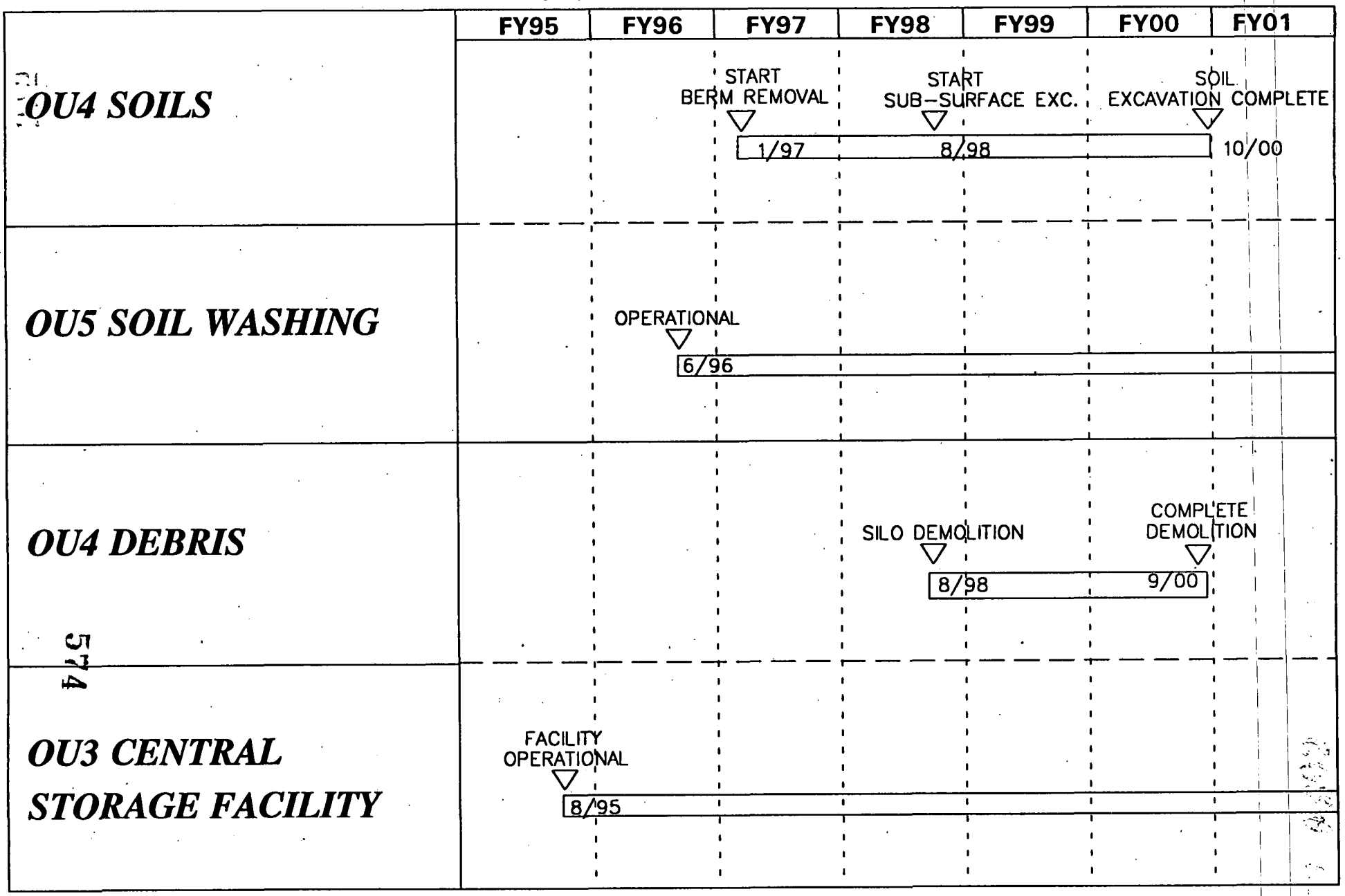
Likewise, Operable Unit 3 has initiated a removal action (Removal Action 17) to manage debris resulting from decontamination and dismantling activities. An engineered Central Storage Facility, to contain contaminated debris from production facility dismantling prior to disposition, is nearing final design. A RI/FS is underway to evaluate various alternatives for decontamination and free-release, disposal, or recycling of contaminated structural debris. The total volume of material to be managed by Operable Unit 3 is also estimated to be several million cubic yards.

The estimated volume of contaminated soils and structural debris comprising Operable Unit 4 Subunit C materials is less than one percent of the Operable Unit 5 soil volume and less than one percent the Operable Unit 3 debris volume.

In the interest of coordinating site-wide cleanup efforts at the FEMP and to fulfill the statutory preference of CERCLA for waste treatment and volume reduction, it is recognized that the decision regarding the type and location of the final disposition of the Operable Unit 4 soil and debris could be placed in abeyance to facilitate the proper integration of this decision with forthcoming decisions for Operable Units 3 and 5. The integration could be achieved by placing the soils and debris resulting from the implementation of the Operable Unit 4 preferred alternative in interim storage. Interim storage would be conducted in accordance with the EPA-approved Work Plan for Removal Action 17. The final disposition of the Operable Unit 4 materials would occur coincidental to the implementation of the ROD for Operable Units 3 and 5. This strategy would promote cost-savings through reduction of volumes requiring disposal and would realize economies-of-scale through treatment by processes developed for larger volumes of soil and debris.

The current remedial action implementation schedules for Operable Units 3, 4, and 5 would favor this proposed approach. Figure 4-12 shows the key milestones for coordination. Operable Unit 4 soil excavation would be initiated in January 1997, approximately six months after the Operable Unit 5 soil washing plant is scheduled to go on line. The duration of Operable Unit 4 soil excavation extends to the year 2000 due to the required sequence for removal and treatment of the silo contents. Thus, there would be ample time for Operable Unit 5 to optimize the washing process to accommodate Operable Unit 4 soils. The Operable Unit 3 Central Storage Facility would be operational nearly five years before the Operable Unit 4 remedial action sequence leads to silo and

## FIGURE 4-12
## OPERABLE UNITS 3, 4, AND 5 COORDINATION SCHEDULE



processing facility decontamination and dismantling. By then, it is expected that Operable Unit 3 would have made significant progress in decontamination and recycling technology.

The overlapping remedial action schedules for Operable Unit 3, 4, and 5 would provide an excellent opportunity to integrate FEMP site-wide cleanup activities in a manner consistent with CERCLA preferences for treatment, minimization of wastes destined for land disposal, and cost-effectiveness.

In the unlikely event unforeseen circumstances would preclude the integration of Operable Unit 4 contaminated rubble and debris with the Operable Unit 3 ROD and the Operable Unit 4 soils with the Operable Unit 5 ROD, a disposal decision for Operable Unit 4 rubble, debris, and soils could be documented in a ROD amendment for Operable Unit 4 in accordance with Section 117(c) of CERCLA and EPA guidance. The ROD amendment would provide the public and the EPA further opportunity to review and comment on the selected disposal option for Operable Unit 4 rubble and debris. However, a ROD amendment to the Operable Unit 4 ROD would not be necessary in the event that the Operable Unit 4 contaminated soils and debris could be dispositioned consistent with the Operable Unit 5 and Operable Unit 3 RODs.

Segregation Criteria

It is understood that there exists the potential to encounter construction rubble and soils during the implementation of remedial actions which contain highly elevated concentrations of contaminants and, in the case of Silos 1 and 2, potentially significant direct radiation fields. These materials, which could be encountered during demolition and directly beneath the silos, are more prudently managed as waste materials in lieu of contaminated environmental media. Specific criteria are not cited within this FS in order to provide flexibility to the RD/RA Work Plans and decisions within the field during implementation. The following criteria have been adopted by this FS without eliminating needed flexibility for the RD/RA phase:

- Soils: Soils exhibiting visible waste materials in matrix or lower detection capability on a hand held detector would be dispositioned as Subunits A and B waste. This criteria would be refined during the RD and RA phase, in consultation with EPA and OEPA to ensure the implementability of the alternative and the protection of human health (i.e., worker protection, etc.,) and the environment.

- Construction Rubble: Rubble exhibiting direct penetrating radiation fields similar to the waste materials and for which there is significant worker health and safety concerns associated with potential decontamination efforts (i.e., surface scabbling, etc.) would be dispositioned as Subunits A and B waste materials. More definitive criteria for the segregation of these materials will be defined in the RD once processing equipment and configurations are more definitively established.

Site Preparation

Site preparation activities would begin by preparing staging areas for the silo demolition equipment, vacuum scabbling machinery, and packaging of contaminated silo rubble, RTS, piping, and foundation. During the D&D of the silos, 4 ha (10 acres) would be cleared and grubbed for the above-grade disposal vault. A haul road approximately 0.5 km (0.8 mi) would be constructed between the Operable Unit 4 and the above-grade disposal vault.

Decontamination and Demolition of Silos 1, 2, 3, and 4

Before Silos 1, 2, and 3 are demolished, loose interior materials and loose concrete would be removed from the silo surfaces. The work platform used for the material removal would be used in this alternative to lower a robotic device, lighting, and video equipment into each silo interior. The robotic device would be equipped with a high-pressure water jet that is capable of moving vertically up the silo walls. A hydraulic pump would be used to remove the water and sediment produced from the pressure washing. The water would be sent to the FEMP AWWT facility for treatment, and the concrete sediment would be dispositioned with the contaminated concrete from the subsequent concrete scabbling operation. It is estimated to take two weeks to complete this activity.

On the basis of available radiological smear data and process knowledge, Silo 4 is expected to exhibit no elevated concentration of COCs.

Silo demolition would consist of the systematic removal and dismantling of the Silo 1, 2, 3, and 4 domes, walls, floor slabs and footers. The dome removal would involve using a diamond wire rope saw to cut each dome into manageable pieces after appropriate bracing has been installed. Concentric cuts would be made around the circumference of the dome using the four existing manways to cut between. The initial section would be approximately 15 m (50 ft) in diameter. The remaining circular section of each dome would be divided into four equal quadrants.

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The demolition would begin with Silo 4 as a testing facility to address any operational difficulties prior to movement to other silos. Following Silo 4, demolition would begin on the Silo 1 dome and then proceed to the Silo 2 dome. A crane would aid in the support of the dome sections during the cutting operation and would transport the sections to a concrete pad for size reduction with a diamond chain saw. While the Silo 2 dome is being dismantled, a second crane would be used to aid in the dismantling and transfer of the Silo 1 wall sections to the pad. A diamond chain saw would be used to cut the walls into sections. At the pad, the wall sections as well as the dome sections would be reduced to manageable sizes with diamond chain saws.

After the Silo 2 dome is removed, one of the two cranes would be transferred to begin the dismantling of the Silo 3 dome. Demolition of the Silos 1 and 2 walls would continue with the remaining crane. Silo 3 would be demolished in a similar fashion to that of Silos 1 and 2. The floor slabs and footers of the silos would also be removed. This procedure would be performed by scoring the floor in a grid pattern with a masonry saw. A front-end loader would break up and transport the pieces to the concrete pad for further size reduction. The footer would be demolished by a backhoe-mounted pneumatic hammer and transported to the concrete pad by a front-end loader.

The existing RTS, Drum Handling Building pad, sump lift station foundation, concrete trench, decant sump tank, and other facilities would also be removed and decontaminated in a similar fashion. Likewise, all remedial facilities and equipment installed and used by Subunits A, B and C would be disassembled, decontaminated (if necessary), characterized and appropriately disposed. Conventional decontamination and demolition techniques and equipment would be employed.

An estimated seven months would be required to complete the demolition of Silos 1, 2, 3, and 4 using the described equipment.

Vacuum Scabbling

After the sections of the silos have been cut into manageable sections by a diamond chain saw, the sections would be transferred by a forklift to a temporary structure. The structure would house three vacuum scabbling machines.

Due to concrete's porous nature, the residues stored within the silos more than likely have penetrated the concrete's surface to some degree. The decontamination efforts associated with the silo concrete structure would focus upon the removal of gross contamination exhibiting direct penetrating radiation

fields similar to the waste material. For the purposes of this alternative, it is assumed that the depth of interior surface contamination of Silos 1 and 2 is 2.5 cm (1 in.) for the floor slab and walls and 0.63 cm (0.25 in.) for the domes. For Silo 3, the depth of contamination for all interior surfaces is assumed to be 0.63 cm (0.25 in.). The scabbling operation is a mechanical concrete removal process. The upper layers of the concrete could be pulverized by high speed, reciprocating pistons equipped with tungsten carbide cutting tips. The scabbling process is contained inside an evacuated shroud to provide control of airborne particulates and to allow personnel to work without the need for respiratory protection. It is estimated that each machine is capable of scabbling 74.3 to 92.9 $m^2$ (800 to 1000 $ft^2$) per 8-hour-day at 0.159-cm (0.06-in) depth. It is estimated that 15 weeks would be required to complete the process.

Concrete exhibiting highly elevated direct radiation fields similar to the waste materials and for which there is significant worker health and safety concerns associated with the decontamination efforts would be dispositioned consistent with the selected alternative for Subunits A and B.

It is estimated that approximately 790 m (2600 ft) of process piping exists in the process piping trenches. The piping would not be decontaminated and would be cut into manageable sections for disposition consistent with the ROD for Operable Unit 3. The majority of the piping, according to drawings provided by Catalytic Construction, is 7.6 cm (3 in.) diameter carbon steel. A backhoe-mounted pneumatic hammer could be used to fracture the concrete piping trenches. The backhoe then could excavate the trench remnants and transfer them to the concrete pad used for silo demolition. The pieces could be further reduced in size to facilitate their management and disposition. It is estimated that 280 $m^3$ (365 $yd^3$) of concrete from the trenches, decant sump tank process piping, and existing RTS would be disposed in the above-grade disposal vault.

Decant Sump Tank, Process Piping, and Trenches

Upon completion of the Silos 1 and 2 demolition, the decant sump tank would be removed. The sludge in the tank would have been removed in a Subunit A alternative.

After the soil above and surrounding the decant sump tank has been excavated to allow its removal, a crane used for the Silos 1 and 2 demolition would extract the tank. The crane would transfer the decant sump tank to a concrete pad used previously for size reduction of the silo structure sections. The decant sump tank would be cut into sections, decontaminated to the extent practicable, and managed for disposal consistent with the ROD for Operable Unit 3.

Contaminated Surface and Subsurface Soils

Characterization of soils completed as part of the RI Report for Operable Unit 4 identified elevated concentrations of COCs in soils within the berms, surface soils, and subsurface soils within the unit. While data are limited, sufficient information is available to derive reasonable estimates of the quantities of contaminated soils requiring remedial action. Available data indicate elevated concentrations of radionuclides in berm soils adjacent to the walls of the silos. Data are not available on the berm soils not immediately adjacent to the silo walls.

Surface soil samples collected from the Operable Unit 4 area indicated elevated concentrations of uranium and other COCs in the upper 15 cm (6 in.) of soils along access roads, around Silo 3, and adjacent to the slurry line. Similar concentrations are anticipated across the Operable Unit 4 area including soils at the original grade beneath the berms.

An investigation of the extent of subsurface soil contamination was conducted as part of the RI/FS through completion of slant borings and the collection of samples during well installation. These samples indicated isolated areas of elevated concentrations of uranium and other COCs. Additionally, on the basis of process knowledge and results from the recently completed hydropunching within Operable Unit 4, elevated concentrations of COCs are anticipated in soils directly underlying Silos 1 and 2 and the decant sump tank.

Proposed Remediation Levels

As part of this alternative, proposed soil remediation levels were developed in Section 2.0 and Appendix D of this FS for each of the COCs. The cleanup criteria for the COCs were developed from available environmental regulations in combination with the results of site specific risk assessment information. Tables 4-12 and 4-13 provide proposed remediation levels for soil and the estimated risk to affected receptors from the residual contaminants left in the soils.

As mentioned earlier, the future land use scenario for Operable Unit 4 would be as a government reserve with continued federal ownership. The on-site receptor of concern under this scenario would be an expanded trespasser. Cancer risks and chemical hazard to the expanded trespasser, from residual contaminants, are presented in both Tables 4-12 and 4-13. For comparison, cancer risks and chemical hazards to an on-property farmer under a future land use scenario without federal ownership are also presented. Proposed remediation goals (PRGs), based on an incremental lifetime cancer (ILCR) risk of $10^{-6}$ and a hazard index (HI) of 0.2 were developed in Section 2 of this FS. These

TABLE 4-12

**PROPOSED REMEDIATION LEVELS IN SOILS - RADIONUCLIDES**

| Constituent of Concern | Expanded Trespasser $10^{-6}$ ILCR PRG pCi/g | Background (95th percentile) pCi/g | ARAR Target pCi/g | Max. Detected Soil Concentration, pCi/g | | Proposed Remediation Level[c] pCi/g | ILCR above background to Receptors from Proposed Remediation Level | |
|---|---|---|---|---|---|---|---|---|
| | | | | Surface | Subsurface | | Expanded Trespasser[a] | On-Property Farmer[b] |
| Pb-210 +2 progeny | 77 | 1.33 | NA | 4.5 | 101 | 78 | $1.0 \times 10^{-6}$ | $8.5 \times 10^{-4}$ |
| Ra-226 +5 progeny | 0.37 | 1.45 | 5 (top 6" soil) 15 (max. below 6") | 88 | 206 | 2 | $1.0 \times 10^{-6}$ | $9.3 \times 10^{-5}$ |
| Ra-228 +1 progeny | 0.77 | 1.19 | NA | 0.48 | 1.24 | 2 | $1.0 \times 10^{-6}$ | $9.3 \times 10^{-5}$ |
| Sr-90 +1 progeny | 1420 | ND | NA | 1.8 | 0.8 | NR | $< 1 \times 10^{-6}$ | $4.7 \times 10^{-5}$ |
| Tc-99 | 38700 | ND | NA | 3.6 | 3.6 | NR | $< 1 \times 10^{-6}$ | $2.0 \times 10^{-4}$ |
| Th-228 | 0.4 | 1.43 | NA | 2.9 | 1.3 | 2 | $1.0 \times 10^{-6}$ | $9.3 \times 10^{-5}$ |
| U-238 +2 progeny | 59 | 1.22 | NA | 37 | 53 | 60 | $1.0 \times 10^{-6}$ | $2.1 \times 10^{-4}$ |

Notes:
a) includes the direct radiation, soil ingestion, and inhalation pathways.
b) includes all pathways including the indirect pathways due to food crops
c) Sum of backround and PRG.
NA = Not Available.
NR = No Remediation Required.
ND = Not Detected.

# TABLE 4-13
# PROPOSED REMEDIATION LEVELS IN SOILS - CHEMICALS

| Constituent of Concern | Expanded Trespasser HI = 0.2 PRG mg/kg | Expanded Trespasser $10^{-6}$ ILCR PRG mg/kg | Background (95th percentile) mg/kg | ARAR Target mg/kg | Max. Detected Soil Concentration, mg/kg | | Proposed Remediation Levels mg/kg | HI to Receptors from Proposed Remediation Levels | | Risk to Receptors from Proposed Remediation Level | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Surface | Sub surface | | Expanded Trespasser | On-Property Farmer | Expanded Trespasser[a] | On-Property Farmer[b] |
| Antimony | 31 | N/A | 7.7 | NA | 32 | 32 | NR | 0.2 | 6.1 | N/A | N/A |
| Arsenic | 510 | 23 | 8.45 | NA | 10 | 12 | NR | N/A | N/A | $<1\times10^{-6}$ | $1.3\times10^{-3}$ |
| Barium | >10000 | N/A | 91.3 | NA | 112 | 142 | NR | <.1 | 0.10 | N/A | N/A |
| Cadmium | 26 | N/A | 0.82 | NA | 6 | 7 | NR | <.1 | 2.8 | N/A | N/A |
| Chromium(III) | NA | N/A | 15.5 | NA | 23 | 25 | NR | <.1 | 0.19 | N/A | N/A |
| Molybdenum | 930 | N/A | 2.6 | NA | 25 | 30 | NR | <.1 | 1.6 | N/A | N/A |
| Nickel | 8300 | N/A | 20.9 | NA | 39 | 39 | NR | <.1 | 0.28 | N/A | N/A |
| Silver | 130 | N/A | 2.6 | NA | 10 | 18 | NR | <.1 | 7.0 | N/A | N/A |
| Thallium | 31 | N/A | 0.58 | NA | 0.5 | 0.5 | NR | <.1 | 0.33 | N/A | N/A |
| Vanadium | 1700 | N/A | 30.4 | NA | 28 | 33 | NR | <.1 | 0.57 | N/A | N/A |
| Zinc | >10000 | N/A | 62.2 | NA | 65 | 67 | NR | <.1 | 2.77 | N/A | N/A |

See footnotes at end of table.

**TABLE 4-13**
**(Continued)**

| Constituent of Concern | Expanded Trespasser HI = 0.2 PRG mg/kg | Expanded Trespasser $10^{-6}$ ILCR PRG mg/kg | Background (95th percentile) mg/kg | ARAR Target mg/kg | Max. Detected Soil Concentration, mg/kg | | Proposed Remediation Levels mg/kg | HI to Receptors from Proposed Remediation Levels | | Risk to Receptors from Proposed Remediation Level | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Surface | Sub surface | | Expanded Trespasser | On-Property Farmer | Expanded Trespasser[a] | On-Property Farmer[b] |
| Benzo(a)anthracene | NA | 61 | ND | NA | 4.7 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $2.4x10^{-4}$ |
| Benzo(a)pyrene | NA | 8.8 | ND | NA | 5.2 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $2.7x10^{-3}$ |
| Benzo(b)fluoranthene | NA | 72 | ND | NA | 9.7 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $1.5x10^{-3}$ |
| Chrysene | NA | 2000 | ND | NA | 3.5 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $1.5x10^{-5}$ |
| Dibenzo(a,h)anthracene | NA | 7.9 | ND | NA | 0.9 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $5.3x10^{-4}$ |
| Indeno(1,2,3-cd)pyrene | NA | 32 | ND | NA | 4.2 | ND | NR | N/A | N/A | $<1x10^{-6}$ | $1.3x10^{-2}$ |

[a]Includes the direct radiation, soil ingestion, and inhalation pathways.
[b]Includes all pathways including the indirect pathways due to food crops.
NA = Not Available.
2N/A= Not Applicable.
ND = Not Detected.
NR = No Remediation Required.



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PRGs, presented in Tables 4-12 and 4-13 for the expanded trespasser, represent allowable incremental concentrations above background for these COCs based on targets of $10^{-6}$ incremental risk and hazard index of 0.2. The PRG was added to the background concentration to derive the proposed remediation level. In those cases where a target concentration level specified by an ARAR is less than the proposed remedial level, the ARAR level was adopted as the remediation level. Remediation would be required for COCs that are present in the surface and subsurface soil at higher concentrations than the proposed remediation level.

All preliminary information indicates that to reduce soil contaminants to essentially background concentrations, necessary to reduce the risk to the on-property farmer to an ILCR of $10^{-6}$, is not feasible. Operable Unit 5 Treatability Study results indicate that soil washing technology is limited to significantly higher concentrations of radiological contamination. Therefore, the proposed final remediation levels for Operable Unit 4 reflect a future land use consistent with the Site-Wide Characterization Report and the Comprehensive Response Action Risk Evaluation.

However, additional input from the Fernald Citizen Task Force and the public is essential before making final recommendations on land use from a site-wide perspective. The Operable Unit 4 soil final remediation levels will be re-examined by the Operable Unit 5 Feasibility Study Report and Record of decision based upon available Operable Unit 5 Feasibility Study conclusions, recommendations from the Fernald Citizen Task Force, and further public comment. If found to be necessary, the Operable Unit 5 Record of Decision will modify the Operable Unit 4 final remediation levels downward to ensure protectiveness of human health and the environment.

Above-Grade Disposal Vault

The material generated by this alternative would be placed directly into an on-property above-grade disposal vault without packaging. It should be recognized that the chemical and radiological properties of the Subunit C wastes are significantly different than the residues being addressed under Subunits A and B. To accommodate these differences, a number of the proposed design features of the representative disposal concept, the above-grade vault, may not be needed to ensure protectiveness. Features that would not be needed include intrusion and radon barriers under 10 CFR § 61 as well as waste packaging. The configuration of any on-property disposal facility would be initialized through the remedial design process. For purposes of this FS, the on-property disposal alternatives for Subunit C waste assume that no intrusion or radon barriers would be needed in order to be protective and that the waste will be disposed in bulk. This is consistent with LLW disposal

operations at numerous federal sites. Specifically, the Department of Energy's, Weldon Springs Site has employed a disposal cell design which incorporates design features similar to those developed in this alternative. In addition, on-site bulk disposal has been implemented at the Maxey Flats Disposal Site in Fleming County, Kentucky, in addition to all Uranium Mill Tailings Radiation Control Act (UMTRCA) site as well as the majority of Formerly Utilized Sites Remedial Action Projects (FUSRAP).

The proposed configuration of the above-grade disposal vault was previously identified in Figure 4-7. Each concrete vault would have a service opening to allow access for the placement of waste. The floor of the vault would have a minimum slope of two percent to facilitate any leachate collection and monitoring. The roof of the vault would also have a minimum slope of two percent to allow storm water runoff. As each vault is filled to capacity, all equipment and temporary utilities would be removed and the vault sealed before the multimedia cap is installed.

The vault would be constructed on a reinforced concrete mat with a minimum thickness of 0.3m (1 ft). The perimeter of the mat would be bounded by a curb with embedded pipes that are connected to the manholes of the underlying multimedia LC/DS to facilitate the collection of any contaminated leachate after final closure. The LC/DS would be composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the groundwater and the Great Miami Aquifer.

The soil of the composite liners would be constructed of a natural, compacted clay with a maximum permeability of $1x10^{-7}$ cm/s. The layers would be a minimum of 0.9 m (3 ft) thick. To improve the performance of the clay, a geomembrane of at least 40 mil in thickness would be placed over the surface of the clay, which has been smooth-rolled to ensure good hydraulic contact. To minimize damage to the geomembrane during construction, a sand layer with a minimum thickness of 20 cm (8 in) would be placed over the geomembranes of the LC/DS.

Between the composite soil liners, drainage layers would be installed to intercept any leachate that may be generated. The drainage layers would be a minimum of 0.6 m (2 ft) each in thickness. The upper 0.3 m (1 ft) of each layer would be a graded natural aggregate and the lower 0.3 m (1 ft) would be a narrow-graded medium aggregate to provide a minimum permeability of $1x10^{-2}$ cm/s. A geotextile membrane would be placed on the upper surface of each drainage layer to prevent the migration of fines from overlying material.

During placement of the aggregate, 10 cm (4 in.) diameter pipes would be installed within the aggregate to collect and direct any leachate to a series of manholes lined with HDPE. The leachate would then be removed from the manholes for treatment at the FEMP AWWT facility. For purposes of this FS, it has been assumed that active maintenance and pumping of the leachate collection system would continue for a period of 30 years. The thirty year time period was adopted since it is considered to best represent the time required to achieve site-wide remedial action objectives for the five FEMP operable units. It is anticipated, however, that active maintenance of the leachate collection system would not be required for the 30 year timeframe due to the design of the capping system (i.e., infiltration barriers). In the unlikely event active maintenance of the leachate collection system is required beyond the end of active on-site remedial activities (i.e., 30 years) to ensure protection of human health or the environment, such active maintenance would be continued until such time as deemed unnecessary by DOE and EPA.

The multimedia cap may be constructed of five distinct layers of media that would provide final closure of the vault. The upper layer of the multimedia cap would be a vegetative layer consisting of topsoil with a hardy, shallow-root grass cover. This layer would be noncompacted and have a minimum thickness of 0.6 m (2 ft) to support plant growth. The vegetative layer would inhibit erosion and allow runoff during storm events. A drainage layer would be beneath the vegetative layer to intercept infiltrating precipitation. Within the layer would be of 0.3 m (1 ft) of pea gravel that would provide a minimum permeability of $1 \times 10^{-2}$ cm/s. A geotextile membrane would be placed between the vegetative layer and the top surface of the drainage layer to prevent the migration of fines from the vegetative layer to the drainage layer.

A layer of cobblestone with a minimum thickness of 0.7 m (2.3 ft) may be provided beneath the peagravel to serve as an inadvertent intrusion barrier and would also serve as part of the drainage layer. Beneath the cobblestone would be a composite soil liner to impede downward moisture movement from the drainage layer. The soil of this layer would be natural, compacted clay with a maximum permeability of $1 \times 10^{-7}$ cm/s. The layer would be 0.9 m (3 ft) thick to ensure the isolation of the disposal containers (Subunits A and B only). A geomembrane of at least 40 mil in thickness would be placed over the surface of the clay, which is smooth-rolled to ensure good hydraulic contact and thus improve the performance of the clay. To minimize slippage of the overlying layers due to interfacial shearing characteristics, the geomembrane would be textured. Similar to the composite soil liners of the LC/DS, a layer of sand would be placed over the geomembrane to minimize damage during construction.

The foundation of the multimedia cap would be clean, compacted soil. This layer would be a minimum of 15 cm (6 in.) to a maximum of 0.6 m (2 ft) in thickness above the vaults. All general and granular material, as well as clay, is regionally available. The spatial requirement for the cap is estimated to be approximately 4.7 ha (11.6 acres). Alternative 2C would include the placement of markers to define waste disposal areas, the use of deed restrictions, and the provision of continued federal ownership of the property to preclude drilling or residential development.

Under continued federal ownership, the government is assumed to discontinue active access controls and site maintenance following completion of remedial activities and attainment of site-wide remedial action objectives. While the federal government would not maintain a continued site presence after completion of site cleanup, the government would continue to exercise its rights of ownership to preclude site development. Monitoring would continue, as necessary, to support CERCLA five-year reviews. The monitoring network would include wells located appropriately to evaluate the effectiveness of the above-grade disposal facility in ensuring the continued protection of human health and the environment.

4.4.2.1 Overall Protection of Human Health and the Environment

Alternative 2C meets the remedial action objectives for Subunit C. The proposed soil remediation levels used to determine which soils to remove for placement in the on-property disposal facility are based on protection of an expanded trespasser. As previously identified, the proposed soil remediation levels were modified, as necessary, to ensure protection of the intruder in the event institutional controls are lost. Implementation of this alternative would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. To meet these objectives, three response actions would be used: 1) removal of materials, 2) containment in an on- property disposal vault and the placement of clean cover over residual contaminated subsurface soils, 3) and implementation of institutional control measures.

Contaminated soils would be excavated to achieve compliance with proposed remediation levels. The excavated soils would then be disposed. Areas of removed soil would be backfilled with clean soil and graded to protect against erosion of remaining lightly contaminated soil, causing dust or runoff.

Containment of the removed contaminated soil and contaminated D&D debris in an on-property capped disposal vault would provide control of contaminant migration to the underlying aquifer. The

disposal vault would also prevent direct access to the contaminated soil and debris. The facility design would include an intruder barrier, and permanent markings would be used to deter purposeful or inadvertent human intrusion through the facility's engineered protective features. The disposal vault would be designed for a life of 1,000 years. The vault would be designed to preclude the need for long-term active maintenance.

The design features of the vault, including the infiltration barriers, are anticipated to eliminate the need for the active operation, maintenance, and monitoring of the leachate collection system. The leachate system would be monitored, with collected waters pumped (if necessary) during the active operational phase of the sites remedial actions (i.e., approximately 30 years). It is anticipated that such operation and maintenance of the leachate collection system would not be warranted (i.e., due to lack of leachate) beyond that timeframe.

As discussed above, long-term effectiveness is uncertain because of eventual degradation of the facility cap and leachate collection system, leading to an increased rate of infiltration, leachate formation, and release. Fate and transport modeling using conservative assumptions supports the conclusion that long-term protection of human health and the environment would still be maintained. Similar disposal facility designs are being employed under federal programs for the long-term containment of similar waste.

Institutional control measures would be used to supplement the removal and containment actions to provide additional assurance that overall protection would be maintained as engineered components degrade. Also, institutional controls would limit access to the remaining contaminated soil that is covered by clean soil. The controls include long-term federal government ownership of the FEMP site. This ownership would preclude future on-property residential and farming uses, which could potentially result in exposure to contaminated soil or disposed material.

To comply with ORC 3734-02, hazardous and solid waste disposal facilities must include a protective covenant to restrict future mining, drilling, and residential use of the areas where waste was managed. A deed restriction would be placed on the FEMP site property deed detailing these prohibitions. The uncertainty associated with very long-term institutional control periods include a possible loss of federal ownership and the loss of or lack of administration of the property records containing the deed restrictions. Exposure to the inadvertent intruder from the residuals in the soil or the disposed waste

would not be expected to be significant due to the low concentrations of COCs in the wastes and soils.

There are no unacceptable short-term risks from Alternative 2C. There are increased worker risks over no action due to radiation and dust exposure during removal and packaging. However, through implementation of a worker health and safety plan in compliance with 29 CFR § 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE Orders.

4.4.2.2 Compliance with ARARs

ARAR compliance for Alternative 2C is similar to that for Alternative 2B/Vit with the exception that Alternative 2C concerns the remediation of demolition debris and soil residuals. This remediation waste associated with Subunit C poses fewer hazards than the more concentrated material associated with Subunits A and B. As a result, the proposed on-property disposal facility in this alternative would require less stringent design and engineering features to meet the requirements of 40 CFR § 192. The discussion of the compliance of this alternative would be similar to that presented in Section 4.3.2.2.

Chemical-Specific ARAR/TBCs

Alternative 2C would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those standards associated with the SDWA drinking water MCLs and MCLGs; the RCRA solid and hazardous waste groundwater protection requirements; the UMTRCA and CAA radon-222 airborne release requirements; and other radionuclide release limits for water and air and their resulting doses to the public under the CAA and DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 2C. Additional documentation of compliance of Alternative 2C with the identified ARARs is presented in Appendix F (Table F.2-4).

Location-Specific ARAR/TBCs

Alternative 2C would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, endangered species and their habitats, cultural resources, and the sole-source aquifer underlying the FEMP site. As was noted, compliance with the OAC 3745-27-07 prohibition on the location a solid waste disposal facility over a sole-source aquifer would be based on demonstrating attainment of the substantive technical criteria for an exemption to this requirement as

discussed in Section 4.2.2.2. Since the final location of the disposal vault would be similar to that for Alternative 2A/Vit, the information regarding the technical demonstration to meet the exemption would also be similar to that alternative.

Action-Specific ARARs

Alternative 2C would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. Included would be those standards associated with the design and operation of the multi-barrier above-grade disposal vault system that meets the principal requirements of RCRA for closure of a hazardous waste landfill (40 CFR § 264.310) and UMTRCA under 40 CFR § 192 Subpart A. Because the material associated with Subunit C poses fewer hazards than the material in Subunit B, the disposal facility proposed for Subunit C material would require less stringent engineering design to meet the requirements established in 40 CFR § 192.

As described in Alternative 2B/Vit, residues from demolition of the silos, contaminated media and debris, and any hazardous or solid wastes generated during the remediation of Operable Unit 4 may be managed in a designated CAMU under 40 CFR § Subpart S, either while undergoing decontamination, or during on-site disposal of the material. TUs, as provided in 40 CFR § 264 Subpart S, and/or containment buildings, as provided in 40 CFR § Subpart DD, might also be used under this alternative for the treatment or storage of remediation waste, including media and debris which may be contaminated with a hazardous waste. Management of the remediation wastes in these units would be in accordance with all pertinent ARARs and TBCs, including compliance with the substantive hazardous waste landfill closure requirements for residuals, and the closure performance standard of 40 CFR § 264.111 as necessary, to ensure protection of human health and the environment from operation of these units.

This alternative would comply with requirements of the CAA (for releases of dust and non-radioactive particulates) and the CWA (for storm water runoff, BMPs and dredge and fill activities). This alternative would comply with the RCRA TSD requirements, including the groundwater monitoring requirements for RCRA solid and hazardous waste disposal facilities. This alternative would also comply with NEPA (for environmental documentation), the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity, and the UMTRCA guidance for control and cleanup of residual radioactive material.

Compliance with requirements under the CAA, CWA, and RCRA would be met by incorporating sound engineering features, BMPs, and ALARA principles into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 2C would comply with the identified ARARs is presented in Appendices D and F (Table F.2-4).

4.4.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2C reduces the residual risk, under the continued federal ownership of land, to viable receptors (off-property resident farmer, trespassing child, and expanded trespasser) to a HI of less than 0.3 and an ILCR of less than $10^{-5}$. The basis of the risk evaluation is presented in Appendix D. The primary concerns associated with soil in Operable Unit 4 is leachability. An additional concern is exposure to the remaining contaminated surface soil through inhalation of particles or incidental ingestion. These concerns would be mitigated by the removal of the contaminated soils in order to achieve PRLs, backfilling of the excavated areas with suitable backfill soils, isolation of the contaminated soil in a disposal vault, and the application of institutional controls.

The disposal vault contributes to a significant reduction in leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude the establishment of an on-property residence or farm. In the absence of institutional controls, the vault would continue to provide adequate protection to the on-property farmer and expanded trespasser. Risk assessment results for the RME on-property farmer are $1.7 \times 10^{-3}$ and indicate that residual risks would be unacceptable with a loss of institutional controls.

Because Alternative 2C includes the on-property disposal of debris and soil and because some residual contamination in the soil would remain, the five-year CERCLA review process to ensure continued performance of the disposal system would be part of this alternative.

Adequacy and Reliability of Controls

As previously identified, the projected residual excess cancer risk attributable to Alternative 2C to viable receptors is less than $10^{-5}$. The on-property disposal vault uses proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes and low-level radioactive waste under both DOE and NRC

programs. Fate and transport modeling to assess the most likely release mechanism under degradation of the facility (leaching) was completed. The results were based on the assumption that components of the system slightly degrade over 1,000 years and that infiltration rates (and consequently exfiltration rates) increase to 1.3 cm/yr (based on the HELP model). Also, the leachability of the soil contaminants was based on geochemical information. Under these assumptions, the leaching of contaminants would not pose a risk to off-site receptors. Even if these input parameters were increased to 15 cm/yr (highest possible with no infiltration barrier) the result would not change. Comparable modeling of leaching from the residual soils (assuming an infiltration rate of 15 cm/yr) also illustrated that there would be no risk to the off-site resident from the soil left behind.

Dismantling and decontamination are proven technologies that have been reliably applied at almost all DOE facilities. Decontamination activities would be conducted to separate the contaminated material from clean material which might be released, thereby minimizing the amount of waste to be disposed.

The combination of institutional controls, soil removal to FRLs protective of a expanded trespasser, and covering excavated areas with clean soil would provide protection to the expanded trespasser and would keep an on-property residence from being established. Therefore, surface exposure pathways are adequately and reliably controlled. In the event institutional controls were lost, the residual risk to the on-property resident farmer would be unacceptable and expected to be less than $1.7 \times 10^{-3}$ and a HI of 15.

Consistent with DOE Order 5400.5, 40 CFR § 264.114, and 40 CFR § 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required five-year CERCLA review. As a result of the findings of the review, there is a potential that the disposal system may require maintenance, modification, or replacement. The risks associated with this replacement would be generally limited to direct radiation to on-property workers. Consistent with 10 CFR § 835, these potential exposures would be maintained ALARA and within regulatory limits.

Long-Term Environmental Impacts

The nature of the long-term impacts after remediation activities associated with the implementation of Alternative 2C are the same as those associated with Alternative 2A/Vit (see Section 4.2.2.3). The following impact analysis for Alternative 2C is a summary.

Soil and Geology

Construction of the disposal vault would result in the permanent disruption of 4.7 ha (11.6 acres) of land. The disposal configuration would prevent erosion of waste material that could result in surface soil contamination and would prevent leaching that would contaminate subsurface soil. Uncontaminated soil would be used as fill. Borrow pit soil for construction would be obtained from clearing and grubbing and clean berm soil.

The regional geology of the FEMP site and surrounding area would not be affected by implementation of Alternative 2C. Geological conditions are important in terms of site suitability for construction of an on-property disposal vault. The facility would incorporate appropriate protection against leaching and seismic damage.

Water Quality and Hydrology

A system to monitor long-term water quality would be implemented by installing monitoring wells around the perimeter of the disposal vault. No significant long-term hydrological impacts to the surrounding area are expected to result from changes to the site. However, after 1,000 years, some degradation could occur. Run-on and runoff controls would be used at the disposal vault, and the remaining areas of the site would be regraded to the surrounding grade and would discharge surface runoff to existing on-property drainageways.

Air Quality

Following implementation of Alternative 2C, the air quality at the FEMP site would be similar to current conditions. There would be no long-term impacts on air because disturbed areas would be revegetated limiting dust production.

Biotic Resources

Long-term impacts may include displacement of potential threatened and endangered species habitat. No critical habitat for threatened and endangered species has been identified in areas to be impacted by Alternative 2C activities. However, potential habitat for threatened and endangered species could exist in the disposal area. State threatened and endangered species observed are identified in Alternative 2A/Vit (Section 4.2.2.3).

The long-term residual risks to ecological receptors associated with Operable Unit 4 would be minimized by the implementation of this alternative. The primary pathways of concern associated

with ecological receptors coming in contact with Operable Unit 4 include surface soil (e.g., ingestion, plant uptake) and runoff of surface soil to surface water bodies (e.g., exposures to aquatic habitat and ingestion of surface water). This alternative involves the removal of the top six inches from the entire operable unit and replacement with clean fill. Therefore, ecological receptors will have very minimal contact with residual contaminants. The residual contaminants of concern remaining in soil after the remedial action would be uranium in the subsurface soil at levels of approximately 60 pCi/g. Therefore, residual contaminants (i.e., uranium) would not pose a risk to ecological receptors within Operable Unit 4 due to their limited ability to enter the surface soil and surface water pathway.

Wetlands and Floodplains

A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and received COE approval in August 1993. The delineation identified approximately 12 ha (29 acres) of jurisdictional wetlands in the northern part of the site. Efforts would be made to site the disposal vault in areas not containing jurisdictional wetlands. However, for NEPA purposes it was assumed that the citing of the facility would result in the loss of approximately 0.2 ha (0.5 acre) of drainage ditch wetlands.

The 100- and 500-yr Paddys Run floodplains would not be permanently altered as a result of implementing Alternative 2C.

Socioeconomics and Land Use

The area of the disposal vault is estimated at less than 0.7 percent of the site. However, the presence of the permanent disposal vault would result in future limitations for use of the site. No change would be expected in the local population growth, nearby industrial and commercial operations, or noise level. The net long-term impact of Alternative 2C on these socioeconomics is expected to be positive because the soil and debris would be isolated and controlled. However, aesthetic impacts would occur as a consequence of on-property material disposal.

Cultural Resources

An archaeological survey would be performed for the non-controlled areas not previously disturbed that could be impacted by Alternative 2C. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment 5205

This alternative does not include treatment of the contaminated silo structures, processing facility debris, berm material, or soils; therefore, no reduction in toxicity, mobility, or volume would be achieved. However, pending the ROD of Operable Unit 3, some additional treatment of this material may occur.

As a part of remedial action work plan preparation, decontamination procedures may be developed, which may also reduce the volume of material requiring management as contaminated waste. Following decontamination, it is conceivable that some impermeable materials might be suitable for free release and could be reused, recycled, or disposed in a solid waste landfill, providing they meet established free release criteria (DOE Order 5400.5) for radioactive contamination and do not exhibit a characteristic for hazardous waste.

4.4.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls and access controls, Alternative 2C would be protective of the community during implementation.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to direct radiation from the debris and soil or dust. In addition to the engineering controls (such as dust suppression) that would be implemented to limit the release of contaminants, access controls during remediation would be used. Through the use of fences and guards, access to the materials by the public would be limited. Access controls are effective, especially in the short term. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 2C is effective in protecting the community in the short term.

Protection of Workers During Remedial Action

There are no unacceptable risks to workers as a result of implementation of Alternative 2C. This alternative involves the handling of contaminated debris and soils; therefore, there are several potential exposure pathways for workers. Both the release of dust particles and exposure to direct radiation from the soil and materials could cause a risk to workers. It has been estimated that appropriate protection to a remediation worker can be taken so there is no risk increase. However,

for the nonremediation worker, the potential exists for any alternative involving soil removal to be associated with an excess cancer risk level of 2.9 x $10^{-7}$ (Appendix D).

There are safety issues associated with the removal and demolition process as there may be accidents. Without considering the nature of the activity, it has been estimated, based solely on labor hours, that Alternative 2C could have 4.5 injuries and 0.066 deaths during remediation activities. All remediation activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR § 1910.120(b)(4). Training and procedures would assure that worker exposure would be ALARA.

Short-Term Environmental Impacts

Short-term impacts for Alternative 2C would be basically the same as those associated with Alternative 2A/Vit. Therefore, the following discussion is provided at a summary level.

Soil and Geology

Soil disturbance during implementation of Alternative 2C would result primarily from preparation of the on-property disposal vault; construction of access roads, decontamination/packaging area, equipment staging area, and support areas; excavation of contaminated areas and borrow pit areas; demolition of the silos, and demolition of the processing facility. Construction and excavation activities could disturb approximately 5.7 ha (14.1 acres) of the site.

Construction and excavation activities at the site could result in the erosion of exposed soil areas. Engineered controls such as straw bales and berms could be used to minimize potential erosion. Following completion of construction and excavation activities, disturbed areas would be filled with clean backfill and revegetated with native grasses.

Water Quality and Hydrology

Through erosion control and dust suppression, contaminants disturbed during remediation would not be transported to adjacent surface water bodies. Surface water near the site would be monitored during remediation in accordance with the existing water discharge permit to assess potential impacts to the water from remediation.

Remediation would not increase the release of contaminants to the groundwater since the most contaminated material would be removed. However, the existing monitoring network on the FEMP

site would be sampled for short-term monitoring of groundwater elevations and concentrations during source removal.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are two potential sources of air emissions: dust from construction and earth-moving activities heavy equipment exhaust. The exhaust emissions from heavy equipment are not expected to impact air quality.

Dust would be controlled as discussed in the soil section. With the appropriate dust suppression, excavation activities are not expected to negatively impact the air quality.

Biotic Resources

The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 2C would result primarily from activities associated with 1) construction of the on-property disposal vault and other facilities, 2) excavation of berm soils, and 3) installation of electric power lines, transformers, process water and sewer lines, and material slurry transfer lines. Local biota (wildlife and wildlife habitat) would be temporarily displaced along with potential threatened and endangered species habitat. However, these impacts would be temporary and permanent habitat losses are expected to be minor.

There also is the potential for impact to biota from contaminant releases such as through erosion and dust emissions. As discussed in previous short-term effectiveness discussions, the releases would be minimized through engineering controls such as erosion control and dust suppression. There should be no negative exposure impact on biota during implementation of Alternative 2C.

Wetlands and Floodplains

A site-wide wetlands delineation has identified several areas of wetlands in or adjacent to areas that could be impacted by the implementation of Alternative 2C. Wetlands north and south of the material treatment facility are not expected to be affected; however, for NEPA purposes it was assumed that there would be disturbance of wetlands during the construction of the on-property disposal vault. Approximately 0.2 ha (0.5 acre) of the drainage ditch wetlands would be affected. Engineering controls through the site activities, such as silt fences and straw bales, would be used to control the migration of eroded soil to wetland areas.

The 100- and 500-year Paddys Run floodplains are located immediately west of Silos 1 and 2. Alternative 2C activities are not planned to occur within the floodplains, and contaminant migration during remediation would be controlled through engineered erosion controls to minimize impacts on the floodplains.

Socioeconomics and Land Use

Short-term impacts to socioeconomics and land use would be minor. Employment needed to implement Alternative 2C would require 48 workers and approximately 56 one-way truck trips per working day. The purpose of these trucks is to transport materials required for the construction and support of remediation facilities, as required. It is assumed for this analysis that many of the workers needed for the remedial activities already work at the site; consequently, the relocation of additional workers to the area would not have a significant impact on public facilities within the CMSA.

The collective revenue for the CMSA would increase by approximately four percent. The additional expenditures would be spent over two years of implementation. Therefore, only minor economic impacts are expected for the CMSA as a result of implementing Alternative 2C.

Cultural Resources

Any areas determined to be of significance resulting from a cultural resources review would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA.

Duration of Remedial Activities

Approximately three months would be required for site preparation; 15 months to demolish, and decontaminate the silo structures, treatment facility, surface soil, subsurface soil, process piping, and decant sump tank. Demobilization activities would extend the duration of the alternative to two years. During this time frame, the disposal vault would be constructed and capped. Physical, substantial, and continuous on-property activities would be initiated within 15 months after the ROD is approved by EPA.

4.4.2.6 Implementability

Technical Feasibility

Silo decontamination with a remotely controlled device is not standard; however, such devices are commonly used and should not be difficult to implement. Silo demolition, process facility

decontamination, and the construction of the above-grade disposal vault are standard civil engineering technologies commonly used throughout industry.

The technologies in Alternative 2C have been widely demonstrated and provided significant and reliable isolation of the material from the environment. Some of the uncertainties related to the alternative would include the availability of on-property borrow material and the amount of time needed to acquire necessary permits. The technologies would involve the use of several contractors. All the technologies would have more than one contractor available for competitive bidding.

The construction of the cap would require delivery of various types of soil including clay. Future remediation requirements could involve above-grade disposal vault repair or replacement or retrieval of the contents of the above-grade disposal vault. Repair or replacement of the cap or LC/DS would involve technologies similar to the original construction and would not be difficult. The contents could be accessed by digging out the multimedia cap and retrieving the waste material.

The effectiveness of the alternative would be monitored to meet the needs of CERCLA five-year review. Visual inspection and groundwater sampling would measure the effectiveness of the alterative in meeting the required conditions. Detection of contaminants in the groundwater or visual abnormalities in the multimedia cap would initiate actions to mitigate the problem.

Administrative Feasibility

No permits or licenses would be required, but permit information summary packages may be required. Coordination with OEPA would be necessary to demonstrate compliance with substantive technical requirements to construct the disposal vault.

Availability of Services and Materials

Components involved in this alternative include: site preparation; silo decontamination and demolition; vacuum scabbling; tank piping; trench removal; contaminated soil excavation; process facility demolition; construction of an above-grade disposal vault; installation of an LC/DS; and construction of the multimedia cap.

Each of these operations requires standard and widely-available construction equipment, materials, and services. No specialty equipment or services would be required and no specialty labor skills

would be necessary for the majority of activities. Specialized equipment and trained personnel would be required to install the vault membranes and liners.

4.4.2.7 Cost

The total present worth cost of Alternative 2C is $34.3 Million. A detailed breakdown of the cost is provided in Table 4-14.

Capital Cost

The capital cost is associated with silo demolition and removal, Subunits A and B processing facilities and equipment, D&D, and construction of the above-grade disposal vault. A breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-14. More detailed information is provided in Appendix E.

The largest component of the capital cost is the disposal vault. This represents approximately 63 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Demolition and Removal

This cost component involves the decontamination and demolition of Silos 1, 2, 3, and 4 and the waste processing facility. Costs were estimated based on the following:

- Site preparation would include clearing and grubbing of approximately 4.7 ha (11.6 acres) for the above-grade disposal vault. A haul road approximately 0.32 km (0.8 mile) would be constructed.
- Waste would be disposed in bulk, directly into the disposal cell.
- The material would include contaminated silo rubble, the existing RTS of Silos 1 and 2, surface and subsurface soils, drum handling pad, the decant sump tank, process piping and trenches, and the waste processing facilities, including the equipment superstructure.
- All of Silos 1, 2, 3, and 4 concrete [2040 $m^3$ (2670 $yd^3$)] would be considered as contaminated and require disposal.
- Approximately 790 m (2,600 ft) of process piping in the process trenches would be cut into manageable sections but not decontaminated prior to disposal.

TABLE 4–14

COST ESTIMATE FOR ALTERNATIVE 2C

| ALTERNATIVE 2C: DEMOLITION, REMOVAL, ON–PROPERTY DISPOSAL | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| DEMOLITION & REMOVAL | $3,980,300 | $5,977,100 | $9,957,400 |
| DISPOSAL VAULT | $6,410,200 | $10,914,800 | $17,325,000 |
| TOTAL CAPITAL | $10,390,500 | $16,891,900 | $27,282,400 |
| RISK BUDGET (11.0%) | $1,143,000 | $1,858,100 | $3,001,100 |
| SUBTOTAL | $11,533,500 | $18,750,000 | $30,283,500 |
| CONTINGENCY (20.0%) | $2,306,700 | $3,750,000 | $6,056,700 |
| TOTAL ESTIMATED INSTALLED COST | $13,840,200 | $22,500,000 | $36,340,200 |
| OPERATION AND MAINTENANCE (O&M) COSTS | | | |
| POST–REMEDIATION | | | $3,567,000 |
| TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%) | | | $34,327,000 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 2
O&M during remediation (years): 0
Post–remediation O&M (years): 30

- A backhoe-mounted pneumatic hammer would be used to fracture the concrete piping trenches. Estimated volume of concrete from trenches, the decant sump tank, drum handling building pad, sump lift station, and the process piping and RTS would be 300m$^3$ (400 yd$^3$).

- Subsurface soils beneath Silos 1 and 2 would be excavated to a depth of approximately 1.5 m (5 ft) and laterally to the toe of the berm. Contaminated pockets of subsurface soils would also be excavated. Subsurface soil quantities were estimated to be 11,198 m$^3$ (14,646 yd$^3$). Berm soil [8060 m$^3$ (10,540 yd$^3$)] and surface soil [3400 m$^3$ (4,440 yd$^3$)] would also be excavated.

- Assuming a bulking factor of 1.3 for all soils and a 10 percent void volume for all materials, approximately 34,956 m$^3$ (1,235,193 ft$^3$) of material requires disposal.

Disposal Vault

The cost of the disposal vault was estimated as follows:

- Cost for the on-property, above-grade disposal vault was estimated at a unit cost of $751 m$^3$ ($574/yd$^3$).

- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 m$^3$ (120,000 ft$^3$) of material. As additional disposal volume space is required, additional modular cells are added for cost estimating purposes. Cell numbers were estimated by rounding up to the nearest whole number.

- The size of the disposal vault was based on assuming a cell size of 3400 m$^3$ (120,000 ft$^3$), 34,956 m$^3$ (1,235,193 ft$^3$) of material. Thus, 11 cells would be required [7664 m$^2$ (82,500 ft$^2$) vault footprint area].

- The design of the vault includes a multimedia cap, liner, and LC/DS. No intrusion or radon barriers would be included in the design.

- The vault would cover approximately 4.7 ha (11.6 acres) of property.

O&M Cost

Long-term O&M costs are $3.6 Million (not considering present worth). Long-term O&M includes maintenance and monitoring which would be performed until the FEMP site-wide remedial action objectives are met, i.e., approximately 30 years. Monitoring would support the required CERCLA five-year review.

4.4.2.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 2C. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this

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modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.4.2.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 2C. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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Adequacy and Reliability of Controls

The reliability of the D&D activities and soil removal actions of Alternative 3C.2 are the same as for Alternative 2C. The reliability of a permitted commercial facility in an arid environment is essentially the same as the NTS facility (Alternative 3C.1) since both are in an arid environment with favorable hydrogeologic characteristics and currently manage low-level disposal of radioactive waste. If there is a release at the permitted commercial facility, corrective action measures would be implemented. Continued monitoring is typically a requirement of the facility's permit.

Long-Term Environmental Impacts

The long-term environmental impacts of removal and treatment actions of Alternative 3C.2 are the same as for Alternative 2C and 3C.1. The discussion presented below focuses on the impacts to a permitted commercial facility located in Utah.

Soil and Geology

Soil at the commercial facility would be permanently disturbed for the disposal of the Subunit C materials. Borrow material may be required for the construction of additional disposal cells at the facility. The commercial facility in Utah would be situated in an hydrogeologic, demographic, ecologic, and climatic setting favorable to radioactive and hazardous waste disposal.

Water Quality and Hydrology

The disposal of contaminated soil and debris at a commercial facility in an arid location under this alternative is not expected to have significant impacts on water quality or hydrology. Typically, there are no continuously flowing streams in arid regions. Stream beds carry water only during unusually intense or persistent rains. Rainfall (which averages 1 cm [0.4 in] per year) infiltrates quickly into moisture deficient soil. These parameters, coupled with very suitable geology, would help minimize long-term impacts to water quality. Engineered controls (capping) and ongoing monitoring activities would also be used to control and minimize water quality impacts.

Air Quality

Following implementation of Alternative 3C.2, the air quality at the commercial disposal site would be similar to current conditions. There would be no long-term impacts on air because of the depth of the cap on the disposal facility and because disturbed areas would be revegetated.

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Biotic Resources

The disposal activities at the commercial disposal facility related to Alternative 3C.2 are not expected to impact the habitat of endangered species or displace any other species since approval for locating the commercial facility would mean that stringent environmental siting requirements would already have been met.

Wetlands and Floodplains

Alternative 3C.2 material would not be disposed within a wetland or floodplain. As with FEMP on-property disposal considerations, the commercial disposal facility would be bound by the same requirements to avoid disposal of the Operable Unit 4 material in a wetland or floodplain.

Socioeconomics and Land Use

Selection of a commercial facility in an arid region means low population density and limited land use potential. The off-site areas adjacent to the facility would be predominantly rural, and aesthetic impacts would not be expected to change. Material disposal activities (associated with this alternative) would not impact socioeconomics or land use.

Cultural Resources

An archaeological survey would be performed for the non-controlled areas not previously disturbed that could be impacted by Alternative 3C.2. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, SHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site or the commercial facility.

4.4.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative would not include treatment of the contaminated silo structures, processing facility debris, berm material, or soil; therefore, no reduction in toxicity, mobility, or volume would be achieved. However, pending the ROD for Operable Unit 3, some additional treatment of this material may occur. As a part of remedial action work plan preparation, decontamination procedures may be developed, which may also reduce the volume of material requiring management as contaminated waste. Following decontamination, it is conceivable that some impermeable materials might be suitable for free release and could be reused, recycled, or disposed in a solid waste landfill,

providing they meet established free release criteria (DOE 5400.5) for radioactive contamination and do not exhibit a characteristic for hazardous wastes.

4.4.4.5 Short-Term Effectiveness

Protection of the Community during Remedial Action

Alternative 3C.2 would provide essentially the same level of short-term protection of the community as Alternative 3C.1. However, short-term effectiveness would be slightly greater for 3C.2 than 3C.1 because the additional waste handling in 3C.1 is not needed. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that both Alternatives 3C.1 and 3C.2 are effective in protecting the community in the short-term.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal, D&D, and off-site disposal are the same for Alternatives 3C.2 as for 3C.1 (Section 4.4.2.5).

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal, D&D, and loading of materials under Alternative 3C.2 are the same as those for Alternative 2C (Section 4.4.2.5). Approximately one, one-way truck trip per working day would be required.

Duration of Remedial Activities

Remedial actions for Alternative 3C.2 are expected to require two years to complete. Physical, substantial, and continuous on-property activities could be initiated within 15 months after the ROD is approved by EPA.

4.4.4.6 Implementability

Technical Feasibility

All activities that would be conducted for Alternative 3C.2 are standard construction techniques that are technically feasible and reliable and are the same (except for disposal location) as Alternative 3C.1 (Section 4.4.3.6).

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Administrative Feasibility

The administrative feasibility of Alternative 3C.2 would involve a variance to DOE policy for disposal at a commercial facility. The public and regulatory agencies from the states located within the transportation route from the FEMP site to the permitted commercial disposal facility might oppose transport; thus, some coordination would be required to solicit concurrence.

Availability of Services and Materials

The availability of services and materials would be the same as that described in Alternative 3C.1 except for the availability of the disposal facility.

4.4.4.7 Cost

The total present worth cost of Alternative 3C.2 is $44 Million. A detailed breakdown of the cost is provided in Table 4-16.

Capital Cost

The capital cost is associated with silo demolition and removal, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-16. More detailed information is provided in Appendix E.

This alternative includes cost components identical to Alternative 2C (Section 4.4.2.7). The largest component of the capital cost is disposal. This represents approximately 51 percent of the total capital costs. The second largest element of the capital costs (27 percent) is the demolition and removal. Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Demolition and Removal

This component is the same as described for Alternative 2C.

Transportation

This cost item includes transportation of the material, and is based on the following assumptions:

- Material would be transported in bulk by rail to the disposal facility.
- Rail costs were estimated using a unit rate of $2.47 per railcar per km ($3.97 per railcar per mi). Railcars were assumed to weigh 8165 kg (180,000 lbs) each.

TABLE 4–16

COST ESTIMATE FOR ALTERNATIVE 3C.2

| ALTERNATIVE 3C.2: SILO DEMOLITION, REMOVAL, OFF–SITE DISPOSAL AT PERMITTED COMMERCIAL DISPOSAL FACILITY | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| DEMOLITION & REMOVAL | $3,980,300 | $5,977,100 | $9,957,400 |
| TRANSPORTATION | $8,039,200 | | $8,039,200 |
| DISPOSAL | $18,526,700 | | $18,526,700 |
| TOTAL CAPITAL | $30,546,200 | $5,977,100 | $36,523,300 |
| RISK BUDGET (11.0%) | $3,360,100 | $657,500 | $4,017,600 |
| SUBTOTAL | $33,906,300 | $6,634,600 | $40,540,900 |
| CONTINGENCY (20.0%) | $6,781,300 | $1,326,900 | $8,108,200 |
| TOTAL ESTIMATED INSTALLED COST | $40,687,600 | $7,961,500 | $48,649,100 |
| TOTAL PRESENT WORTH COST (CAPITAL @ 7%) | | | $43,978,800 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 2
O&M during remediation (years): 0
Post–remediation O&M (years): 0

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Disposal

- Material would be disposed at a permitted commercial facility.
- Unit disposal cost was estimated based upon a bulk rate of $530/m^3$ ($15/ft^3$).

O&M cost

There are no short-term or long-term O&M costs associated with this alternative.

4.4.4.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 3C.2. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.4.4.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 3C.2. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

## 4.5 MONITORING AND MITIGATIVE MEASURES

Monitoring and mitigation measures would be used at the FEMP site during implementation of any of the action alternatives. These measures would provide a high degree of effectiveness in minimizing potential adverse impacts associated with the implementation of the alternatives. Depending on the alternative selected, DOE would prepare a Mitigation Action Plan (MAP) to track mitigation commitments made in the ROD for this remedial action, in accordance with DOE procedures for implementing NEPA (10 CFR § 1021). For activities related to off-site disposal, it is expected that similar measures would be implemented at the off-site facilities.

Alternatives 2A, 2B, 4B, and 2C would involve the disposal of Operable Unit 4 waste material on-property. In all cases, the appropriate design features would be engineered into the on-property disposal facilities. These features include a LC/DS, low permeability caps, and monitoring systems. Monitoring systems for groundwater would detect releases from the on-property disposal facilities, and the data would support any decisions, if required, regarding the appropriate response action to be

implemented. In addition, some loss of terrestrial habitat and wetlands could result from the construction activities and commitment of land to on-property disposal. Areas of terrestrial habitat disturbed during construction activities and not committed to on-property disposal would be revegetated. Mitigation measures would be taken to offset losses to wetland areas incurred during construction of on-property disposal facilities.

Alternatives 3A, 3B, 3C.1, and 3C.2 would require the disposal of Operable Unit 4 waste material off site. Monitoring systems would be in place at both the NTS and the selected permitted commercial facility to detect any releases from waste material. In addition, disposal facilities would be designed with the appropriate LC/DS. The implementation of specific mitigation measures to offset losses to biotic resources, wetlands, etc., would be the responsibility of the individual disposal sites.

With respect to general environmental monitoring at the FEMP site, air, surface water, and groundwater would be monitored before, during, and after remedial activities. If adverse effects are detected in any of these media, work would be stopped until the effects are controlled and/or appropriate response actions are implemented.

## 4.6 UNAVOIDABLE ADVERSE IMPACTS

A number of unavoidable adverse impacts (Table 4-17) would occur when any of the action alternatives are implemented. As stated in the alternatives and in Table 4-17, many of these impacts would only be temporary.

## 4.7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Implementing remedial action Alternatives 2A, 2B, 4B, and 2C (i.e., on-property disposal) would result in permanent commitment of on-property land for material disposal at the FEMP site. Land at NTS and the permitted commercial disposal site would be permanently committed for disposal for Alternatives 3A, 3B, 3C.1, and 3C.2.

Soil at the FEMP site and NTS would be disrupted by construction and excavation activities. Many impacts would be temporary, pending completion of remedial activities and restoration programs. The implementation of Alternatives 3A, 3B, 3C.1, and 3C.2 would temporarily disturb between 1.0 ha and 1.5 ha (2.5 and 3.5 acres) at the FEMP site (e.g., excavation and construction) and permanently disrupt approximately 4 ha (10 acres) at the NTS for each disposal facility. Alternatives

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TABLE 4-17

UNAVOIDABLE ADVERSE IMPACTS ON RESOURCES

| Affected Resource | Impact Type |
|---|---|
| Soil and Geology | Soil at the FEMP site, NTS and a commercial disposal facility would be disrupted by construction and excavation activities. Many impacts would be temporary, pending completion of remedial activities and restoration programs. The implementation of Alternatives 3A and 3B would temporarily disturb between 1 to 1.5 ha (2 to 3.5 acres) at the FEMP (e.g., excavation and construction) and permanently disrupt approximately 5 ha (10 acres) at NTS or a commercial disposal facility. Alternative 3C.2 would permanently commit approximately 5 ha (10 acres) of land for disposal at a commercial facility. Alternatives 2A, 2B, and 4B would commit 2.4 to 4.3 ha (6 to 10.6 acres). Alternative 2C would commit 4.7 ha (11.6 acres) of land at the FEMP site. All areas disturbed at the FEMP site would be regraded and revegetated. The regional geology of the FEMP site and surrounding area would not be affected by any of the alternatives. Implementation of Alternatives 3A, 3B, 3C.1 and 3C.2 would not affect the regional geology of NTS or the commercial disposal facility and surrounding areas. |
| Water Quality and Hydrology | Short-term impacts (e.g., release of sediment and fugitive dust) on water quality and hydrology would be minimal for all alternatives. Several alternatives would use regrading and revegetation around the silos to minimize potential water quality impacts. Institutional actions implemented around disposal facilities at the FEMP site (Alternatives 2A, 2B, 4B and 2C) would eliminate impacts to water quality and hydrology. Assuming monitoring and maintenance activities continue at NTS and the commercial disposal facility, no long-term impacts would be expected from waste disposal at NTS (Alternatives 3A, 3B, and 3C.1) or the commercial disposal facility (Alternative 3C.2). |
| Air Quality | Some temporary impacts to air quality at the FEMP site would result from fugitive dust emissions associated with construction and excavation activities (e.g., grading, compacting, loading). Lesser impacts would also be incurred from vehicle and equipment exhausts. These impacts are not expected to affect human health or the environment. No long-term impacts on air quality would be expected from activities associated with any alternatives. Disturbed areas would be restored (e.g., regraded and revegetated) after completion of the remedial activities, thus minimizing the potential for the fugitive dust release. Waste disposal facilities at all sites would be designed to prohibit emission from stored waste. Only in the case of an accident during remedial actions would appreciable air quality impacts occur. |

**TABLE 4-17**
**(Continued)**

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| Affected Resource | Impact Type |
|---|---|
| Biotic/Ecological Resources | Short-term disturbance of on-property vegetation and riparian and aquatic habitat would be expected. Approximately 5.8 ha (14.3 acres) would be temporarily disturbed under either Alternative 2A, 2B, or 4B. Alternative 2C would disturb approximately 5.7 ha (14.1 acres) of habitat at the FEMP site during excavation and construction activities. Alternative 2C would displace 4.7 ha (11.6 acres) of habitat. In addition, 2.4 to 3.2 ha (6 to 8 acres) would be permanently committed to disposal. The long-term impacts from the on-property disposal alternatives would be minimal (e.g., potential for temporary displacement of threatened and endangered species, terrestrial biota). Habitat at NTS and the commercial disposal facility (Alternatives 3A, 3B, 3C.1 and 3C.2) is limited and it is believed little displacement of native species would occur. |
| Wetlands and Floodplains | Approximately 5 ha (12.4 acres) of wetlands at the FEMP site would be impacted by Alternatives 2A, 2B and 4B. Alternative 2C would impact approximately 0.2 ha (0.5 acre) utilized for on-property disposal. If either alternative is selected, appropriate notification and mitigation activities would be initiated. No wetlands or floodplains are present at NTS (Alternatives 3A, 3B, and 3C.1) or the commercial disposal facility (Alternative 3C.2). |
| Socioeconomics and Land Use | Most alternatives would result in minimal short-term impacts (e.g., increased traffic noise) to the socioeconomics and land use. The long-term socioeconomic and land use impacts for the FEMP site would be positive because the waste would be isolated and controlled, thus no changes from current land use would be expected. Several alternatives entail removing waste from the site, thus helping to eliminate impacts on future populations and economic growth at the FEMP site. Disposal of this waste at the NTS or a commercial disposal facility would not be expected to impact socioeconomics or land use. Total costs of each alternative considered ranged from approximately $0 to $60M. For this analysis it is assumed that all resources required for remedial activities, can be found within the thirteen county Consolidated Metropolitan Statistical Area (CMSA). The cumulative operating budget for the CMSA was approximately $805,000,000.00. Depending on the subunit alternatives chosen, the collectible revenue for the CMSA could increase up to approximately 8% over a 5 to 7-year period. |

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**TABLE 4-17**
**(Continued)**

| Affected Resource | Impact Type |
|---|---|
| Visual Resources | Construction and excavation activities would result in some minor incremental increases over the current visual and aesthetic impacts of the former FEMP Production Area. Following completion of remedial action activities, some visual and aesthetic impact would remain (e.g., well-lighted, fenced disposal area), but there would be lower magnitude than current impacts at the FEMP site. Visual impacts would be reduced through the maintenance of a vegetative cover. The long-term impacts would be incremental for off-site disposal locations for Alternatives 3A, 3B, 3C.1, and 3C.2. Short-term impacts would be incurred at off-site locations for all of the action alternatives during construction, excavation, and transportation activities. These impacts would be temporary and would cease following completion of remedial action activities and site restoration. |
| Noise | Ambient noise levels would temporarily increase as a result of construction, excavation, and transportation activities. All noise impacts would be temporary and would cease following completion of remedial activities. |

2A, 2B, 4B, and 2C would disturb between 2.4 ha to 4.7 ha (6 acres to 11.6 acres) for waste disposal. All areas disturbed at the FEMP site would be regraded and revegetated.

Alternatives 2A, 2B, 4B, and 2C would disturb between 3.9 ha to 5.8 ha (9 to 14.3 acres) of terrestrial habitat at the FEMP site during excavation and construction activities. In addition, 2.4 to 4.7 ha (6 to 11.6 acres) would be permanently committed to disposal. The long-term impacts from the on-property disposal alternatives would be minimal (e.g., potential for temporary displacement of threatened and endangered species, and terrestrial biota). Terrestrial habitat at the off-site disposal areas (Alternatives 3A, 3B, 3C.1, and 3C.2) is limited and little displacement of species would be expected to occur.

Between 0.2 to 5.0 ha (0.5 to 12.4 acres) of forested wetlands could be affected by Alternatives 2A, 2B, 4B, and 2C utilized for on-property disposal. If either alternative is selected, appropriate notification and mitigation activities would be initiated. No wetlands or floodplains are present at the off-site facilities (Alternatives 3A, 3B, 3C.1, and 3C.2).

Consumptive use of geological resources (e.g., quarried rock, sand, and gravel) and petroleum products (e.g., diesel fuel and gasoline) would be required for removal, construction, and disposal activities of all the action alternatives. Supplies of these materials would be provided by the construction contractor. Additional fuel use would result from off-site transport of the materials. However, adequate supplies are available without affecting local requirements for these products.

The treatment processes for the action alternatives would require the consumptive use of materials and energy. The cement stabilization process would require additives such as cement and flyash. The vitrification process would be energy-intensive and require commitment of a considerable supply of electricity. Cement and flyash are readily available locally in the quantities required, and electricity can be obtained from the local utility.

The committed land would be actively monitored and maintained. Periodic monitoring of nearby surface water and groundwater from monitoring wells around the perimeter of the facility would be performed, and periodic site inspections would identify any damage to the above-grade disposal vault. Maintenance activities would be performed as necessary. Hence, no impacts to groundwater are expected to occur from Operable Unit 4 remedial activities.

## 4.8 IMPACTS OF POTENTIAL LOSS OF INSTITUTIONAL ACTIONS

To assess whether each of the alternatives achieve and maintain protection of human health (and the associated criteria of compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness), an FS risk assessment was performed employing the methodologies identified in the Risk Assessment Work Plan. The FS risk assessment is included as Appendix D of this report. To assess protectiveness, two viable land use scenarios were evaluated along with representative receptors in order to provide a boundary of risk information to decision makers. The land use scenarios examined included a Future Land Use without Continued Federal Ownership scenario and a Future Land Use with Continued Federal Ownership scenario. The assumptions for these scenarios are summarized below.

### Future Land Use without Continued Federal Ownership Scenario

This scenario was examined to provide risk for the least restrictive future land use assumption. Under this scenario, the facility is assumed to revert to the primary land use of the land surrounding the FEMP site, a family farm. For this scenario, an on and off-property farmer is examined. For the on-property farmer, two receptors are examined, a RME and a CT resident farmer. The RME resident farmer uses risk parameters to provide an upper bound estimate of the risk an on-property farmer could reasonably be expected to receive. Under the CT resident farmer receptor, risk parameters are adjusted as identified in Appendix D to provide an estimate of the risk the on-property farmer could reasonably be expected to receive under typical living conditions. For this land use scenario, active operations and maintenance are assumed to continue until site-wide remedial action objectives are attained. After this time, active maintenance is assumed to be discontinued. Five-year CERCLA statutory reviews are assumed to continue. The residue containment system is assumed to remain relatively unchanged with no direct intrusion into the waste materials occurring. Exfiltration from the capped residues is estimated to increase to 1.3 cm/yr to the underlying Great Miami Aquifer. The on-property farmer is assumed to withdraw his drinking, crop irrigation, and livestock water from the Great Miami Aquifer from a point adjacent to the disposal vault or within the Operable Unit 4 boundary.

### Future Land Use with Continued Federal Ownership Scenario

This scenario was examined to provide risk information for a viable future site land use which incorporates passive institutional controls. Under this scenario, the FEMP site is assumed to remain under the ownership of the federal government. The government is assumed to continue to exercise its rights as owners of the property to preclude further development of the site. Continued federal

ownership would preclude certain activities on the property including homesteading, farming, and contrived recreational use. Active access controls are assumed to be discontinued following the attainment of site remedial action objectives. To provide an upper bound estimate of the risk contribution reasonably expected to be received under this land use, an expanded trespasser is examined in addition to the off-property farmer. The expanded trespasser is assumed to be an individual who plays on the property as a child and uses the property less frequently for recreational purposes as an adult. Assumptions for operations and maintenance and exfiltration rates from the capped residues are consistent with the other land use scenario described above.

To evaluate the alternatives for attainment of overall protection of the environment, the remaining pathways to environmental receptors were examined to determine the degree to which the alternatives mitigate environmental degradation. Section 2.0 and Appendix D summarize benchmark values which are considered to be protective of ecological receptors. These can be compared to contaminant concentrations determined by the fate and transport modeling conducted for assessing alternative performance. The prevention of degradation of the Great Miami Aquifer due to migration of contaminants from residual wastes and soils is a remedial action objective which is protective of both human health and the environment. Attainment of this objective can be measured by compliance with MCLs, proposed MCLs, and MCLGs established under the SDWA. Each alternative is also assessed for its short-term and long-term effects on soil and geology, water quality and hydrology, air quality, biotic resources, wetlands and floodplains, socioeconomics and land use, and cultural resources.

If any deterioration of containment system is detected, DOE would take any necessary actions to ensure the safety of the nearby environment. In the unlikely event that institutional controls are lost at some time in the distant future, deterioration of the containment system without corrective measures could result in the eventual release of contaminants and potential future impacts on human health and the environment under any of the alternatives.

For disposal on the FEMP site, the likelihood of protracted exposure at the above-grade disposal vault is low because the local community is expected to retain awareness of the site and permanent markers would be in place. To comply with ORC 3742.02, solid waste disposal facilities, such as the one proposed for on-property construction for Alternatives 2A, 2B, 4B and 2C, would require a protective covenant to restrict future mining, drilling, and residential development in any conveyance deeds.

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At the FEMP site, deterioration of the multimedia caps over waste material could result in the release of radon gas and contaminated particulates to the air; water infiltration into the cell could result in leaching of contaminated material to surface water and groundwater if the cap of foundation material is breached. Nearby individuals could be exposed to radiation if releases occurred. The impacts to human health at the FEMP disposal areas could be measurable because there are residents within 2 to 3 km (1 to 2 mi). Any material transported from the disposal area could be in a range where it could be in contact with humans. There could also be adverse human impacts due to intrusion into the facility if institutional controls are lost. In addition, contaminants released to off-site areas via surface water or groundwater transport could impact biota and habitats off site. The magnitude of the future impacts would depend on the extent of the release and on local land use conditions at the time it occurred.

The overall potential environmental impacts of losing institutional controls after disposal at the off-site location (NTS) would affect air quality, surface water, and groundwater quality. Air quality could be impacted by deterioration of the containment cap by exposing material to the air. Because the conditions at the off-site disposal areas are located in an arid climate with high wind velocities and little vegetation, a portion of any material exposed to the air could be suspended in air and transported for some distance, because there is little vegetation or terrain to act as a barrier. Dispersion of material, however, could be great because of high wind velocities. Impact to surface and groundwater would be minimal because of the lack of rainwater that could transport any material. Even though there is low annual rainfall, periodic and heavy rains could transport material a short distance from the disposal area. Groundwater would be impacted little because of the depth to groundwater and dry climate. Ecological impact would not occur to threatened and endangered species or other biotic resources unless they maintained a habitat within a short distance of the off-site disposal areas.

The impacts to human health at the off-site disposal areas would be small because the nearest resident to NTS is 30 to 40 km (19 to 25 mi) away. Any material transported from the disposal area would be at a more limited distance. There could be adverse human health impacts due to intrusion into the facility if institutional controls are lost. Because of the low population density of the area where the off-site disposal facilities are located, there should be no significant impact.

## 4.9 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Implementation of any of the final action alternatives would require the short-term use of the FEMP site to support cleanup activities and the short-term commitment of depletable resources such as construction materials, petroleum-based products, and natural gas. All final action alternatives would involve the long-term commitment of land for material disposal at the FEMP site, NTS, or the permitted commercial disposal site. This commitment of land at any one of the three sites would be consistent with current land uses. The short-term commitments would be more than offset by the long-term gain that would result from this action, i.e., cleanup of the FEMP site to levels that are protective of human health and the environment. Following remediation, portions or all of the current site could be released for future uses, as appropriate, to enhance long-term productivity. However, a likely scenario is that portions of the site would be committed to disposal and would, therefore, be controlled and monitored. Thus, other portions of the site could be released for limited use.

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### 4.4.3 Analysis of Alternative 3C.1

This removal alternative is identical to Alternative 2C (Section 4.4.3) except the on-property disposal, monitoring, and institutional control will be replaced by transportation and off-site disposal of the material.

Off-Site Disposal

The off-site disposal option for Alternative 3C.1 involves the packaging, loading, and shipping of the contaminated material generated by this alternative to NTS. The material to be disposed would consist of silo rubble, building debris, process equipment from the RTS for Silos 1 and 2, surface and subsurface soils, the decant sump tank, process piping, and process piping trenches.

The contaminated material would be packaged in DOT specification 7A Type A containers at the FEMP site and transported by an existing road from Operable Unit 4 to a transfer facility. Shipping of the material to NTS would involve rail transportation from the FEMP site through East St. Louis, Illinois, on the CSX rail lines. From St. Louis, Missouri the material would be transported on the UP rail lines through North Platte, Nebraska, and Salt Lake City, Utah. Currently, there are no direct rail lines to NTS. Presently, the material would be transported to either a point near Las Vegas, Nevada or one of the areas north of Las Vegas. From either location, the containers carrying the material would be transferred to trucks for transportation over roads to NTS. If a direct rail line to NTS becomes available before this alternative is implemented, it may be used in lieu of shipping the material by truck on the last leg of its trip. Waste containers may be staged or placed into interim storage at the FEMP site as required to accommodate interruptions in the availability of disposal capacity.

#### 4.4.3.1 Overall Protection of Human Health and the Environment

Alternative 3C.1 meets the remedial action objectives for Subunit C. The proposed soil remediation goals used to determine which soils to remove and dispose off site are based on protection of a expanded trespasser. The proposed soil cleanup levels also adequately protect the expanded trespasser in the event that institutional controls fail. Implementation of this alternative would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. To meet these objectives, three response actions would be used: removal and placement of clean cover, off-site disposal, and implementation of institutional control measures.

Contaminated soils would be excavated for disposal to the same levels as in Alternative 2C (Section 4.4.2.1). These soils include soils in the top six inches that exceed contamination levels protective of a expanded trespasser. Areas of removed soil would be backfilled with clean soil to protect against erosion of remaining lightly contaminated soil causing dust or runoff. After the silos are removed, contaminated soil with high radiological contaminant concentrations would also be removed as discussed in Alternative 2C. The excavated silo areas would be backfilled with clean soil to grade to protect receptors from contact with remaining contaminated soil.

Institutional control measures would be used to preclude site development to limit access to the remaining contaminated soil that is covered by clean soil. As in Alternative 2C, the controls include continued federal ownership of the FEMP site. This ownership would preclude future on-property residential and farming land uses which could potentially result in exposure to contaminated soil or material disposed in the vault. The uncertainty associated with long-term institutional control periods include a possible loss of federal ownership.

The off-site disposal provides a final element of protection under Alternative 3C.1. The off-site disposal facility at NTS would provide protection by eliminating access to the soil or debris and from migration of contaminants out of the material as much as the on-property disposal facility would under Alternative 2C. The NTS facility is located in a sparsely populated, arid environment with a reduced potential for contaminant release, migration, and direct contact with contaminants. The long-term effectiveness of the necessary institutional controls at the disposal facility is estimated to be more reliable than those that would be implemented at the FEMP site. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. Further, the climatic (low average annual precipitation) and hydrogeologic [depths to groundwater ranging from 157 to 600 m (515 to 2000 ft) below ground surface] characteristics would tend to mitigate impacts to human health and the environment in the event that engineering and institutional controls fail.

There are no unacceptable short-term risks from Alternative 3C.1. There are worker risks due to radiation and dust exposure material during removal and packaging. Through the use of shielding and implementation of a worker health and safety plan in compliance with 29 CFR § 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE Orders. There are also increased risks to workers and the community from moving the waste off site. Both rail and trucks would be used, but most of the potential risk is from truck movement.

4.4.3.2 Compliance with ARARs

ARAR compliance for Alternative 3C.1 is similar to ARAR compliance for Alternative 2C with the exception that Alternative 3C.1 requires disposal of demolition debris and soil residuals at a DOE-owned off-site facility. Only applicable requirements pertain to off-site portions of alternatives selected. In cases where relevant and appropriate requirements, or TBC criteria are identified for activities under this alternative, the reference citation pertains only to that portion of the activity conducted on site. Because Alternative 3C.1 involves off-site disposal of remediation wastes, the State of Ohio criteria for solid waste disposal facilities would not be relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3C.1 are similar to those for Alternative 2C (see Table F.2-1 in Appendix F). Consequently, the discussion of the compliance of this alternative would be similar to that presented in Section 4.4.2.2, which is summarized below. Additional compliance documentation for Alternative 3C.1 with the identified ARARs is presented in Appendix F (Table F.2-4).

Chemical-Specific ARAR/TBCs

Alternative 3C.1 would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those requirements for compliance with State of Ohio water quality standards, the control of radionuclide releases other than radon to air and water, and their resulting doses to the public under the CAA and DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 3C.1.

Location-Specific ARAR/TBCs

Alternative 3C.1 would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, and endangered species during the on-property remediation. As noted above, the State of Ohio solid waste disposal facility location requirements would not be relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARARs

Alternative 3C.1 would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative, including those standards in 40 CFR § 192.12 for cleanup of lands contaminated with residual radioactive material. This alternative would comply with requirements of the CAA (for releases of dust and non-radioactive particulates) and the CWA (for storm water runoff, BMP, and dredge and fill activities). This alternative would also comply with criteria and

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requirements for use of the CAMU, TU, and containment building for management of remediation wastes. This alternative would also comply with NEPA (for environmental documentation), the annual average dose requirement of 100 mrem/yr in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity, with ALARA principles, and with the UMTRCA guidance for control and cleanup of residual radioactive material.

Off-site disposal would require shipment of waste materials. Hazardous materials transport requirements would be complied with by following the pertinent regulations under 40 CFR §§ 262 and 263, and the appropriate DOT shipping requirements under 49 CFR §§ 172 and 173.

4.4.3.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 3C.1 would reduce the residual risk, under the continued federal ownership of land, to viable receptors (off-property resident farmer, trespassing child, and expanded trespasser) to a HI of less than 0.3 and an ILCR of less than $10^{-5}$ similar to Alternative 2C. As with Alternative 2C, residual contamination would remain at the site in the soil. The level of risk from the residual soil is controlled by excavating soil that exceeds proposed remediation levels. These levels provide adequate protection to the expanded trespasser and the on-property resident farmer. The excavated contaminated soil and debris would be disposed at NTS.

Adequacy and Reliability of Controls

The reliability of the D&D activities and soil removal actions of Alternative 3C.1 would be the same as for Alternative 2C (Section 4.4.2.3). Off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be more reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrologic conditions, and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct contact in the event of disposal facility failure. In the event institutional controls were lost at the FEMP site, exposure would be expected to be acceptable to the on-property resident farmer due to the nature and level of residual contamination.

Long-Term Environmental Impacts

The long-term environmental impacts of removal and treatment actions of Alternative 3C.1 are the same as for Alternative 2C. The difference between the two alternatives is the disposal option. The

impacts for NTS would be the same as those associated with Alternative 3B.1/Vit (Section 4.3.3.3). Reference is made to these discussions and it will not be repeated here.

4.4.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative does not include treatment of the contaminated silo structures, processing facility debris, berm material, or soil; therefore, no reduction in toxicity, mobility, or volume would be achieved. However, pending the ROD for Operable Unit 3, some additional treatment of this material may occur. As a part of remedial action work plan preparation, decontamination procedures may be developed, which may also reduce the volume of material requiring management as contaminated waste. Following decontamination, it is conceivable that some impermeable material might be suitable for free release to be reused, recycled, or disposed in a solid waste landfill, providing they meet established free release criteria (DOE Order 5400.5) for radioactive contamination and do not exhibit a characteristic for hazardous waste.

4.4.3.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Alternative 3C.1 provides the same level of short-term protection of the community during removal and D&D as does Alternative 2C (Section 4.4.2.5). There would be added risk to the public through transporting the soil and debris off site. Because of the overall low radiological activity of the soil and debris, the estimated increase in radiation exposure to the public during transportation would be an ILCR of $4.8 \times 10^{-12}$. It is estimated that 1.3 injuries and 0.33 deaths would occur due to transportation accidents. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 3C.1 is effective in protecting the community in the short term. The basis for these estimates is provided in Appendix D.

The disposal of Operable Unit 4 materials at NTS would not be expected to exceed protective levels for the community around NTS over the short term. The contaminated soil and debris would meet NTS waste acceptance criteria and, therefore, would be managed within the bounds of the NTS facility's protectiveness criteria. Additional discussion is provided in Section 4.2.4.5 (Alternative 3A.1/Vit).

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Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal and D&D are the same for Alternatives 3C.1 as for 2C. The estimated occurrences of injuries during remediation activities is 1.4 injuries and 0.021 deaths. There are additional radiation exposure risks to workers from transporting the material to NTS. The excess ILCR is estimated at $3.0 \times 10^{-8}$, below the EPA's target risk level of $10^{-6}$. The accident and radiological risks to workers during off-loading activities at NTS are conservatively assumed to be similar to those for remediation activities at the FEMP site.

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal, D&D, packaging, and loading of materials under Alternative 3C.1 are the same as those for Alternative 2C (Section 4.4.2.5).

The total area disturbed at the FEMP site as part of this alternative would be 1 ha (2 acres). The short-term impacts for Alternative 3C.1 disposal operations at NTS would be similar to those under Alternative 3B.1/Vit (Section 4.2.4.5). Reference is made to that discussion, and it will not be repeated here. Approximately one, one-way truck trip per working day would be required.

Duration of Remedial Activities

Remedial actions for Alternative 3C.1 are expected to require two years to complete. This time frame includes transporting the containers of soil and debris to NTS. Physical, substantial, and continuous on-property activities would be initiated within 15 months after the ROD is approved by EPA.

4.4.3.6 Implementability

Technical Feasibility

The technical feasibility of Alternative 3C.1, with the exception of the disposal activities, is the same as that of Alternative 2C (Section 4.4.2.6). The technical feasibility of off-site transport and disposal at NTS is straightforward and reliable. Off-site transport to NTS would consist of rail transport from the FEMP to within 483 km (300 mi) of NTS. Currently, NTS is not accessible by rail; therefore, the material would be transferred to trucks and transported to NTS. The soil and debris would be placed in appropriate containers that meet transportation and disposal requirements.

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Administrative Feasibility

The wastes generated in this alternative would be similar to FEMP waste streams currently approved for disposal at NTS; therefore, an addendum to the FEMP NTS Waste Shipping Application would not likely be required. All material shipments would be required to meet applicable federal and state regulations.

Availability of Services and Materials

Alternative 3C.1 would include the activities of Alternative 2C with the exception of the disposal facility component. The shipping of the material to NTS would require the services of transporters (both rail and truck), standard construction equipment and trades for loading the transport vehicles, and the services of NTS for disposal. NTS currently accepts low-level waste from the FEMP and has adequate facilities to accept Subunit C waste. Transfer areas, storage areas, decontamination facilities, and a laboratory are available on the site.

4.4.3.7 Cost

The total present worth cost of Alternative 3C.1 is $75.6 Million. A detailed breakdown of the cost is provided in Table 4-15.

Capital Cost

The capital cost is associated with silo demolition and removal, packaging, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-15. More detailed information is provided in Appendix E.

This alternative includes cost components identical to Alternative 2C (Section 4.4.2.7). The largest component of the capital cost is packaging. This represents approximately 40 percent of the total capital costs. The second largest element of the capital costs (27 percent) is the disposal. Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Demolition and Removal

This component is the same as described for Alternative 2C.

TABLE 4–15

COST ESTIMATE FOR ALTERNATIVE 3C.1

| ALTERNATIVE 3C.1: SILO DEMOLITION, REMOVAL, OFF–SITE DISPOSAL AT NTS | | | |
|---|---|---|---|
| DESCRIPTION | DIRECT COST | INDIRECT COST | TOTAL COST |
| CAPITAL COSTS | | | |
| DEMOLITION & REMOVAL | $3,980,300 | $5,977,100 | $9,957,400 |
| TRANSPORTATION | $11,000,200 | | $11,000,200 |
| DISPOSAL | $16,749,500 | | $16,749,500 |
| PACKAGING (26,215 PKGS. @ $955/PKG.) | $6,920,800 | $18,114,600 | $25,035,400 |
| TOTAL CAPITAL | $38,650,800 | $24,091,700 | $62,742,500 |
| RISK BUDGET (11.0%) | $4,251,600 | $2,650,100 | $6,901,700 |
| SUBTOTAL | $42,902,400 | $26,741,800 | $69,644,200 |
| CONTINGENCY (20.0%) | $8,580,500 | $5,348,400 | $13,928,900 |
| TOTAL ESTIMATED INSTALLED COST | $51,482,900 | $32,090,200 | $83,573,100 |
| TOTAL PRESENT WORTH COST (CAPITAL @ 7%) | | | $75,550,100 |

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 2
O&M during remediation (years): 0
Post–remediation O&M (years): 0

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation. Estimated cost is based on the following:

- Packages would be DOT specification 7A Type A containers with exterior dimensions of 1.2 m (4 ft) width by 1.2 m (4 ft) length by 1.2 m (4 ft) depth. Interior dimensions would be 1.1 m (3.5 ft) width by 1.1 m (3.5 ft) length by 1.1 m (3.5 ft) depth, providing 1.22 $m^3$ (43 $ft^3$) of storage per package.

- Final packaging volume was estimated to be 2,040 $m^3$ (2,670 $yd^3$) of silo concrete, 280 $m^3$ (370 $yd^3$) of material from the decant sump tank, process piping, piping trenches, and the RTS, and 20 $m^3$ (30 $yd^3$) of concrete from the drum handling building pad, and 29,458 $m^3$ (38,519 $yd^3$) of soil (including a 1.3 bulking factor).

- The number of packages for silo concrete and soil are based on maximum volume 1.22 $m^3$ (43 $ft^3$) per package since the density is less than the maximum allowable load of 2698 $kg/m^3$ (168 $lb/ft^3$). The number of packages for the decant sump tank process piping, piping trenches, and RTS is based on weight due to material density of 3935 $kg/m^3$ (245 $lb/ft^3$).

- Packaging and disposal of materials generated during operations for Subunits A and B are included in this cost.

- Total packaging cost was estimated assuming 26,215 containers.

- A unit cost of $955 per container was determined based on a material cost of $650 per unit and a labor cost of 16 man-hours per unit for handling, filling, and documentation.

Transportation

This cost item includes transportation of the containerized material, and is based on the following assumptions:

- Packages would be transported by rail to within 483 km (300 mi) of the disposal facility (NTS) and then transported by truck the remainder of the distance.

- Rail costs were estimated using a unit rate of $2.47 per railcar per km ($3.97 per railcar per mile). Railcars were assumed to weigh 8165 kg (180,000 lbs) each.

- Truck costs were estimated using a unit rate of $0.24 per pound [for the total 483 km (300 mi) trip].

Disposal

- Packaged material would be disposed at NTS.

- Unit disposal cost was estimated as $353 $m^3$ ($10/$ft^3$).

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O&M Cost

There are no short-term or long-term O&M costs associated with this alternative.

4.4.3.8 State Acceptance

This criterion addresses the comments made by the OEPA on Alternative 3C.1. Because formal state comments will not be received until after the FS/PP-DEIS has been issued for public review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.4.3.9 Community Acceptance

This criterion addresses the comments made by the community on Alternative 3C.1. Because formal public comments will not be received until after the FS/PP-DEIS has been issued for review, this modifying criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

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### 4.4.4 Analysis of Alternative 3C.2

This removal alternative is identical to Alternative 3C.1 (Section 4.4.3) except that the off-site disposal of the material is at a permitted commercial disposal site.

Off-Site Disposal

The off-site disposal option for Alternative 3C.2 involves the loading and shipping of the contaminated material generated by this alternative to a permitted commercial disposal site. The material to be disposed would consist of contaminated silo rubble, building debris, process equipment from the RTS for Silos 1 and 2, surface and subsurface soils, the decant sump tank, process piping, and process piping trenches.

For the purposes of this FS, it was assumed that the representative commercial disposal facility would be located east of Clive, Utah. The location has an annual precipitation rate of approximately 12 cm (5 in.) and an evaporation rate greater than 152 cm (60 in.). The soil of the site is a naturally low permeability clay. Consistent with 3C.1, staging or interim storage of the wastes at the FEMP site may be required to accommodate interruptions in the availability of disposal capacity.

The material would be loaded in bulk railcars at the FEMP site and transported from the FEMP site to the representative commercial disposal facility by rail. The length of the route is estimated to be 3057 km (1900 mi).

#### 4.4.4.1 Overall Protection of Human Health and the Environment

Alternative 3C.2 meets the remedial action objectives for Subunit C in the same manner as Alternative 3C.1 (Section 4.4.3.1). The proposed soil remediation levels used to determine which soils to remove and dispose off site are based on protection of a expanded trespasser. Implementation of this alternative would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. To meet these objectives, three response actions are used: removal and placement of clean cover, off-site disposal, and implementation of institutional control measures.

Contaminated soils would be excavated for disposal to the same levels as in Alternative 2C (Section 4.4.2.4). The excavated areas would be backfilled with clean soil to grade and reseeded to protect potential receptors from contact with remaining contaminated soil.

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As in Alternative 2C and 3C.1, Alternative 3C.2 includes institutional controls through continued federal government ownership of the FEMP site. This ownership would preclude future on-property residential and farming uses which could potentially result in exposure to contaminated soil.

The off-site disposal provides an element of protection for Alternative 3C.2. A commercial facility located in an arid environment would be protective against direct contact with the soil or debris as well as migration of contaminants and material to the same extent as NTS (Alternative 3C.1). Disposal of the soil and debris at an off-site commercial facility is subject to some uncertainties associated with long-term protectiveness. As long as the facility owner maintains operations in compliance with applicable permits, protectiveness is ensured.

There are no unacceptable short-term risks from Alternative 3C.2. The risks are slightly less than disposal at NTS because the waste can be sent by rail instead of a rail/truck combination. Through the use of shielding and implementation of a worker health and safety plan in compliance with 29 CFR § 1910.120(b)(4), exposures would be kept to ALARA levels and would comply with DOE Orders.

4.4.4.2 Compliance with ARARs

ARAR compliance for Alternative 3C.2 is similar to ARAR compliance for Alternative 2C with the exception that Alternative 3C.2 requires disposal of demolition debris and soil residuals at an off-site commercial facility. Because Alternative 3C.2 involves off-site disposal of remediation wastes, the State of Ohio location criteria for solid waste disposal facilities would not be relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3C.2 are similar to those for Alternative 2C (see Table F.2-1 in Appendix F). Consequently, the discussion of the compliance of this alternative would be substantially identical to that presented in Section 4.4.2.2, which is summarized below. Additional documentation of compliance of Alternative 3C.2 with the identified ARARs is presented in Appendix F (Table F.2-4).

Chemical-Specific ARAR/TBCs

Alternative 3C.2 would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F.2-1a) for this alternative. Included would be those requirements associated with the Ohio water quality standards, and the control of radionuclide releases other than radon to air and water and

their resulting doses to the public under the CAA and DOE Order 5400.5. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 3C.2.

Location-Specific ARAR/TBCs

Alternative 3C.2 would comply with all pertinent location-specific ARARs identified in Appendix F (Table F.2-1b) for this alternative. Included would be those requirements associated with the protection of floodplains, wetlands, and endangered species during the on-property remediation. As noted above, the State of Ohio solid waste disposal facility location requirements would not be relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARARs

Alternative 3C.2 would comply with all pertinent action-specific ARARs identified in Appendix F (Table F.2-1c) for this alternative. Included would be those requirements in 40 CFR § 192.12 for cleanup of lands contaminated with residual radioactive material.

This alternative would comply with requirements of the CAA (for releases of dust and non-radioactive particulates) and the CWA (for storm water runoff, BMPs, and dredge and fill activities). This alternative would also comply with criteria and requirements for use of the CAMU, TU, and containment building for management of remediation wastes. This alternative would also comply with NEPA (for environmental documentation), the annual average dose requirement of 100 mrem in DOE Order 5400.5 for protection of any member of the public from all pathways of exposure to radioactivity, with ALARA principles, and with the UMTRCA guidance for control and cleanup of residual radioactive material.

Off-site disposal would require the shipment of Operable Unit 4 waste materials. Hazardous materials transport requirements would be complied with by following the pertinent regulations under 40 CFR §§ 262 and 263, and the appropriate DOT shipping requirements under 49 CFR §§ 172 and 173.

#### 4.4.4.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 3C.2 would reduce the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than $10^{-6}$, similar to Alternative 2C (Section 4.4.2.3).

# 5.0 COMPARATIVE ANALYSIS

## 5.1 INTRODUCTION

Section 5.0 presents a comparative analysis of the final remedial action alternatives for Operable Unit 4 with respect to the CERCLA evaluation criteria described in Section 4.0. This analysis is the second stage of the detailed evaluation process and provides information which forms the basis for selecting a preferred remedial alternative for Operable Unit 4. The Proposed Plan, which is issued concurrently with this FS-DEIS, will identify DOE's preference for an Operable Unit 4 remedial action alternative and will solicit public comments as part of the modifying criteria evaluation used to document the selection of the final remedial alternative in the ROD. For this analysis, the evaluation criteria include two categories, threshold and primary balancing. More information concerning the evaluation criteria can be found in Section 4.1.2, Overview of the Detailed Analysis. The modifying criteria of state and community acceptance will not be addressed in this comparative analysis. Because formal state and community comments will not be received until after the FS/PP-DEIS has been issued for public review, these two modifying criteria will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

The threshold category contains the two criteria that must be satisfied by the selected alternative:

- Overall protection of human health and the environment
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

These criteria are of greatest importance in the comparative analysis because they reflect the key statutory mandates of CERCLA, as amended. If an alternative does not satisfy both of these criteria, it cannot be carried forward to the primary balancing category and is not eligible to be selected as the final remedy.

The primary balancing category contains the five criteria under which the relative advantages and disadvantages of the alternatives are compared to determine the most appropriate remedy:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The first and second criteria address the statutory preference for treatment as a principal element of the remedy and the bias against off-site land disposal of untreated material. Together with the third and fourth criteria, they form the basis for determining the general feasibility of each potential remedy and determining whether costs are proportional to the overall effectiveness, considering both the cleanup period and the time following cleanup. By this means, it can be determined whether a potential remedy is cost effective.

Consistent with the format of the detailed analysis of alternatives in Section 4.0, a comparative analysis under the threshold and primary balancing criteria for Subunits A, B, and C is presented in Sections 5.2, 5.3, and 5.4, respectively. Tables 5-1 through 5-3 summarize the comparative analysis for each subunit. Table 5-4 presents a comparison of the environmental impacts associated with each alternative. Table 5-5 summarizes the long-term and short-term radiological incremental lifetime cancer risks estimated for each alternative. Short-term risks are provided to assess the potential impacts to the public and remedial action workers during implementation of the alternative. The basis for determining the risks are detailed in Appendix D. The results of the comparative analysis are summarized in Appendix G.

The preferred alternative for Operable Unit 4 to be described in the Proposed Plan is assembled by combining the preferred alternatives selected from each of Subunits A, B, and C. This comparative analysis provides the basis for the selection.

## 5.2 SUBUNIT A

Subunit A alternatives compared include:

- Alternative 0A - No Action
- Alternative 2A/Vit - Removal, Vitrification, On-Property Disposal
- Alternative 2A/Cem - Removal, Cement Stabilization, On-Property Disposal
- Alternative 3A.1/Vit - Removal, Vitrification, Off-Site Disposal at NTS
- Alternative 3A.1/Cem - Removal, Cement Stabilization, Off-Site Disposal at NTS

A summary of the Subunit A comparative analysis results is presented in Table 5-1.

## TABLE 5-1

## SUBUNIT A - COMPARATIVE ANALYSIS

| Alternative | Overall Protection of Human Health and Environment | Compliance with ARARs | Long-Term Effectiveness and Permanence | Reduction of Toxicity, Mobility, or Volume Through Treatment | Short-Term Effectiveness | Implementability | Present Worth Cost |
|---|---|---|---|---|---|---|---|
| 0A - No Action | Not protective | Does not meet all ARARs | Not effective or permanent | No treatment | High | Reliable Technology Easy | -0- |
| 2A/Vit - Removal, Vitrification, On-Property Disposal | Protective[1] | Complies with all ARARs[2] | Effective and reliable | Reduces toxicity, mobility, and volume | Medium | Innovative Technology Moderately Difficult | $43.6M |
| 2A/Cem - Removal, Cement Stabilization, On-Property Disposal | Protective[1] | Complies with all ARARs[2] | Effective and reliable | Reduction of mobility | Medium | Reliable Technology Easy | $74.0M |
| 3A.1/Vit - Removal, Vitrification, Off-Site Disposal - Nevada Test Site | Protective | Complies with all ARARs | Effective and most reliable | Reduces toxicity, mobility, and volume | Medium | Innovative Technology Moderately Difficult | $43.7M |
| 3A.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - Nevada Test Site | Protective | Complies with all ARARs | Effective and most reliable | Reduces mobility | Medium | Reliable Technology Difficult | $73.1M |

[1]Assessment of protectiveness adopts the use of continued federal government ownership and evaluates risk to the off-property farmer.
[2]Assumes substantive technical requirements for the State of Ohio disposal facility siting are met.



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## TABLE 5-2

## SUBUNIT B - COMPARATIVE ANALYSIS

| Alternative | Overall Protection of Human Health and Environment | Compliance with ARARs | Long-Term Effectiveness and Permanence | Reduction of Toxicity, Mobility, or Volume Through Treatment | Short-Term Effectiveness | Implementability | Present Worth Cost |
|---|---|---|---|---|---|---|---|
| 0B - No-Action | Not protective | Does not meet all ARARs | Not effective or permanent | No treatment | High | Reliable Technology Easy | -0- |
| 2B/Vit - Removal, Vitrification, On-Property Disposal | Protective[1] | Complies with all ARARs[2] | Effective and reliable | Reduces toxicity, mobility, and volume | Medium | Innovative Technology Moderately Difficult | $28.0M |
| 2B/Cem - Removal, Cement Stabilization, On-Property Disposal | Protective[1] | Complies with all ARARs[2] | Effective and reliable | Reduces mobility | Medium | Reliable Technology Easy | $37.4M |
| 3B.1/Vit - Removal, Vitrification, Off-Site Disposal - NTS | Protective | Complies with all ARARs | Effective and most reliable | Reduces toxicity, mobility, and volume | Medium | Innovative Technology Moderately Difficult | $28M |
| 3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - NTS | Protective | Complies with all ARARs | Effective and most reliable | Reduces mobility | Medium | Reliable Technology Difficult | $36M |
| 4B - Removal, On-Property Disposal | Protective | Complies with all ARARs[2] | Effective but least reliable | No treatment | Medium | Reliable Technology Easy | $22M |

[1]Assessment of protectiveness adopts the use of continued federal government ownership and evaluates risk to the expanded trespasser and the off-property farmer.
[2]Assumes substantive technical requirements for the State of Ohio disposal facility siting are met.



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## TABLE 5-3

## SUBUNIT C - COMPARATIVE ANALYSIS

| Alternative | Overall Protection of Human Health and Environment | Compliance with ARARs | Long-Term Effectiveness and Permanence Through Treatment | Reduction of Toxicity, Mobility, or Volume | Short-Term Effectiveness | Implementability | Present Worth Cost |
|---|---|---|---|---|---|---|---|
| 0C - No-Action | Not protective | Does not meet all ARARs | Not effective or permanent | No treatment | High | Reliable Technology Easy | -0- |
| 2C - Demolition, Removal, On-Property Disposal | Protective[1] | Complies with all ARARs[2] | Effective and reliable | No treatment | High | Reliable Technology Easy | $34.3M |
| 3C.1 - Demolition, Removal, Off-Site Disposal - NTS | Protective | Complies with all ARARs | Effective and most reliable | No treatment | Medium | Reliable Technology Moderately Difficult | $75.5M |
| 3C.2 - Demolition, Removal, Off-Site Disposal - Permitted Commercial Disposal Site | Protective | Complies with all ARARs | Effective and most reliable | No treatment | Medium | Reliable Technology Moderately Difficult | $44M |

[1]Assessment of protectiveness adopts the use of continued federal government ownership and evaluates the risk to the expanded trespasser and the off-property farmer.
[2]Assumes substantive technical requirements for the State of Ohio disposal facility siting are met.

## TABLE 5-4

## SUMMARY OF ENVIRONMENTAL IMPACTS FOR REMEDIAL ALTERNATIVES

| ALTERNATIVE | SOIL AND GEOLOGY[1] | WATER QUALITY AND HYDROLOGY | AIR QUALITY | BIOTIC RESOURCES | WETLANDS AND FLOODPLAINS | SOCIOECONOMICS AND LAND USE | CULTURAL RESOURCES | TRANSPORT IMPACTS |
|---|---|---|---|---|---|---|---|---|
| SUBUNIT A | | | | | | | | |
| 0A | No Impacts | Potential release to surface and groundwater | Potential release to ambient air | Potential exposure to ecological receptors | Potential release to 0.32 ha of wetlands | • Restriction of site's future use<br>• No impact on energy resources | No impacts | No impacts |
| 2A/Vit | 4.3 ha temporarily disturbed<br>2.8 ha committed to disposal | Minor impacts assuming monitoring and controls wastewater recycled | Fugitive dust emissions<br>Minor impacts assuming controls (e.g., HEPA) | 4.3 ha disturbed<br>2.8 ha terrestrial habitat lost | 5.0 ha forested wetlands lost | • Up to 5.0% increase in CMSA revenue<br>• Restricted site use<br>• 18,521,530 KWHR used | No impact due to identification of management | Fugitive dust due to on-property movement |
| 3A/Vit | 1.5 ha temporarily disturbed<br>Approximately 5.0 ha committed at NTS | Minor impacts due to geology at NTS<br>Wastewater recycled | Fugitive dust emissions<br>Minor impacts assuming controls (e.g., HEPA) | 3.2 ha disturbed<br>Minor impacts at NTS | No impacts | • Up to 5.0% increase in CMSA revenue<br>• 18,521,530 KWHR used | No impact due to identification and management | ILCR of $8.3 \times 10^{10}$ along route to NTS |
| 2A/Cem | 5.8 ha temporarily disturbed<br>4.3 ha committed to disposal | Minor impacts assuming monitoring and controls | Minor impacts assuming monitoring and controls | 5.8 ha disturbed<br>4.3 ha committed | 6.0 ha forested wetlands lost | • Up to 5.0% increase in CMSA revenue<br>• Restricted site use<br>• 11,575,780 KWHR used | • Up to 5.0% increase in CMSA revenue<br>• Restricted site use<br>• 11,575,780 KWHR used | Fugitive dust due to on-property movement |

See footnote at end of table.



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**TABLE 5-4**
**(Continued)**

| ALTERNATIVE | SOIL AND GEOLOGY[1] | WATER QUALITY AND HYDROLOGY | AIR QUALITY | BIOTIC RESOURCES | WETLANDS AND FLOODPLAINS | SOCIOECONOMICS AND LAND USE | CULTURAL RESOURCES | TRANSPORT IMPACTS |
|---|---|---|---|---|---|---|---|---|
| 3A/Cem | 1.5 ha temporarily disturbed<br><br>Approximately 5.0 ha committed at NTS | Minor impacts due to geology at NTS | Minor impacts due to geology at NTS | 5.8 ha disturbed<br><br>Minor impacts at NTS | No impacts | • Up to 5.0% increase in CMSA revenue<br><br>• 11,575,780 KWHR used | Up to 5.0% increase in CMSA revenue<br><br>• 11,575,780 KWHR used | ILCR of $4.3 \times 10^{10}$ along route to NTS |

See footnote at end of table.



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**TABLE 5-4**
**(Continued)**

| ALTERNATIVE | SOIL AND GEOLOGY[1] | WATER QUALITY AND HYDROLOGY | AIR QUALITY | BIOTIC RESOURCES | WETLANDS AND FLOODPLAINS | SOCIOECONOMICS AND LAND USE | CULTURAL RESOURCES | TRANSPORT IMPACTS |
|---|---|---|---|---|---|---|---|---|
| SUBUNIT B | | | | | | | | |
| 0B | No impacts | Potential release to surface and groundwater | Potential release to ambient air | Potential exposure to ecological receptors | Potential release to 0.32 ha of wetlands | • Restriction of site's future use<br>• No impact on energy resources | No impacts | No impacts |
| 2B/Vit | 3.9 ha temporarily disturbed<br>2.4 ha committed to disposal | Minor impacts assuming monitoring and controls<br>Wastewater recycled | Fugitive dust<br>Minor impacts assuming controls (e.g., HEPA) | 3.9 ha disturbed<br>2.4 ha terrestrial habitat lost | 5.0 ha forested wetlands lost | • Up to 4.0% increase in CMSA revenue<br>• Restricted site use<br>• 7,232,243 KWHR used | No impact due to identification and management | Fugitive dust due to on-property movement |
| 3B/Vit | 1.5 ha temporarily disturbed<br>Approximately 5.0 ha committed at NTS | Minor impacts due to geology at NTS | Fugitive dust<br>Minor impacts assuming controls (e.g., HEPA) | 1.5 ha habitat disturbed<br>Minor impacts at NTS | No impacts | • Up to 4.0% increase in CMSA revenue<br>• 7,232,243 KWHR used | No impact due to identification and management | ILCR of $17 \times 10^{11}$ along route to NTS |
| 2B/Cem | 4.5 ha temporarily disturbed<br>3.0 ha committed to disposal | Minor impacts assuming monitoring and controls | Minor impacts assuming monitoring and controls | 4.5 ha disturbed<br>3.0 ha terrestrial habitat lost | 6.0 ha forested wetlands lost | • Up to 4.0% increase in CMSA revenue<br>• Restricted site use<br>• 3,858,593 KWHR used | • Up to 4.0% increase in CMSA revenue<br>• Restricted site use<br>• 3,858,593 KWHR used | Fugitive dust due to on-property movement |

See footnote at end of table.

**TABLE 5-4**
**(Continued)**

| ALTERNATIVE | SOIL AND GEOLOGY[1] | WATER QUALITY AND HYDROLOGY | AIR QUALITY | BIOTIC RESOURCES | WETLANDS AND FLOODPLAINS | SOCIOECONOMICS AND LAND USE | CULTURAL RESOURCES | TRANSPORT IMPACTS |
|---|---|---|---|---|---|---|---|---|
| 3B/Cem | 1.5 ha temporarily disturbed<br><br>Approximately 5.0 ha committed at NTS | Minor impacts due to geology at NTS | Minor impacts due to geology at NTS | 1.5 ha habitat disturbed minor impacts at NTS | No Impacts | • Up to 4.0% increase in CMSA revenue<br><br>• 3,858,593 KWHR used | • Up to 4.0% increase in CMSA revenue<br><br>• 3,858,593 KWHR used | ILCR of $1.9 \times 10^{11}$ along route to NTS |
| 4B | 4.3 ha temporarily disturbed<br><br>2.8 ha committed to disposal | Minor impacts assuming monitoring and controls | Fugitive dust | 4.3 ha disturbed<br><br>2.8 ha terrestrial habitat lost | 6.0 ha forested wetlands lost | • Up to 4.0% increase in CMSA<br><br>• Restricted site use<br><br>• Minimal energy impacts | • Up to 4.0% increase in CMSA<br><br>• Restricted site use<br><br>• Minimal energy impacts | Fugitive dust due to on-property movement |

See footnote at end of table.



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**TABLE 5-4**
**(Continued)**

| ALTERNATIVE | SOIL AND GEOLOGY[1] | WATER QUALITY AND HYDROLOGY | AIR QUALITY | BIOTIC RESOURCES | WETLANDS AND FLOODPLAINS | SOCIOECONOMICS AND LAND USE | CULTURAL RESOURCES | TRANSPORT IMPACTS |
|---|---|---|---|---|---|---|---|---|
| SUBUNIT C | | | | | | | | |
| 0C | No impacts | Potential runoff to surface water | Potential for airborne contamination | Potential exposure to ecological resources | Potential runoff to 0.32 ha of wetlands | Restriction of site's future use<br><br>Restricted site use<br><br>No energy impacts | No impacts | No impacts |
| 2C | 5.7 ha temporarily disturbed<br><br>4.7 ha committed to disposal at FEMP | Minor impacts assuming monitoring and controls | Fugitive dust<br><br>Minor impacts assuming controls | 4.7 ha terrestrial habitat lost | 0.20 ha drainage ditch wetlands lost | Up to 4.0% increase in CMSA revenue<br><br>Minimal energy impacts | No impact due to identification and proper management if required | Fugitive dust due to on-property movement |
| 3C.1 | 1.0 ha temporarily disturbed<br><br>Approximately 5.0 ha committed at NTS | Minor impacts due to geology at NTS | Fugitive dust<br><br>Minor impacts assuming controls | Minor impacts at NTS | No impacts | Up to 4.0% increase in CMS revenue<br><br>Minimal energy impacts | No impact due to identification and proper management if required | ILCR of $4.8 \times 10^{12}$ along route to NTS |
| 3C.2 | 1.0 ha temporarily disturbed<br><br>Approximately 5.0 ha committed at off-site permitted commercial disposal site | Minor impacts due to geology at off-site permitted commercial disposal site | Minor impacts at off-site permitted commercial disposal site | Minor impacts at off-site permitted commercial disposal site | No impacts | Up to 4.0% increase in CMSA revenue<br><br>Minimal energy impacts | No impact due to identification and proper management if required | ILCR of $2.4 \times 10^{12}$ along route to off-site permitted commercial disposal site |

[1]Commitment of acres is at the FEMP unless indicated otherwise.

## TABLE 5-5

## SUMMARY OF LONG-TERM AND SHORT-TERM RADIOLOGICAL INCREMENTAL LIFETIME CANCER RISKS

| Alternative | Future Land use w/continued Federal Ownership | Future Land Use w/o Cont. Federal Ownership | Short-term Risks | |
|---|---|---|---|---|
| | Off-Property Farmer | On-Property Farmer | Public | Worker[a] |
| **SUBUNIT A - SILOS 1 AND 2 CONTENTS** | | | | |
| 0A - No Action | $1.0 \times 10^{-4}$ | $\approx 1$[b] | N/A | N/A |
| 2A/Vit - Removal, Vitrification, On-Property Disposal | B.S.L.[c] | B.S.L.[c] | $3.2 \times 10^{-7}$[e] | $4.0 \times 10^{-4}$ |
| 2A/Cem - Removal, Cement Stabilization, On-Property Disposal | B.S.L.[c] | B.S.L.[c] | $3.2 \times 10^{-7}$[e] | $4.0 \times 10^{-4}$ |
| 3A.1/Vit - Removal, Vitrification, Off-Site Disposal at NTS | N/A[d] | N/A[d] | $3.2 \times 10^{-7}$ | $4.0 \times 10^{-4}$ |
| 3A.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - at NTS | N/A[d] | N/A[d] | $3.2 \times 10^{-7}$ | $4.0 \times 10^{-4}$ |
| **SUBUNIT B - SILO 3 CONTENTS** | | | | |
| 0B - No-Action | $1.0 \times 10^{-4}$ | $\approx 1$[b] | N/A[f] | N/A[f] |
| 2B/Vit - Removal, Vitrification, On-Property Disposal | B.S.L.[c] | B.S.L.[c] | N/A | $4.1 \times 10^{-5}$ |
| 2B/Cem - Removal, Cement Stabilization, On-Property Disposal | B.S.L.[c] | B.S.L.[c] | N/A | $4.1 \times 10^{-5}$ |
| 3B.1/Vit - Removal, Vitrification, Off-Site Disposal at NTS | N/A[d] | N/A[d] | $1.7 \times 10^{-11}$ | $4.1 \times 10^{-5}$ |
| 3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal at NTS | N/A[d] | N/A[d] | $1.9 \times 10^{-11}$ | $4.1 \times 10^{-5}$ |
| 4B - Removal, On-Property Disposal | B.S.L.[c] | B.S.L.[c] | N/A[f] | $4.5 \times 10^{-6}$ |

See footnote at end of table.



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**TABLE 5-5**
**(Continued)**

| Alternative | Future Land use w/continued Federal Ownership | Future Land Use w/o Cont. Federal Ownership | Short-term Risks | |
|---|---|---|---|---|
| | Off-Property Farmer | On-Property Farmer | Public | Worker[a] |
| **SUBUNIT C - SILOS 1, 2, AND 3 STRUCTURES, SOILS AND DEBRIS** | | | | |
| 0C - No-Action | $1.0 \times 10^{-4}$ | $1 \times 10^{-1}$ | N/A[f] | N/A[f] |
| 2C - Demolition, Removal, On-Property Disposal | $3.9 \times 10^{-6}$ | $1.7 \times 10^{-3}$ | N/A | $2.9 \times 10^{-7}$ |
| 3C.1 - Demolition, Removal, Off-Site Disposal at NTS | $3.9 \times 10^{-6}$ | $1.7 \times 10^{-3}$ | $4.8 \times 10^{-12}$ | $2.9 \times 10^{-7}$ |
| 3C.2 - Demolition, Removal, Off-Site Disposal at a Permitted Commercial Disposal Site | $3.9 \times 10^{-6}$ | $1.7 \times 10^{-3}$ | $2.4 \times 10^{-12}$ | $2.9 \times 10^{-7}$ |

[a]Worker receiving highest risk (worker near the soil/berm excavation activities or remediation worker).
[b]Total radiological ILCR from groundwater, air, silo contents, and soil exposure pathways, assuming the future source term scenario. ILCR includes contributions from Subunits A and B combined.
[c]Below screening level ($10^{-6}$ excess cancer risk and HICI).
[d]Long-term risk pathways are eliminated because the material is disposed of off property.
[e]Exposure to public from radon.
[f]N/A - Not applicable or not calculated because the risk is less than $10^{-6}$.

### 5.2.1 Threshold Criteria

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#### 5.2.1.1 Overall Protection of Human Health and the Environment

Assessment of protectiveness for Operable Unit 4 alternatives assumes a reasonable future land use scenario which incorporates passive institutional controls. Under this scenario, the FEMP site is assumed to remain under the ownership of the federal government, precluding such activities as homesteading, farming, and the installation of domestic wells. Three potential receptors examined under this scenario are an off-property farmer, expanded trespasser and trespassing child.

To assess each alternative's long-term effectiveness for maintaining protective levels, a less restrictive future land use scenario was assumed. Under this scenario, the federal government loses control of the FEMP site and the facility is assumed to revert to the primary use of the surrounding land, the family farm. For this scenario, an on- and off-property farmer receptor are examined. Appendix D provides detail on the assumptions used to develop the scenarios and examine risks to the receptors.

Table 5-5 summarizes both the long-term and short-term radiological incremental lifetime cancer risks for each subunit alternative. Short-term risks are provided to assess the potential impacts to the public and remedial action workers during implementation of each alternative.

All of the Subunit A alternatives, except 0A - No Action, would provide overall protection of human health and the environment. All of the action alternatives (2A/Vit, 2A/Cem, 3A.1/Vit, and 3A.1/Cem) would limit exposures to contaminants by removing the sources of contamination, treating the source materials, and placing the treated materials either in an on-property above-grade disposal vault or an off-site facility (NTS) owned by DOE. The basic differences among the action alternatives are the treatment options (vitrification or cement stabilization) and the disposal options (on property or off site).

Both treatment options provide a stabilized material which reduces the potential for contaminant migration. Treatability study results demonstrate that the vitrified residue form would be expected to have greater durability over time, thereby reducing the potential for contaminant migration to human and ecological receptors. Short-term risks to the public and workers associated with the implementation of both treatment options are similar. Vitrification is considered to pose a higher risk to workers because of high operating temperatures and limited field experience.

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The off-site disposal location would be the NTS facility, which has been used selectively by DOE for disposal of low-level radioactive waste. The NTS incorporates engineering and institutional controls to ensure protectiveness and is located in a climatic, demographic, and hydrogeologic setting which favors minimization of contaminant migration to both human and environmental receptors. In the long-term event of degradation of engineered features or loss of institutional controls, these site characteristics coupled with the treated residue would ensure continued protectiveness.

The on-property disposal option would employ an above-grade disposal vault designed for a life of 1,000 years with no active maintenance. The vault would prevent exposure to direct radiation and would minimize infiltration of water and subsequent leaching of contaminants from the treated material into the Great Miami Aquifer. The vault design would incorporate an intruder barrier to inhibit purposeful or inadvertent human destruction of its protective features. The FEMP site demographic characteristics, as compared to NTS, would provide a higher probability of purposeful or inadvertent intrusion into the vault. Potential direct radiation doses to the intruder could be significant.

As the result of additives which increase the volume of untreated residue by up to 216 percent, Alternative 2A/Cem would provide more protection from direct radiation than Alternative 2A/Vit in the event of a breach of the intruder barrier. The tradeoff is that the increased waste volume requires a much larger, more costly disposal vault.

Short-term risks to the public and workers are slightly greater for the off-site disposal option due to the increased risks of transportation accidents resulting in injuries or radiation exposure. The greatest short-term risk of this type is associated with Alternative 3A.1/Cem because of the increased volume of treated material requiring transportation off site.

The nature and extent of impacts to biota from implementing Alternatives 2A/Vit and 2A/Cem would be similar. Both alternatives involve site preparation and construction for a processing facility and disposal vault, construction of a hydraulic mining device work platform, removal of the Silos 1 and 2 contents, and stabilization of the contents. Potential environmental impacts associated with implementing Alternatives 2A/Vit and 2A/Cem include the permanent loss of some on-property habitats. Short-term impacts include the temporary loss of habitats at the FEMP site and possible impacts of accidental spills of construction and operational materials. Mitigative measures would be employed to minimize these short-term risks.

Environmental impacts associated with implementing alternatives 3A.1/Vit and 3A.1/Cem include those identified with alternatives 2A/Vit and 2A/Cem, in addition to potential impacts from transportation to and disposal activities at NTS.

Alternative 0A would not provide adequate overall protection of human health and the environment. Alternative 0A would not eliminate, reduce, or control the migration of contaminants to human and environmental receptors. Based on the results of the Baseline Risk Assessment presented in the RI Report for Operable Unit 4 (DOE 1993c), the no-action alternative would not be adequately protective. Over the long term, risks to human health and the environment would increase with loss of current site access controls.

5.2.1.2 Compliance with ARARs

Except for Alternative 0A - No Action, the attainment of pertinent ARARs under each of the Subunit A alternatives would be comparable. A comprehensive list of potential ARARs is presented in Appendix F. Key requirements are discussed in Section 4.0 within the evaluation of each alternative against this criterion. The following summarizes those evaluations.

Chemical-Specific ARARs

All of the action alternatives (2A/Vit, 2A/Cem, 3A.1/Vit, and 3A.1/Cem) for Subunit A meet the chemical-specific ARARs associated with potential releases to groundwater, air, and surface water. As demonstrated by fate and transport modeling, the Subunit A action alternatives would attain the SDWA concentration-based limits for specific chemicals under 40 CFR § 141.11 et al., and 40 CFR § 264.94. Additionally, dose-based requirements for the protection of potential public receptors using affected groundwaters are defined in DOE Order 5400.5. DOE Order 5400.5 limits the allowable annual effective dose equivalent from exceeding 100 mrem from all pathways, including groundwater, to any member of the public.

Guidance is provided in 40 CFR § 264.94 as to the point of compliance for demonstrating whether the groundwater protection requirements for inorganic and organic contaminants would be attained. 40 CFR § 264.94 requires the disposal vault to meet the concentration-based limits in the uppermost aquifer underlying the waste management area beyond the point of compliance. The uppermost aquifer is the Great Miami Aquifer. One thousand year fate and transport modeling of uranium, the principal groundwater constituent of concern, indicates that the uranium concentration would not exceed the proposed 20 $\mu$g/L MCL, defined in 40 CFR § 141, at the point of compliance.

The most critical chemical-specific ARAR relative to airborne releases for Subunit A materials relates to radon. The maximum permissible surface release rate of radon-222, as specified in National Emissions Standards for Hazardous Air Pollutants (NESHAP), 40 CFR § 61 Subpart Q, is 20 $pCi/m^2/s$, surface averaged. This requirement is supplemented by 40 CFR § 192.02(b), which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 pCi/L above background. Requirements for other radionuclides are established in 40 CFR § 61 Subpart H and DOE Order 5400.5, Chapter III. Compared to the untreated Subunit A materials, the vitrified waste form is more effective in reducing radon emanation than the cement stabilized form. Engineered barriers and packaging associated with the disposal of treated materials, in either form, would effectively control the radon flux. A radon treatment system would be employed during treatment operations for both Alternative 2A/Vit and 2A/Cem to control radon release over the short term.

Alternative 0A - No Action would not meet 40 CFR § 61 Subpart Q radon flux requirements based on the projected deterioration of Silos 1 and 2. Also, several criteria for the protection of groundwater would not be met. In the event existing access controls were discontinued and a family farm was established on the FEMP site, exposure limits embodied within DOE Order 5400.5 for members of the general public could be exceeded.

Location-Specific ARARs

Alternatives 3A.1/Vit and 3A.1/Cem would comply with all pertinent location-specific ARARs identified for these alternatives. Included would be those associated with the protection of wetlands (10 CFR § 1022 and 40 CFR § 258.12) and endangered species (50 CFR §§ 200 and 204) during the on-property treatment of materials. Disposal facility location requirements would not be relevant and appropriate to Alternatives 3A.1/Vit and 3A.1/Cem since they propose off-site disposal.

Alternatives 2A/Vit and 2A/Cem would meet all of the ARARs cited above; in addition, they would meet the ARARs associated with construction of an on-property disposal vault. In particular, the State of Ohio maintains a number of solid waste disposal design considerations within Ohio Administrative Code (OAC) 3745-27-07. Through the definition of a Corrective Action Management Unit (CAMU) for Operable Unit 4, which includes the area encompassing the operable unit boundary and any proposed on-property treatment and disposal areas, these requirements would be considered relevant and appropriate to the implementation of Alternatives 2A/Vit and 2A/Cem. The OAC requirements contain setback requirements pertaining to the distance of the disposal vault from the

property line as well as the distance from the nearest domicile or water supply well. An additional requirement specifies a distance of 4.5 m (15 ft) from the bottom of the liner system and the top of the uppermost aquifer.

OAC 3745-27-07 (B)(5) prohibits solid waste disposal facilities from being constructed over sole-source aquifers. Exemptions to this requirement have been granted on the basis of technical considerations including: presence of a significant thickness of low permeability material between the disposal vault liner and the aquifer; no significant interconnection between the aquifer and any significant zones of saturation that exist above the aquifer; and, no adverse impact to human health or the environment. The disposal facility proposed for Alternatives 2A/Vit and 2A/Cem would meet these technical considerations. A discussion of the data to support this position is in Section 3.2.2.1 and Appendix D.

Alternative 0A - No Action would meet all location-specific ARARs identified for this alternative. The Ohio requirements for location of a solid waste disposal facility contained in OAC 3745-27-07 are not an ARAR for this alternative.

Action-Specific ARARs

All Subunit A action alternatives would comply with all pertinent action-specific ARARs identified for these alternatives. For Alternatives 2A/Vit and 2A/Cem, the above-grade disposal vault would incorporate the design requirements for the disposal of uranium mill tailings (40 CFR § 192) and hazardous waste under RCRA [i.e., the Treatment, Storage, and Disposal Facility (TSDF) requirements under 40 CFR § 264]. As a result of elevated direct penetrating radiation associated with the treated Subunit A residues, the prescriptive intruder protection requirements defined in 10 CFR § 61.7 have been adopted for on-property disposal.

The design of the on-property disposal vault would also include appropriate engineered features that satisfy the requirements of the Clean Water Act (40 CFR §§ 125.100 and 104), the Ohio Water Quality Standards, and RCRA Subtitle C - Hazardous Waste (40 CFR §§ 262.11, 261.7, and the other § 264 requirements identified in Appendix F).

An action-specific ARAR and to be considered (TBC) requirement particular to on-property disposal of Subunit A material at the FEMP site is 40 CFR § 191 (Standards for the Management, Storage, and Disposal of Spent Nuclear, High Level, and Transuranic Wastes). In October 1990, EPA

directed DOE to consider 40 CFR § 191 Subpart A (dealing with the storage and management of waste) as an ARAR to the on-property portions of remedial activities involving the K-65 residues, and to consider Subpart B (pertaining to waste disposal) as a TBC requirement for on-property Subunit A disposal alternatives.

40 CFR § 191 Subpart A specifies a public dose limit to be complied with during waste storage and remediation operations. Estimates of the dose to the public calculated for the short-term risk assessment indicate that exposures would be a small fraction of the one mrem/yr limit (Appendix D). Alternatives 2A/Vit and 2A/Cem would comply with all pertinent provisions of 40 CFR § 191.

Alternatives 3A.1/Vit and 3A.1/Cem would comply with all pertinent action-specific ARARs identified in Appendix F, including 40 CFR § 191 Subpart A. Hazardous waste transport requirements would be complied with by following the regulations under 40 CFR §§ 262 and 263, and the appropriate Department of Transportation (DOT) shipping standards under 49 CFR §§ 172 and 173.

### 5.2.2 Primary Balancing Criteria

Those alternatives that satisfy the threshold criteria comparative analysis are carried forward for further comparative analysis under the primary balancing criteria. The no-action alternative, Alternative 0A, will be carried forward as the baseline alternative for comparison purposes in accordance with the NCP. Alternatives that will be carried forward will include:

- Alternative 0A - No Action
- Alternative 2A/Vit - Removal, Vitrification, On-Property Disposal
- Alternative 2A/Cem - Removal, Cement Stabilization, On-Property Disposal
- Alternative 3A.1/Vit - Removal, Vitrification, and Off-Site Disposal at NTS
- Alternative 3A.1/Cem - Removal, Cement Stabilization, and Off-Site Disposal at NTS

#### 5.2.2.1 Long-Term Effectiveness and Permanence

All Subunit A alternatives, with the exception of Alternative 0A - No Action, would ensure long-term protectiveness to human health and the environment. For all alternatives, projected FEMP site residual risk to viable receptors (off-property farmer and recreational user) would be less than $10^{-6}$ ILCR, and no non-carcinogenic effects (HI less than 0.2) would be indicated for either receptor.

Alternatives 3A.1/Vit and 3A.1/Cem include removal and treatment of the source materials, followed by transportation and off-site disposal at NTS. Removal and treatment of the Subunit A materials eliminate the potential for exposure to direct radiation and mitigates the migration of constituents to the air, soil, and water. Treatability studies demonstrated that both the vitrified and the cement-stabilized material exhibits reduced leachability of constituents compared to the untreated materials. Both treated materials have TCLP results below RCRA limits. Vitrification of the untreated materials reduced radon emanation significantly and reduced the residue volume by approximately 50 percent.

Vitrification is an innovative technology which has not been previously applied to the stabilization of waste materials at the same scale as contemplated under Alternative 2A/Vit. The results of treatability tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics. Cement stabilization is a proven technology that has been previously applied to the stabilization of similar waste materials as those contemplated under Alternative 2A/Cem. The performance characteristics of the cement-stabilized material in reducing leachability are generally comparable to those of the vitrified material; however, degradation and leachability results for some constituents indicate that cement stabilization is not an irreversible treatment process.

Off-site disposal at NTS would provide protection by eliminating access to the treated materials and preventing migration of constituents from the materials. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant migration, and direct contact with contaminants. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. As the result of a low average annual precipitation and depths to groundwater ranging from 157 - 600 m (515 - 2000 ft) below ground surface, impacts to human health and the environment would be mitigated in the event that engineering and institutional controls fail.

Long-term environmental impacts under Alternatives 3A.1/Vit and 3A.1/Cem would include those associated with the removal and treatment activities performed at the FEMP and disposal activities at NTS. There are no long-term environmental impacts at the FEMP site pertaining to the removal and treatment processes. Long-term environmental impacts at NTS would include some permanent disturbance of soils (i.e., acquisition of borrow material) associated with disposal activities. No significant long-term impacts would be expected for water quality and hydrology, air quality, biotic

resources, socioeconomics and land use, or cultural resources. No wetland or floodplain areas have been delineated at the NTS.

Alternatives 2A/Vit and 2A/Cem include the removal and treatment of source materials followed by on-property disposal in an above-grade disposal vault. The long-term effectiveness afforded by the removal and treatment processes would be identical for both Alternatives 2A/Vit and 2A/Cem. The design features of the disposal vault would provide effective long-term containment of the treated material. The vault would use proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low-level radioactive waste under both DOE and NRC programs, and uranium mill tailings under the DOE UMTRCA and FUSRAP.

Fate and transport modeling was performed to assess leaching of constituents under degradation of the facility (slight degradation of components over 1,000 years). The results of this modeling, based on conservative assumptions for infiltration rates, show that the leaching of constituents would not pose a risk to off-site receptors. Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the treated material by future human and ecological receptors. Exposures to receptors through these pathways would be expected to initially be minimal due to the positive attributes of the treated materials. Direct radiation exposure could be significant in the event that the disposal vault is breached.

Long-term environmental impacts associated with construction of the on-property disposal vault for Alternatives 2A/Vit and 2A/Cem include permanent disruption of up to 5.8 ha (14.3 acres) of land. No significant long-term impacts are expected for water quality and hydrology, air quality, socioeconomics, or cultural resources. A potential habitat for threatened and endangered species has been identified in the area proposed for the disposal vault. This same area has been identified as forested wetlands. No floodplains would be permanently altered as the result of implementing either of these two alternatives.

Alternative 0A - No Action would not be protective of human health and the environment in the long term because it would not prevent exposure to the Silos 1 and 2 residues. Silo collapse and subsequent loss of containment would lead to increased contamination levels in air, soils, groundwater, surface water, and sediments. Based on the results of the baseline risk assessment,

Alternative 0A-No Action would not be adequately protective under all evaluated land use scenarios, except current land use conditions with continuation of access controls. For these land use scenarios, at least one receptor receives risks which are calculated to exceed $10^{-4}$.

5.2.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 2A/Vit, 2A/Cem, 3A.1/Vit, and 3A.1/Cem would employ one of two treatment processes for the Subunit A residues. Alternatives 2A/Vit and 3A.1/Vit would use vitrification to physically bind the constituents in a glass-like matrix, which would significantly reduce contaminant mobility. Vitrification would also significantly reduce radon emanation significantly. Treatability tests of the vitrification process have demonstrated that an overall material volume reduction of about 59 percent could be expected. The high operating temperatures of the vitrification process have also been shown to effectively destroy any organic compounds present in the residue matrix. The effects of vitrification as a treatment are essentially irreversible.

TCLP tests were conducted on both the untreated and vitrified form of the residues. The results showed that the leachate concentrations of hazardous metals were below regulatory limits for all glasses made during the bench-scale tests. Product Consistency Tests (PCT) were also performed on the vitrified materials. PCT leach testing demonstrated a high degree of durability for the vitrified materials. Literature data on the leachability of the vitrified product from a variety of material types indicate similar leach resistance. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates; however, on the basis of the longevity of volcanic glass (a natural analog to the vitrified product), the vitrified product would be expected to withstand environmental exposure for thousands of years.

Alternatives 2A/Cem and 3A.1/Cem would use the cement stabilization process to treat the Subunit A residues. Cement stabilization would reduce the mobility of constituents by binding them into a cement mixture. Radon emanation would be reduced somewhat, but not as much as through the vitrification process. Various reagents would be added to the mixture to improve the characteristics of the final treated material, e.g., improved metals adsorption, increased leachability resistance, and decreased effects of process inhibitors. The addition of reagents to the untreated residues causes an overall increase in volume ranging from 136 to 216 percent.

TCLP tests were conducted on both the untreated and cement stabilized form of the residues. The results showed that the leachate concentrations of RCRA metals were below regulatory limits for all cement stabilized forms produced during the bench-scale tests.

Treatability tests have been performed to determine the best formulations resulting in a product having the most favorable leach resistance and durability characteristics. Static leach tests were generally the same order of magnitude as for the TCLP leachate results. Degradation and durability testing indicate that cement stabilization is not an irreversible process.

In summary, the primary differences between vitrification and cement stabilization performance are:

- Vitrification significantly reduces volume
- Cement stabilization significantly increases volume
- Cement stabilization is reversible

Alternative 0A - No Action does not include treatment; therefore, it does not provide any reduction in toxicity, mobility, or volume of contaminants.

5.2.2.3 Short-Term Effectiveness

For the Subunit A action alternatives, the various removal, treatment, and disposal activities would result in increased short-term exposures compared with Alternative 0A. The short-term effectiveness of removal is expected to be the same among the alternatives for Subunit A that include removal. The risks from transportation accidents would be incrementally higher for the cement stabilization alternatives than for the vitrification alternatives because of the larger volume of material.

Short-term impacts associated with the action alternatives would include temporary disruption of approximately 3.2 ha (7.8 acres) of land at the FEMP site. Increased fugitive dust during excavation activities and the potential for minor impacts to biota and wetlands [0.36 ha (0.9 acre)] does exist. However, the appropriate engineering controls would minimize these potential short-term impacts. All transportation to NTS would be in compliance with DOT and DOE guidelines.

The time required to implement any of the removal and treatment alternatives is estimated to be approximately six to seven years.

The short-term effectiveness for Alternative 0A would remain unchanged from current conditions so that no significant changes in potential exposure are expected. The estimated risks are summarized in Appendix G.

5.2.2.4 Implementability

The removal and treatment activities in Alternatives 2A/Cem and 3A.1/Cem could be implemented using standard equipment, procedures, and readily available resources. Hydraulic removal is a standard mining technology that is normally reliable and uses readily available equipment. The cement stabilization technology has been applied successfully at a number of remedial sites. EPA considers cement stabilization a demonstrated treatment technology and has approved its use in the final remedy for many NPL sites. This technology has also been applied at other sites that are radioactively contaminated. The cement stabilization process would require large quantities of cement, flyash, and blast furnace slag, which are available.

Alternatives 2A/Vit and 2A/Cem would require on-property disposal vaults. Alternatives 3A.1/Vit and 3A.1/Cem would not require on-property disposal vaults. Off-site transportation would be technically straightforward, and the necessary resources are available. For disposal, NTS has the resources and capacity to accept the treated Subunit A material. However, off-site transport and disposal would be subject to various state and federal requirements; therefore, administrative feasibility may require increased coordination efforts with jurisdictional agencies for off-site disposal. A Waste Certification Acceptance Program for the Subunit A materials would be required to be prepared and approved for shipment to NTS. Public acceptance and approval of treated material shipment by the State of Nevada must be obtained for these alternatives. Opposition by the State of Nevada may require extensive negotiations with the Nevada Division of Environmental Protection to facilitate the disposal at NTS.

Although removal and disposal are the same for Alternative 2A/Vit as for Alternative 2A/Cem and for Alternative 3A.1/Vit as for Alternative 3A.1/Cem, the vitrification process is more difficult to implement than the cement stabilization process. The vitrification process would require fewer chemical reagents than for the cement stabilization process but larger amounts of energy (electricity). In addition, the vitrification process equipment would be more complex to construct and operate than that of the cement stabilization process. There is limited experience available for the types and quantities of the material from the silos and decant sump tank on which to base an assessment of the likely performance of the vitrification technology. The vitrification technology is not as widely

available as the cement stabilization technology. Off-gas treatment is also an additional complexity with vitrification where delays could occur. The combination of these complexities makes implementation of Alternatives 2A/Vit and 3A.1/Vit more difficult than Alternatives 2A/Cem and 3A.1/Cem. However, operational experience is being gained as part of the structured treatability studies and vitrification pilot facility planning currently in progress.

Because there are no actions required, Alternative 0A would be easy to implement.

5.2.2.5 Cost

Cost estimates are used in the feasibility study process under the CERCLA to eliminate those remediation alternatives which are significantly more expensive than competing alternatives but do not offer commensurate performance or overall protection of human health and the environment. The cost estimates developed are order-of-magnitude estimates with an intended accuracy range of -30 to +50 percent. Estimates are considered to be order-of-magnitude because of the uncertainties in the information used to develop the estimates. Final costs would depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final scope, final schedule, final engineering design, and other variables.

The categories of costs developed were capital, short-term Operation and Maintenance (O&M) (during remediation), and long-term O&M (post-remediation). Total present worth costs were developed for each alternative, assuming a discount rate of seven percent, so that all alternatives with costs incurred over differing time periods could be compared on an equivalent basis. Capital and O&M costs for each Subunit A alternative evaluated in the detailed analysis (Section 4.0) are presented in Table 5-6.

There are no capital or O&M costs associated with Alternative 0A-No Action. Alternative 3A.1/Vit is the least expensive action alternative. The present worth cost of Alternative 2A/Vit is approximately that of Alternative 3A.1/Vit. Alternatives 3A.1/Cem and 2A/Cem are approximately 67 percent and 70 percent more expensive, respectively, than Alternative 3A.1/Vit. The alternatives that include cement stabilization are more expensive than the vitrification alternatives primarily due to the additional packaging, transportation (for Alternative 3A.1/Vit), and disposal of the larger volume of cement-stabilized material. Use of the cement stabilization treatment process results in over six times the volume that the vitrification process generates.

TABLE 5-6

SUBUNIT A ALTERNATIVE COSTS

| Alternative | COST[a] | | | |
|---|---|---|---|---|
| | Capital | O&M During Remediation | Post-Remediation O&M | Total Present Worth |
| 0A | 0 | 0 | 0 | 0 |
| 2A/Vit | 36,537,400 | 11,692,500 | 3,425,400 | 43,601,900 |
| 2A/Cem | 71,238,200 | 11,715,700 | 3,582,000 | 74,038,600 |
| 3A.1/Vit | 38,304,500 | 11,692,500 | 0 | 43,730,700 |
| 3A.1/Cem | 71,843,300 | 11,715,700 | 0 | 73,086,300 |

[a]Values are given in dollars ($).

Sensitivity Analysis of Present Worth Costs

Some factors that can greatly impact present worth costs are the extent of remediation required, i.e., scope of project, duration of construction, remediation or O&M, and discount rate. The quantity of material included in Subunit A (Silos 1 and 2 material) is fairly well defined. A detailed construction schedule was developed for the duration of construction and remediation, so these factors are not likely to change significantly. Since the relative cost of post-remediation O&M is relatively low in comparison to the capital and short-term O&M costs, a change in the post-remediation time period is not likely to have a major impact on present worth cost. Therefore, discount rate is one factor that can be varied at this time to provide a sensitivity analysis on present worth costs.

A range of three to ten percent for the discount rate was analyzed, and the results are provided in Table 5-7. The sensitivity analysis indicates that the relative cost comparison presented for a discount rate of seven percent does not significantly change for the other discount rates evaluated in the sensitivity analysis.

## 5.3 SUBUNIT B

Subunit B alternatives compared include:

- Alternative 0B - No Action
- Alternative 2B/Vit - Removal, Vitrification, On-Property Disposal
- Alternative 2B/Cem - Removal, Cement Stabilization, On-Property Disposal
- Alternative 3B.1/Vit - Removal, Vitrification, Off-Site Disposal at NTS
- Alternative 3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal at NTS
- Alternative 4B - Removal, On-Property Disposal

A summary of the Subunit B comparative analysis is presented in Table 5-2.

### 5.3.1 Threshold Criteria

#### 5.3.1.1 Overall Protection of Human Health and the Environment

All of the Subunit B alternatives, except 0B-No Action, provide for the protection of human health and the environment. Table 5-5 summarizes both the long-term and short-term incremental lifetime cancer risks for each alternative. Long-term risks represent the residual risks to the hypothetical

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TABLE 5-7

SENSITIVITY ANALYSIS
SUBUNIT A PRESENT WORTH COSTS

| Discount Rate (%) | PRESENT WORTH COST[a] | | | |
|---|---|---|---|---|
| | Alternative 2A/Vit | Alternative 2A/Cem | Alternative 3A.1/Vit | Alternative 3A.1/Cem |
| 3 | 47,718,700 | 80,565,800 | 47,147,200 | 78,796,100 |
| 4 | 46,587,100 | 78,797,000 | 46,247,200 | 77,292,100 |
| 5 | 45,531,800 | 77,129,900 | 45,380,600 | 75,843,700 |
| 6 | 44,544,500 | 75,555,500 | 44,547,300 | 74,451,100 |
| 7 | 43,601,900 | 74,038,600 | 43,730,700 | 73,086,300 |
| 8 | 42,714,900 | 72,601,600 | 42,947,400 | 71,777,200 |
| 9 | 41,863,000 | 71,212,200 | 42,180,800 | 70,495,900 |
| 10 | 41,059,000 | 69,894,400 | 41,447,500 | 69,270,400 |

[a]Values are given in dollars ($).

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RME receptor potentially remaining at the site following implementation of the alternative. Short-term risks are provided to assess the potential impacts to the public and remedial action workers during implementation of the alternative. All of the action alternatives, except Alternative 4B, would limit exposures to contaminants by removing the residues from the deteriorated silo structure, treating the materials (using either vitrification or cement stabilization) to reduce the mobility of the radiological and inorganic chemical constituents, and placing the treated materials in an on-property, above-grade disposal vault or off-site facility (NTS) owned by DOE. Alternative 4B would mitigate the migration of contaminants and prevent direct access to the residues by removing the residues and placing them in an above-grade disposal vault.

For alternatives that include treatment, both the vitrification and cement stabilization treatment processes provide a waste form which significantly reduces the potential for contaminant migration and radon emanation. The results of treatability studies completed on the two treatment processes for Silo 3 residues demonstrate that the vitrified residue form would be expected to be more durable over the long term, with both a reduced volume and radon emanation rate. These factors would contribute to the conclusion that the vitrified material better supports the overall goal of providing for the long-term protection of human health and the environment than does the cement stabilized material. Short-term risks to the public, workers, and the environment associated with the implementation of the treatment process would be expected to be similar.

As a result of the necessary additives to facilitate cement stabilization, the volume of waste requiring disposal for alternatives including this treatment technology would be expected to increase by over 62 percent. The vitrification process would reduce the volume of contaminated material requiring disposal by 55 percent. Since no treatment would be performed in Alternative 4B, the volume of residue material to be disposed is not impacted for this alternative.

The off-site disposal location would be the NTS facility, which has been used for FEMP low level waste disposal since August 1985. NTS disposal methods include engineering and institutional control measures to preclude contact with the waste and minimize the potential for migration of contaminants from the disposed wastes. These controls, when coupled with the climatic, demographic, and hydrogeologic setting of the NTS site, provide assurance of the long-term protection of human health and the environment.

Alternatives 2B and 4B include an on-property disposal vault. The on-property disposal option would employ an above-grade disposal vault designed for a life of 1,000 years with the requirement for no active maintenance. The disposal vault would prevent exposure to direct radiation and minimize infiltration of water and subsequent leaching of contaminants to the underlying clays and ultimately to the Great Miami Aquifer. Disposal vault design features would inhibit purposeful or inadvertent intrusion into the disposed residues. In the event intrusion did occur, the exposures and resultant risks to these intruders would not be expected to be significant for Alternative 2B due to the characteristics of the treated residues. For Alternative 4B, loss of institutional controls in combination with disposal vault failure over the long term could result in potential contaminant migration or direct exposure to the untreated material by human and ecological receptors. Exposures to receptors through these pathways in the event of disposal vault failure would be expected to be significant due to the lack of treatment of the residues. The FEMP site demographic features, as compared to NTS, provide a higher probability of intrusion into the disposed residues.

Short-term risks to the public and workers are slightly greater for the off-site disposal option due to the increased risks of transportation accidents resulting in injuries or radiation exposure. The greatest short-term risk of this type is associated with Alternative 3B.1/Cem because of the increased volume of treated material requiring transportation off site.

Table 5-4 provides a summary of the environmental impacts associated with the implementation of each of the remedial alternatives. The potential short-term environmental impacts associated with each of the alternatives are comparable. Short-term impacts include the temporary loss of habitats at the FEMP site and possible impacts of accidental spills of construction and operation materials. Mitigative measures would be employed to minimize these impacts.

Long-term environmental impacts associated with each of the treatment alternatives are comparable and would not be expected to be significant. Impacts from implementing Alternatives 2B/Vit and 2B/Cem would include the permanent loss of some on-property habitats.

Alternative 0B would not provide adequate overall protection of human health or the environment. Alternative 0B would not adequately eliminate, reduce, or control the migration of contaminants to human and environmental receptors. Based on the results of the baseline risk assessment presented in the RI Report for Operable Unit 4 (DOE 1993c), the no-action alternatives would not be adequately protective. Risks to human health would increase in the event current access controls were lost.

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5.3.1.2 Compliance with ARARs

Except for Alternative 0B - No Action, all Subunit B alternatives would attain all pertinent chemical, location, and action-specific ARARs and TBCs. A comprehensive list of potential ARARs is presented in Appendix F. Key requirements are discussed in Section 4.0 within the evaluation of each alternative against this criterion. The following summarizes those evaluations.

Chemical-Specific ARARs

All of the action alternatives (2B/Vit, 2B/Cem, 3B.1/Vit, 3B.1/Cem, and 4B) for Subunit B meet the chemical-specific ARARs associated with potential releases to groundwater, air, and surface water. As demonstrated by fate and transport modeling, the Subunit B action alternatives, including on-property disposal, would attain the SDWA concentration-based limits for specific chemicals under 40 CFR § 141.11 and et al., 40 CFR § 264.94, and dose-based requirements for the protection of potential public receptors defined in DOE Order 5400.5.

Guidance is provided in 40 CFR § 257.3-4 and 40 CFR § 264.94 as to the point of compliance for demonstrating whether the groundwater protection requirements for inorganic and organic contaminants would be attained. The most restrictive requirements for these constituents appears in 40 CFR § 264.94, which requires the disposal vault to meet the concentration-based limits in the uppermost aquifer underlying the waste management area beyond the point of compliance. The uppermost aquifer is the Great Miami Aquifer. Fate and transport modeling of potential releases of uranium, the principal groundwater constituent of concern, from the on-property disposal vault indicates the uranium concentration would not exceed the proposed 20 $\mu$g/L MCL at the point of compliance during the 1,000 year modeling horizon both for the treated or untreated residues.

The most critical chemical-specific ARAR relative to airborne releases for Subunit B materials relates to radon. The maximum permissible flux rate of radon-222, as specified in the NESHAP, 40 CFR § 61 Subpart Q, is 20 pCi/m$^2$/s, surface averaged. This requirement is supplemented by 40 CFR § 192.02(b), which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 pCi/L over background. Requirements for other radionuclides are established in 40 CFR § 61 Subpart H and DOE Order 5400.5, Chapter III. Compared to the untreated Subunit B materials, both the vitrified and the cemented residue forms are effective in reducing radon emanation from the treated residues to less than these prescriptive requirements. Engineered barriers associated with the disposal of treated materials, in either form, would provide additional controls to ensure these chemical-specific

ARAR/TBCs are attained. Engineered barriers associated with disposal would provide control for untreated material (Alternative 4B)

Alternative 0B - No Action would not meet several requirements for the protection of groundwater used for drinking water supply. Also, in the event existing access controls were discontinued and a family farm was established on the FEMP site, exposure limits embodied within DOE Order 5400.5 for members of the general public could be exceeded.

Location-Specific ARARs

Alternatives 3B.1/Vit and 3B.1/Cem would comply with all pertinent location-specific ARARs. Disposal facility location requirements would not be relevant and appropriate to Alternatives 3B.1/Vit and 3B.1/Cem since the alternatives provide for off-site disposal of the treated residues.

Alternatives 2B/Vit, 2B/Cem and 4B would meet all of the location-specific ARARs, including those associated with the design and construction of an on-property disposal vault. As discussed in the comparative analysis section for Subunit A alternatives, the Subunit B alternatives which include on-property disposal will attain all State of Ohio solid waste disposal facility design considerations.

Alternative 0B - No Action would meet all location-specific ARARs identified for this alternative. The Ohio requirements for location of a solid waste disposal facility contained in OAC 3745-27-07 one not on ARAR for this alternative.

Action-Specific ARARs

All Subunit B action alternatives would comply with all pertinent action-specific ARARs identified for these alternatives. For Alternatives 2B/Vit, 2B/Cem, and 4B, the above-grade disposal vault would incorporate the design requirements for the disposal of uranium mill tailings (40 CFR § 192) and hazardous waste under RCRA (i.e., the TSDF requirements under 40 CFR § 264).

The design of the on-property disposal vault also would include appropriate engineered features that satisfy the requirements of the Clean Water Act (40 CFR §§ 125.100 and 104), the Ohio Water Quality Standards, and RCRA Subtitle C - Hazardous Waste (40 CFR §§ 262.11, 261.7, and the other 264 requirement identified in Appendix F).

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Alternatives 3B.1/Vit and 3B.1/Cem would comply with all action-specific ARARs identified in Appendix F. Hazardous material transport requirements would be complied with by following the regulations under 40 CFR §§ 262 and 263, and the appropriate DOT shipping standards under 49 CFR §§ 172 and 173.

### 5.3.2 Primary Balancing Criteria

Those alternatives that satisfy the threshold criteria comparative analysis are carried forward for comparative analysis under the primary balancing criteria. The no-action alternative, Alternative 0B, will be carried forward as the baseline alternative for comparison purposes in accordance with the NCP. Alternatives that will be carried forward include:

- Alternative 0B - No Action
- Alternative 2B/Vit - Removal, Vitrification, On-Property Disposal
- Alternative 2B/Cem - Removal, Cement Stabilization, On-Property Disposal
- Alternative 3B.1/Vit - Removal, Vitrification, Off-Site Disposal at NTS
- Alternative 3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal at NTS
- Alternative 4B - Removal, On-Property Disposal

#### 5.3.2.1 Long-Term Effectiveness and Permanence

All Subunit B alternatives, with the exception of Alternative 0B - No Action, would ensure long-term protectiveness to human health and the environment. For all alternatives, projected FEMP site residual risk to viable receptors (off-property farmer and recreational user) would be less than $10^{-6}$ ILCR, and no non-carcinogenic effects (HI less than 0.2) would be indicated for either receptor.

Alternatives 3B.1/Vit and 3B.1/Cem include removal and treatment of the source materials, followed by transportation and off-site disposal at NTS. Removal and treatment of the Subunit B materials eliminates the potential for residual risks to remain at the FEMP site following completion of the actions.

Treatability studies demonstrated that both the vitrified and the cement-stabilized residue forms exhibit reduced leachability of constituents compared to the untreated materials. However, treatability data for the vitrification process option indicated that the ratio of the activity of uranium-238 in the leachate from the untreated Silo 3 material to the activity in the leachate from vitrified Silo 3 material

was one. Both treated forms exhibited TCLP leachate concentrations for hazardous constituents that were below relevant and appropriate limitations defined in RCRA. Vitrification and cement stabilization both reduced radon emanation significantly. The vitrification alternatives are anticipated to achieve a better than 50 percent reduction in volume requiring disposal. The cement stabilization alternatives would increase volumes requiring disposal by greater than 55 percent due to the addition of additives. No treatment (Alternative 4B) does not impact volume requiring disposal.

Vitrification is an innovative technology which has not been previously applied to the stabilization of waste materials on the same scale as contemplated under Alternative 2B/Vit and 3B/Vit. The results of treatability tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics for the exception noted above. Cement stabilization is a proven technology that has been previously applied to the treatment of similar waste materials. The performance characteristics of the cement-stabilized material in reducing leachability are generally comparable to those of the vitrified material. Vitrification provides added flexibility in processing not afforded by cementation, because glass exhibiting unacceptable characteristics can be remelted and reformed.

Off-site disposal at NTS would provide protection by eliminating access to the treated materials and preventing migration of constituents from the materials. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant migration, and direct contact with contaminants. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. As the result of a low average annual precipitation and depths to groundwater ranging from 157 - 600 m (515 - 2000 ft) below ground surface, impacts to human health and the environment would be mitigated in the event that engineering and institutional controls fail.

Long-term environmental impacts under Alternatives 3B.1/Vit and 3B.1/Cem would include those associated with the removal and treatment activities performed at the FEMP site and disposal activities at the NTS. There are no long-term environmental impacts at the FEMP site pertaining to the removal and treatment processes. Long-term environmental impacts at NTS would include some permanent disturbance of soils (i.e., acquisition of borrow material) associated with disposal activities. No significant long-term impacts would be expected for water quality and hydrology, air

quality, biotic resources, socioeconomics and land use, or cultural resources. No wetland or floodplain areas have been delineated at the NTS.

Alternatives 2B/Vit and 2B/Cem include removal and treatment of Subunit B source materials followed by placement in an above-grade disposal vault. The long-term effectiveness afforded by the removal and treatment processes would be identical for both Alternatives 2B/Vit and 2B/Cem. Alternative 4B includes the removal of Silo 3 residues followed by placement in an above-grade disposal vault. Since no treatment would be provided, the long-term effectiveness of this alternative is less certain. For all three alternatives, the design features of the disposal vault would provide effective long-term containment of the treated or untreated residue forms. The vault would use proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low-level radioactive waste, and uranium mill tailings. Fate and transport modeling was performed to assess leaching of constituents under degradation of the vault (slight degradation of components over 1000 years). The results of this modeling, based on conservative assumptions for infiltration rates, show that the leaching of constituents would not pose a risk to off-site receptors. Exposures to receptors in the event institutional controls were lost would not be expected to be significant due to characteristics of the treated residue.

Long-term environmental impacts associated with construction of the on-property disposal vault for Alternatives 2B/Vit, 2B/Cem, and 4B include permanent disruption of 2.4 ha (5.9 acres), 4.5 ha (11.1 acres), and 2.8 ha (6.9 acres) of land, respectively. No significant long-term impacts are expected for water quality and hydrology, air quality, socioeconomics, or cultural resources. A potential habitat for threatened and endangered species has been identified in the area proposed for the disposal vault. This same area has been identified as forested wetlands. No floodplains would be permanently altered as the result of implementing these three alternatives.

Alternative 0B - No Action would not be protective of human health and the environment in the long term because it would not prevent exposure to the silo residues. Silo collapse and subsequent loss of containment would lead to increased contamination levels in air, soils, groundwater, surface water, and sediments. Based on the results of the Baseline Risk Assessment, Alternative 0B would not be adequately protective under all evaluated land use scenarios, except current land use conditions with continuation of access controls. For these land use scenarios, at least one receptor receives risks which are calculated to exceed $10^{-4}$.

5.3.2.2 Reduction of Toxicity, Mobility, or Volume

Alternatives employing vitrification would exhibit a greater overall reduction in the toxicity, mobility, and volume of the material. Alternatives 2B/Vit and 3B.1/Vit use the vitrification process to treat the contaminated material. This technology will physically bind the contaminants in a glass-like matrix, which will significantly reduce contaminant mobility and material volume. Mobility would be reduced since the contaminants would be bound in the matrix and the volume of the treated material would be approximately 62 percent of the untreated Subunit B material volume. Although most contaminants in the treated material would be incorporated into the vitrified product to reduce mobility over the long term, some contaminants would be released during the vitrification process and must be treated through the off-gas treatment system. The material generated through the off-gas treatment system may require additional stabilization to limit subsequent contaminant mobility.

Alternatives 2B/Cem and 3B.1/Cem use the cement stabilization process to treat the contaminated material. This technology would physically and chemically bind the contaminants in a cement-like matrix, so the mobility of contaminants via leaching from this treated material would be greatly reduced. However, the inherent toxicity of the material would not be reduced because no contaminants would be destroyed, and the total volume of material would increase by approximately 50 to 68 percent as a result of adding the cement stabilizing and setting agents.

No treatment occurs under Alternatives 0B and 4B; therefore, these alternatives do not provide any reduction of toxicity, mobility, or volume of contaminated material.

5.3.2.3 Short-Term Effectiveness

Alternative 2B/Cem provides fewer short-term impacts due to reduced emissions during treatment and minimal transportation related risks. The short-term effectiveness of removal is higher for Alternatives 3B.1/Vit and 3B.1/Cem than Alternatives 2B/Vit and 2B/Cem due to the additional risks of transporting the treated material to NTS. Alternative 3B.1/Cem will have higher risk due to transporting the larger volume of treated material to NTS.

Under Alternatives 2B/Vit, 2B/Cem, 3B.1/Vit, 3B.1/Cem, and 4B, short-term disturbance of soil would occur. Fugitive dust and exhaust emissions as a result of excavation and construction activities could temporarily result in minimal impacts to air quality and water quality at the FEMP site and/or NTS. However the proper engineering controls and mitigative measures should limit these impacts.

Minimal impacts to biotic resources is expected at both NTS and/or the FEMP site. In addition, minimal impacts to wetlands and floodplains would occur.

The time required to implement either treatment alternative is approximately six years. Alternative 4B would require two years.

The short-term effectiveness for Alternative 0B would remain unchanged from the current conditions so that no significant changes in potential exposure are to be expected. The estimated risks are summarized in Appendix G.

5.3.2.4 Implementability

Alternative 4B would be the most implementable action alternative since no treatment would be performed. Alternative 2B/Cem represents the most implementable alternative of all treatment alternatives due to use of proven treatment and disposal technology in addition to use of existing FEMP site controlled property for disposal.

The removal and treatment activities in Alternatives 2B/Cem and 3B.1/Cem could be implemented with standard equipment, procedures, and readily available resources. Pneumatic removal is a standard technology that is normally reliable and uses readily available equipment. The cement stabilization technology has been applied successfully at a number of remedial sites. EPA considers cement stabilization a demonstrated treatment technology and has approved its use in the final remedy for many NPL sites. This technology has been also applied at other sites that are radioactively contaminated. The cement stabilization process would require large quantities of cement, flyash, and blast furnace slag, which are readily available.

Although the removal and disposal aspects are the same for Alternatives 2B/Vit and 3B.1/Vit as for Alternatives 2B/Cem and 3B.1/Cem, the treatment component (vitrification) of these alternatives is more difficult to implement. The vitrification process would require fewer chemical reagents than for the cement stabilization process but larger amounts of energy (electricity). In addition, the vitrification process equipment would be more complex to construct and operate than that of the cement stabilization process. There is limited experience available for the types and quantities of the material from the silo on which to base an assessment of the likely performance of the vitrification technology. The vitrification technology is not as widely available as the cement stabilization technology. Off-gas treatment is also an additional complexity with vitrification where delays could

occur. The combination of these complexities makes implementation of Alternatives 2B/Vit and 3B.1/Vit more difficult than Alternatives 2B/Cem and 3B.1/Cem. However, operational experience is being gained as part of the structured treatability studies and from the vitrification pilot facility currently in start-up.

Alternative 2B/Vit, 2B/Cem, and 4B are less difficult to implement due to the straightforward disposal vault design. Administrative feasibility is less difficult than Alternatives 3B.1/Vit and 3B.1/Cem because no outside state agencies or regional EPA office agencies would become involved.

Alternatives 3B.1/Vit and 3B.1/Cem would not require an on-property disposal vault. Off-site transportation would be technically straightforward, and the necessary resources are available. For disposal, NTS has the resources and capacity to accept the treated Silo 3 material. Off-site transport and disposal would be subject to coordination with various state and federal agencies to address transport. Approval to dispose the Silo 3 11(e)2 by-product material at NTS would need to be received from NTS and DOE-HQ.

5.3.2.5 Cost

The categories of costs developed were capital, short-term O&M (during remediation), and long-term O&M (post-remediation). Total present worth costs were developed for each alternative, assuming a discount rate of seven percent, so that all alternatives with costs incurred over differing time periods could be compared on an equivalent basis. Capital and O&M costs for each Subunit B alternative evaluated in the detailed analysis (Section 4.0) are presented in Table 5-8.

There are no capital or O&M costs associated with Alternative 0B-No Action. Alternative 4B is the least expensive action alternative. The present worth cost of Alternatives 2B/Vit and 3B.1/Vit treatment are approximately the same, and are about $6.0M higher than that of Alternative 4B. This is due to the component of those alternatives that is not included in Alternative 4B. Alternatives 3B.1/Cem and 2B/Cem are approximately 27 percent and 34 percent more expensive, respectively, than the corresponding vitrification alternatives.

Alternative 3B.1/Cem is more expensive than Alternative 3B.1/Vit primarily due to the additional packaging, transportation, and disposal of the larger volume of the cement-stabilized material. Use of the cement stabilization treatment process results in over six times the volume that the vitrification process generates.

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TABLE 5-8

SUBUNIT B ALTERNATIVE COSTS

| Alternative | COST[a] | | | |
|---|---|---|---|---|
| | Capital | O&M During Remediation | Post-Remediation O&M | Total Present Worth |
| 0B | 0 | 0 | 0 | 0 |
| 2B/Vit | 25,221,500 | 4,923,000 | 3,162,000 | 27,971,300 |
| 2B/Cem | 35,932,600 | 4,923,000 | 3,207,000 | 37,358,600 |
| 3B.1/Vit | 26,779,800 | 4,923,000 | 0 | 28,026,400 |
| 3B.1/Cem | 36,782,300 | 4,056,000 | 0 | 35,964,600 |
| 4B | 21,825,300 | 1,094,000 | 3,207,000 | 22,045,600 |

[a]Values are given in dollars ($).

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Sensitivity Analysis of Present Worth Costs

Some factors that can greatly impact present worth costs are the extent of remediation required, i.e., scope of project, duration of construction, remediation or O&M, and discount rate. The quantity of material included in Subunit B (Silo 3 material) is fairly well defined. A detailed construction schedule was developed for the duration of construction and remediation, so these factors are not likely to change significantly. Since the relative cost of post-remediation O&M is relatively low in comparison to the capital and short-term O&M costs, a change in the post-remediation time period is not likely to have a major impact on present worth cost. Therefore, discount rate is one factor that can be varied at this time to provide a sensitivity analysis on present worth costs.

A range of three to ten percent for the discount rate was analyzed. Results are provided in Table 5-9. The sensitivity analysis indicates that the relative cost comparison presented for a discount rate of seven percent does not significantly change for the other discount rates evaluated in the sensitivity analysis.

## 5.4 SUBUNIT C

Subunit C alternatives compared include:

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, Off-Site Disposal at NTS
- Alternative 3C.2 - Demolition, Removal, Off-Site Disposal at a Permitted Commercial Disposal Site

A summary of the Subunit C comparative analysis is presented in Table 5-3.

### 5.4.1 Threshold Criteria

#### 5.4.1.1 Overall Protection of Human Health and the Environment

Assessment of protectiveness for Operable Unit 4 alternatives adopts the use of continued federal ownership of the FEMP site and evaluates risk to the expanded trespasser for the on-property disposal alternatives; the assessment also evaluates risk to the expanded trespasser and off-site resident for off-site disposal alternatives. The summary of remedial alternatives and both short-term and long-term

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TABLE 5–9

SENSITIVITY ANALYSIS
SUBUNIT B PRESENT WORTH COSTS

| Discount Rate (%) | PRESENT WORTH COST[a] | | | | |
|---|---|---|---|---|---|
| | Alternative 2B/Vit | Alternative 2B/Cem | Alternative 3B.1/Vit | Alternative 3B.1/Cem | Alternative 4B |
| 3 | 30,629,900 | 40,759,900 | 31,209,100 | 38,008,000 | 24,017,600 |
| 4 | 29,888,400 | 39,822,100 | 30,660,300 | 37,321,200 | 23,461,400 |
| 5 | 29,199,600 | 38,944,800 | 25,921,400 | 36,654,400 | 22,946,800 |
| 6 | 28,565,600 | 38,129,800 | 29,613,900 | 36,015,700 | 22,477,000 |
| 7 | 27,971,300 | 37,358,600 | 29,116,800 | 35,393,200 | 22,045,600 |
| 8 | 27,410,600 | 36,628,300 | 28,633,400 | 34,790,700 | 21,636,000 |
| 9 | 26,875,800 | 35,927,800 | 28,159,300 | 34,200,200 | 21,255,800 |
| 10 | 26,377,200 | 35,270,900 | 27,708,900 | 33,637,800 | 20,901,700 |

[a]Values are given in dollars ($).

radiological ILCRs is provided in Table 5-5.

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All of the Subunit C alternatives, except 0C - No Action, would provide overall protection of human health and the environment. All of the action alternatives (Alternatives 2C, 3C.1, and 3C.2) would limit exposure to contaminants by decontaminating, demolishing, and removing the material to either an on-property disposal vault or off-site disposal facility, as well as excavation of contaminated soils and placement of a clean cover over residual contaminated subsurface soils. These alternatives would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. The basic difference between the action alternatives is the disposal options. On-property disposal would be an above-grade disposal vault. Off-site disposal options include NTS, a DOE-owned facility (for Alternative 3C.1), or disposal at a permitted commercial disposal site (for Alternative 3C.2).

The on-property disposal vault design would include sufficient barrier to withstand 1000 years of potential erosion with little or no maintenance. Permanent markers would be used to deter purposeful or inadvertent human destruction of the facility's engineered protective features. Although long-term effectiveness is uncertain because of eventual degradation of the facility cap and leachate collection system, fate and transport modeling using conservative assumptions concludes that long-term protection would still be maintained.

NTS and the commercial disposal facility incorporate engineering controls to ensure protectiveness. Both are located in a climatic, demographic, and hydrogeologic setting which favors minimization of contaminant migration to human or environmental receptors. In the event of degradation of engineered features or loss of institutional controls, these site characteristics would help to ensure continued protectiveness.

Alternative 0C would not provide protection of human health and the environment. Long-term risks to on-property receptors would not be within the $10^{-4}$ to $10^{-6}$ acceptable risk range.

Short-term risks to the public and workers are slightly greater for the off-site disposal options due to the increased risks of transportation accidents resulting in injuries or radiation exposure.

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5.4.1.2 Compliance with ARARs

Alternatives 2C, 3C.1, and 3C.2 would meet all pertinent ARARs identified for these alternatives. Appendix F includes a comprehensive list of potential ARARs and TBCs and describes how each alternative meets the regulatory requirement. For the on-property disposal option, compliance with the OAC 3745-27-07 requirements for the location of a solid waste disposal facility over a sole-source aquifer would be based on demonstrating attainment of the substantive technical criteria for an exemption to this requirement. In addition, because the material associated with Subunit C poses fewer hazards than the material in Subunits A and B, the on-property disposal vault would require less stringent engineering designs to meet the requirements established in 40 CFR § 192.

Alternative 0C would not comply with all pertinent chemical-, location-, and action-specific ARARs.

5.4.2 Primary Balancing Criteria

Those alternatives that satisfy the threshold criteria of compliance with ARARs and overall protection of human health and environment were carried forward for comparative analysis under the primary balancing criteria. The no-action alternative was carried forward for comparison purposes in accordance with the NCP. Those alternatives include:

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, Off-Site Disposal at NTS
- Alternative 3C.2 - Demolition, Removal, Off-Site Disposal at a Permitted Commercial Disposal Site

5.4.2.1 Long-Term Effectiveness and Permanence

All action alternatives, Alternatives 2C, 3C.1, and 3C.2, provide long-term effectiveness associated with contaminated material. The application of each of the action alternatives reduces the residual risk (under continued federal ownership of land) to viable receptors (off-property resident farmer, trespassing child and expanded trespasser) to a HI of less than 0.3 and an ILCR of less than $10^{-5}$. The residual contamination would remain at the site in the soil, the level of risk from the residual soil would be mitigated by excavating soil that exceeds proposed final remediation levels.

The difference between the action alternatives is the final disposition of contaminated materials. The issues with the different disposal options are the adequacy and reliability of controls and the long-term

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environmental impacts. The disposal vault in Alternative 2C significantly reduces leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude the establishment of an on-property residence or farm. In the absence of institutional controls, the on-property vault would continue to provide adequate protection from the most highly contaminated Operable Unit 4 soils. However, off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be more reliable at NTS and the permitted commercial disposal site than on property. Also, the climatic, hydrologic, and geologic characteristics at both off-site disposal facilities would considerably reduce the potential for contaminant migration in the event of a release.

Construction of the on-property disposal vault would permanently disturb 4.7 ha (11.6 acres) of property at the FEMP site. Off-site disposal would result in permanent disturbance at the respective facilities rather than at the FEMP site.

Alternative 0C does not provide risks within the acceptable $10^{-4}$ to $10^{-6}$ range for either the on-property or off-property receptors.

5.4.2.2 Reduction of Toxicity, Mobility, or Volume

Alternatives 0C, 2C, 3C.1, and 3C.2 do not include treatment of the contaminated silo structures, berm material, or soils. Therefore, no reduction in toxicity, mobility, or volume would be achieved through treatment. However, as part of the remedial action work plan preparation for the action alternatives (Alternatives 2C, 3C.1, and 3C.2), an approach would be developed to reduce the volume of material requiring management as radioactive waste. Following decontamination, some of the concrete and other structural materials might be suitable for free-release and could be reused, recycled, or disposed in a solid waste landfill.

It should be recognized that the volume of contaminated soils and rubble being addressed under Subunit C is less than one percent of the volumes of similar contaminated materials anticipated to be generated and handled on a sitewide basis under the five FEMP operable units. In the development of all remedial alternatives for Subunit C materials, this FS has considered the integration of several treatment programs currently under development, which potentially can offer waste minimization opportunities in the near future. Operable Unit 3 is currently developing pilot plant programs which focus upon the treatment of rubble and debris prior to disposal. Likewise, Operable Unit 5 is

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currently evaluating technologies and alternatives which have the potential to treat the Operable Unit 4 contaminated soils.

To ensure the proper integration of sitewide cleanup strategies, activities and the responsible expenditure of available resources, interim storage of Operable Unit 4 generated soils, rubble, and debris may be necessary for a period of time. Interim storage would be provided to enable full utilization of projected treatment systems (e.g., Operable Unit 5 soil washing) and to provide for consistency in FEMP waste management strategies. Interim storage facilities and practices would be consistent with approved removal action procedures, identified ARARs and other direction provided by EPA.

As discussed in Section 4.2.2, the overlapping remedial action schedules for Operable Units 3, 4, and 5 would provide an excellent opportunity to integrate FEMP site-wide cleanup activities in an manner consistent with CERCLA preferences for treatment, minimization of wastes destined for land disposal, and cost-effectiveness.

In the unlikely event unforeseen circumstances preclude the integration of Operable Unit 4 rubble and debris with the Operable Unit 3 Record of Decision and the Operable Unit 4 soils with the Operable Unit 5 Record of Decision, a disposal decision for Operable Unit 4 rubble, debris, and soils could be documented in a ROD amendment for Operable Unit 4 in accordance with Section 117(c) of CERCLA and EPA guidance. The ROD amendment would provide the public and the EPA further opportunity to review and comment on the selected disposal option for Operable Unit 4 rubble and debris. However, a ROD amendment to the Operable Unit 4 ROD would not be necessary in the event that the Operable Unit 4 contaminated soils and debris could be dispositioned consistent with the Operable Unit 5 and Operable Unit 3 RODs.

5.4.2.3 Short-Term Effectiveness

This evaluation criterion addresses the effects of alternatives during the construction and implementation of the remedial action. For the no-action alternative (Alternative 0C), no remedial action will be taken; therefore, there would be no increase in short-term risks. For the action alternatives (Alternatives 2C, 3C.1, and 3C.2), the various demolition and removal activities would result in increased short-term exposures compared with the no-action alternative (Alternative 0C). However, through a combination of engineering controls and access controls, all of the action alternatives would be protective of the community during implementation.

There would be added risk to the public through transporting the soil and debris off site (Alternatives 3C.1 and 3C.2). Because of the overall low radiological activity of the soil and debris, there would be no estimated increase in radiation to the public during transportation to NTS or the permitted commercial disposal site.

5.4.2.4 Implementability

Implementability includes technical feasibility, administrative feasibility, and availability of services and materials. The technical feasibility of all other alternatives would be similar, and all alternatives should not be difficult to implement. Alternative 0C would be the easiest to implement in the short term because no construction activities are required.

Alternatives 3C.1 and 3C.2 are more administratively difficult to implement than Alternative 2C because of the off-site disposal involved and agency approvals and coordination that would be required for interstate shipments of material to the off-site facilities. Opposition by the public and state agencies may require extensive negotiations with the regulatory agencies to facilitate the use of this facility. There would be no long-term maintenance associated with Alternatives 3C.1 and 3C.2 at the FEMP site.

5.4.2.5 Cost

The categories of costs developed were capital, short-term O&M (during remediation), and long-term O&M (post-remediation). Total present worth costs were developed for each alternative, assuming a discount rate of seven percent, so that all alternatives with costs incurred over differing time periods could be compared on an equivalent basis. Capital and O&M costs for each Subunit C alternative evaluated in the detailed analysis (Section 4.0) are presented in Table 5-10.

There are no capital or O&M costs associated with Alternative 0C-No Action. Alternative 2C, which includes the bulk (without packaging) on-property disposal of the waste soils and debris, is the least expensive action alternative. Transportation to NTS (Alternative 3C.1) or to a permitted commercial disposal facility (Alternative 3C.2) are both more expensive than constructing an on-property vault. However, the overall cost of disposal at a permitted commercial disposal facility is anticipated to be approximately 71 percent lower than the cost of disposal at a DOE-owned facility. This is primarily due to the packaging requirements of the DOE-owned facility. The commercial disposal facility accepts bulk shipment of material. The unit cost for disposal at a DOE-owned facility is approximately 67 percent of the unit cost for disposal at a commercial facility.

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## TABLE 5–10

## SUBUNIT C ALTERNATIVE COSTS

| Alternative | COST[a] | | | |
|---|---|---|---|---|
| | Capital | O&M During Remediation | Post–Remediation O&M | Total Present Worth |
| 0C | 0 | 0 | 0 | 0 |
| 2C | 36,340,200 | 0 | 3,567,000 | 34,327,000 |
| 3C.1 | 83,573,100 | 0 | 0 | 75,550,100 |
| 3C.2 | 48,649,100 | 0 | 0 | 43,978,800 |

[a]Values are given in dollars ($).

Sensitivity Analysis of Present Worth Costs

Some factors that can greatly impact present worth costs are the extent of remediation required, i.e., scope of project, duration of construction, remediation or O&M, and discount rate. The quantity of material included in Subunit C, particularly, could not be well defined based on the existing soils analytical data. Excavation of surface soils to a depth of 15 cm (6 in.) was assumed for cost estimating purposes since analytical data indicated the presence of contamination at this depth at various parts of the site.

A detailed construction schedule was developed for the duration of construction and remediation, so these factors are not likely to change significantly. Since the relative cost of post-remediation O&M is relatively low in comparison to the capital and short-term O&M costs, a change in the post-remediation time period is not likely to have a major impact on present worth cost. Therefore, the discount rate is another factor that can be varied at this time to provide a sensitivity analysis on present worth costs.

Sensitivity analyses varying soil quantities or discount rate were performed. Total present worth costs were estimated for each alternative assuming excavation of surface soils to a depth of 0.3 m (1 ft) and 0.45 m (1.5 ft) (using a seven percent discount rate). As indicated in Table 5-11, increasing the quantity of surface soils has an impact on present worth costs because surface soil is a major component of Subunit C materials.

A range of three to ten percent for the discount rate was analyzed. Results are provided in Table 5-12. The sensitivity analysis indicates that the relative cost comparison presented for a discount rate of seven percent does not significantly change for the other discount rates evaluated in the sensitivity analysis.

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TABLE 5-11

SENSITIVITY ANALYSIS-
IMPACT OF SURFACE SOIL VOLUME
SUBUNIT C PRESENT WORTH COSTS

| Surface Soil Excavation Depth (inches) | PRESENT WORTH COST[a] | | |
|---|---|---|---|
| | Alternative 2C | Alternative 3C.1 | Alternative 3C.2 |
| 6 | 34,327,000 | 75,550,100 | 43,978,800 |
| 12 | 35,077,000 | 77,050,100 | 44,728,800 |
| 18 | 35,827,000 | 78,550,100 | 45,478,800 |

[a]Values are given in dollars ($), estimated assuming seven percent discount rate.

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TABLE 5-12

SENSITIVITY ANALYSIS-
IMPACT OF DISCOUNT RATE ON
SUBUNIT C PRESENT WORTH COSTS

| Discount Rate (%) | PRESENT WORTH COST[a] | | |
|---|---|---|---|
| | Alternative 2C | Alternative 3C.1 | Alternative 3C.2 |
| 3 | 37,089,800 | 79,937,700 | 46,532,900 |
| 4 | 36,324,800 | 78,809,400 | 45,876,100 |
| 5 | 35,605,900 | 77,681,200 | 45,219,300 |
| 6 | 34,942,500 | 76,594,700 | 44,586,900 |
| 7 | 34,327,000 | 75,550,100 | 43,978,800 |
| 8 | 33,735,900 | 74,505,400 | 43,370,700 |
| 9 | 33,182,800 | 73,502,500 | 42,786,900 |
| 10 | 32,664,200 | 72,541,500 | 42,227,400 |

[a]Values are given in dollars ($).

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