Department of Energy
Oak Ridge Operations
Weldon Spring Site
Remedial Action Project Office
7295 Highway 94 South
St. Charles, Missouri 63304

November 25, 1992

Addressees:

Enclosed are copies of four documents prepared by the U.S. Department of Energy for cleanup activities at the Weldon Spring Site. These documents are the Remedial Investigation, Feasibility Study, Baseline Assessment and Proposed Plan. Together they compromise the ***draft Remedial Investigation/Feasibility Study-Environmental Impact Statement (RI/FS-EIS) for Remedial Action at the Chemical Plant Area of the Weldon Spring Site***. This information has been prepared by DOE in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. For remedial actions taken under CERCLA, it is DOE policy to integrate the values of the National Environmental Policy Act (NEPA) into the procedural and documentation requirements of CERCLA. Accordingly, an integrated RI/FS-EIS has been prepared to assess site problems and to analyze alternatives for managing contaminated material at the Chemical Plant of the Weldon Spring site.

The draft RI/FS-EIS analyzes the potential environmental impacts of DOE's preferred alternative: removal of contaminated materials, treatment as appropriate using chemical stabilization/solidification, and disposal of treated and untreated materials in an engineered on-site disposal facility. Additionally, this document analyzes a no action alternative involving no further action at the site other than the completion of certain interim actions for which decisions have been finalized under the CERCLA process. Other alternatives analyzed involve removal of contaminated material, treatment as appropriate using vitrification and disposal of treated and untreated material either on-site, at the Envirocare facility near Clive, Utah, or at the DOE Hanford Site in Richland, Washington.

DOE invites you or your representative to comment on the enclosed draft RI/FS-EIS. Information relevant to the proposed remedial action is located in the administrative record and public reading room at the Weldon Spring Site Remedial Action Project Office. To assist the public in providing comments on the document, copies have been placed in four information repositories identified in Section 7 of the Proposed Plan volume of the RI/FS-EIS.

Written comments must be postmarked no later than January 20, 1993 and sent to the following:

Stephen H. McCracken, Project Manager
ATTN: RI/FS-EIS Comments
U.S. Department of Energy
Weldon Spring Site Remedial Action Project Office
7295 Highway 94 South
St. Charles, Missouri 63304

Comments may also be provided at the public hearing scheduled for 7:00 p.m. Wednesday, December 16, 1992, at The Columns, a meeting center in St. Charles, Missouri. An information exposition showing studies and activities that have taken place at the site will begin at 1:30 p.m. and continue through the public hearing. Presenters will be available at each display to help explain the activity and to answer any questions. You are strongly encouraged to attend the exposition in order to gain a better understanding of the work that is planned for the Weldon Spring Site.

For more information contact Jim McKee, Community Relations Department at (314)441-8086.

Sincerely,

Stephen H. McCracken
Project Manager
Weldon Spring Site
Remedial Action Project

Enclosure:
As stated

RI/FS-EIS DOCUMENT: DOE/EIS-0185D
FEASIBILITY STUDY: DOE/OR/21548-148, VOL. I

Feasibility Study for Remedial Action at the Chemical Plant Area of the Weldon Spring Site

Volume I: Main Text

November 1992

U.S. Department of Energy
Oak Ridge Field Office
Weldon Spring Site Remedial Action Project

Documents Comprising the Draft
Remedial Investigation/Feasibility Study-Environmental Impact Statement
for the Weldon Spring Site Remedial Action Project

DOE/EIS-0185D

Baseline Assessment for the Chemical Plant Area of the Weldon Spring Site, DOE/OR/21548-091, U.S. Department of Energy, Oak Ridge Field Office, Oak Ridge, Tennessee, November 1992.

Feasibility Study for Remedial Action at the Chemical Plant Area of the Weldon Spring Site, DOE/OR/21548-148, Volumes I-II, U.S. Department of Energy, Oak Ridge Field Office, Oak Ridge, Tennessee, November 1992.

Proposed Plan for Remedial Action at the Chemical Plant Area of the Weldon Spring Site, DOE/OR/21548-160, U.S. Department of Energy, Oak Ridge Field Office, Oak Ridge, Tennessee, November 1992.

Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site, DOE/OR/21548-074, Volumes I-II, U.S. Department of Energy, Oak Ridge Field Office, Oak Ridge, Tennessee, November 1992.

Addendum to the Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site, DOE/OR/21548-272, U.S. Department of Energy, Oak Ridge Field Office, Oak Ridge, Tennessee, November 1992.

Reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

DOCUMENT CONTENTS

CONTENTS — VOLUME I

CONTENTS — VOLUME I (Cont.)

CONTENTS — VOLUME I (Cont.)

CONTENTS — VOLUME I (Cont.)

CONTENTS — VOLUME I (Cont.)

CONTENTS — VOLUME I (Cont.)

CONTENTS — VOLUME I (Cont.)

FIGURES — VOLUME I

FIGURES — VOLUME I (Cont.)

FIGURES — VOLUME I (Cont.)

TABLES — VOLUME I

TABLES — VOLUME I (Cont.)

TABLES — VOLUME I (Cont.)

TABLES — VOLUME I (Cont.)

NOTATION — VOLUME I

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document. Acronyms used in tables only are defined in the respective tables.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
BA	baseline assessment
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended
CFR	Code of Federal Regulations
CSR	Code of State Regulations
DNB	dinitrobenzene
DNT	dinitrotoluene
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	environmental assessment
EE/CA	engineering evaluation/cost analysis
EIS	environmental impact statement
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
FONSI	finding of no significant impact
FS	feasibility study
HEPA	high-efficiency-particulate-air (filter)
ICRP	International Commission on Radiological Protection
MDOC	Missouri Department of Conservation
MSA	material staging area
MSL	mean sea level
NAAQS	National Ambient Air Quality Standards
NB	nitrobenzene
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act of 1969
NESHAPs	National Emission Standard for Hazardous Air Pollutants
NORM	naturally occurring radioactive material
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PM-10	particulate matter with an aerodynamic mean diameter of $\leq 10\ \mu m$
PP	proposed plan

NOTATION — VOLUME I (Cont.)

RCRA	Resource Conservation and Recovery Act, as amended
RI	remedial investigation
ROD	record of decision
RS	responsiveness summary
SHPO	State Historic Preservation Office
TBC	to-be-considered (requirement)
TCLP	toxicity characteristic leachate procedure
TNB	trinitrobenzene
TNT	trinitrotoluene
TSA	temporary storage area
TSCA	Toxic Substances Control Act
TSP	total suspended particulates
UL_{95}	95% upper confidence limit of the arithmetic average
UMTRA	Uranium Mill Tailings Remedial Action (Project)

UNITS OF MEASURE

°C	degree Celsius
°F	degree Fahrenheit
Ci	curie
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
d	day
dL	decaliter
ft	foot
ft^2	square foot
ft^3	cubic foot
g	gram
gal	gallon
gpd	gallon per day
gpm	gallon per minute
h	hour
ha	hectare
in.	inch
kg	kilogram
km	kilometer
km^2	square kilometer
kPa	kilopascal
L	liter
lb	pound
µg	microgram
m	meter
m^2	square meter
m^3	cubic meter
meq	milliequivalent
mg	milligram
mi	mile
mi^2	square mile
min	minute
mL	milliliter
mm	millimeter
MPa	megapascal
mph	mile per hour
mrem	millirem
pCi	picocurie
ppm	part per million
psi	pound per square inch
rem	roentgen equivalent man
s	second
t	metric ton
WL	working level
WLM	working-level month
WLR	working-level ratio
yd	yard
yd^2	square yard
yd^3	cubic yard
yr	year

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) -32	0.5555	degrees Celsius (°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		
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 (°C) +17.78	1.8	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)

SUMMARY

This feasibility study (FS) has been prepared to support the decision-making process for remedial action at the chemical plant area of the Weldon Spring site, located in St. Charles County, Missouri. The site consists of an 88-ha (217-acre) chemical plant area and a 3.6-ha (9-acre) limestone quarry, both of which are chemically and radioactively contaminated as a result of past processing and disposal activities. The Weldon Spring site is listed on the National Priorities List of the U.S. Environmental Protection Agency (EPA). The U.S. Department of Energy (DOE) is responsible for cleanup activities at the site under its Environmental Restoration and Waste Management Program.

Nitroaromatic explosives were processed by the U.S. Department of the Army at the chemical plant area during the 1940s, and radioactive materials were processed by DOE's predecessor agency, the U.S. Atomic Energy Commission, during the 1950s and 1960s. During the latter period, waste slurries were piped to four on-site raffinate pits that were excavated from existing clay. A small amount of solid waste was placed in one of the pits and in two dump areas on-site; most solid waste was disposed of in the quarry, which had also been used by the Army for waste disposal. Low levels of radioactive and chemical contaminants are present in soil at the chemical plant area as a result of plant operations, and more than 40 buildings and structures that were part of the chemical plant contain varying degrees of contamination.

Cleanup activities at the Weldon Spring site are conducted in accordance with both the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, and the National Environmental Policy Act (NEPA). For remedial action sites, it is DOE policy to integrate NEPA values into the procedural and documentational requirements of CERCLA, wherever practicable. To support cleanup decisions for contaminated material at the chemical plant area, DOE has prepared an integrated remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) in accordance with this policy. That is, the RI/FS documents under CERCLA have been written to incorporate NEPA values at the level of an EIS. These documents are the RI and addendum, the baseline assessment (BA), this FS, and the proposed plan (PP); together they constitute the draft RI/FS-EIS now being issued. The content of the documents prepared for this project is not intended to represent a statement on the legal applicability of NEPA to remedial actions conducted under CERCLA.

The RI and addendum present general information on the site environment and the nature and extent of contamination. The BA evaluates health and environmental effects that might occur if no cleanup action were taken. This FS evaluates alternatives for site cleanup. The PP summarizes key information from the RI, BA, and FS and identifies the preferred alternative for this remedial action. Responses to public comments on these documents will be presented in a responsiveness summary (RS). The RS — which combined with the RI, BA, FS, and PP comprises the final RI/FS-EIS — will be issued to the public for review. The cleanup decisions made for the chemical plant area on the basis of these documents will be presented in the record

of decision (ROD) for this action. The ROD will include a summary of the RS and will be issued after the review period for the final RI/FS-EIS.

The DOE is currently preparing a programmatic EIS for environmental restoration and waste management, and the document is expected to be issued as a draft for public comment in the fall of 1993. The draft implementation plan for the programmatic EIS listed a number of NEPA documents prepared for site-specific actions, many of which are considered to qualify as interim actions for the programmatic EIS under the conditions established in Title 40, Code of Federal Regulations, Part 1506.1(c); the 1987 draft EIS for the Weldon Spring site was considered in that list. At this time, the action proposed for the chemical plant area of the Weldon Spring site is considered an appropriate interim action because it is justified independently of the program, would be accompanied by an adequate environmental impact statement, and does not prejudice the ultimate decision on the program by determining subsequent development or limiting alternatives. Before issuing the ROD pursuant to the RI/FS-EIS for the Weldon Spring site, DOE will further review these conditions to ensure that they are met at that time.

A number of interim cleanup decisions have previously been made for contaminated material at both the chemical plant area and the quarry. Some of the major actions involve the following: (1) a water treatment plant has recently been constructed at each location to treat contaminated surface water, (2) the chemical plant buildings are being decontaminated and dismantled, and (3) the bulk waste that was dumped in the quarry more than 20 years ago will soon be excavated. The contaminated material generated by each of these actions will be placed in short-term storage facilities at the chemical plant area to await the disposal decision that will be made on the basis of the evaluations in this RI/FS-EIS and subsequent public review.

Certain additional media and locations are not part of the current remedial action, such as sediment in a natural drainage channel from the chemical plant area (termed the Southeast Drainage) and groundwater at both the chemical plant area and the quarry. The need for remedial action for those contaminated locations and media will be determined from additional analyses to be conducted over the next several years, after the primary cleanup actions have been taken to control the sources of that contamination. Nevertheless, because contaminated material that could be generated by future cleanup activities for these media would be similar to the material being addressed under the current remedial action, the upcoming disposal decision will also include that material. By this approach, a comprehensive disposal decision will be made for the project at this major stage of site cleanup.

This FS presents information to support the selection of the most appropriate cleanup remedy for the chemical plant area. The analyses in this FS address (1) technologies that could be applied to the various contaminated media, including the practicability of chemical and thermal treatment; (2) the specific areas and media to be remediated; (3) the goals for soil cleanup levels; (4) potential health and environmental impacts associated with cleanup; and (5) the disposal location for contaminated material generated by site cleanup activities.

Potential remedial action alternatives for the chemical plant area have been developed, screened, and analyzed to determine an appropriate cleanup remedy. The preliminary alternatives developed for the site are:

- No Action;
- In-Situ Containment and Limited Disposal;
- In-Situ Chemical Stabilization/Solidification and Limited Disposal;
- In-Situ Vitrification and Limited Disposal;
- Removal, Minimal Treatment, and Disposal;
- Removal, Chemical Stabilization/Solidification, and Disposal; and
- Removal, Vitrification, and Disposal.

Each preliminary action alternative was further divided into four disposal options: (a) disposal in an engineered cell at the Weldon Spring site; (b) disposal at the commercial Envirocare site near Clive, Utah; (c) disposal at DOE's Hanford site near Richland, Washington; and (d) disposal at a hypothetical site in the state of Missouri within 160 km (100 mi) of the Weldon Spring site. The preliminary alternatives were evaluated for applicability to remediating the Weldon Spring site and were screened on the basis of effectiveness, implementability, and cost.

On the basis of the screening analysis, the final alternatives retained for detailed evaluation are:

- Alternative 1: No Action;
- Alternative 6a: Removal, Chemical Stabilization/Solidification, and Disposal On-Site;
- Alternative 7a: Removal, Vitrification, and Disposal On-Site;
- Alternative 7b: Removal, Vitrification, and Disposal at the Envirocare Site near Clive, Utah; and
- Alternative 7c: Removal, Vitrification, and Disposal at the Hanford Site near Richland, Washington.

Except for the no-action alternative, which was retained to provide a baseline for comparison, these alternatives would provide a permanent solution to the contamination problems at the site. Each action alternative would reduce exposures and risks to humans and biota toward background levels by removing the sources of contamination, treating the waste that is most heavily contaminated, and isolating both the treated and untreated materials from the environment in an engineered disposal cell designed and maintained to ensure long-term protection.

Applicable environmental requirements would be attained by each action alternative, with few waivers during the cleanup period, and the protectiveness and effectiveness of the overall cleanup response would be comparable. Potential impacts to human health and the environment from site cleanup activities, including releases of radon and dust, would be minimized by engineering controls such as wetting contaminated surfaces during excavation. Estimated health effects for members of the general public from exposures to possible site releases during the cleanup period are below EPA's target limits for National Priorities List sites. Air, surface water, and groundwater would be monitored during and following cleanup to assess the effectiveness of the control measures and identify any maintenance needs over time.

The two basic differences between the final alternatives are (1) the treatment method for the most heavily contaminated waste, which includes the sludge in the raffinate pits and soil from the quarry and beneath the pits, and (2) the location of the disposal cell. The total volume of waste currently at the site is estimated to be about 675,000 m^3 (883,000 yd^3). Two options were considered for the primary treatment technology. The first is chemical stabilization/solidification, which would involve mixing the waste with cement and fly ash to generate a cement-like product. The second is thermal treatment by vitrification, which would involve melting the waste in a ceramic melter to generate a fritted glass-like product. It is projected that cleanup could be completed under either option within 10 years of the remedy selection.

The chemical treatment process is a standard technology that has been proven at a number of other contaminated sites, and it could be implemented with resources that are readily available. In contrast, the vitrification process is developmental for waste treatment applications, and it has not been applied at the large scale required for the Weldon Spring site. Equipment is not readily available, and extensive testing and engineering scale-up would be required. The vitrification facility would also require specially trained workers, and the high operating temperatures and process complexity would result in increased safety hazards and high costs. In addition, a considerable amount of energy (fossil fuel) would be required to sustain the continuous melting operations.

To achieve a 7-year treatment schedule, the vitrification process would be operated continuously, i.e., 24 hours per day for 365 days per year, compared with a standard work schedule (8 hours per day for 5 days per week) and a 3-month winter shutdown for the chemical treatment process. The vitrification process would generate stack emissions whereas the chemical treatment process would not, but the facility would be equipped with an extensive air pollution control system to control releases. No health impacts would be expected from those releases for a member of the general public.

If engineering scale-up and optimization could be achieved in a timely manner, the vitrification process would more effectively reduce contaminant toxicity, mobility, and volume. Both treatment processes would immobilize contaminants in a solid matrix, but neither would reduce the radiation toxicity of the waste. Vitrification would reduce the overall waste volume by 24% because certain contaminants would be volatilized and released as gases (including hydrogen, oxygen, nitrogen, and radon) and the pore space would be reduced; in contrast, the overall waste volume would increase by 12% under the chemical treatment method because cement and fly ash would be added to stabilize and solidify the treated material.

An effectively vitrified waste would be expected to resist leaching for thousands of years compared with hundreds to thousands of years for chemically stabilized/solidified waste. The disposal cell, which would serve as the primary containment measure, would be designed to withstand natural forces such as heavy rains and earthquakes and to ensure protection for at least 200 to 1,000 years. However, if it were hypothetically assumed that the disposal cell failed in the extended future and no corrective measures were taken, the effectiveness of the chemical treatment alternative might be slightly lower than the vitrification alternatives in the distant future because that portion of the waste that was vitrified would be expected to resist leaching for a longer time than the chemically treated form. This vitrified portion would represent only about 15% of the total waste volume and the mobility of contaminants in the larger volume of other materials would be the same under each alternative; therefore, no significant difference would be expected between the vitrification and chemical treatment alternatives.

Three final options were considered for the disposal location: the Weldon Spring site, the Envirocare site, and the Hanford site. The results of numerous hydrogeological and geotechnical studies conducted on-site indicate that the site is suitable for waste disposal. The long-term impacts of waste disposal are expected to be comparable at each of the three alternative locations.

For the on-site disposal alternatives, the DOE would maintain custody of and accountability for the disposal area, but property outside of that area could be released for other uses. Institutional controls such as access restrictions would be maintained at the disposal area, and the effectiveness of the remedy would be reviewed every 5 years because the waste would remain at the Weldon Spring site within the engineered disposal cell. For the off-site disposal alternatives, all of the Weldon Spring site could be released for other uses.

Off-site disposal at either the Envirocare or Hanford site would involve hauling waste by truck from the Weldon Spring site over existing highways to a rail siding in Wentzville, Missouri. This activity would require about 38,600 truck trips and would extend over a period of 7 years. In Wentzville, the waste would be transferred to rail cars for shipment to either of the distant sites, which would require more than 500 train trips of 25 railcars each over the 7-year period. For the off-site disposal alternatives, administrative procedures would have to be developed to coordinate with the many states through which the waste would be transported and the host state in which it would be disposed. Transportation accidents and worker exposures would result from the large number of trips and considerable distance traveled — i.e., 24 km (15 mi) by road to the Wentzville siding and 2,400 or 3,400 km (1,500 or 2,100 mi) by rail to the Envirocare site or Hanford site.

The estimated cost of the chemical treatment alternative with on-site disposal is $157 million. Vitrification with on-site disposal would cost about $25 million more, with no significant incremental benefit. By comparison, the off-site disposal alternatives would be much more expensive (by about $150 million and $200 million for the Hanford and Envirocare sites, respectively) because they combine the high cost of vitrification with the considerable cost of waste transport and off-site disposal. The potential benefits of vitrification associated with a reduced cell size and a possible incremental leach resistance in the distant future could be offset by short-term impacts associated with energy expenditures, stack releases, and technical implementation difficulties that could delay site cleanup. Additional adverse impacts would be associated with the off-site disposal alternatives because of the potential for accidents and exposures during the extended transportation activities.

1 INTRODUCTION

The U.S. Department of Energy (DOE) is responsible for cleanup activities at the Weldon Spring site under its Environmental Restoration and Waste Management Program. The major goals of this program are to eliminate potential hazards to human health and the environment that are associated with contamination and to make surplus real property available for other uses, to the extent possible.

The Weldon Spring site is located in St. Charles County, Missouri, about 48 km (30 mi) west of St. Louis (Figure 1.1). The site became contaminated as a result of processing and disposal activities that took place from the 1940s through the 1960s, and it is listed on the National Priorities List (NPL) of the U.S. Environmental Protection Agency (EPA). The site consists of two noncontiguous areas: a chemical plant area and a limestone quarry. Explosives were produced at the chemical plant during the 1940s, and uranium and thorium materials were produced during the 1950s and 1960s. In the latter operational period, waste slurries at the chemical plant area were piped to four retention ponds, referred to as raffinate pits. Various solid wastes (i.e., process residues and decontamination residuals such as soil, rubble, metal debris, and equipment) were disposed of in the quarry between 1942 and 1969. Both the chemical plant area and the quarry are fenced and closed to the public.

This feasibility study (FS) addresses remedial action alternatives for the chemical plant area and related properties outside the site fence that are contaminated as a result of past site activities and ongoing releases. These properties include ten areas of localized soil contamination, which have been designated vicinity properties, and three lakes nearby. Although this report focuses on the chemical plant area and related properties, most of the waste from the quarry is also included because it will be stored at the chemical plant area following its upcoming excavation from the quarry under an interim action. Contamination remaining at the quarry area and other locations is also considered in the context of comprehensive planning to develop an integrated disposal decision for all site waste at this major stage of site cleanup.

The discussions in this FS and in the companion documents for the current remedial action have used the term "on-site" to refer to the property located within the fence of the chemical plant area and the term "off-site" to refer to contaminated locations outside the fence. The formal definition of the term "site" in the context of this remedial action includes the chemical plant area, related soil vicinity properties, and other areas contaminated by the migration of a hazardous substance, pollutant, or contaminant from any of the properties under the custody and accountability of DOE. However, in these documents, the term site refers to the chemical plant area only; this approach was taken to reflect the more common use of the term and to simplify the presentation with regard to distinguishing between the chemical plant proper and the smaller areas of contamination nearby.

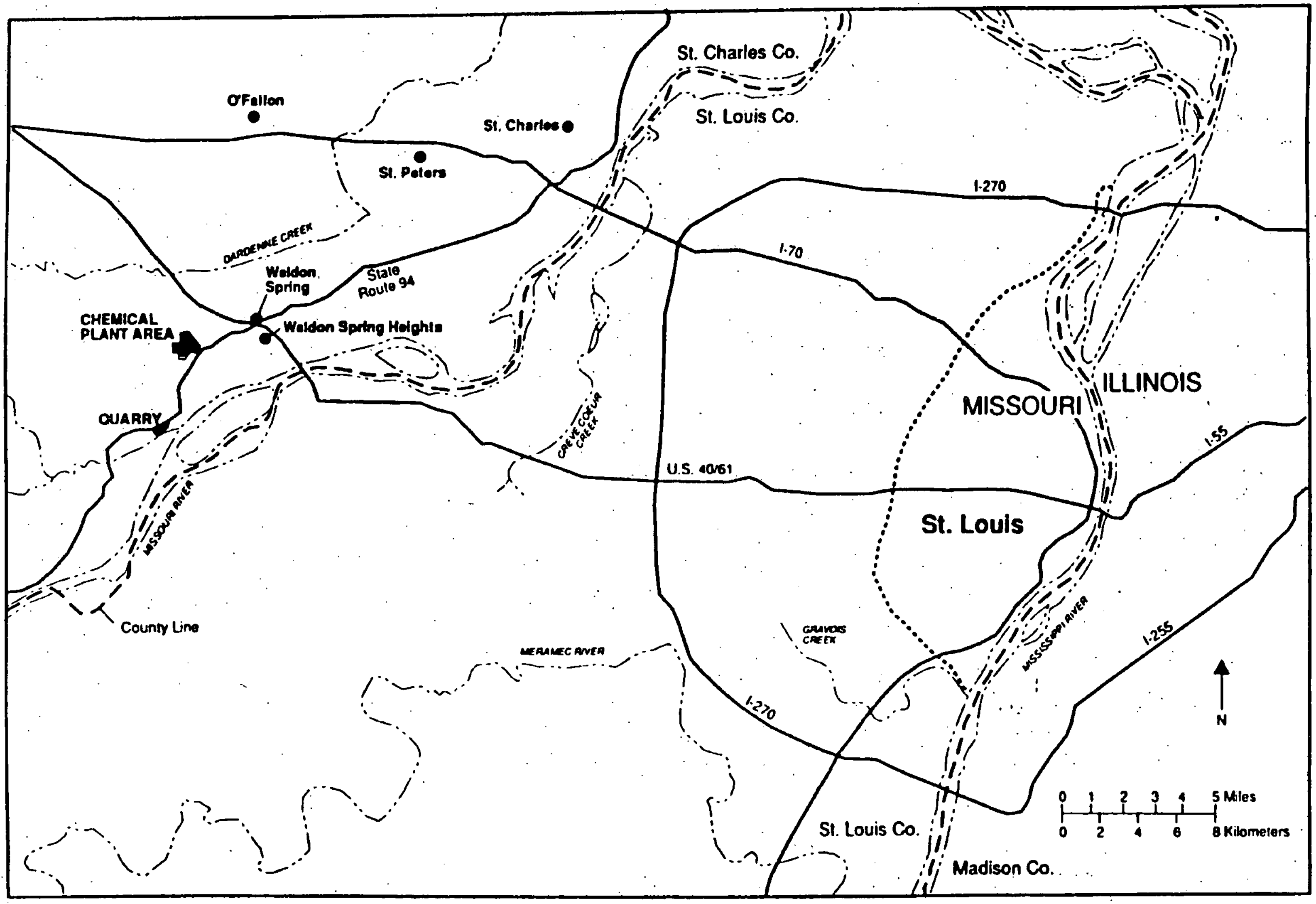


Figure 1.1 Location of the Weldon Spring Site

1.1 PURPOSE AND NEED FOR DECISION

The Weldon Spring site is radioactively and chemically contaminated at levels that exceed certain standards and guidelines for protecting human health and the environment. The DOE has custody of the site and restricts access with fences and security guards, so it is very unlikely that a member of the general public would be exposed to the heavily contaminated areas. However, to focus cleanup decisions for sites on the NPL, a hypothetical scenario is evaluated under which it is assumed that access is not controlled and an individual could be repeatedly exposed to site contaminants. Results of the analysis for this hypothetical case at the Weldon Spring site indicate that an individual who frequently enters the site and accesses the most highly contaminated areas, i.e., the raffinate pits and process buildings, could incur adverse health effects (DOE 1992a).

The land surrounding the site is owned by the federal and state governments. Public access to the adjacent Army property is restricted, and the remaining land is managed by the state as wildlife area. Therefore, potential exposures of the general public at off-site locations are somewhat limited because activities are primarily recreational. Also, the extent of contamination in off-site areas is localized, and contaminant levels are generally low. Thus, the potential for unacceptable impacts to humans or biota off-site under current conditions is low (DOE 1992a).

The ongoing site characterization and environmental monitoring programs provide information on the nature and extent of contamination, including information for off-site areas to which contaminants have migrated or could migrate in the future. These programs support DOE's ability to implement source-control and/or exposure-control measures in the event that conditions change, e.g., if off-site contaminant levels were to increase in the future.

Although humans and biota are not adversely impacted by site contaminants at this time (DOE 1992a), the purpose of DOE's remedial action program is to preclude the potential for such impacts in the future by implementing long-term environmental restoration and waste management decisions. The DOE is addressing long-term management of the Weldon Spring site through an integrated environmental decision-making process.

1.2 PURPOSE AND ORGANIZATION OF THE REPORT

The purpose of this feasibility study is to evaluate potential options for addressing contamination at the chemical plant area of the Weldon Spring site in accordance with the integrated environmental compliance process for the Weldon Spring Site Remedial Action Project. The FS is an important component of this process, and its purpose is to provide sufficient information to support an informed decision regarding an appropriate remedy for the chemical plant area. The FS is organized as follows:

- The remainder of Chapter 1 presents (1) a brief description of the history and environmental setting of the chemical plant area and its contamination (Section 1.3), emphasizing key information from the remedial investigation

(RI) report (DOE 1992c); (2) an overview of the environmental compliance process for the project (Section 1.4); (3) a summary of the environmental activities and documentation for the project (Section 1.5); and (4) a brief discussion of human health and environmental impacts that might occur in the absence of remedial action at the chemical plant area (Section 1.6), summarizing information from the baseline assessment (BA) report (DOE 1992a) and from the rebaseline assessment (Appendix E of this FS).

- Chapter 2 identifies (1) the scope of remedial action at the chemical plant area; (2) preliminary estimates of the areas and volumes of various contaminated media addressed in this FS; and (3) remedial action objectives and goals, including cleanup criteria for site soil.

- Chapter 3 identifies and evaluates potential response technologies for managing the chemical plant area.

- Chapter 4 develops and screens preliminary alternatives for the remedial action.

- Chapter 5 describes the final remedial action alternatives.

- Chapter 6 evaluates the final alternatives in detail.

- Chapter 7 presents a comparative analysis of the alternatives.

- Chapter 8 is a list of the references cited in Chapters 1 through 7 of this FS.

- Chapter 9 is a list of agencies contacted for supporting information.

- Chapter 10 provides information regarding the contributors to this FS.

Supporting information is provided in Appendixes A through J. This information addresses scoping (Appendix A), engineering technologies (Appendix B), potential health and environmental impacts (Appendixes C, D, E, F, H, and I), regulatory requirements (Appendix G), and letters of consultation received from the various agencies contacted (Appendix J). Additional engineering information is presented in supporting technical reports.

1.3 SITE BACKGROUND

The chemical plant area of the Weldon Spring site is radioactively and chemically contaminated as a result of past processing and disposal activities. The radioactive contaminants are associated with the uranium-238, uranium-235, and thorium-232 decay series (see Figures 2.1, 2.2, and 2.3 of the BA); the chemical contaminants are associated with processing operations for both nitroaromatic compounds and uranium and thorium products.

1.3.1 Site History

In April 1941, the U.S. Department of the Army acquired about 7,000 ha (17,000 acres) of land in St. Charles County, Missouri, to construct and operate the Weldon Spring Ordnance Works. From November 1941 through January 1944, the Atlas Powder Company operated the ordnance works for the Army to produce trinitrotoluene (TNT) and dinitrotoluene (DNT) explosives; information on the processes and chemicals used for operating the ordnance works is presented in the RI (DOE 1992c).

The plant was reopened in 1945 but was closed and declared surplus to Army needs in April 1946. By 1949, all but about 810 ha (2,000 acres) of the property had been transferred to the state of Missouri (August A. Busch Memorial Wildlife Area) and the University of Missouri (agricultural land). Much of the land transferred to the university was subsequently transferred to the Missouri Conservation Commission and developed into the Weldon Spring Wildlife Area. Except for several small parcels transferred to St. Charles County, the remaining property became the Weldon Spring Uranium Feed Materials Plant and the U.S. Army Reserve and National Guard Training Area.

The land for the feed materials plant (now referred to as the chemical plant) was acquired in May 1955, when 83 ha (205 acres) of the former ordnance works was transferred from the Army to the U.S. Atomic Energy Commission (AEC, a predecessor of DOE) through a memorandum of understanding. About 6 ha (15 acres) of additional land was later transferred from the Army to the AEC for expansion of waste storage capacity, i.e., to construct the fourth raffinate pit. Considerable explosives decontamination and regrading activities were conducted prior to constructing the feed materials plant.

Uranium and thorium ore concentrates were processed at the plant from June 1957 to December 1966; the Uranium Division of Mallinckrodt Chemical Works acted as the AEC operating contractor. During plant operations, an average of 14,000 t (16,000 tons) of uranium material was processed per year to produce uranium trioxide, uranium tetrafluoride, and uranium metal. A small amount of thorium ore concentrates was also processed at the plant. Information on the processes and chemicals used for operating the feed materials plant is presented in Appendix D of the RI (DOE 1992c) and summarized in Section 2.1 of the BA (DOE 1992a).

Plant operations generated several chemical and radioactive waste streams, including raffinates from the refinery operation and magnesium fluoride slurry (washed slag) from the uranium recovery process. Raffinates and waste slurries were piped to the raffinate pits, where the solids settled to the bottom and the supernatant liquids were decanted to the plant process sewer; this sewer drained off-site to the Missouri River via a 2.4-km (1.5-mi) natural drainage channel termed the Southeast Drainage (Figure 1.2). Some solid waste was disposed of on-site during the operational period of the plant; the remainder was placed in the quarry.

The Army reacquired the chemical plant in 1967 and initiated decontamination and dismantling operations in January 1968 to prepare the plant for conversion to a herbicide

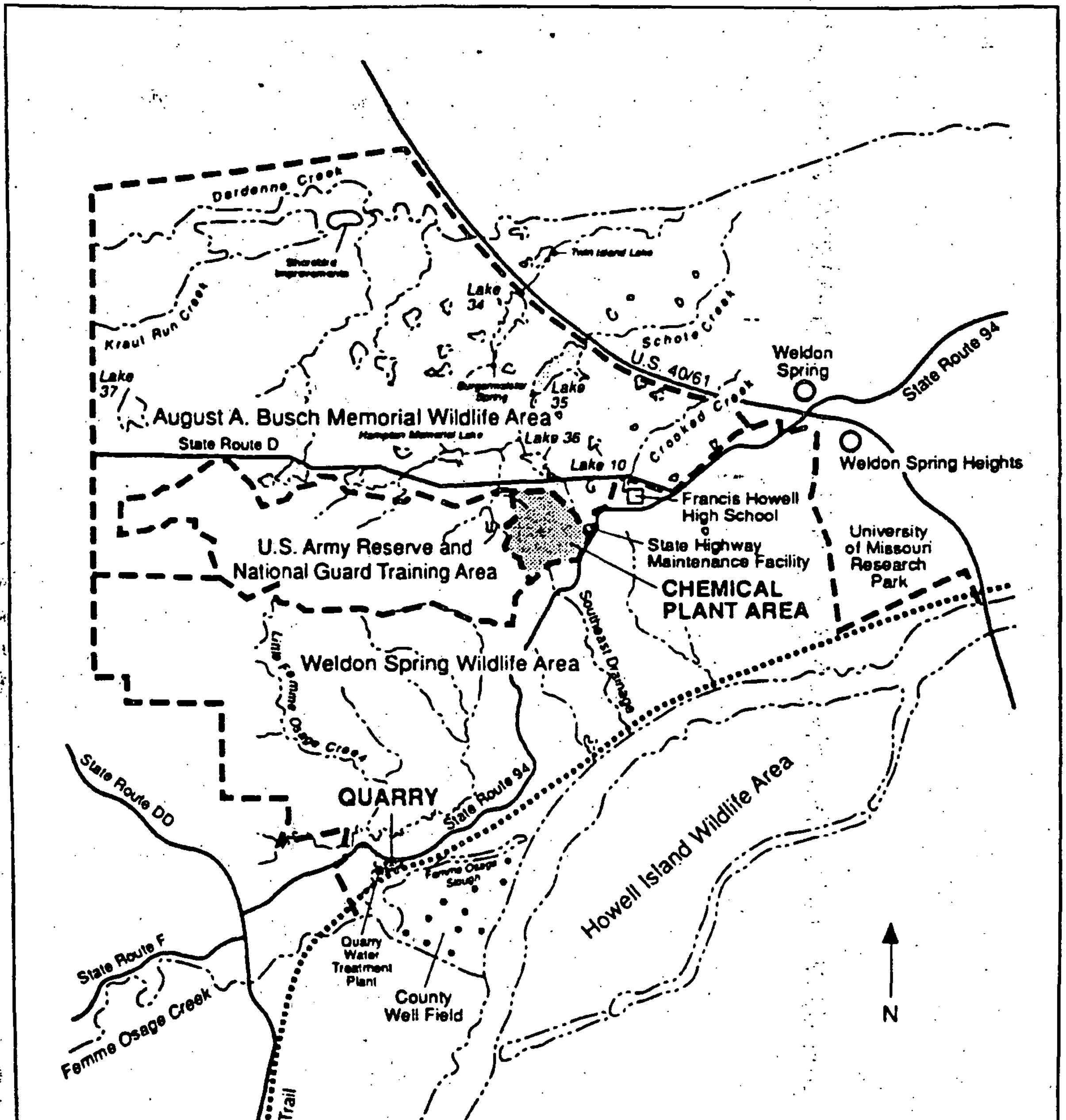


FIGURE 1.2 Surface Features near the Weldon Spring Site

production facility. Much of the resultant debris was placed in the quarry, although a small amount was also placed in the fourth raffinate pit. The extensive decontamination effort and associated costs required to meet extant radioactive contamination limits, combined with reduced requirements for the herbicide, resulted in cancellation of the project in February 1969 prior to any herbicide production. The Army retained responsibility for the land and facilities at the chemical plant, and the site entered care and custody status. In 1984, the Army repaired several buildings, conducted additional decontamination, and isolated some contaminated equipment.

In 1975, the AEC contracted the National Lead Company of Ohio to perform environmental monitoring and maintenance of the raffinate pits and quarry. In October 1981, Bechtel National, Inc., assumed management responsibility from National Lead Company of Ohio under contract to DOE. In November 1984, DOE was directed by the Office of Management and Budget to assume custody and accountability for the chemical plant from the Army; this transfer occurred in October 1985. In May 1985, DOE designated the control and decontamination of the Weldon Spring site as a Major Project; it was redesignated as a Major System Acquisition in May 1988. A project office was established in October 1986, and the site is currently under the control of DOE and is managed by DOE's project management contractor, MK-Ferguson Company.

In October 1985, the EPA proposed to list the Weldon Spring quarry on the NPL; this listing occurred in July 1987 (EPA 1987b). In June 1988, the EPA proposed to expand the listing to include the chemical plant area; this listing occurred in March 1989 (EPA 1989c). The balance of the former Weldon Spring Ordnance Works property, which is adjacent to the DOE portion and for which the Army has responsibility, was proposed for NPL listing in July 1989; this listing was finalized in February 1990 (EPA 1990b).

1.3.2 Site Description

The Weldon Spring site is located in St. Charles County, Missouri, near the town of Weldon Spring (Figure 1.1). The chemical plant area of the site is about 3.2 km (2 mi) southwest of the junction of Missouri (State) Route 94 and U.S Route 40/61. The Weldon Spring quarry is about 6.4 km (4 mi) south-southwest of the chemical plant area. Both the chemical plant area and the quarry are accessible from State Route 94 and are fenced and closed to the public. This FS focuses on alternatives for remediating the chemical plant area; hence, the following site description is limited to the chemical plant area and vicinity. Separate documentation and review processes have been carried out for the quarry, and additional work is under way for both areas (see Sections 1.5.1 and 1.5.3).

The 88-ha (217-acre) chemical plant area, hereafter generally referred to as the site, contains about 40 buildings and structures, four raffinate pits, two ponds (Ash Pond and Frog Pond), and two former dump areas (North Dump and South Dump). These surface features are shown in Figure 1.3, which also reflects the changes resulting from recent interim actions at the site (e.g., the construction of storage, staging, and treatment facilities and the dismantlement of site structures). A baseline map of the site is shown in Figure 1.5 of the BA (DOE 1992a). The

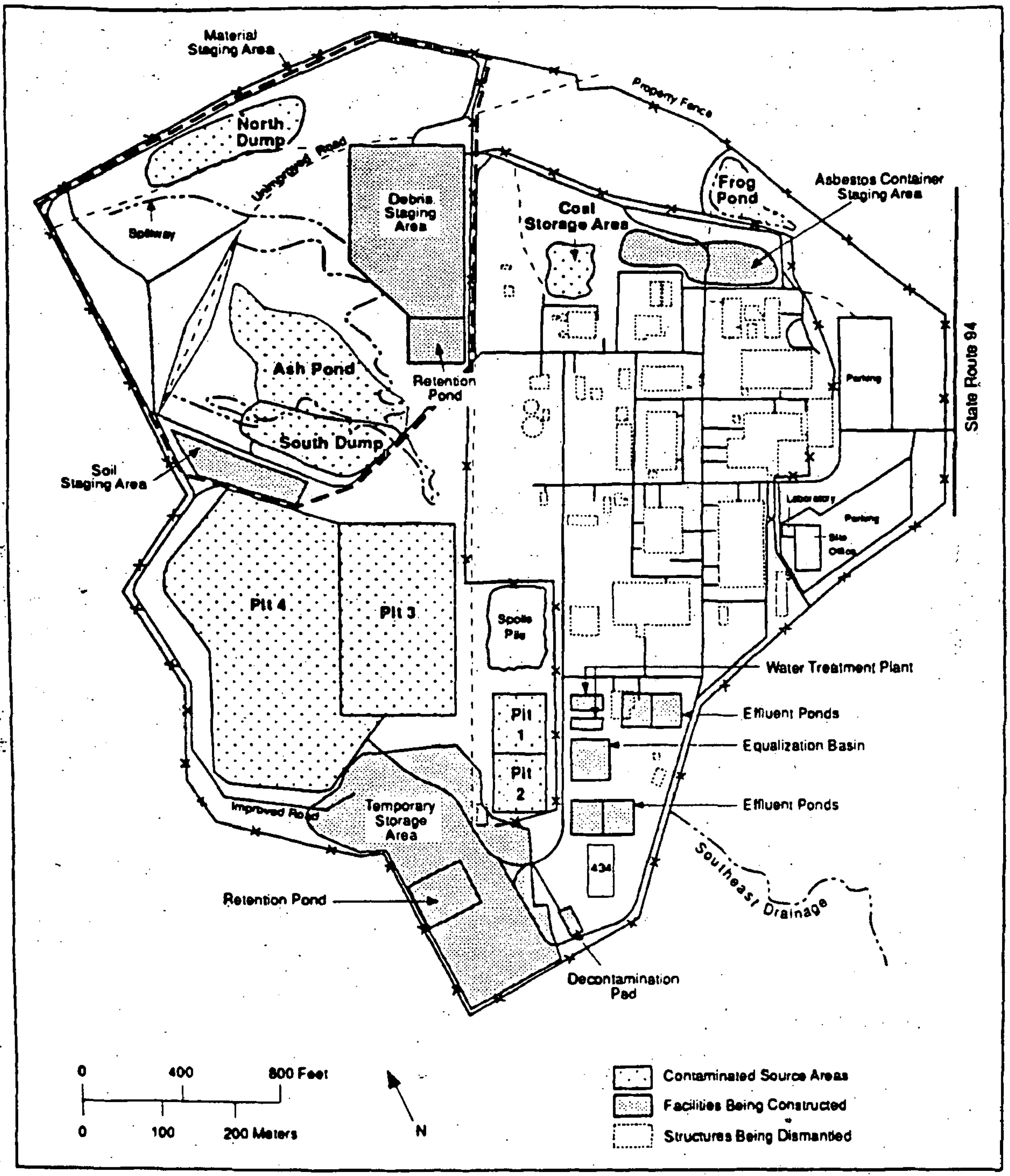


FIGURE 1.3 General Layout of the Chemical Plant Area

various environmental resources at the site are described briefly in Sections 1.3.2.1 through 1.3.2.8; extensive details on these resources are presented in the RI (DOE 1992c) and BA (DOE 1992a) and in supporting characterization documents for the site.

1.3.2.1 Soil and General Surface Features

The Weldon Spring site was extensively regraded following decommissioning of the ordnance works and prior to construction of the uranium feed materials plant. The predominant soil type is the Harvester-Urban complex. This soil is primarily composed of silty loess material of moderate permeability and high water content and can easily erode when exposed. The Harvester group has been transported and shaped by earth-moving equipment; the Urban group has been covered by roads, parking lots, buildings, and other surface features. Also present in the chemical plant area and vicinity is Mexico fine loam, which typically occupies irregular areas of 20 to 80 ha (50 to 200 acres) to a depth of approximately 33 cm (13 in.). This soil type is characterized by slow permeability and high water content. Mexico fine loam has been classified as prime farmland soil by the U.S. Soil Conservation Service (1982). Additional information on overburden material at the site is summarized in Section 1.3.2.2.

Soil at the Ash Pond area includes fly ash from the former coal-fired steam plant. The South Dump is located at the southern end of Ash Pond and was used to store drums of radioactive materials, as well as equipment, rubble, and other debris; portions were also used to burn trash. The North Dump is located at the northern boundary of the site and was used to store barrels of radioactive materials. Much of the land surface around the buildings, which include five major process buildings, is paved or covered with gravel. The spoils pile is located adjacent to the raffinate pits and contains the soil excavated for their construction. In contrast to Ash Pond and the two dump areas, the spoils pile is not considered a contaminated source area at the site. Over time, it has generally been incorporated into the surrounding soil.

1.3.2.2 Topography, Seismicity, and Geology

The site is located in the southwest uplands of St. Charles County, which is bounded by the Mississippi River to the north and the Missouri River to the south; about half of the county land is uplands, and the other half is floodplain. Gently rolling topography characterizes the area to the north and west of the site, whereas the terrain to the south and east is heavily wooded, rugged, and ravined. Except for the embankments built around the raffinate pits, the land surface on-site is gently sloping.

The site is located in a stable, tectonically quiet, central seismic region. Scattered seismic events have been recorded throughout Missouri and Illinois, but they have generally been of small magnitude. No evidence has been found of tectonic surface ruptures related to historic earthquakes in the nearby area. The New Madrid seismic zone, about 260 km (160 mi) south of the site, is the nearest zone of major seismic activity. Isoseismal maps compiled by Hopper et al. (1983) for the 1811, 1843, 1895, and 1968 earthquakes show that the Weldon Spring area has experienced Modified Mercalli earthquake intensities ranging from V to VII. A review and evaluation of published earthquake studies indicate that maximum intensities at the site could be VII or VIII on the Modified Mercalli scale. These intensities would be associated with near-site earthquakes ranging in magnitude from 5.3 to 5.8 on the Richter scale, or with larger earthquakes at some distance from the site (Bechtel National 1983). The maximum earthquake predicted for the Weldon Spring site with a return period of 1,000 years would result in a peak ground acceleration of 0.26 g (MK-Environmental Services Group 1991).

The geology at the site is characterized by 5 to 18 m (15 to 60 ft) of clayey overburden overlying an argillaceous cherty limestone bedrock. The overburden has been divided into five layers on the basis of physical characteristics: topsoil and loess, Ferrelview clay, clay till, basal till, and residuum.

Borehole data indicate that the Mississippian Burlington-Keokuk Limestone bedrock can be divided into two units on the basis of the degree of fracturing and weathering. The upper weathered unit ranges in thickness from 3 m (9 ft) to more than 15 m (50 ft); the lower competent (unweathered) unit ranges from about 27 to 46 m (90 to 150 ft). The bedrock surface is highest on the eastern portion of the site and lowest on the northern/northwestern portion of the site. The upper unit is highly weathered at the top, with solution features ranging from pinpoint vugs (cavities, often with a mineral lining) to small cavities that are generally filled with clay. A more detailed description of the site geology is presented in Section 4.3 of the RI (DOE 1992c).

1.3.2.3 Groundwater

Groundwater at the site consists of perched groundwater in the unconsolidated deposits (e.g., near the raffinate pits), a shallow unconfined aquifer in the Burlington-Keokuk Limestone, and a deep confined aquifer in the St. Peter Sandstone. Current data indicate that the shallow limestone aquifer has been contaminated as a result of past processing and disposal activities by the Army and the AEC.

The shallow aquifer consists primarily of saturated rocks of the Mississippian Burlington-Keokuk Limestone and occasionally residuum. Groundwater in this aquifer appears to flow by diffuse flow (porous media flow), along horizontal bedding planes, and to a lesser extent through fractures. Because the intensity of weather and fracturing decreases with depth, the aquifer becomes more homogeneous, flow paths are more widely spaced, and the influence of vertical fractures is more limited with depth. Groundwater off-site flows by diffuse flow and also via certain free-flow conduits on both sides of the groundwater divide. Discharge points for the conduits are perennial springs such as Burgermeister Spring and springs in the Southeast Drainage (DOE 1992c).

The water table surface in the upper portion of the shallow aquifer exhibits an east-northeasterly trending groundwater divide that passes within about 100 to 200 m (330 to 660 ft) of the southern edge of the site (Figure B.2 of the BA [DOE 1992a]). Groundwater north of the divide flows north toward Dardenne Creek and the Mississippi River; groundwater south of the divide flows toward the Missouri River. A similar divide is indicated for the deeper aquifer, displaced slightly to the north (Figure B.3 of the BA [DOE 1992a]).

1.3.2.4 Surface Water

The raffinate pits cover about 10 ha (26 acres) and contain residues from uranium- and thorium-processing operations previously conducted at the chemical plant (Section 1.3.1). Ash Pond covers about 4.5 ha (11 acres) and is located in a topographic low in the northwestern portion of the site. Ash Pond received fly ash piped from the coal-fired power plant that provided steam to the chemical plant during its operational period, and it currently receives surface runoff from the northwestern portion of the site. Frog Pond covers about 0.3 ha (0.7 acres) near the eastern boundary of the site; it was used as a settling basin for storm-sewer flow and for fire control during the operational period of the plant, and it currently receives surface runoff and storm flows from the sewer system at the northeastern portion of the site. These impoundments cover approximately 15 ha (38 acres) and are currently classified as wetlands (U.S. Fish and Wildlife Service 1989). The raffinate pit wetlands are contaminated and of very poor quality. Ash Pond and Frog Pond are also contaminated (see Section 1.3.3). The DOE is surveying the areas and has initiated consultations with the U.S. Fish and Wildlife Service regarding the loss of these habitats as a result of site cleanup (McCracken 1991b).

The site straddles a surface water divide (see Figure 1.4) and contains three general drainage systems. Ash Pond and the raffinate pits drain to the northwest, Frog Pond and related streams drain to the north, and a small area at the southern end of the site drains to the southeast into a natural channel referred to as the Southeast Drainage; detailed information on these drainage systems is presented in the RI (DOE 1992c). The first two drainage systems flow north toward the Mississippi River and are hydrologically connected to streams, lakes, and springs in the Busch Wildlife Area. A small portion of the northern area of the site is within the 100-year floodplain of Schote Creek, a perennial off-site stream.

Dye-tracing studies indicate that surface water lost to groundwater beyond the northwestern site boundary from the first drainage system reemerges at Burgermeister Spring. The third system is hydrologically connected to springs and streams in the Weldon Spring Wildlife Area and drains south to the Missouri River through the Southeast Drainage channel (Missouri Department of Natural Resources 1989).

1.3.2.5 Climate, Meteorology, and Air Quality

The Weldon Spring area has a modified continental climate characterized by moderately cold winters and warm summers. Temperatures measured from 1958 through 1988 ranged from -28 to 42°C (-18 to 107°F). Evapotranspiration and precipitation in the area generally balance each other. Average annual precipitation typically totals approximately 86 cm (34 in.), of which about 25 cm (10 in.) occurs in the spring. Thunderstorms usually occur between 40 and 50 days per year; as much as 25 cm (10 in.) of rain has been recorded in 24 hours during a heavy storm. Winter is the driest season, with precipitation averaging about 15 cm (6 in.). From 1937 through

1988, annual snowfall in the area averaged 50 cm (20 in.); most snowfalls occur from December through March. Tornadoes occur in Missouri most often in April and May. Tornadoes may occur in the Weldon Spring area once or twice per year, but they usually have a narrow path and often disintegrate after a few kilometers. The probability of a tornado striking the site in any year has been estimated to be about 0.002 (DOE 1990d).

The Weldon Spring site is located in the St. Louis Air Quality Control Region, which includes St. Charles County, St. Louis and St. Louis County, Franklin County, and Jefferson County. The National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants are used by the state of Missouri to assess regional air quality and to designate nonattainment areas (i.e., those areas for which one or more of the standards is not met). The criteria pollutants are sulfur oxides (as SO_2), carbon monoxide, ozone, nitrogen dioxide, PM-10 (particulate matter with an aerodynamic diameter less than or equal to 10 µm), and lead.

The Weldon Spring area is currently an attainment area for five of the six criteria pollutants, i.e., all but ozone (Cassin 1990). Violations of the ozone standard have been recorded at the nearest state monitoring station located 22 km (14 mi) southeast of the site (Queeny Park), as well as at the majority of stations in the St. Louis area (Missouri Department of Natural Resources 1984, 1985; Shissler 1990). As a result, all of St. Charles County — which includes the Weldon Spring site — has been designated as a nonattainment area for ozone since 1979.

1.3.2.6 Biotic Resources

Except for the northern 22 ha (55 acres) of the site, which is unmanaged, little undisturbed and/or natural habitat exists; most of the site is maintained in a pasture-like condition by an active management program that includes routine mowing. The managed vegetated portions of the site are essentially grassland; some unmanaged secondary forest growth occurs in the northern region. Wildlife in unmanaged areas of the site are more diverse than in managed areas. Specific information on the areas and types of habitat and vegetation on-site is presented in Section 5.5 of the RI (DOE 1992c) and in Section 7.1 of the BA (DOE 1992a).

Portions of the forested area in the northern portion of the site were used in the early 1940s as a storage and dump site (the North Dump) (DOE 1992c). As a result of these past activities, the forest community in the northern/northwestern portion of the chemical plant area is probably no more than 50 years old. Because much of the site is highly disturbed and actively managed (e.g., mowed), it probably supports amphibian, reptilian, and mammalian species typically associated with urban or industrial settings (related surveys have not been conducted in these areas). Few reptiles or amphibians are expected to be present, but some turtles and frogs have been observed; those amphibians present would be found in surface impoundments and drainage ditches. Mammals that have been observed include the cottontail rabbit, deer, raccoon, and squirrel. The predominant bird species at the site are those typically associated with grassy urban residential/industrial areas. These birds include the starling, crow, robin, and a variety of swallows and sparrows; wild turkey and raptors have also been observed. The on-site surface impoundments (Figure 1.3) also provide aquatic habitat suitable for waterfowl, and ducks and geese have been observed resting on the raffinate pits and Frog Pond.

The site does not provide critical habitats for any federal listed threatened or endangered species, and no such species are known to occur or utilize habitats in this area. The bald eagle, *Haliaeetus leucocephalus*, and the peregrine falcon, *Falco peregrinus*, are federal endangered species that could occur intermittently near the Weldon Spring area. However, no critical habitat for these species exists at the site (Brabander 1990; Nash 1990). Except for the pied-billed grebe, a state rare species, no state listed threatened, endangered, or special concern species have been reported for the site. The pied-billed grebe has been observed on raffinate pits 2 and 4 (MK-Ferguson and Jacobs Engineering Group 1992d).

1.3.2.7 Land Use and Demography

The Weldon Spring site is bordered by the August A. Busch Memorial Wildlife Area to the north, the Weldon Spring Wildlife Area to the south and east, and the U.S. Army Reserve and National Guard Training Area to the west (Figure 1.2). The Busch Wildlife Complex consists of the 2,828-ha (6,987-acre) Busch Wildlife Area, the 2,977-ha (7,356-acre) Weldon Spring Wildlife Area, and the 1,031-ha (2,547-acre) Howell Island Wildlife Area. This complex is managed by the Missouri Department of Conservation and is open throughout the year for recreational use. The Busch and Weldon Spring wildlife areas receive an estimated 1,200,000 visitors each year; annual visitors to these areas may exceed 2 million by 1994 (Crigler 1992).

The 670-ha (1,655-acre) U.S. Army Reserve and National Guard Training Area is fenced, and access by the general public is restricted. Throughout the year, the area is occupied by one full-time staff person and numerous part-time and temporary personnel. Approximately 3,300 local Army reservists and 3,400 other military reserve troops may use the area each year. An average of 150 to 400 Army reservists are present in the area on weekends during 35 to 48 weeks of the year for 2-day drill training. Military reserve troops use a limited portion of the area, including the firing range, for training exercises (Daubel 1992).

Several small areas on the adjacent Army property and wildlife areas are contaminated as a result of previous activities at the chemical plant; these areas are termed vicinity properties. The DOE is responsible for the vicinity properties associated with past AEC activities at the site. The locations of these vicinity properties are shown in Figure 1.4; properties located on the Army land are identified with the letter "A", and those in the wildlife areas are identified with the letter "B" (except property A4, which is in the Weldon Spring Wildlife Area but was associated with the Army property during designation activities).

A state highway maintenance facility is located on State Route 94 just east of the site. The facility employs nine full-time staff and one mechanic (Sizemore 1991). These individuals work at the facility and off-site, performing road maintenance activities on nearby state highways. Francis Howell High School is located about 1 km (0.6 mi) east of the site, also on Route 94, on 16 ha (40 acres) of land owned by the St. Charles County Public School District. The school employs approximately 160 faculty and staff and is attended by about 1,600 students (Hartwig 1992). Adjacent to the school is the former St. Charles County Extension Center, which was operated by the University of Missouri until 1988; the area is now used as a school

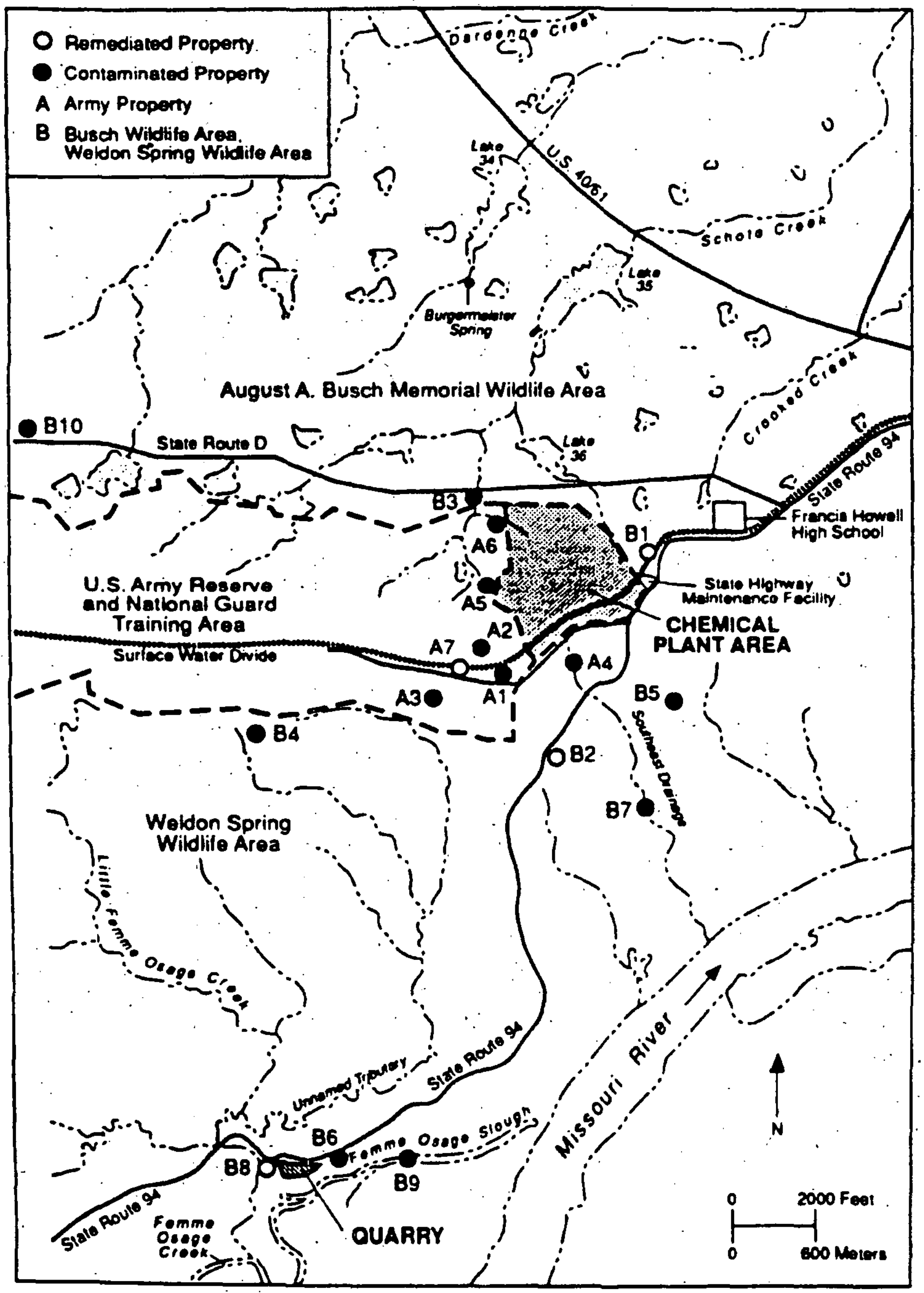


FIGURE 1.4 Location of Contaminated Vicinity Properties in the Area of the Weldon Spring Site

administration annex. The university also owns 300 ha (740 acres) of land between the annex and the site, and the northwestern portion of this land is currently being developed into a research park.

A former elementary school about 3.2 km (2 mi) east-northeast of the site was recently converted to a daycare facility for children of school district employees. This facility was designed to accommodate 10 to 45 children during the 3-week vacation period between school quarters* (Meyer 1992).

The communities of Weldon Spring and Weldon Spring Heights are located about 3.2 km (2 mi) east of the site and have a combined population of about 850. The city of St. Charles, the largest in the county, is located about 24 km (15 mi) northeast of the site and has a population of about 40,000.

1.3.2.8 Archaeological and Cultural Resources

Archaeological remains from all periods of the regional prehistoric record in the vicinity of the Weldon Spring site have been recovered in northeastern Missouri (Chapman 1975, 1980; Donham 1982; O'Brien and Warren 1983). These data have contributed to research concerning a variety of issues in regional prehistory (e.g., O'Brien et al. 1982). Euro-American settlers first penetrated the region near the Weldon Spring site in the 1600s and encountered Algonquin-speaking Native American groups. Although the city of St. Louis was founded in 1764, widespread Euro-American settlement did not begin until after the Louisiana Purchase in 1803. Overviews of Missouri history have been presented by Meyer (1963), March (1967), and others.

Archaeological sites and historic structures that meet the criteria established for eligibility to the *National Register of Historic Places* would require mitigative action if subject to adverse effects. In 1986, the Missouri State Historic Preservation Officer (SHPO) determined that the Weldon Spring chemical plant area was not eligible for the *National Register* (Weichman 1986). This determination was made on the basis of prior disturbance, low potential for archaeological remains, and possible health risks. Activities associated with the site continue to be coordinated with the Missouri SHPO. For example, the Missouri SHPO has been consulted regarding the representative off-site borrow area currently being evaluated to support site cleanup activities (this area is described in Section 5.2.1.10).

1.3.3 Nature and Extent of Contamination

An extensive characterization program has been conducted at the Weldon Spring site over the past several years to determine the nature and extent of contamination, and sample

*Subsequent to completion of the analyses in this FS, the former Weldon Spring Elementary School was destroyed by fire on July 17, 1992. Nevertheless, the risks estimated for a potential receptor at that location during site cleanup activities have been retained in this document (Appendix F) to address the possibility that the facility might be rebuilt for a similar use.

collection and analysis has generated over 100,000 data points. Additional information continues to be collected through an ongoing environmental monitoring program, and further specific characterization studies are planned. Sampling locations for soil, surface water, groundwater, and air are shown elsewhere (e.g., see Figure B.1 of the BA [DOE 1992a], Figures 3.2-1 and 5.3-1 and Plate 2 of the RI [DOE 1992c], and Figure 4-1 of the annual site environmental report for 1991 [MK-Ferguson Company and Jacobs Engineering Group 1992d]).

Several areas of contamination have been identified from results of the site characterization (Figure 1.3). Detailed information on the nature and extent of this contamination, including concentration ranges and averages for various contaminants in each of the affected media, is presented in the RI (DOE 1992c) and is summarized in the BA (DOE 1992a). Specific sources of contamination within the scope of the current remedial action and the primary media and key contaminants associated with each source are listed in Table 1.1. Related discussion, including affected areas and volumes, is presented in Chapter 2.

Most of the contaminated media on-site and at locations outside the property fence are addressed in the current remedial action. Additional contamination is associated with past activities at the chemical plant area but is outside the scope of this action. This contamination is present in the Southeast Drainage vicinity property and in groundwater in the shallow aquifer, which is located in the Burlington-Keokuk Limestone. Cleanup decisions for these locations and affected media will be addressed in documentation to be prepared within the next several years, as will decisions for material remaining at the quarry following excavation of the bulk waste (see Section 1.5.3).

The Southeast Drainage was previously used to channel decanted water from the raffinate pits to the Missouri River. This natural drainage now carries only effluent from the sanitary treatment plant at the project office building and storm-water runoff from the southeastern portion of the site. Until recently, this drainage was also considered as the discharge channel for effluent from the newly constructed water treatment plant (see Section 1.5.1.4). Surface water in the drainage contains radionuclides, inorganic anions, and nitroaromatic compounds; sediment and soil contain radionuclides. Specific information on the nature and extent of contamination in the Southeast Drainage is presented in Section 5.2.3.2 of the RI (DOE 1992c).

Contamination is also present in groundwater beneath the site due to leaching from the raffinate pits and other contaminant sources. The groundwater contains elevated levels of uranium, nitrate, sulfate, and nitroaromatic compounds (2,4-DNT, 2,6-DNT, TNT, DNB, NB, and TNB); some metals (e.g., antimony, chromium, lithium, and manganese) have also been detected at levels above background in isolated wells on-site. Specific information on the nature and extent of groundwater contamination is presented in Section 5.4 of the RI (DOE 1992c) and in Appendix B of the BA (DOE 1992a). Both the Southeast Drainage and groundwater at the site will be addressed as separate response actions (see Section 1.5.3).

TABLE 1.1 Sources of Contamination at the Weldon Spring Site

Area/Medium	Description[a]
Primary On-Site Sources	
Raffinate pits	The four raffinate pits previously received process waste from the chemical plant and constitute the most heavily contaminated source area at the site.
Surface water	Although currently present in the pits, this water is targeted for removal and treatment under an interim action. Key contaminants: uranium, radium, arsenic, manganese, selenium, cyanide, nitrate, and fluoride.
Sludge	Solids from waste slurries of the uranium- and thorium-processing operations have settled to the bottom of each pit. Key contaminants: uranium, thorium, radium, arsenic, molybdenum, vanadium, and sulfate.
Soil	Contamination in berms and beneath the pits is a result of contact with and leaching from the sludge and surface water. Characterization of this soil is limited because of difficulty in sampling under current conditions; additional characterization will be conducted after the surface water and sludge are removed. Key contaminants: radionuclides, metals, and nitrate (see sludge).
Structural debris	A small amount of debris consisting of concrete, tanks, piping, drums, and structural material is present in raffinate pit 4. These materials were placed in pit 4 during closure of the chemical plant when the Army began converting the plant for herbicide production. Key contaminants: uranium, thorium, and radium.
Frog Pond	Frog Pond previously received flow from storm and sanitary sewers at the pilot chemical plant and currently receives overland flow from the northeastern portion of the site.
Surface water	Although currently present in the pond, this water is targeted for removal and treatment under an interim action. Key contaminants: uranium and chloride.
Sediment	The sediment contains transported and settled solids from the surface water. Key contaminant: uranium.
Soil	Soil around or beneath the pond could be contaminated as a result of leaching from the surface water and sediment. Additional characterization will be conducted after the water and sediment have been removed. Key contaminant: uranium.
Ash Pond	Ash Pond previously received fly ash slurry from the power plant and currently receives overland flow from the northwestern portion of the site.
Surface water	Although currently present in the pond, this water is targeted for removal and treatment under an interim action. Key contaminants: uranium and nitrate.
Sediment	The sediment contains transported and settled solids from the surface water. Key contaminants: uranium and nitrate.
Soil	Soil around and beneath the pond could be contaminated as a result of leaching from the surface water and sediment. Additional characterization will be conducted after the water and sediment have been removed. Key contaminant: uranium.

TABLE 1.1 (Cont.)

Area/Medium	Description[a]
Primary On-Site Sources (Cont.)	
North Dump and South Dump	These dump areas were previously used to store and dispose of radioactive material.
Soil	Key contaminants: uranium, thorium, radium, arsenic, and lead.
Drums and metal building and equipment debris	Key contaminants: uranium, thorium, and radium.
Material Staging Area (MSA)	The MSA is located in the northwestern portion of the site and provides a staging area for contaminated material resulting from dismantlement, construction, and excavation activities. The original MSA was planned as part of interim actions for building dismantlement and debris consolidation, and it includes a 3-ha (7-acre) gravel pad staging area with a runoff collection system and retention pond; this portion of the MSA is now referred to as the debris staging area. The facility was subsequently expanded to include a soil staging area, to support excavation and construction activities for the interim quarry bulk waste and site water treatment plant actions. The MSA will continue to expand within the northwestern quadrant of the site, as needed (e.g., to stage construction materials), as part of the current remedial action.
Metal building and equipment debris	Key contaminants: uranium, thorium, and radium.
Concrete building debris	Key contaminants: uranium, thorium, and radium.
Decontamination debris (including drummed personal protective equipment)	Key contaminants: uranium, thorium, radium, asbestos, and PCBs.
Soil	Key contaminants: uranium, thorium, and radium.
Temporary Storage Area (TSA)	The TSA is being constructed to store the bulk waste that will be excavated from the quarry under an interim action and water treatment plant process wastes from additional interim actions for surface water at the quarry and chemical plant area. The bulk waste will be further characterized after excavation.
Drums and metal building and equipment debris	Key contaminants: uranium, thorium, and radium.
Concrete building debris and rock	Key contaminants: uranium, thorium, and radium.
Soil	Key contaminants: uranium, thorium, radium, arsenic, lead, nickel, and selenium; also, in some spots, PCBs, PAHs, and nitroaromatic compounds such as TNT, 2,4-DNT, 2,6-DNT, NB, and TNB.

TABLE 1.1 (Cont.)

Area/Medium	Description[a]
Primary On-Site Sources (Cont.)	
Temporary Storage Area (cont.)	
Sludge and sediment	Key contaminants: uranium, thorium, radium, arsenic, and 2,4-DNT.
Vegetation	Key contaminants: uranium and radium.
Containerized process wastes from the two water treatment plants	Key contaminants: uranium, thorium, radium, arsenic, fluoride, and nitroaromatic compounds.
Residual soil and sediment from the quarry area	This material could be placed in short-term storage at the TSA if it were removed from the quarry and/or Femme Osage Slough; it will be further characterized within the next several years. (The contaminated material that could result from future actions is included in the development of general treatment/disposal analyses in this document.) Key contaminants: same as the bulk waste soil and sediment.
Building 434	
Containerized chemicals	Building 434 was remodeled to use for controlled storage of containerized material resulting from interim response actions. (As a contingency, this building might be used to store containerized process wastes from the water treatment plants.) Key contaminants: nitric acid, sulfuric acid, hydrofluoric acid, sodium hydroxide, PCBs, heavy metals, and paint solvents.
Scattered On-Site Sources[b]	
Soil in areas adjacent to and beneath the chemical plant buildings	Areas adjacent to the buildings were previously used to unload and store process material and to house electrical equipment. Key contaminants: uranium, thorium, radium, sulfate, nitrate, PCBs, and PAHs. Soil beneath the buildings might be contaminated as a result of spills and leaks from floors, pipes, and sumps. This soil will be characterized after the structures are removed.
Soil in areas adjacent to the raffinate pits	These areas were previously impacted by spills or overland flow. Key contaminants: uranium, thorium, radium, fluoride, nitrate, and sulfate.
Chemical storage tanks	Tributyl phosphate is currently stored in two tanks with double containment systems that are located adjacent to the MSA.

TABLE 1.1 (Cont.)

Area/Medium	Description[a]
Off-Site Sources	
Burgermeister Spring and Lakes 34, 35, and 36 in the Busch Wildlife Area	These areas are contaminated by surface runoff and groundwater discharge from contaminated areas on-site. (They also receive runoff from a much larger area, including the adjacent Army property and local agricultural land.)
Surface water	Key contaminants: uranium and nitrate.
Sediment	Key contaminant: uranium.
Soil at vicinity properties	These areas were previously impacted by transport and storage activities. Key contaminants: uranium, thorium, and radium.

[a] More detailed information, including specific contaminant data, are provided in the RI (DOE 1992c). Notation: TNB, 1,3,5-trinitrobenzene; 2,4-DNT, 2,4-dinitrotoluene; 2,6-DNT, 2,6-dinitrotoluene; TNT, 2,4,6-trinitrotoluene; NB, nitrobenzene; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls.

[b] Although not considered a primary contaminant source, site vegetation could be contaminated as a result of biouptake. If contaminated, it would be placed in the TSA with vegetation from the quarry; if uncontaminated, it would be placed in a mulch pile at the northern portion of the site. Key contaminants: uranium and radium.

1.4 OVERVIEW OF THE ENVIRONMENTAL COMPLIANCE PROCESS

1.4.1 General Compliance Process

The EPA has developed procedural and documentational requirements for cleaning up hazardous waste sites under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. The general compliance approach that incorporates these requirements is termed the remedial investigation/feasibility study (RI/FS) process. A diagram of the RI/FS process is presented in Figure 1.5. Three primary evaluation documents comprise the RI/FS package:

- The remedial investigation — which presents information on the environmental setting at a site and the nature and extent of contamination;

- The baseline risk assessment — which addresses the environmental fate and transport of contaminants and assesses potential impacts to human health and the environment associated with exposures under current and possible future conditions; and

- The feasibility study — which develops, screens, and evaluates technologies and alternatives for site remediation and indicates potential cleanup criteria.

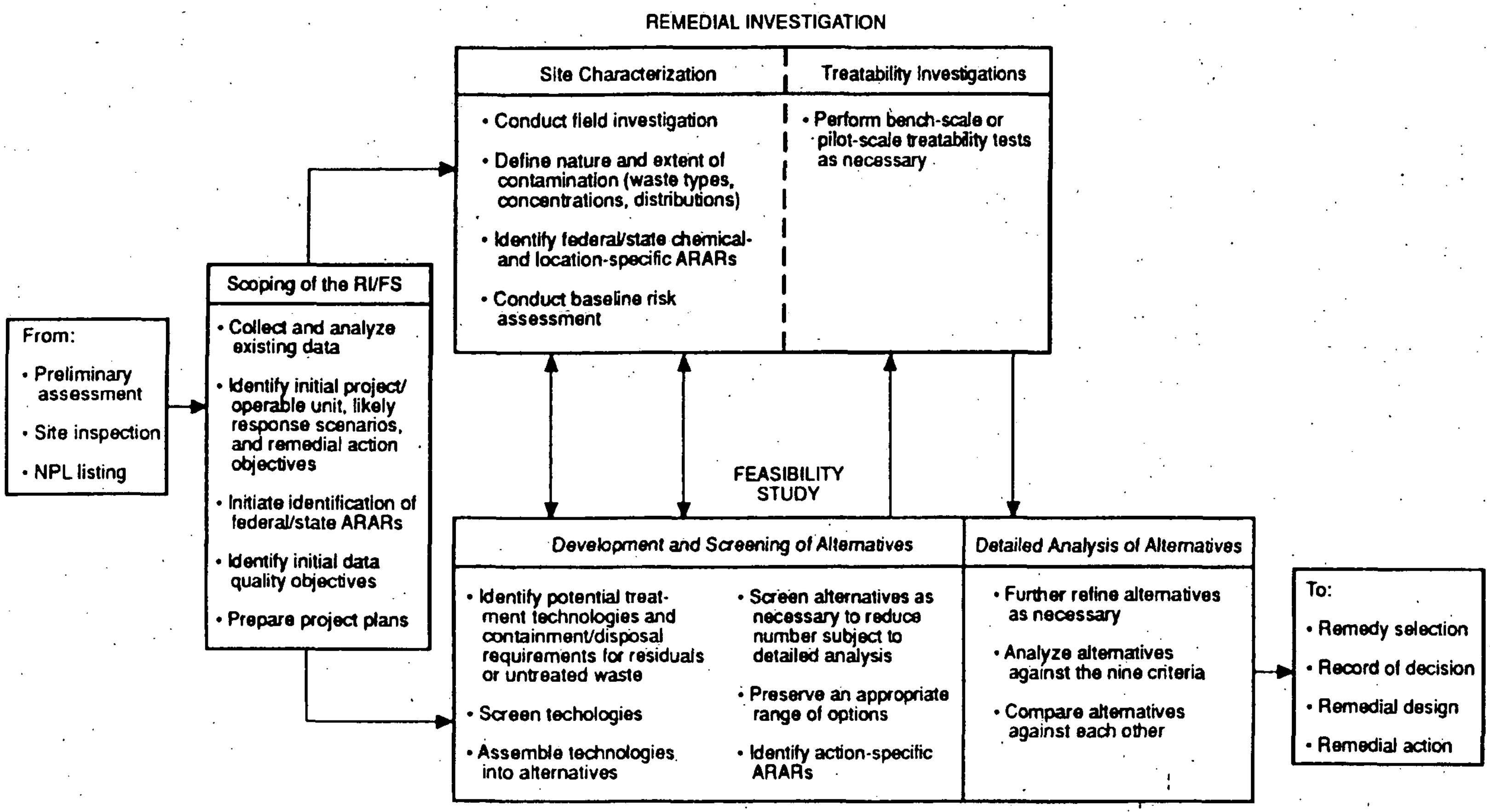


FIGURE 1.5 Summary Diagram of the RI/FS Process (Source: EPA 1988a)

A fourth document — the proposed plan (PP) — summarizes key information from the RI/FS and identifies the preferred alternative.

The RI/FS documents for the chemical plant area have been prepared in accordance with the requirements of both CERCLA and the codified National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA 1990a). The guidance established by EPA for conducting an RI/FS and a risk assessment at Superfund sites has also been followed (EPA 1988a, 1989d, 1989e).

For remedial action sites, it is DOE policy to integrate values of the National Environmental Policy Act (NEPA) into the procedural and documentational requirements of CERCLA, wherever practicable. In accordance with this policy, the RI/FS documents prepared under CERCLA to support cleanup decisions for the chemical plant area of the Weldon Spring site have been written to incorporate elements of an environmental impact statement (EIS) prepared under NEPA. The resultant integrated process and document package is termed the RI/FS-EIS. The content of the documents prepared for the project are not intended to represent a statement on the legal applicability of NEPA to remedial actions conducted under CERCLA.

In integrating the CERCLA and NEPA processes for these documents, the CERCLA baseline risk assessment prepared for the chemical plant area was expanded to include NEPA elements of the no-action alternative. This integrated assessment presents potential impacts to human health and environmental resources in the absence of site cleanup. The resultant document can be more broadly termed a baseline assessment (BA), and it provides a combined analysis of the no-action alternative for the chemical plant area under both CERCLA and NEPA.

In the primary evaluation documents prepared to support this remedial action, the RI (DOE 1992c) incorporates the affected environment description of an EIS, the BA (DOE 1992a) provides the no-action alternative evaluation of an EIS, and the FS incorporates the action alternatives evaluation of an EIS. The PP (DOE 1992b) presents the preferred alternative component of an EIS. Together, the RI, BA, FS, and PP comprise the revised draft EIS for the Weldon Spring site (see Section 1.4.2). The activities and environmental compliance documents for the Weldon Spring Site Remedial Action Project are developed by the DOE in coordination with the EPA Region VII and the state of Missouri. In accordance with both CERCLA and NEPA processes, these documents are also made available to the public for comment, and public involvement is an important factor in the decision-making process for site cleanup.

Responses to public comments on the draft RE/FS-EIS now being issued — i.e., the RI, BA, this FS, and the PP — will be provided in a responsiveness summary (RS). The RS (combined with the draft RI/FS-EIS now being issued to comprise the final RI/FS-EIS) will be issued to the public for a 30-day review. Public comments will be used to develop the decision for the current remedial action, which will be presented in a record of decision (ROD). The ROD will include a summary of the RS and will be issued after the review period for the final RI/FS-EIS. Applying the integrated approach for NEPA and CERCLA, a single ROD will be prepared for this action, and it will be signed by both DOE and EPA. Following the cleanup decision, remedial design and remedial action activities will be planned and implemented at the site. An overview of this process is presented in Figure 1.6.

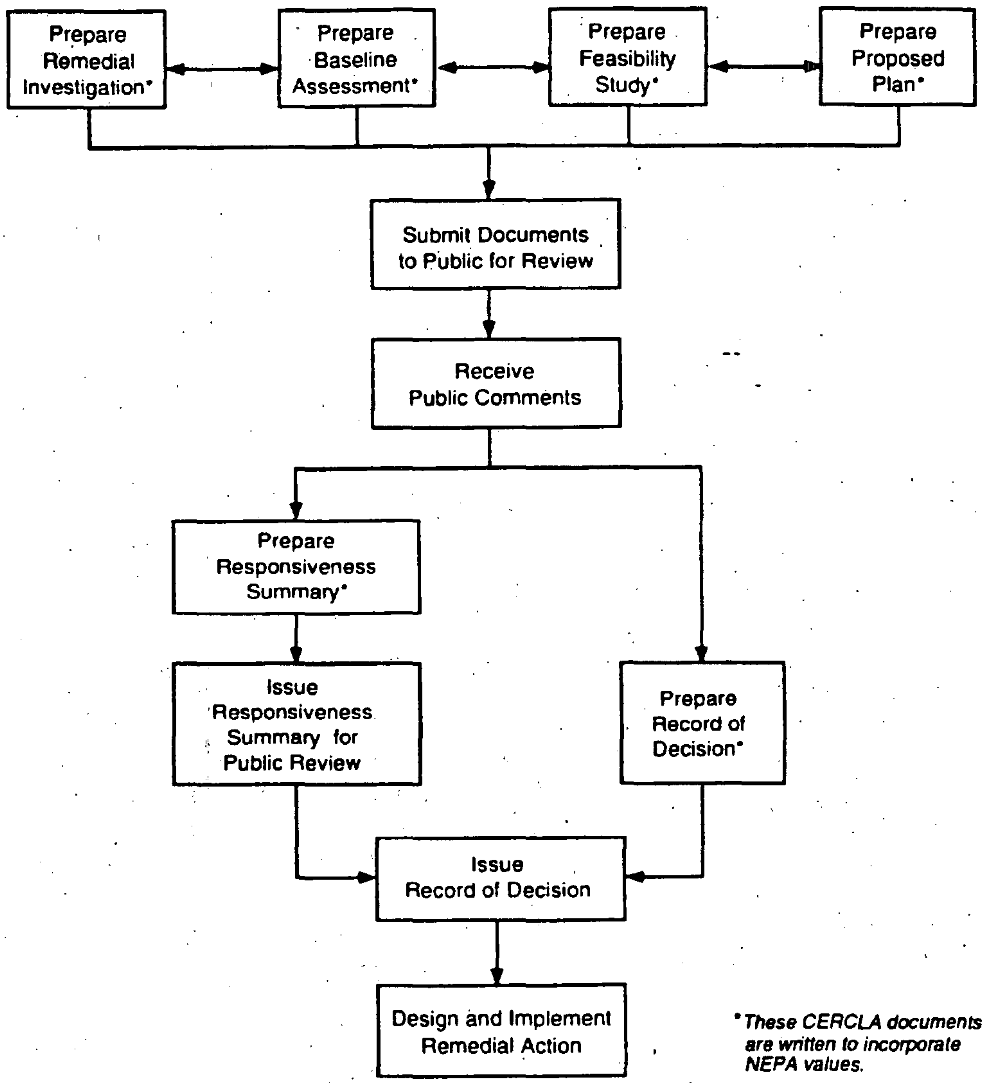


FIGURE 1.6 Primary Documents of the Integrated Environmental Compliance Process for the Proposed Remedial Action at the Chemical Plant Area

1.4.2 History of the Compliance Process for the Project

A notice of intent to prepare a draft EIS for assessing remedial action alternatives at the Weldon Spring site was issued in the *Federal Register* on March 2, 1984, initiating the public scoping process. This scoping process was conducted in accordance with environmental compliance requirements to identify (1) types of response actions that might be implemented to address site problems; (2) interim actions that might be necessary or appropriate to mitigate potential threats in a timely manner; (3) an appropriate sequence of site actions and investigative activities; and (4) public input. Comments received during this scoping process were considered during document preparation, and a summary was provided in Appendix B of the draft EIS (DOE 1987).

The draft EIS was prepared in accordance with DOE's implementing guidelines for NEPA and regulations promulgated by the Council on Environmental Quality (CEQ). The document was issued in February 1987, several months after Congress passed the CERCLA amendments and prior to DOE's explicit policy for integrating NEPA values into the procedural and documentational requirements of CERCLA for remedial action sites, wherever practicable. Extensive comments were received on the draft EIS, both by letter and verbally at a public hearing held on April 10, 1987, at Hollenbeck Junior High School in Harvester, Missouri.

Following publication of the draft EIS, significant new information became available that was relevant to environmental concerns at the Weldon Spring site; this information indicated that groundwater beneath the chemical plant area contained elevated concentrations of nitrates and nitroaromatic compounds. In response to this development, DOE announced in June 1987 its intent to issue for public comment a revised draft EIS that would incorporate the new information. Subsequent to this decision, EPA Region VII formally requested that DOE prepare an RI/FS for the site pursuant to the requirements of CERCLA, as amended. The DOE agreed to prepare an RI/FS that would incorporate revisions to the draft EIS. Since that time, DOE has conducted an integrated CERCLA/NEPA compliance process at the Weldon Spring site.

Results of the public scoping process — including responses to the major issues raised on the draft EIS — were presented in the RI/FS-EIS work plan subsequently prepared for the project (Peterson et al. 1988). All comments received on the draft EIS (DOE 1987) have been treated as scoping input for the RI/FS-EIS; the issues addressed as a result of such input are summarized in Appendix A of this FS.

1.4.3 Consultation with Other Agencies

Response actions for the Weldon Spring site are subject to EPA oversight because the site is listed on the NPL; this oversight is being provided by EPA Region VII. The DOE and EPA entered into a federal facility agreement in August 1986 whereby the respective responsibilities of these two agencies for the project were defined. This agreement was revised to incorporate new requirements pursuant to the CERCLA amendments. The first amended agreement was signed by DOE in December 1991 and by EPA in January 1992; it became effective in July 1992. The EPA's primary responsibility is to ensure compliance with CERCLA requirements under the Superfund program. In addition, EPA reviews and provides input to engineering and characterization plans and to federal environmental requirements and reports developed for the project.

The DOE also consults with the state of Missouri regarding the Weldon Spring Site Remedial Action Project. The DOE interfaces directly with the Missouri Department of Natural Resources, the agency designated by the state of Missouri to coordinate state involvement. Along with the EPA, the state of Missouri reviews and provides input to engineering and characterization plans and reports; the state also provides input on state environmental requirements, conducts independent environmental monitoring, and performs additional studies as appropriate. In addition, DOE coordinates characterization activities and shares information with the U.S. Department of the Army to address issues common to both the Weldon Spring site and the adjacent NPL site for which the Army is responsible.

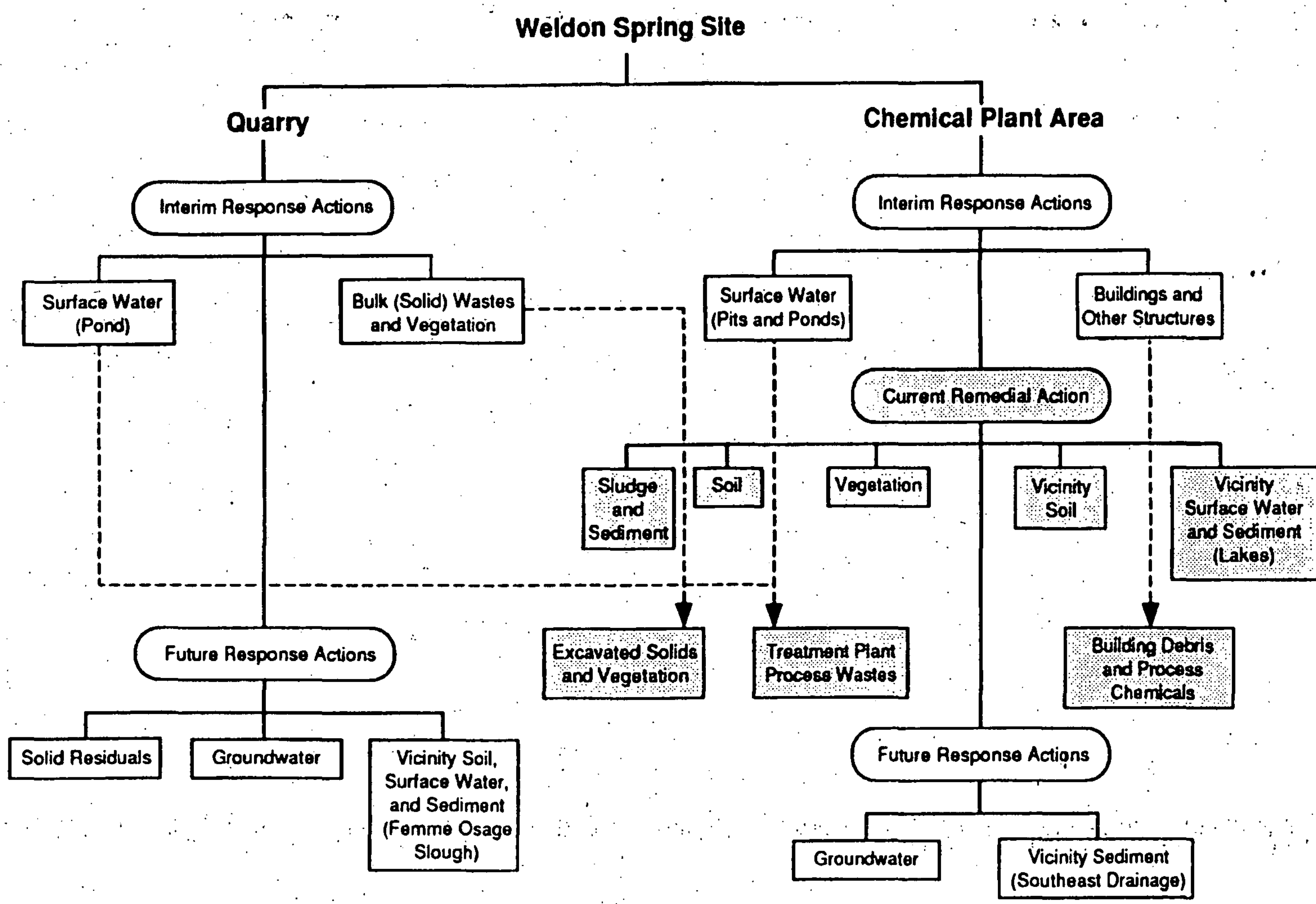
Formal consultation is also undertaken with the U.S. Army Corps of Engineers to address wetlands and floodplains. The U.S. Fish and Wildlife Service (Department of the Interior) is also consulted regarding wetlands and floodplains, in addition to consultations regarding the status of threatened and endangered species. The Missouri SHPO is consulted regarding archaeological sites and other cultural resources, and the U.S. Department of Agriculture, Soil Conservation Service, is consulted for issues relating to prime farmland. Two other organizations directly involved in this project are the U.S. Geological Survey and the University of Missouri. These organizations are funded by DOE to perform specific geological and hydrological studies because of their related expertise and experience. Agencies that have been consulted regarding the current remedial action for the Weldon Spring Site Remedial Action Project are listed in Chapter 9.

1.5 SCOPE OF SITE ENVIRONMENTAL ACTIVITIES AND DOCUMENTATION

Cleanup of the Weldon Spring site consists of several integrated components, which are shown together with the affected media in Figure 1.7. An overview of the relationship between environmental compliance activities and documents for the project is presented in Figure 1.8. This FS is one of the primary evaluation documents of the RI/FS-EIS for the current remedial action at the chemical plant area. The scope of this action encompasses all media except groundwater and includes vicinity properties related to the chemical plant area except the Southeast Drainage. Additional documents will be prepared within the next several years to support decisions for both groundwater and the Southeast Drainage.

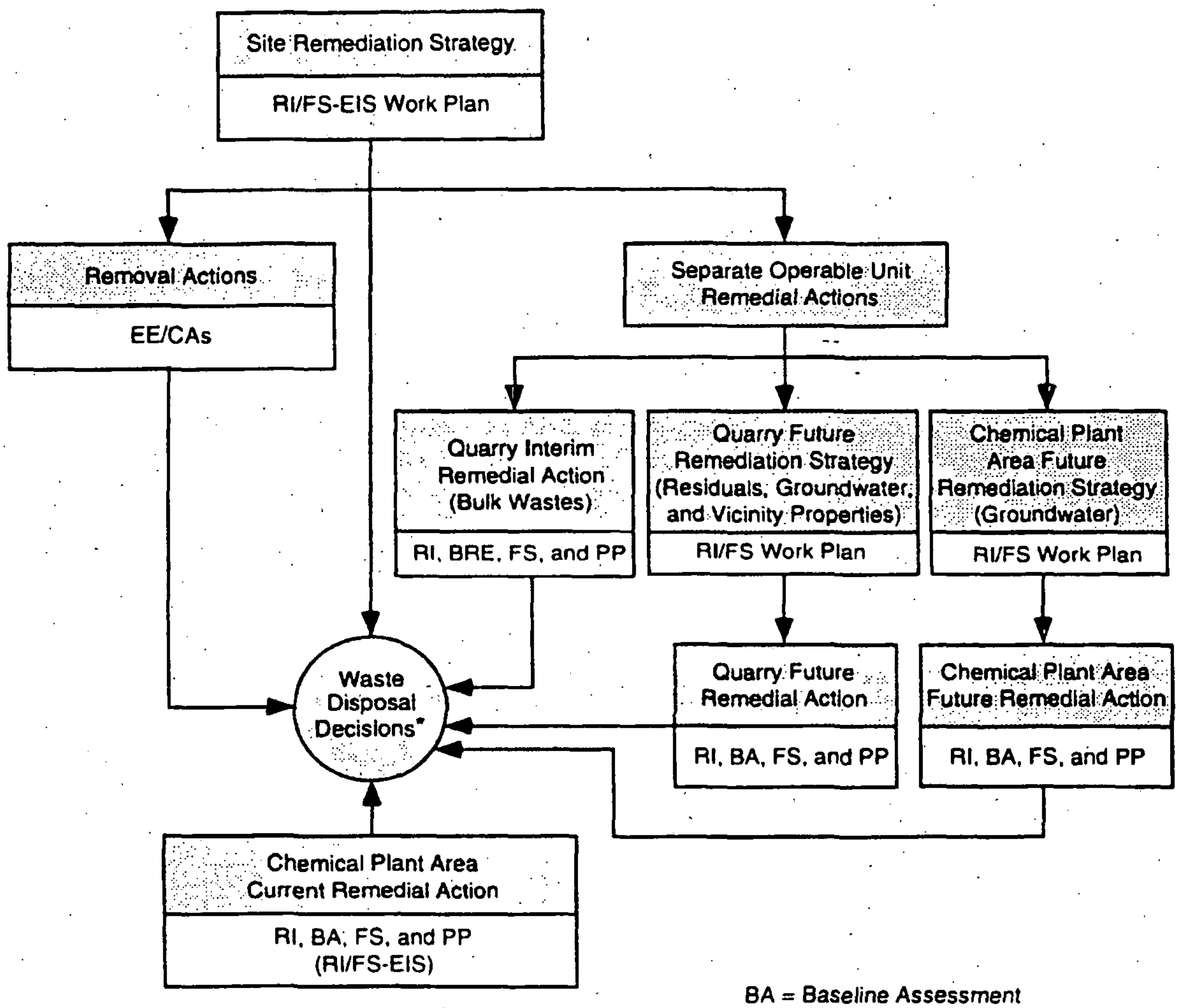
The RI/FS-EIS also addresses comprehensive disposal decisions for the project, including the disposition of contaminated material generated as a result of previous response actions and material that might be generated by upcoming response actions. The scope of this FS in relation to the chemical plant area component of site remediation is discussed in Section 1.5.2.

A number of interim actions have already been documented to address other components of the site remediation process, including the first and second stage of quarry cleanup (i.e., the surface water and bulk waste components). These actions and related documents are described in Section 1.5.1. Additional documents will be prepared within the next several years to address the remaining quarry components — i.e., residual solid material; vicinity soil, sediment, and surface water; and groundwater. Those actions and related documents are discussed in Section 1.5.3.



Note: The boxes represent contaminated media addressed by the project's cleanup actions for the chemical plant area and the quarry, and they are connected by solid lines to the appropriate phase of site cleanup. Dashed lines identify waste stored at the chemical plant area as a result of the interim actions. The media for which specific treatment and disposal decisions will be made as part of the current remedial action are indicated by shading.

FIGURE 1.7 Components of Site Remediation (Note that the disposition of contaminated material from future response actions is addressed in the current remedial action.)



BA = Baseline Assessment
BRE = Baseline Risk Evaluation
EE/CA = Engineering Evaluation/Cost Analysis
EIS = Environmental Impact Statement
FS = Feasibility Study
PP = Proposed Plan
RI = Remedial Investigation

**Disposal decisions for all site material will be determined from the evaluations in the RI/FS-EIS for the current remedial action.*

FIGURE 1.8 Major Environmental Compliance Activities and Related Documents for the Weldon Spring Site Remedial Action Project

All interim actions for the project, both expedited response (removal) actions and interim remedial actions, have been performed in accordance with CERCLA requirements and within the constraints of CEQ regulations for NEPA for interim actions while an EIS is in preparation (Title 40, Code of Federal Regulations, Part 1506.1 [40 CFR 1506.1]). That is, the interim actions have been justified independently, have been accompanied by adequate environmental documentation, and have not prejudiced the ultimate decision for which the RI/FS-EIS is being prepared (e.g., by limiting the choice of reasonable alternatives). The interim actions have not addressed decisions on remediating the entire chemical plant area or comprehensive waste disposal. Contaminated material generated by the interim actions is being placed in short-term storage at the chemical plant area, pending the final waste disposal decision for the project. This decision will be based on the information and analyses presented in the RI/FS-EIS.

1.5.1 Previous Response Actions

Various interim actions have been identified for the project to mitigate actual or potential releases of radioactive or chemical contaminants into the environment. A number of small-scope expedited response actions have been documented in focused engineering evaluation/cost analysis (EE/CA) reports. As discussed below, some of these CERCLA reports have been supplemented to incorporate NEPA values and to serve as environmental assessment (EA) reports under NEPA; in other cases, a memorandum-to-file was appropriate as the NEPA review for the proposed action (this was a level of NEPA review that was discontinued by DOE on September 30, 1990).

1.5.1.1 Expedited Actions at the Chemical Plant Area

Expedited actions at the chemical plant area were defined to mitigate health and safety threats to on-site personnel and/or to respond to off-site contaminant releases. Pursuant to the integrated EE/CA process, which included a public review and comment period, the following actions have been implemented:

- Inactive power lines and poles that were falling to the ground have been taken down. Uncontaminated material has been released off-site for reuse, and contaminated material has been placed in the debris staging area of the MSA.

- Overhead external piping insulated with deteriorating asbestos coverings has been taken down. The asbestos coverings have been removed, and all material has been surveyed and classified. Most of the piping has been released off-site for reuse; the remainder has been placed in the debris staging area of the MSA. The asbestos has been bagged and placed in bin containers for short-term storage in the northeastern portion of the site (Figure 1.3).

- Polychlorinated biphenyls (PCBs) have been flushed from electrical equipment. Items contaminated with PCBs only have been transported off-site to a permitted treatment and disposal facility; PCB-contaminated items that are also radioactively contaminated are stored on-site within an empty nonprocess building that was recently converted for waste storage (Building 434).

- Chemicals from various buildings have been (and continue to be) containerized and consolidated in Building 434.

- A small amount of radioactively contaminated soil from a vicinity property on the adjacent Army Reserve area has been excavated, drummed, and placed in controlled storage in Building 434.

- A dike and diversion system has been constructed at Ash Pond to direct surface runoff around a contaminated area (the South Dump) in order to reduce contaminant releases (principally uranium) off-site via surface drainage from the northern site boundary.

- Several nonprocess buildings have been dismantled (including the former administration building and steam plant), and the resultant contaminated material has been placed in the debris staging area of the MSA.

More extensive interim actions have also been documented for the project (Figure 1.7), but these actions are in the detailed design and site preparation stage and have not yet been fully implemented. Two such actions, management of contaminated pond water and management of the bulk (solid) waste, address quarry components of site remediation (see Sections 1.5.1.2 and 1.5.1.3).

1.5.1.2 Management of Quarry Pond Water

Management of contaminated surface water in the quarry was proposed as an expedited response action to mitigate the potential threat to a nearby drinking water supply, i.e., the county well field located within 1.6 km (1 mi) of the quarry (Figure 1.2). Monitoring results have indicated that contaminants are migrating from the quarry pond into the local groundwater and moving in the direction of the well field. The quarry pond is contaminated as a result of contact with the solid wastes that were placed in the quarry more than 20 years ago. This pond provides a gradient for contaminant migration because the pond surface is higher than the nearby groundwater table. An EE/CA, written to incorporate NEPA values appropriate for an EA, was prepared to support this action (MacDonell et al. 1989).

The alternative selected pursuant to the integrated EE/CA process, which included public review and comment, was to treat the pond water in a facility constructed adjacent to the quarry and release the treated water to the Missouri River in compliance with a permit issued to DOE by the Missouri Department of Natural Resources. A responsiveness summary was prepared to respond to public comments on the EE/CA, and the documents were adopted as an EA under NEPA. A finding of no significant impact (FONSI) was issued in February 1990. The water treatment plant has recently become operational and is expected to treat water during the quarry remedial action period, e.g., for 8 to 10 years. The treatment plant process waste will be containerized for transport to the TSA, as described for the quarry bulk waste. In addition to mitigating a potential threat to human health and the environment at the quarry, this action supports the second component of quarry cleanup, i.e., management of the bulk waste.

1.5.1.3 Management of Quarry Bulk Waste

Management of the bulk (solid) waste was proposed as an interim remedial action to mitigate the potential threat associated with that waste, which is the source of contaminants migrating into the air and the underlying groundwater at the quarry. A focused RI/FS package was prepared to support the action and was written to incorporate NEPA values appropriate for an EA. This document package consisted of (1) an RI, which presented characterization information for the quarry and the waste therein (DOE 1989); (2) a baseline risk evaluation, which assessed potential exposures to this waste in the short term under current conditions (DOE 1990a); (3) an FS, which developed, screened, and evaluated potential alternatives for managing the bulk waste (DOE 1990b); and (4) a PP, which summarized key information from the other primary documents (DOE 1990c).

The alternative selected pursuant to the integrated RI/FS process, which included public review and comment, was to excavate the bulk waste from the quarry and transport it to the chemical plant area of the Weldon Spring site for short-term storage, pending the disposal decision that will be determined from the current RI/FS-EIS. Removal of the quarry pond water will facilitate the excavation of this waste. Following excavation, the waste is to be placed in controlled storage in an engineered facility (termed the TSA) constructed adjacent to the raffinate pits. The TSA includes an equipment decontamination pad and contains a retention pond to collect water such as precipitation runoff and any leachate generated during the projected 3- to 6-year storage period. Also included in this action was the decontamination and dismantlement of four buildings in the area targeted for the TSA and the construction of an MSA debris staging area for short-term storage of this material (and other debris from similar actions [Section 1.5.1.1]), pending the upcoming disposal decision.

A responsiveness summary was prepared to respond to public comments on the quarry RI/FS, and a ROD prepared in accordance with the CERCLA decision process was signed by EPA in September 1990 and issued by DOE in March 1991. (The NEPA review process for this action was addressed together with a related response action for surface water at the chemical plant area, as discussed in Section 1.5.1.4.) Waste excavation is expected to be initiated in 1993 and to continue for 2 to 3 years.

1.5.1.4 Management of Water Impounded at the Chemical Plant Area

An additional expedited response action for the project, management of contaminated water impounded at the chemical plant area, was proposed to mitigate the potential threat associated with ecological exposures and contaminant releases to on-site groundwater and off-site surface water. An EE/CA, written to incorporate NEPA values appropriate for an EA, was prepared to support this action (MacDonell et al. 1990). The alternative selected pursuant to the integrated EE/CA process, which included public review and comment, was to treat the impounded water in a facility constructed adjacent to the raffinate pits and release the treated water to the Missouri River in compliance with a permit issued to DOE by the Missouri Department of Natural Resources. The treatment plant process waste will be containerized and placed in short-term storage at the TSA, pending the upcoming disposal decision. Also included in this action was the decontamination and dismantlement of three structures in the area targeted for treatment plant construction, with short-term storage of debris in the staging area at the MSA. This water treatment action supports the quarry bulk waste action because the plant would be available to treat water collected in the TSA retention pond.

A responsiveness summary was prepared to respond to public comments on the EE/CA, and a removal action decision document was prepared to support the CERCLA decision process. The integrated RI/FS for the bulk waste interim action and the EE/CA for this water treatment plant were jointly adopted as an EA under NEPA, and a FONSI was issued in November 1990.

The original discharge plan for the water treatment plant, which was to release the effluent to the Southeast Drainage for gravity flow to the Missouri River, was subsequently modified during detailed design of the treatment system. As part of the design effort, flows in the drainage were studied to assess the potential for contaminant resuspension at the expected discharge rates. Clean water was released from a hydrant at the upper end of the channel and then sampled for uranium at several locations downstream. Results indicated that uranium in the sediment from past releases (e.g., from decanting the raffinate pit water) could be resuspended at levels comparable to those naturally occurring in the Southeast Drainage after rainfall or snowmelt. To limit the potential for this resuspension, the design was changed such that treated water would be released through a buried 15-cm (6-in.) pipe similar to that designed for the quarry water treatment plant. The route determined for this pipeline follows the haul road recently constructed for transporting the bulk waste from the quarry to the chemical plant area, then parallels an abandoned railroad embankment and turns to follow a dirt road toward the Missouri River, with discharge through a submerged outfall.

A separate NEPA review (categorical exclusion) was conducted to address this design modification, and a floodplain/wetlands assessment was published in the *Federal Register* on September 15, 1992. The treatment plant and pipeline are expected to be completed soon and the facility is expected to be operational in early 1993. It would continue to treat water at the chemical plant area during the remedial action period, e.g., for 8 to 10 years.

1.5.1.5 Management of Chemical Plant Structures

A further interim action for the chemical plant area, management of 15 nonprocess buildings, was documented as an expedited response action to mitigate potential health and safety threats to on-site personnel. This action also addressed the potential threats associated with contaminant releases off-site. The chemical plant buildings have been inactive for more than 20 years and are in varying stages of disrepair; the roofs of some of these buildings have deteriorated to the extent that rainfall enters during storms, resulting in potential contaminant resuspension and transport off-site via water that enters the old process sewers.

An EE/CA and addendum, written to incorporate NEPA values appropriate for an EA, were prepared to support this action (MacDonell and Peterson 1989, 1990). The alternative selected pursuant to the EE/CA process, which included public review (no formal comments were received), was to decontaminate and dismantle the buildings and place the material in controlled storage within the MSA, pending the upcoming disposal decision; uncontaminated salvageable material such as structural steel could be released off-site for reuse.

A similar interim action to decontaminate and dismantle the remaining chemical plant structures was subsequently documented as an expedited response action, to mitigate similar threats. An EE/CA, written to incorporate NEPA values appropriate for an EA, was also prepared to support this action (Peterson and MacDonell 1991). The alternative selected pursuant to the EE/CA process, which included public review (no formal comments were received), was the same as that selected for the 15 nonprocess buildings. A removal action decision document was prepared for the CERCLA decision process. The two EE/CAs and the addendum were jointly adopted as an EA under NEPA, and a FONSI was issued in October 1991.

1.5.2 Currently Proposed Response Action

Two basic components of the chemical plant area are addressed in this FS:

- Assessment of the appropriate response for contaminated soil, sludge, sediment, and vegetation; and
- Assessment of the appropriate response for vicinity properties associated with the chemical plant area, except the Southeast Drainage; these vicinity properties include localized areas of contaminated soil and water, sediment, and shoreline soil at lakes in the Busch Wildlife Area.

This RI/FS-EIS also addresses the disposition of material resulting from previous interim actions (Section 1.5.1), including:

- Bulk waste excavated from the quarry and stored at the TSA;
- Demolition debris, equipment, tanks, and other material resulting from the decontamination and dismantlement of site structures (referred to as structural material in this FS) and stored at the MSA debris staging area;

- Chemicals stored in Building 434;
- Asbestos removed from piping and structures and stored in the staging area in the northern portion of the site; and
- Containerized process wastes generated by water treatment plants at both the quarry and the chemical plant area and stored at the TSA.

Future cleanup decisions for the quarry are not included in the scope of the current remedial action for the chemical plant area; these will be addressed in documentation to be prepared within the next several years, as will the decisions for the Southeast Drainage and groundwater (see Figures 1.7 and 1.8 and Section 1.5.3). However, contaminated material that could be generated as a result of future activities is expected to be similar to that addressed by the current action. Hence, the disposition of that material is included in this RI/FS-EIS process for planning purposes to ensure a comprehensive disposal decision for the project.

The BA (DOE 1992a) addresses conditions as they existed at the site in early 1992, irrespective of interim responses for which decisions had already been made but had not yet been fully implemented. In contrast, the updated conditions for this FS reflect the configuration of the site as it will soon exist as the result of those interim actions. That is, although the bulk waste is still in the quarry, this waste was assumed to be in storage at the TSA for the analyses in this document. In addition, although many buildings and underground tanks are still in place at the chemical plant area, contaminated material resulting from their decontamination and dismantlement was assumed to be in storage at the debris staging area of the MSA. Finally, although surface water is still present in the quarry pond and in the pits and ponds at the chemical plant area, it was assumed that the water treatment plants are operating at both locations.

The locations of the TSA and MSA, including the debris staging area, are shown in Figure 1.3. The volume of material at the TSA is expected to total about 115,000 m^3 (150,000 yd^3), and the volume of material at the debris staging area is estimated to total about 73,000 m^3 (95,000 yd^3); the latter will consist of contaminated material generated from building dismantlement. In addition, up to 168,000 m^3 (220,000 yd^3) of contaminated soil and rubble generated by cleanup and support activities (e.g., for construction of the water treatment plant and TSA) would be staged in the MSA soil staging area, as needed, over the remedial action period. The materials assumed to be stored at the TSA and MSA are summarized in Table 1.1 and are also described in the RI report for the quarry bulk waste (DOE 1989) and the design criteria report for the MSA (MK-Ferguson Company and Jacobs Engineering Group 1990).

The locations of the water treatment plants are shown in Figures 1.2 and 1.3. The annual average volume of process wastes generated by water treatment is not expected to exceed about 30 m^3 (50 yd^3) for the quarry system and about 70 m^3 (90 yd^3) and 290 m^3 (380 yd^3) for the physicochemical and distillation process trains, respectively, of the chemical plant area system. The types of process wastes that would be generated are described in the respective EE/CA reports (MacDonell et al. 1989, 1990). Volume estimates for the contaminated media at the site are summarized in Section 2.1.

1.5.3 Future Response Actions

Additional response actions are proposed for the project to address the last two components of the chemical plant area remediation — the Southeast Drainage and groundwater. Further actions are also proposed to address the final stage of quarry remediation, i.e., to manage residual material at the quarry area following bulk waste removal.

The response for the Southeast Drainage has been separated from the current response action in part because conditions in the drainage will change as a result of the upcoming decision for the chemical plant area. For example, water quality will improve because cleanup activities on-site are expected to reduce contaminant transport in surface runoff down the drainage, which would also limit potential deposition of suspended solids. Also, further sampling is needed to fully characterize the drainage so more representative impacts can be assessed. Therefore, the Southeast Drainage will be addressed as a removal action within the next several years, and an EE/CA will be prepared to support related decisions.

The groundwater response action has been separated from the current response action because the comprehensive data needed to support a final decision are not currently available. This approach will also permit coordination with the Army, which is responsible for the adjacent NPL site at which groundwater is also contaminated (Section 1.3.1). Therefore, groundwater remediation is being addressed as a separate operable unit remedial action. Over the next several years, an RI/FS work plan will be prepared to describe the scope of this action, and an RI, BA, FS, and PP will be prepared to support related decisions.

The scope of the follow-on actions for the quarry will also be defined in an RI/FS work plan that will be prepared within the next year to support the final decision-making process for this area (Figure 1.8). This follow-on effort will assess the appropriate response for (1) residual solid materials in the cracks and crevices of the quarry, (2) groundwater at the quarry, and (3) contaminated media at quarry vicinity properties, which include surface water and sediment in Femme Osage Slough and nearby areas of contaminated soil. After the bulk waste has been excavated from the quarry, the quarry walls, floor, and subsurface will be characterized. Additional data will also be collected for the other media. This information will be presented in an RI and will be evaluated in a BA for the final quarry response. Alternatives for the permanent disposition of the quarry area will be developed and evaluated in an FS, and a PP will be prepared to propose the final response.

As for the other documents, these future documents will incorporate NEPA values whenever practicable, and they will be issued to the public for comment. The types and volumes of contaminated material that could be generated as a result of upcoming activities have been conservatively estimated in this FS for planning purposes to support comprehensive project decisions. These volumes and those estimated for other contaminated media are presented in Section 2.1.

1.6 SUMMARY OF SITE RISKS

Potential human health and environmental effects have been assessed for the baseline conditions at chemical plant area of the Weldon Spring site and nearby locations outside the property fence (referred to in this discussion as off-site areas) to help focus forthcoming cleanup decisions. The health effects were estimated from radiological and chemical doses that could result from exposures to site contaminants if no cleanup actions were taken. These contaminants include radionuclides, metals, inorganic anions, nitroaromatic compounds, PAHs, PCBs, and asbestos (Table 1.2). Because the baseline configuration of the site is changing as interim actions are conducted (Section 1.5), risks were assessed for several stages of site conditions. The assessment of baseline conditions addresses the site configuration as of early 1992 and is presented in the BA (DOE 1992a). The human health assessment of rebaseline conditions addresses the transitional or interim site configuration resulting from interim actions and also focuses on a range of possible exposures to soil contamination under hypothetical future conditions. This assessment is presented in Appendix E of this FS. The environmental assessment of rebaseline conditions is presented in Section 6.1 and 6.11 of this FS.

1.6.1 Human Health Assessment

1.6.1.1 Exposure Scenarios

To address the changing site configurations, five assessments were conducted for the chemical plant area that considered time, institutional controls, and land use. A sixth assessment was conducted for the off-site areas impacted by site releases. The receptors, areas and media contacted, and routes of exposure evaluated for these assessments are summarized in Tables 1.3 and 1.4 and are described as follows.

For the first assessment, the site configuration as of early 1992 was evaluated to identify potential health effects under baseline conditions. These conditions include the presence of the raffinate pits and buildings but not the temporary facilities such as the TSA, MSA, and water treatment plant that will soon be completed to support interim actions. About 200 workers are currently on-site, and public access is controlled by a perimeter fence and security guards. The potential on-site receptors identified for these conditions are a site maintenance worker and a trespasser.

The worker was assumed to conduct routine maintenance activities across the site. Direct contact with source areas such as the raffinate pits and buildings is restricted for this worker because of access controls and worker protection measures. Hence, potential exposures were assessed only for on-site soil and air for this individual. In contrast, the trespasser was assumed to access all areas of the site. Hence, in addition to the exposures identified for the worker, the trespasser could be exposed to surface water and sludge at the raffinate pits and to air and residues in the buildings. To address the possibility that an intruder might swim in the

TABLE 1.2 Contaminants of Concern for the Weldon Spring Site

Radionuclides[a,b]	Metals	Other Inorganic Compounds	Nitroaromatic Compounds	PCBs and PAHs
Actinium-227	Aluminum[c]	Asbestos[a]	DNB	PCBs[a]
Lead-210	Antimony	Fluoride	2,4-DNT[a]	Acenaphthene
Protactinium-231	Arsenic[a]	Nitrate	2,6-DNT[a]	Anthracene
Radium-226	Barium	Nitrite	NB	Benz(a)anthracene[a]
Radium-228	Beryllium[a]		TNB	Benzo(b)fluoranthene[a]
Radon-220	Cadmium[a]		TNT[a]	Benzo(k)fluoranthene[a]
Radon-222	Chromium[a]			Benzo(g,h,i)perylene
Thorium-230	Cobalt			Benzo(a)pyrene[a]
Thorium-232	Copper			Chrysene[a]
Uranium-235	Lead[a]			Fluoranthene
Uranium-238	Lithium			Fluorene
	Manganese			Indeno(1,2,3-cd)pyrene[a]
	Mercury			2-Methylnaphthalene
	Molybdenum			Naphthalene
	Nickel[a]			Phenanthrene
	Selenium			Pyrene
	Silver			
	Thallium			
	Uranium			
	Vanadium			
	Zinc			

[a] Potential carcinogen.

[b] Exposure to gamma radiation resulting from the presence of these radionuclides was also evaluated.

[c] A contaminant of concern only for the ecological risk assessment.

raffinate pits, a swimmer was also evaluated. Exposures for this first assessment were assumed to extend over the next 10 years.

For the second assessment, the same baseline site configuration was evaluated as for the first assessment but it was hypothetically assumed that DOE and other workers were no longer at the site and access was no longer controlled; this assessment permits an evaluation of long-term impacts that might occur in the absence of any further cleanup. Under these conditions, land use on-site was assumed to be recreational because the site is adjacent to two wildlife areas for which recreational use is expected to continue into the reasonably foreseeable future. Therefore, a recreational visitor was identified as the future on-site receptor. The same types of exposures were evaluated for the on-site recreational visitor as for the trespasser. To address possible exposures to contaminated game, a sportsman who was assumed to hunt on-site was also evaluated. Because a sportsman might also fish at the off-site lakes, on-site and off-site exposures were combined for this receptor. This second assessment was assumed to extend over the next 30 years. Potential exposures were also assessed for an individual (youth) who was assumed to swim in the raffinate pits over a 10-year period. The first and second assessments are presented in the BA (DOE 1992a).

TABLE 1.3 Scenario Descriptions for On-Site Receptors under Current and Future Conditions

Site Conditions and Receptor	Description	On-Site Area	Medium	Routes of Exposure
Baseline site configuration, with access restrictions				
Maintenance worker	An individual conducts routine maintenance activities 8 hours per day, 200 days per year, for 10 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
Trespasser	An individual enters the site 5 times per year for 1 hour per visit for 10 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
		Raffinate pits	Surface water	Ingestion
			Sludge	External gamma irradiation Incidental ingestion
		Buildings	Residues	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
Swimmer[a]	An individual swims in the raffinate pits once per year for 1 hour for 10 years.	Raffinate pits	Surface water	Incidental ingestion Dermal contact
			Sludge	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation

TABLE 1.3 (Cont.)

Site Conditions and Receptor	Description	On-Site Area	Medium	Routes of Exposure
Baseline site configuration, with no access restrictions				
Recreational visitor	An individual visits the site 20 times per year, 4 hours per visit, for 30 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
		Raffinate pits	Surface water	Ingestion
			Sludge	Incidental ingestion
		Buildings	Residues	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
Sportsman	An individual hunts at the site 15 days per year, 4 hours per day, for 30 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
			Game	Ingestion

TABLE 1.3 (Cont.)

Site Conditions and Receptor	Description	On-Site Area	Medium	Routes of Exposure
Interim site configuration, with access restrictions				
Maintenance worker[b]	An individual conducts maintenance activities 8 hours per day, 200 days per year, for 10 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
		TSA and MSA	Waste/debris	External gamma irradiation
Trespasser	An individual enters the site 5 times per year, 1 hour per visit, for 10 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
Interim site configuration, with no access restrictions				
Recreational visitor	An individual visits the site 20 times per year, 4 hours per visit, for 30 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
		Raffinate pits	Surface water	Ingestion
			Sludge	Incidental ingestion
		TSA and MSA	Waste/debris	External gamma irradiation

TABLE 1.3 (Cont.)

Site Conditions and Receptor	Description	On-Site Area	Medium	Routes of Exposure
Modified site configuration, with no access restrictions				
Recreational visitor	An individual visits the site 20 times per year, 4 hours per visit, for 30 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
Ranger	An individual works outdoors and in a ranger station on-site 8 hours per day, 250 days per year, for 25 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
Resident[c]	An individual lives in a house on-site 24 hours per day, 350 days per year, for 30 years.	Sitewide	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
Farmer[c]	An individual lives on a farm on-site 24 hours per day, 350 days per year, for 30 years.	Ash Pond	Soil	External gamma irradiation Incidental ingestion Dermal contact
			Air	Inhalation
		Ash Pond	Fruits, vegetables, beef, dairy products	Ingestion

[a] Conditions for this receptor also represent those for a swimmer under the baseline configuration with no access restrictions.

[b] Exposures were assessed for a worker performing routine maintenance activities such as mowing and fence repair (as for the worker under the baseline configuration) and also for a worker performing maintenance activities at the TSA and MSA debris staging area.

[c] Although ingestion of groundwater was evaluated for this receptor, the results are not included in this summary because of the preliminary nature of the assessment (see Appendix E, Section E.4).

TABLE 1.4 Scenario Descriptions for Off-Site Receptors under Current and Future Conditions

Receptor	Description	Off-Site Area	Medium	Routes of Exposure
Recreational visitor	An individual visits the off-site location 20 times per year, 4 hours per visit, for 30 years.	Vicinity properties[a]	Soil	External gamma irradiation Incidental ingestion
		Southeast Drainage	Surface water	Ingestion
			Sediment/soil	External gamma irradiation Incidental ingestion
		Burgermeister Spring	Surface water	Ingestion
		Lakes 34, 35, and 36	Surface water	Ingestion
			Sediment/soil	External gamma irradiation Incidental ingestion Dermal contact
Swimmer	An individual swims in Lake 34, 35, or 36 once per year for 1 hour for 10 years.	Lakes 34, 35, and 36	Surface water	Incidental ingestion Dermal contact
			Sediment/soil	External gamma irradiation Incidental ingestion Dermal contact
Sportsman	An individual fishes at Lakes 34, 35, and 36 7 days per year, 4 hours per day, for 30 years.	Lakes 34, 35, and 36	Surface water	Ingestion
			Sediment/soil	External gamma irradiation Incidental ingestion Dermal contact
			Fish	Ingestion

[a] Soil vicinity properties except the Southeast Drainage, which is addressed separately.

For the third and fourth assessments, which are presented in Appendix E of this FS, the site configuration was assumed to reflect conditions associated with recent interim actions that are in various stages of planning and implementation. These actions include dismantling the chemical plant buildings and storing the material at the MSA, storing the bulk wastes excavated from the quarry at the TSA, and removing and treating water from the raffinate pits (Section 1.5.1). The purpose of these two assessments was to identify potential impacts that could occur if no further cleanup actions were taken at the site beyond those that have already been initiated, and assuming they are completed. These actions will result in interim or transitional site conditions because they represent only a partial completion of overall cleanup plans, pending implementation of those actions being evaluated in this RI/FS-EIS.

Both short-term and long-term assessments were conducted for the interim site configuration. The short-term assessment evaluated possible health effects for the transitional site conditions for the reasonable scenario under which DOE remains on-site and existing institutional controls such as access restrictions are maintained. The maintenance worker and trespasser were the receptors evaluated, and exposures were assumed to occur over the next 10 years. The long-term assessment of the interim site configuration evaluated exposures that could occur in the more extended future, e.g., after 100 years, hypothetically assuming that DOE is no longer present and access to the site is unrestricted. Under these conditions, the most likely land use is recreational. Therefore, a recreational visitor was evaluated, and on-site exposures were assumed to extend over a period of 30 years.

The fifth assessment was conducted to focus the development of preliminary cleanup criteria for site soil. Soil is the only medium for which criteria were developed within the scope of the current remedial action because the other media have been addressed by interim actions (Section 2.1). Therefore, a modified site configuration was evaluated that focused on soil areas and did not include the raffinate pits, buildings, or temporary facilities. For this assessment, which is presented in Appendix E of this FS, it was hypothetically assumed that DOE is no longer present, access is unrestricted, and land use in the area might change in the extended long term, e.g., after 100 to 200 years and beyond. Four receptors were evaluated for this long-term assessment of the modified site configuration: a recreational visitor, ranger, resident, and farmer. The ranger and recreational visitor were assumed to be exposed to contaminated soil and air over periods of 25 and 30 years. Additional exposures were evaluated for the resident and farmer to address full-time exposures and ingestion of homegrown food and ingestion of drinking water from the contaminated aquifer. These two receptors were assumed to be exposed over a period of 30 years.

For the sixth assessment, off-site exposures were evaluated for a member of the general public at Burgermeister Spring; Lakes 34, 35, and 36; the Southeast Drainage; and specific soil vicinity properties. Although most of these areas are located in the Weldon Spring and Busch wildlife areas, several vicinity properties are located on the adjacent Army land to which access is currently restricted. Recreational use of the wildlife areas is expected to continue for the reasonably foreseeable future. Hence, this assessment estimated exposures to the contaminated areas for a recreational visitor. These exposures were assumed to occur over a period of 30 years. (Ongoing and likely future exposures on the Army land would be bounded by those associated with recreational use because use by Army personnel is less frequent. To be conservative, recreational use of those vicinity properties was evaluated for both the current and future assessments.) A swimmer was also evaluated for the off-site lakes, assuming exposures could occur over a period of 10 years.

Contaminant levels at the off-site locations are expected to remain the same or be somewhat lower in the future because interim actions are mitigating site releases. Therefore, one assessment was conducted for both current and future exposures that extend to 100 or 200 years and beyond. This assessment is presented in the BA (DOE 1992a). The combined approach was considered reasonable for the current stage of the decision-making process because separate plans have already been developed for Lakes 34, 35, and 36 and the Southeast Drainage that affect the estimation of future exposures. The Missouri Department of Conservation expects to drain and dredge the lakes within the next several years as part of a routine sedimentation management program for the Busch Wildlife Area. Current data for the Southeast Drainage are limited (generally to hot spots), so exposures associated with this location will be reevaluated in greater detail within the next several years after more data become available. For the remaining vicinity properties, to address the possibility that local land use might change in the extended future, the results of the long-term assessment of the modified site configuration that considered nonrecreational land uses for on-site soil will be incorporated into decisions for off-site soil.

1.6.1.2 Risk Characterization

Potential carcinogenic risks from radiological and chemical exposures were estimated for the human health assessment in terms of the increased probability that an exposed individual could develop cancer over the course of a lifetime. The EPA has identified a range of 1×10^{-6} to 1×10^{-4} — or 1 in 1 million to 1 in 10,000 — for the incremental risk associated with an NPL site (EPA 1990a). This range is referred to as the target range in this discussion, and it provides a point of reference for the site-specific risks presented in the BA and FS. For comparison, about one in three Americans will develop cancer from all sources, and it is estimated that 60% of cancers are fatal (American Cancer Society 1992). These estimates translate to a cancer risk of about 2×10^{-1}, or 1 in 5. The individual lifetime risk of fatal cancer associated with background radiation, primarily from naturally occurring radon, is estimated to be about 1×10^{-2}, or 1 in 100 (EPA 1989b).

The potential for adverse health effects other than cancer from exposure to site contaminants was assessed by estimating the hazard index. The hazard index is determined from the ratios of the doses estimated for an individual from site exposures to standard reference doses determined by the EPA. Noncarcinogenic health effects are not expected for endpoint-specific (segregated) hazard indexes of 1 or less; conversely, an endpoint-specific hazard index of greater than 1 indicates a potential for adverse health effects (EPA 1989e).

To determine whether cleanup is warranted at NPL sites, the EPA considers incremental risks relative to the target range of 1×10^{-6} to 1×10^{-4}, in combination with other site-specific factors (EPA 1991b). In the following summary presentation of the risk results, estimates are generally presented as total risks. Potential incremental risks from exposures to site contaminants were assessed in developing cleanup criteria for site soil, which are discussed in Chapter 2 of this FS and presented in Chapter 4 of the proposed plan for this remedial action (DOE 1992b). An integrated summary of total and incremental risks for the baseline and rebaseline human health assessments is presented in Chapter 4 of the proposed plan.

The estimated risks and hazard indexes evaluated for exposures at the site under the baseline configuration are summarized in Tables 1.5 and 1.6. For the baseline configuration with continued access controls, the estimated radiological risk for the maintenance worker from exposures to sitewide soil and air is 5×10^{-4}; inhalation of radon accounts for most of this risk. However, it was assumed that the worker accessed all soil areas and a conservative estimate was used for the radium concentration in soil. A more realistic risk estimate would probably be lower because of the high bias in the data for radium in soil from which the radon concentrations were derived. In addition, a maintenance worker would not access highly contaminated areas because access to these areas is restricted. In fact, these results confirm the appropriateness of such access restrictions. The estimated risk to a worker from sitewide exposures to chemical contaminants is 1×10^{-5}, and the hazard index is less than 1. The radiological and chemical risks for a trespasser repeatedly entering the site are 9×10^{-5} and 1×10^{-4}, which are at the upper end of EPA's target range; the hazard index is slightly above 1. For a swimmer in the raffinate pits, the estimated radiological and chemical risks are 2×10^{-4} and 5×10^{-6}, and the hazard index is less than 1. Dermal absorption from water is the major contributor to the risk; however, considerable uncertainty is associated with related estimates because of limitations in the methodology for estimating intakes. The combined radiological risk from all other exposure routes for the swimmer is within EPA's target range (the estimates for chemical health effects are within or below the levels of concern).

For the baseline configuration under which it is hypothetically assumed that DOE has left the site and access is no longer controlled, the risk estimated for an on-site recreational visitor is 1×10^{-3} for both radiological and chemical exposures, and the hazard index exceeds 1. The radiological and chemical risks estimated for the sportsman from combined on-site and off-site exposures are 5×10^{-5} and 3×10^{-6}, and the hazard index is less than 1.

For the interim site configuration with continued access controls, worker requirements would change as a result of additional maintenance activities needed at the temporary facilities — particularly the TSA and the MSA. The health effects for the original maintenance worker would be essentially the same as those estimated for the baseline configuration. However, a radiological risk would be incurred by an additional worker assigned to maintain the temporary facilities. The risk to this new worker from external gamma irradiation would be about three times higher than that estimated for the routine maintenance worker; the new worker would also be exposed to sitewide soil and air. Accounting for the shorter time spent on-site for periodic maintenance, the overall radiological risk for this worker under the interim configuration would be generally similar to (about 20% of) that estimated for the routine maintenance worker under the baseline configuration. The chemical risk and hazard index are expected to be the same as those estimated for the worker under the baseline configuration.

TABLE 1.5 Estimated Carcinogenic Risks for On-Site Receptors under the Baseline Configuration[a]

	Maintenance Worker		Trespasser[b]		Recreational Visitor[b]	
Area and Medium	Radio-logical	Chemical	Radio-logical	Chemical	Radio-logical	Chemical
Sitewide soil and air	5×10^{-4}	1×10^{-5}	2×10^{-6}	2×10^{-7}	6×10^{-5}	3×10^{-6}
Raffinate pit surface water and sludge	NQ[c]	NQ	2×10^{-4}	9×10^{-6}	3×10^{-3}	1×10^{-4}
Building air and residues	NQ	NQ	1×10^{-4}	4×10^{-4}	1×10^{-3}	3×10^{-3}
Combined risk	5×10^{-4}	1×10^{-5}	9×10^{-5}	1×10^{-4}	1×10^{-3}	1×10^{-3}

[a] The maintenance worker and trespasser were evaluated for the baseline configuration under which existing site controls were assumed to be maintained; the recreational visitor was evaluated for the baseline configuration under which controls were assumed to no longer exist.

[b] The individual risks correspond to the reasonable maximum exposures, which were estimated by assuming that the entire exposure occurs at the indicated area and medium. The combined risks correspond to exposures that were assumed to be equally distributed among sitewide soil and air, raffinate pit surface water and sludge, and building air and residues. For a swimmer, the estimated radiological and chemical risks from exposures to raffinate pit surface water and sludge and sitewide air are 2×10^{-4} and 5×10^{-6}.

[c] NQ indicates that the risk was not quantified for this receptor.

TABLE 1.6 Estimated Hazard Indexes for On-Site Receptors under the Baseline Configuration[a]

Area and Medium	Maintenance Worker	Trespasser[b]	Recreational Visitor[b]
Sitewide soil and air	0.5	0.005	0.03
Raffinate pit surface water and sludge	NQ[c]	0.7	2
Building air and residues	NQ	3	10
Combined hazard index	0.5	1	4

[a] The maintenance worker and trespasser were evaluated for the baseline configuration under which existing site controls were assumed to be maintained; the recreational visitor was evaluated for the baseline configuration under which controls were assumed to no longer exist.

[b] The individual hazard indexes correspond to the reasonable maximum exposures, which were estimated by assuming that the entire exposure occurs at the indicated area and medium. The combined hazard index corresponds to exposures that were assumed to be equally distributed among sitewide soil and air, raffinate pit surface water and sludge, and building air and residues. For a swimmer in the raffinate pits, the estimated hazard index is 0.02.

[c] NQ indicates that a hazard index was not quantified for the worker from those exposures.

The radiological and chemical risks estimated for the trespasser under this interim configuration are expected to decrease to about 2% of those for the baseline configuration, to 2×10^{-6} and 2×10^{-7}, and the hazard index would be well below 1. These decreases would occur because (1) trespassing inside the buildings would no longer be possible because the buildings would have been dismantled and (2) trespassing at the raffinate pits would be very unlikely because workers would be present at the treatment plant adjacent to the pits to support the removal and treatment of surface water. Similarly, exposures are not expected at the other temporary facilities because of the increased activity levels of workers.

For the interim configuration under which it is hypothetically assumed that DOE has left the site and access is unrestricted, it is expected that the raffinate pits could refill with water over time so exposures at the pits could be the same as those estimated for the recreational visitor under the baseline configuration. In addition, the quarry bulk waste and building material in storage at the TSA and MSA would no longer be controlled and might therefore be accessed and/or dispersed over time. The reductions associated with building dismantlement (specifically from the absence of exposure to indoor radon) would be offset by new exposures associated with this stored material. These changes would essentially balance each other such that overall health effects would be similar to those estimated for the recreational visitor under the baseline configuration.

The risks and hazard indexes estimated for four future land-use scenarios under the modified site configuration are summarized in Table 1.7. These analyses focused on exposures related to soil contaminants, and the results shown in the tables represent the range of values estimated from data for different locations across the site. Radiological and chemical risks estimated for the recreational visitor from exposures to soil and air are 6×10^{-5} and 2×10^{-6}, and the hazard index is much less than 1. For the ranger, resident, and farmer, the estimated radiological risks exceed EPA's target range at most locations, primarily from inhalation of radon. The chemical risk estimated for the ranger is 2×10^{-5} and the hazard index is less than 1 at all locations. The chemical risk for the resident exceeds the target range at one location, and it ranges from 3×10^{-6} to 6×10^{-4} across the site; the hazard index ranges from 0.09 to 9 and exceeds 1 at 14 locations. These effects are associated with incidental ingestion of soil, and the primary contributors are arsenic, PCBs, and uranium. For the farmer, the estimated radiological and chemical risks are 1×10^{-2} and 2×10^{-4}, and the hazard index exceeds 1. Considerable limitations and uncertainties exist in the data and methodologies available for estimating potential health effects from ingesting homegrown food, and the results for this pathway for nonradiological exposures are comparable to those determined for an off-site background location. The radiological and chemical risks estimated for the farmer from the other exposure pathways (for which the uncertainty is lower) are 1×10^{-2} and 5×10^{-5}, and the hazard index exceeds 1.

The risks and hazard indexes estimated for a recreational visitor at the off-site locations are shown in Table 1.8. The radiological and chemical risks at Burgermeister Spring and Lakes 34, 35, and 36 are less than 1×10^{-5}, as are the chemical risks at the Southeast Drainage; the hazard indexes at each of these locations are well below 1. The radiological risks for the soil

TABLE 1.7 Estimated Carcinogenic Risks and Hazard Indexes for Exposures to Soil and Air under the Modified Site Configuration

Receptor	Carcinogenic Risk: Radiological	Carcinogenic Risk: Chemical	Health Hazard Index for Noncarcinogenic Effects
Recreational visitor	6×10^{-5}	2×10^{-6}	0.02
Ranger			
Range[a]	6×10^{-4} - 1×10^{-2}	2×10^{-5}	0.3 - 0.5
Median	7×10^{-4}	2×10^{-5}	0.4
Resident			
Range	1×10^{-6} - 9×10^{-2}	3×10^{-6} - 6×10^{-4}	0.09 - 9
Median	2×10^{-4}	3×10^{-5}	0.6
Farmer[b]	1×10^{-2}	2×10^{-4}	11

[a] For chemical risks, because the variation is small and the results are rounded to one significant figure, the range and median are represented by the same value in this table.

[b] Results for the farmer include the contribution from ingesting food grown on contaminated soil. Considerable uncertainty is associated with the methodology used to estimate intakes for this pathway, and the chemical risk and hazard index estimated from a parallel analysis for a nearby background location are comparable to those estimated for the on-site farmer location. Excluding the contribution from this pathway, the estimated radiological and chemical risks for the farmer are 1×10^{-2} and 5×10^{-5}, and the hazard index is 2.

vicinity properties — estimated by assuming that 600 exposures occur at each individual property over the 30 years — are within or below the target range except for vicinity property B4 (Figure 1.4). The risk estimated for repeated exposures at this remote location in the Weldon Spring Wildlife Area is 3×10^{-4}. The radiological risk estimated for the Southeast Drainage with the same conservative assumptions described for the soil vicinity properties is 2×10^{-4}. Most of this risk results from repeated incidental ingestion of thorium-230 from the sediment, based on data from only 5 samples taken from the most highly contaminated areas. These estimates are preliminary because the data are limited and biased high; potential impacts will be reevaluated within the next several years after additional characterization data become available (Section 1.5.3). For a swimmer in the lakes, the total radiological and chemical risks are 3×10^{-7} and 4×10^{-8}, and the hazard index is less than 1. These values are below EPA's target levels.

1.6.2 Ecological Risk Assessment

The Weldon Spring site is adjacent to two state wildlife areas and near a third, and more than 200 species of plants and animals are expected to occur on-site. Several species listed by the state and/or federal government as threatened or endangered have been identified for

TABLE 1.8 Estimated Carcinogenic Risks and Hazard Indexes for a Recreational Visitor at Off-Site Areas[a]

Area and Medium	Radiological Risk	Chemical Risk	Hazard Index
Lakes 34, 35, and 36 surface water and sediment	8×10^{-6}	5×10^{-6}	0.1
Burgermeister Spring surface water	4×10^{-6}	9×10^{-7}	0.04
Southeast Drainage surface water and sediment	2×10^{-4}	2×10^{-6}	0.2
Vicinity property soil	6×10^{-7} - 3×10^{-4}	NQ[b]	NQ

[a] The results shown in this table represent both current and future conditions (see text).

[b] NQ indicates that a carcinogenic risk or hazard index was not estimated for this location.

the general area. These species have not been reported at the site from the studies conducted to date, although the pied-billed grebe, a state rare species, has been observed at the raffinate pits.

At scattered soil locations, elevated levels of naturally occurring metals such as arsenic, cadmium, copper, lead, mercury, uranium, and zinc could potentially impact certain biota (i.e., invertebrates). If exposure to the maximum measured on-site concentrations of these metals is assumed, possible ecological effects reported in the scientific literature include decreases in the diversity, density, and biomass of invertebrate species. This information was incorporated into the development of cleanup criteria for site soil. No adverse ecological impacts are associated with either the radionuclides or chemicals in soil at the cleanup levels developed for the site on the basis of the human health assessment.

Under baseline conditions, certain contaminants present in surface water in the raffinate pits exceed either water quality criteria established by the EPA and/or the state of Missouri or concentrations reported in the scientific literature to adversely impact biota. For example, levels of arsenic, beryllium, cadmium, chromium, copper, lead, mercury, selenium, silver, uranium, fluoride, and nitrate could pose a threat to aquatic and semiaquatic biota. Selenium is present at concentrations exceeding those shown to adversely affect waterfowl. Furthermore, because selenium bioconcentrates, it could pose a hazard to wildlife species higher in the food chain. This information confirms the previous decision to remove and treat the contaminated surface water from the pits as an interim action; it also supports plans to address the remaining waste (raffinate pit sludge), which serves as the source of the water contamination, as part of the current remedial action.

For off-site surface water, the maximum concentrations measured for nitrate in the Southeast Drainage and Burgermeister Spring exceed the level that poses a potential for adverse impacts to aquatic biota, as indicated by the EPA. Similarly, the maximum concentrations measured for arsenic, lead, mercury, and silver exceed water quality criteria for protection of freshwater biota. Although the maximum measured concentration of uranium in the Southeast Drainage exceeds levels shown to be toxic to *Daphnia* (water fleas), estimates of related exposures are well below the 1 rad/d dose limit for protection of aquatic biota. However, uranium metal is also chemotoxic to animals, and the elevated concentrations reported for certain sediment locations and in water at certain locations during the periods of intermittent flow could potentially pose a threat to aquatic biota at the confluence of the drainage with the Missouri River if no mixing were to occur. The concentrations of other metals and radioactive contaminants are sufficiently low that no threats to biota are anticipated. (For the off-site surface water, only elevated levels of radionuclides are directly associated with the site. Site runoff contributes only a fraction of the flow in the drainage areas for the off-site lakes and streams. For example, these areas also receive runoff from the Army property adjacent to the site and from local agricultural land.)

Certain contaminant levels in the drainage have decreased from the maximum concentrations evaluated in this assessment; these decreases have resulted from natural attenuation and specific source control measures that have been implemented as part of interim actions at the site (including surface runoff controls). The information from this assessment confirms the plans to collect additional data from the Southeast Drainage to support final decisions for that location, which will be made within the next several years; these decisions will evaluate the potential adverse impacts associated with environmental disturbance in the drainage relative to the potential benefits associated with the cleanup measures being considered.

No obvious adverse ecological impacts have been observed to date at the site or surrounding areas, except for circumstantial evidence (the paucity of biota) at the raffinate pits. However, adverse ecological impacts might occur if the site were not cleaned up and contaminants remained in their current state, particularly at the raffinate pits. The results of this assessment were used to focus remaining decisions for site cleanup, e.g., for sludge in the raffinate pits.

1.6.3 Assessment of Other Environmental Resources

In addition to the ecological assessment, potential impacts to other environmental resources in the absence of remedial action at the site were also assessed. On the basis of current site information, no significant adverse impacts to other environmental resources are expected to result from a continuation of current conditions, with the possible exception of groundwater. Additional studies to further characterize the nature and extent of groundwater contamination are under way and will be incorporated into documentation to be prepared within the next several years in support of the decision for site groundwater.

2 PURPOSE AND OBJECTIVES OF THE REMEDIAL ACTION AND DEVELOPMENT OF CLEANUP CRITERIA

2.1 PURPOSE AND OBJECTIVES OF THE REMEDIAL ACTION

The overall objectives of remedial action at the Weldon Spring site are to:

- Protect human health and the environment by developing actions that address the radioactive and chemical contaminants in various media at the site and control related exposures;
- Implement the actions in a manner that will ensure compliance with applicable environmental requirements; and
- Release the property for unrestricted use, to the extent practicable.

Additional objectives include removing physical hazards to ensure worker and public safety, minimizing contaminant transport to off-site areas, and instituting permanent control measures for waste material. The comprehensive risk-based objective for the project is to minimize exposures of both humans and biota to contaminants in each environmental medium (e.g., air, water, and soil) via each exposure route (e.g., inhalation, ingestion, and external gamma irradiation), in order to minimize the possibility of adverse health and ecological effects.

The specific areas of contamination at the site and the types of affected media are shown in Figure 2.1. Potential risks associated with exposures to site contamination have been assessed in considerable detail (in the BA [DOE 1992a] and Appendix E of this FS) to indicate those contaminated areas and media that should be addressed to achieve the cleanup objectives for the current stage of site remediation. From the results of these assessments, the following source areas and contaminated media of concern have been identified:

- Soil at the North Dump and South Dump, at scattered locations across the site (including subsurface soil around process sewer pipes), and at several specific off-site locations.
- Sludge and soil at the raffinate pits (surface water at the pits has been addressed by an interim action).
- Sediment and soil at Ash Pond and Frog Pond (surface water at the ponds has been addressed by an interim action).
- Surface water at Burgermeister Spring and surface water, sediment, and shoreline soil at Lakes 34, 35, and 36.
- Sediment and soil that could be removed from the quarry area or the Southeast Drainage as part of forthcoming response actions for the project.

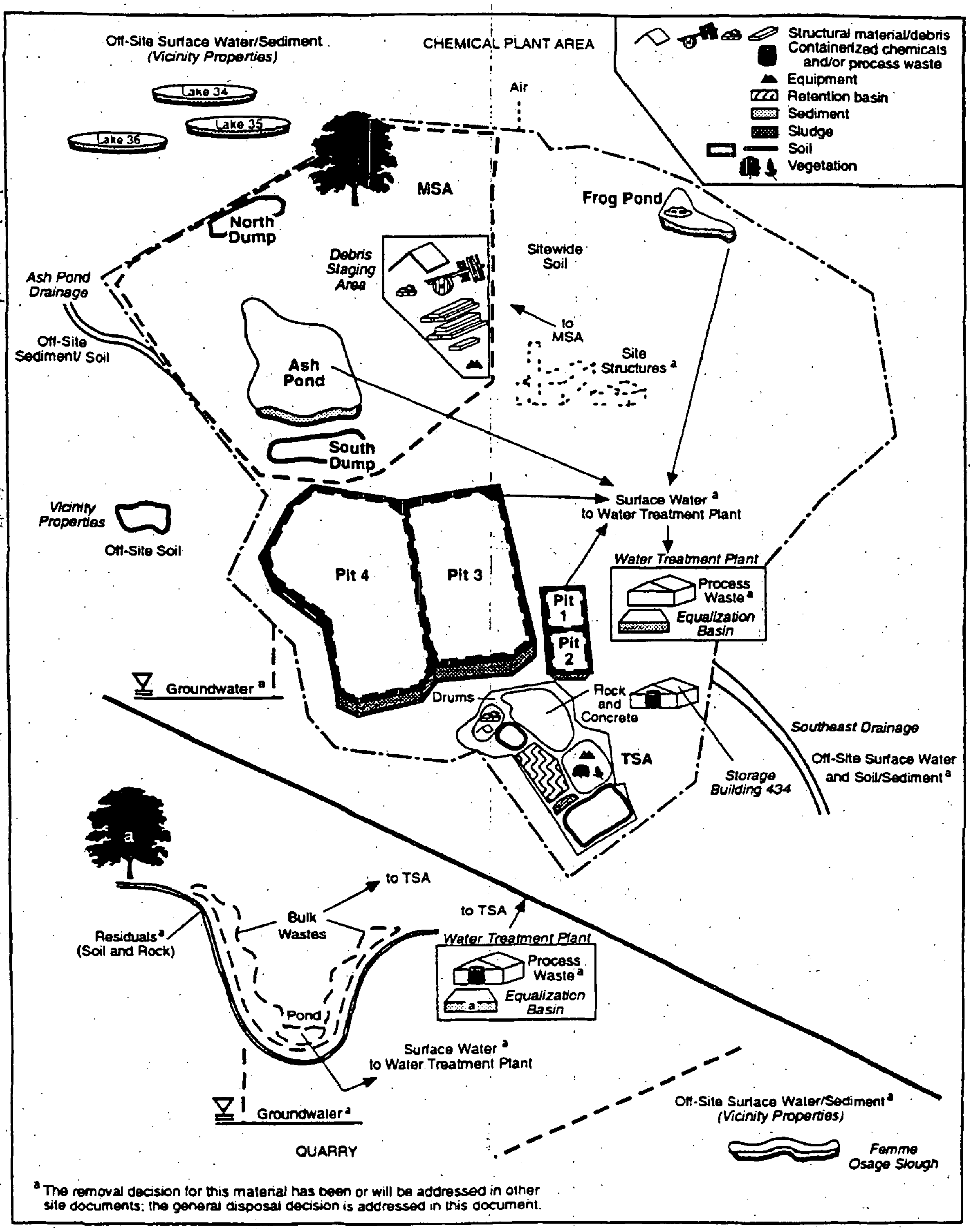


FIGURE 2.1 Contaminated Media and Source Areas at the Weldon Spring Site

- Vegetation resulting from clearing and grubbing activities, and contaminated railroad ties and power poles that have been removed under interim actions.

- Metal building debris, equipment, and tanks; rock and concrete; soil, sludge, and sediment; and vegetation removed from the quarry under the bulk waste interim action and stored at the TSA (surface water in the TSA retention ponds has been addressed by a separate interim action).

- Structural material and other debris — including steel, concrete, roofing material, and drummed decontamination material (e.g., worker protective clothing) — generated by the interim action to decontaminate and dismantle site structures and stored at the debris staging area in the MSA. This category also includes material associated with newly constructed temporary facilities such as the water treatment plant that will be dismantled after use at the site.

- Containerized asbestos resulting from the interim action to dismantle and decontaminate site structures and stored at the container storage area.

- Containerized chemicals resulting from the interim action to consolidate chemicals and stored on-site (most chemicals are stored in Building 434 [Figure 1.3]; tributyl phosphate is stored in two outdoor tanks near the debris staging area of the MSA).

- Process wastes generated by both the quarry and chemical plant area water treatment plants as a result of interim actions, stored at the TSA (and possibly Building 434).

- Air, as it is affected by soil contamination (e.g., fugitive dust generation and radon emanation).

Technologies that could be applied to the media addressed by this remedial action are discussed in Chapter 3 of this FS, and specific alternatives are evaluated in Chapters 4 through 7. Preliminary area and volume estimates for these media are included in Table 2.1. (For completeness, estimates for other contaminated media not included in the scope of this action are also shown in the table.)

The cleanup criteria developed for various media at a contaminated site represent one of the key factors used to determine whether alternatives that will provide long-term protection of human health and the environment. These criteria are used to identify what areas of a site should be cleaned up, what areas could be appropriately left in their current condition, and what exposure controls (such as access restrictions) might be needed to ensure long-term protection of human health and the environment under possible future uses. Certain media associated with the Weldon Spring site are outside the scope of the current remedial action, and other media

TABLE 2.1 Estimated Areas and Volumes of Contaminated Media

Contaminated Media and Locations	Area (acres)	Volume (yd^3)
Sludge		
Raffinate pits	25.8	220,000
Sediment		
Ash Pond	8.6	8,200
Frog Pond	1.9	7,000
TSA	1.0	4,100
Lakes 34, 35, and 36	113	20,000
Femme Osage Slough	3.5	80,500
Total sediment	**128**	**119,800**
Soil		
North Dump	1.9	7,600
South Dump	4.2	16,900
Other sitewide soil	20	85,400
TSA	2.0	52,000
Raffinate pits	25.8	153,500
Soil at subsurface piping	4.5	20,000
Off-site (vicinity properties)	1.2	3,600
Total soil	**59.6**	**339,000**
Structural material		
Concrete at TSA	2.3	30,200
Steel at TSA	0.8	10,500
Rubble/concrete at MSA	2.5	59,000
Steel at MSA	2.5	51,400
Debris at MSA	0.5	3,700
Asbestos	0.5	9,800
Building 434	0.5	5,000
Total structural material	**9.6**	**169,600**
Process chemicals		
Treatment plant process waste	0.5	3,600
Consolidated chemicals	0.5	360
Total process chemicals	**1.0**	**3,960**
Vegetation		
From quarry	0.4	6,500
From building demolition	0.1	750
From sitewide areas	3.8	23,400
Total vegetation	**4.3**	**30,650**
Total volume	**-[a]**	**883,000**

[a] A value for total area would not be indicative of the total area impacted because some areas are counted more than once (e.g., sludge and soil are shown separately for the raffinate pits).

have already been addressed by interim actions that included the development of cleanup criteria. These media and criteria are discussed in Table 2.2. Because of those separate actions, cleanup criteria are developed only for soil under the current remedial action.

Cleanup criteria are developed by addressing the two main factors used to evaluate appropriate cleanup options for a site: (1) long-term protection of human health and the environment — as indicated by results of site-specific risk assessments, and (2) compliance with environmental requirements. The first factor addresses the potential effects of exposures to site (residual) contaminants, and the second factor addresses environmental standards and guidelines — referred to as "applicable or relevant and appropriate requirements" (ARARs) and "to-be-considered" requirements (TBCs). The ARARs and TBCs typically serve as a starting point and the site-specific risk assessments provide the key input for determining the preliminary remediation goals for a given site.

Available ARAR and TBC values for the key contaminants in soil at the Weldon Spring site are identified in Section 2.2 and tabulated with specific citations in Appendix G (Table G.2). The general process that was applied to develop cleanup criteria for site soil is discussed in Section 2.3, and specific criteria are indicated for the key contaminants in Section 2.4. It is important to note that the following discussion is intended to serve as input to the decisions that DOE will make in determining the appropriate means for managing the risks associated with the Weldon Spring site. This decision will depend on the specific remedy selected for the site, which will be based on the analyses presented in the RI/FS-EIS and comments received from the public and from the agencies involved. To be conservative, the cleanup criteria developed in this chapter assume that the site could support a variety of uses in the future, including residential use. This approach provides a range of information that can bound potential impacts associated with the site contaminants.

2.2 ENVIRONMENTAL STANDARDS AND GUIDELINES

Federal standards and guidelines are available for only a few of the soil contaminants at the Weldon Spring site: radium-226, radium-228, thorium-230, thorium-232, PCBs, and lead. The pertinent ARARs and TBCs for radionuclides and chemicals are summarized in Sections 2.2.1 and 2.2.2, respectively. Standards and guidelines are also available for radon in air; because this contaminant is generated from radium in soil at the site, the related standards are included in the following discussion.

Relative to state standards or guidelines, the Missouri Department of Health recently proposed standards for chemicals that could be considered safe for soil under any use, including residential use in unrestricted areas (Appendix G, Table G.2). These draft standards were published in the *Missouri Register* in September for public review and comment (Missouri Department of Health 1992). The listed values were derived from generally conservative exposure assumptions for residential settings, and they do not consider background concentrations in soil.

TABLE 2.2 Cleanup Criteria for the Weldon Spring Site Remedial Action Project

Medium	Source of Cleanup Criteria	Comments
Vegetation	Radiological release criteria for vegetation were previously developed as part of the interim action for bulk waste at the quarry. Therefore, no new criteria were developed in this FS (characterization results indicate that the vegetation is not chemically contaminated).	To apply these criteria, vegetation from uncontaminated off-site locations is sampled to establish background levels of radioactivity. Site vegetation is then compared to determine whether the measured activity levels are statistically elevated above background (determined from a *t*-test at the 95% confidence level for a minimum of three measurements for each sample set). Vegetation in which the level of radioactivity is statistically elevated is retained on-site.
Building debris and other structural material	Radiological release criteria were previously developed for structural building material and equipment with surficial contamination as part of the interim action to dismantle site structures. These criteria were adopted from guidelines established by the U.S. Nuclear Regulatory Commission (NRC) guidance, which have been incorporated into DOE Order 5400.5 (listed in Appendix G, Table G.3), and they have been accepted by EPA Region VII for application at the Weldon Spring site. Therefore, no new radiological criteria were developed in this FS.	The criteria developed for soil in this FS will be adopted for concrete rubble, in accordance with DOE Order 5400.5. Radiological release criteria have not been established for other material with volumetric contamination (e.g., by either the NRC or DOE), so separate criteria have not been developed for this material and it would be managed as a waste for disposal rather than salvaged. If any material is chemically contaminated with PCBs but is not radioactively contaminated, the EPA criteria for PCBs on solid surfaces (listed in Appendix G, Table G.3) could be applied.
Containerized chemicals	Radiological criteria for the release of containerized chemicals for expedited treatment off-site were previously developed as part of an interim action to determine what waste was nonradioactive and could therefore be released for treatment and disposal at an approved commercial facility. (Commercial facilities are not currently available for radioactively contaminated material, so the purpose of the criteria was to distinguish between material that is radioactive and nonradioactive.) Therefore, no new criteria were developed in this FS.	The statistical comparison described for assessing vegetation was also used for this material. Chemicals with levels of radioactivity statistically elevated above background are being retained on-site (e.g., for possible treatment at another DOE facility that can accept such material); others would be releasable for treatment and disposal at a permitted commercial facility.

TABLE 2.2 (Cont.)

Medium	Source of Cleanup Criteria	Comments
Raffinate pit sludge and treatment plant process waste	Cleanup criteria are not relevant for waste material such as the raffinate pit sludge and process waste from the water treatment plants because this material is heavily contaminated and would not be releasable. The residual material remaining at the raffinate pits after the waste sludge has been removed will be addressed as soil.	Exposure mitigation measures (e.g., maintaining a water cover at the pits) are currently being implemented, and performance criteria for controlling releases (e.g., reduced leachability through treatment) are developed in this FS.
On-site surface water	Chemical and radiological criteria for water from the on-site impoundments were previously developed as part of the interim action to remove and treat this water in a newly constructed treatment plant. Because these criteria are available and appropriate, no new criteria were developed in this FS.	These criteria were also developed for and will apply to the surface water that will result from activities for the current action, such as washing equipment at the decontamination facility.
On-site soil	Chemical and radiological criteria are not available for all key contaminants in site soil, which are those contaminants that could potentially impact humans or biota as indicated by the site-specific risk assessments (DOE 1992a and Appendix E of this FS). Therefore, criteria were developed for on-site soil in this FS.	These criteria will also be applied to sediment and soil at Ash Pond and Frog Pond and to material (e.g., berms) remaining at the raffinate pits after the sludge is addressed.
Off-site surface water	The Missouri Department of Conservation will drain Lakes 34, 35, and 36 in the Busch Wildlife Area within the next several years under the sedimentation management program for the wildlife area. Results of the various risk assessments conducted for these lakes indicate that no adverse health or environmental impacts are associated with contaminants from the site, and estimated health effects from the surface water are within or below the target range identified by the EPA (DOE 1992a). Therefore, criteria have not been developed for off-site surface water within the scope of the current remedial action.	Water at the Femme Osage Slough will be addressed by DOE as part of a separate remedial action for residual material at the quarry, within the next several years.

TABLE 2.2 (Cont.)

Medium	Source of Cleanup Criteria	Comments
Off-site soil and sediment	The Missouri Department of Conservation will remove sediment and shoreline soil from Lakes 34, 35, and 36 in the Busch Wildlife Area as part of the sedimentation management program for the wildlife area; the contaminated sediment and soil will be identified after the lakes are drained. Because this material might be used as fill, the cleanup criteria developed for on-site soil in this FS will also be applied to the off-site sediment and soil. Radionuclides are associated with this material as a result of past spills and contaminant releases from the site, but chemicals are not (Section 1.6.2). Thus, the radiological cleanup criteria for soil would be applied to this material.	Sediment and soil will be removed from Lakes 34, 35, and 36 under the Missouri Department of Conservation's sedimentation management program. Available data indicate that risks associated with possible recreational exposures to the sediment are within or below the target range identified by the EPA (DOE 1992a).
Groundwater	See comments.	Decisions for groundwater will be addressed by DOE as a separate operable unit for the project within the next few years. This separation from the current remedial action will allow for further characterization of groundwater and will also allow coordination with the Army with regard to the adjacent NPL site, which represents an additional source of groundwater contamination.
Air	Criteria for air would be related to those for soil (all contaminants of concern except asbestos), raffinate pit sludge (radon), and buildings (asbestos). The buildings and asbestos have been addressed by an interim action, and the sludge would be addressed as indicated above. Therefore, criteria for air were indirectly included with the development of soil cleanup criteria in this FS.	The primary airborne contaminant of concern is radon, and the cleanup criteria developed for its parent (radium in soil) will incorporate information on standards and guidelines for this gas as well as potential health effects from related exposures.

In contrast, site-specific information was incorporated into the risk assessments prepared for the Weldon Spring site, including information for chemicals in local soil that could be used as backfill. Therefore, these assessments were used as the primary source of input for developing cleanup criteria specifically for the site. Nevertheless, the levels recently proposed by the Missouri Department of Health for statewide consideration have been evaluated for the key contaminants at the Weldon Spring site. These standards will be reviewed for applicability to the site as the public evaluation process continues. This review will address their relevance per future land-use considerations for the site, as indicated by the remedial action to be identified in the ROD. The review will also consider the appropriateness of those standards relative to technical practicability and potential greater risks associated with replacement by local backfill. Public comments received on the information in this RI/FS-EIS, including the cleanup criteria, will be factored into the remedy selected for this action.

2.2.1 Radioactive Contaminants

2.2.1.1 Radium and Thorium

The EPA has promulgated standards for radium-226 and radium-228 in soil at uranium and thorium mill tailings sites; 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 (1,100 ft^2). Because the Weldon Spring site is not a mill tailings site, these standards do not specifically apply to site cleanup. However, they can be considered relevant and appropriate because the material at the site is similar to mill tailings. The DOE has established guidelines for radium-226, radium-228, thorium-230, and thorium-232 for soil in areas of unrestricted access; these apply to site cleanup for scenarios under which future access would be unrestricted. These guidelines include the EPA standards for radium at mill tailings sites, and they also include similar standards for the thorium isotopes and procedures for addressing nonsecular equilibrium conditions (between thorium-232 and radium-228 and between thorium-230 and radium-226). The background concentration of these radionuclides in the vicinity of the site is 1.2 pCi/g, so the surface and subsurface standards would be 6.2 pCi/g and 16.2 pCi/g, respectively. These levels are exceeded in site soil at a number of locations.

2.2.1.2 Uranium

No federal or state ARARs or TBCs are available for uranium in soil. In accordance with the DOE process, results of the site-specific risk assessment were used in combination with a preliminary ALARA analysis to develop a site-specific cleanup criterion for this radionuclide.

2.2.1.3 Radon

The standards identified in the Missouri Radiation Regulations for areas without access restrictions are 1 pCi/L for radon-222 and 10 pCi/L for radon-220, as quarterly averages above background. The limit identified by DOE in its Order for Radiation Protection of the Public (DOE Order 5400.5) for both radon-222 and radon-220 in an uncontrolled area is 3 pCi/L, as an annual average above background. These standards apply to site cleanup for scenarios under which future access would be unrestricted. The measured concentrations of radon at the site perimeter currently meet these standards.

2.2.1.4 Nonspecific Radiological Doses

The EPA has identified standards for airborne emissions of radionuclides other than radon-222 for a member of the public that limit exposures to levels that would not exceed an effective dose equivalent of 10 mrem/yr (EPA 1989b). In addition, the EPA has identified annual dose limits of 25 mrem/yr to the whole body, 75 mrem/yr to the thyroid, and 25 mrem/yr to any other organ for exposures associated with management of uranium and thorium by-product material. State standards for nonspecific radiological exposures identify the following limits for the maximum permissible whole-body dose to an individual in an uncontrolled area: 2 mrem/h, 100 mrem in any 7 consecutive days, and 500 mrem in any year.

As a general standard for radiological doses, the DOE requires compliance with all federal requirements for limiting doses from specific exposure modes. Standards for nonspecific radiological exposures are also identified in DOE Order 5400.5. These standards require that the committed effective dose equivalent to a member of the public not exceed 100 mrem/yr above background from all nonoccupational routes of exposure and, further, that these exposures be reduced to levels as low as can reasonably be achieved. (Dose terminology is defined in Section 3.4.1 of the BA [DOE 1992a].) With this Order, the DOE formally identifies its process for reducing residual exposures and risks to levels as low as reasonably achievable (ALARA) below applicable standards, considering technical, economic, and social factors as appropriate.

These radiological dose standards are considered applicable to site cleanup. Current dose estimates for the site perimeter are within the listed limits. Applying the ALARA process to reduce residual concentrations of specific radionuclides would result in a similar reduction in the resulting radiological doses. The greatest dose reduction is associated with decreasing the residual levels of radium-226 because this radionuclide and its decay products account for most of the total dose estimated for the site, from both external gamma irradiation and inhalation of radon.

2.2.2 Chemical Contaminants

2.2.2.1 Lead

The EPA has identified two different guidelines for establishing a residual level for lead in soil at a residential setting; these guidelines are considered TBCs. The first is a general interim guidance that considers the natural presence of lead in soil and recommends a cleanup level of 500 to 1,000 mg/kg, as determined by site-specific conditions (EPA 1989a). The second is draft guidance in the form of an uptake/biokinetic model that can be applied to site-specific data to estimate blood lead levels in children, the most sensitive subpopulation; a blood lead level of 10 µg/dL or less is EPA's preferred end point. With this model, data for lead concentrations in surface soil, air, and groundwater at the site were used to derive a health-based level of 450 mg/kg for lead in surface soil. The soil concentration recently proposed for statewide consideration by the Missouri Department of Health as safe for any use, including residential settings, is 240 mg/kg. Lead has been detected in surface soil at three locations above the modeled level and at four locations above the state level.

2.2.2.2 Other Metals

The levels recently proposed for statewide consideration by the Missouri Department of Health as safe for soil in residential settings include 11 mg/kg for arsenic, 5,600 mg/kg for total chromium (280 mg/kg where hexavalent chromium is likely or documented to exceed 4 mg/kg), and 3.9 mg/kg for thallium. The levels for arsenic and thallium are exceeded in soil at most areas of the site and also in local background soil.

2.2.2.3 Nitroaromatic Compounds

No federal ARARs or TBCs are available for nitroaromatic compounds in soil. The levels recently proposed for statewide consideration by the Missouri Department of Health as safe for soil in residential settings are as follows: 5.6 mg/kg for DNB; 7.4 mg/kg for 2,4-DNT and 2,6-DNT; 28 mg/kg for NB; and 14 mg/kg for TNT. Of these compounds, none has been detected in surface soil, and only TNT has been detected above the listed concentrations in subsurface soil (at two locations).

2.2.2.4 PAHs

No federal ARARs or TBCs are available for these organic compounds in soil. Of the PAHs and other organic compounds (e.g., naphthalene) detected in site soil, the Missouri Department of Health has recently proposed the following levels for statewide consideration as safe for soil in residential settings: 17,000 mg/kg for anthracene; 0.44 mg/kg for benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene; 2,300 mg/kg for fluoranthene and fluorene; 230 mg/kg for naphthalene; and 1,700 mg/kg for pyrene. These levels are exceeded at one location on-site.

2.2.2.5 PCBs

A standard for cleanup of soil following a spill of material containing more than 50 ppm (mg/kg) PCBs is identified in the Toxic Substances Control Act. As part of site characterization, the PCBs were measured above this level at one location on-site. The standard indicates that soil in areas of unrestricted access at which such a spill occurs can be decontaminated to 10 mg/kg by weight by excavating at least 25 cm (10 in.) and backfilling with material containing less than 1 mg/kg PCBs. Because the PCB contamination in site soil resulted from spills of material that occurred long before the effective date of these standards, they do not specifically apply; however, they could be considered relevant and appropriate. Thus, the excavated areas would be backfilled with soil containing less than 1 mg/kg PCBs. Relative to the concentration in soil that would be considered for excavation, the level recently proposed for statewide consideration by the Missouri Department of Health as safe for soil in residential settings is 0.65 mg/kg. The PCBs have been measured above this level in surface soil at several locations on-site.

2.3 GENERAL PROCESS FOR DEVELOPING SOIL CLEANUP CRITERIA

Cleanup criteria (also referred to as risk-based remediation goals) can be defined as concentrations for individual contaminants that correspond to specific risk levels and hazard indexes, and they are generally selected when ARARs are not available (EPA 1991a). Criteria were developed for the Weldon Spring site by considering (1) the target levels for health effects that EPA has identified to address exposures at NPL sites and (2) several factors that affect the site-specific process for identifying cleanup goals for soil contaminants. These factors address site-specific issues that include the nature of site contamination, the possible future uses of the site, and the goal of reducing residual risks to levels below available standards.

2.3.1 Risk-Based Targets

Potential health effects resulting from exposures to radioactive and chemical contaminants are divided into two categories — carcinogenic and noncarcinogenic effects. For carcinogens, the EPA has identified a target range for incremental risks of 1×10^{-6} to 1×10^{-4} — or 1 in 1 million to 1 in 10,000 — to limit the possibility that an individual could develop cancer from exposures to residual contaminants at an NPL site (EPA 1990a). The range is used as a point of reference for the risk estimates presented in this analysis. For noncarcinogenic contaminants, the EPA has identified a hazard index of 1 as the level of concern for potential adverse health effects associated with site exposures (EPA 1989e).

To provide some perspective for the following discussion, the process EPA follows to make risk management decisions for NPL sites is presented here. As part of cleanup at NPL Superfund sites, the EPA strives to manage possible incremental cancer risks within the target range with 1×10^{-6} generally serving as the point of departure. For sites where the estimated incremental risk is less than 1×10^{-4} and the hazard index is less than 1, action is usually not warranted. Furthermore, although the upper end of the target range is generally used to make a risk management decision to determine whether a remedial action is necessary or warranted, the EPA does not consider 1×10^{-4} a discrete limit; that is, risks above that level may be considered acceptable on the basis of site-specific conditions (EPA 1991b). For example, the presence of radionuclides at the Weldon Spring site represents a somewhat unique condition compared with typical Superfund sites for which the target range was originally developed. In addition, factors other than the results of the site-specific risk assessment are used to make the final risk management decision — including the conservative assumptions applied to estimate risks from possible exposures at the site and other health-based guidance available for certain contaminants.

These considerations were incorporated into the development of soil cleanup criteria for the Weldon Spring site. The following general principles for carcinogenic and noncarcinogenic contaminants were applied to identify general risk-based objectives for remedial action at the site:

- Exposures to radionuclides should be reduced to levels as far below health-based criteria as can reasonably be achieved — as limited by the natural presence of radionuclides in soil.
- Exposures to carcinogenic chemicals should not result in a total incremental lifetime risk to an individual of more than 1×10^{-6} to 1×10^{-4} — as limited by the natural presence of chemicals in soil.
- Exposures to noncarcinogenic contaminants should not result in significant adverse health effects to an individual, indicated by a segregated hazard index above 1 — as limited by the natural presence of chemicals in soil.
- Exposures of biota should be limited to levels that are not associated with significant adverse ecological effects, considering available criteria and experimental and field data — as limited by the natural presence of radionuclides and chemicals in soil.

The methodology and assumptions used to estimate cancer risks and noncarcinogenic effects from exposures to site contaminants are described in detail in the BA (DOE 1992a) and are also discussed in Appendix E of this FS. The discussions in the remainder of this chapter follow from these detailed analyses.

2.3.2 Land Use, Receptors, and Key Contaminants

Cleanup criteria were developed for site soil by hypothetically assuming that institutional controls might be lost at some time in the future. Because recreational and residential use are the most likely long-term land uses in the area, it was assumed that a recreational visitor, ranger, or resident (including a resident farmer) could eventually occupy the site. These receptors represent different combinations of sitewide, location-specific, and area-specific exposures, so their evaluation provides information for potential health effects associated with a variety of exposures under the two likely future land uses.

The development of health-based cleanup criteria for site soil focuses on the analyses for the resident and farmer. This approach permits various cleanup options to be evaluated on the basis of maximum exposures, thereby assuring that potentially significant contaminants are not be overlooked. It also permits a more comprehensive application of the ALARA process (Section 2.3.2.2). The application of cleanup criteria for other receptors and land uses is discussed in Section 2.5.

Evaluating the resident addresses the spatial variability of contaminants at the site because potential health effects were estimated for this receptor at each borehole location. The farmer represents an extension of the typical resident and was included in this assessment for two reasons. First, the farmer would occupy an area that encompasses many boreholes; this permits the application of an area modeling approach that has been developed for radiological cleanup criteria, the results of which can then be applied on a location-specific basis. By evaluating an area larger than that represented by a single borehole, relatively widespread, combined radioactive contamination can be addressed. A 4-ha (10-acre) area that encompasses Ash Pond and the South Dump was selected for this analysis because it contains the highest levels of contiguous radioactive contamination and represents a reasonable location and size for a small farm (Appendix E, Figure E.1).

The farmer analysis also permits consideration of an additional pathway — ingestion of homegrown food. Although considerable uncertainty is associated with the estimation method for this pathway, the results can provide a qualitative indication of incremental impacts that can be used as ancillary information in developing the cleanup criteria. Thus, results of both the location-specific analysis for the resident and the area analysis for the farmer were used to develop the radiological cleanup criteria.

Cleanup criteria for chemical contaminants were not specifically developed from the farmer-area approach because the key contaminants are present at scattered locations and no single area contains combined contamination as described for the radionuclides. Therefore, results of the location-specific analysis for the resident provided the primary input to the development of chemical cleanup criteria because that analysis emphasized areas with organic contaminants or elevated concentrations of naturally occurring metals that could result in adverse health effects. Nonetheless, chemical exposures were quantified for the farmer to provide a comprehensive risk evaluation and address food ingestion. Results for this pathway were considered as ancillary information to support the development of chemical cleanup criteria, as described for the radiological analysis.

To address contaminant variability in site soil and the differences in receptor exposures, a staged approach was applied to develop the site-specific cleanup criteria and indicate areas for potential soil remediation. Under this approach, the key contaminants were evaluated separately by first considering carcinogenic effects and then determining what additional criteria were needed to ensure protection from noncarcinogenic effects. The four basic components of this approach are as follows:

- For radionuclides, areas considered for remediation were identified from the risks estimated for the resident and farmer, and contaminant-specific criteria were developed for uranium-238, thorium-232, thorium-230, radium-228, and radium-226. Criteria were also determined indirectly for uranium-235, protactinium-231, actinium-227, and lead-210 on the basis of the criteria for the five principal radionuclides and information from the radiological source term analysis for the site.

- For carcinogenic chemicals, areas considered for remediation were identified from the risks estimated for the resident, and contaminant-specific criteria were developed for the key contributors — arsenic, PAHs, and PCBs. Criteria were also developed for the carcinogenic nitroaromatic compounds — 2,4-DNT, 2,6-DNT and TNT — to ensure that each of the anthropogenic chemicals of concern would be considered and to address levels recently proposed for statewide consideration by the Missouri Department of Health.

- For noncarcinogenic chemicals, areas considered for remediation were identified on the basis of a segregated hazard index greater than 1 estimated for a resident. Contaminant-specific criteria were then developed for the key contributors — arsenic, chromium, thallium, and uranium. Cleanup criteria were also developed for the nitroaromatic compounds to address the anthropogenic contaminants of concern and the levels recently proposed for statewide consideration by the Missouri Department of Health.

- For lead — for which toxicity values are not available to quantify a risk or hazard index — areas considered for remediation were developed on the basis of the criterion determined from a site-specific application of the EPA biokinetic/uptake model. The level recently proposed for statewide consideration by the Missouri Department of Health was also addressed.

The results for each of these components were then integrated to identify target areas for cleanup and estimate health effects that could be associated with site exposures to residual contamination. The intent of this stepwise approach was to identify cleanup criteria that would be protective at all locations, considering different health effects and contaminant overlap. For example, both carcinogenic and noncarcinogenic health effects are associated with arsenic and uranium. By developing cleanup criteria on the basis of carcinogenic effects first, with an ALARA analysis for each contaminant, the resulting target levels can then be assessed to determine whether they also provide protection from noncarcinogenic effects so that separate criteria are not developed on the basis of the two different health effects.

In the final stage of this stepwise process for developing cleanup criteria for site soil, potential ecological effects were evaluated to determine whether the criteria that had been developed on the basis of protecting human health would also be protective of environmental resources. On the basis of the ecological assessment in the BA (DOE 1992a), no significant adverse ecological impacts are expected to result from exposure to either the radionuclides or chemicals in soil at the levels indicated for protecting human health from the first stages of the process. That is, the health-based cleanup criteria developed for site soil are also expected to be protective of the environment. For this reason, the remainder of this discussion focuses on the development of those criteria.

2.3.3 The ALARA Process

The goal of DOE's ALARA process is to reduce exposures and risks associated with residual contamination as far below protective criteria as can reasonably be achieved. In applying the ALARA process to the Weldon Spring site, the two factors that are addressed for developing cleanup criteria — environmental standards and protectiveness (determined from site-specific risk estimates) — are combined with technical, economic, and social considerations in order to identify various levels of risk reduction that might be achieved.

The ALARA process includes both a planning component and a field component. The discussion in this chapter constitutes the first component, in which ALARA goals are estimated for residual soil contamination across the site on the basis of hypothetical exposures. This initial analysis will be used to support the implementation of ALARA in the field during excavation activities, at which time additional contamination might be removed below levels that have been determined from the planning phase, where this can reasonably be achieved depending on specific field conditions.

The site-specific nature of this analysis cannot be overemphasized. Applying the ALARA process at another site, with different contaminant conditions and likely exposure scenarios, would be expected to produce different results.

2.3.4 Effects of Background

Information for local background was incorporated into the development of health-based cleanup criteria so estimated effects from exposures to site contaminants could be considered in the context of effects associated with natural levels of these contaminants. For radionuclides, soil was sampled at several off-site locations that have not been affected by site releases (Section 2.3.1 of the BA). The off-site location that was evaluated for chemicals covers 30 ha (70 acres) and is located about 1.6 to 2.3 km (1 to 1.4 mi) east of the site along State Route 94. This area was selected because it contains soil and vegetation similar to the site and it is not affected by surface runoff or other releases from either the site or the adjacent Army property (MK-Ferguson Company and Jacobs Engineering Group 1988). It also represents a potential source of uncontaminated borrow soil that would be used to backfill excavated areas of the site as part of the current remedial action (and also to construct the cover of the disposal cell, if on-site disposal were a component of the selected remedy).

For radionuclides, incremental risks estimated for a resident on-site exceed the upper limit of EPA's target range (1×10^{-4}) at most locations. However, the risks associated with natural levels of radioactivity also greatly exceed this limit. Therefore, rather than comparing site risks to the standard target range to identify areas for remediation, a more appropriate benchmark for the radioactive contaminants is the risk for a resident or farmer from exposures to soil at an uncontaminated off-site location. Because local soil would be used to backfill areas excavated on-site, the risks for future receptors at remediated areas would be represented by those estimated for exposures to background soil. The background radiological risk for these two receptors is about 3×10^{-3}, which is 30 times higher than the upper end of EPA's target range for NPL sites. Therefore, the incremental risks associated with the radionuclides present at the Weldon Spring site cannot be reduced to EPA's target levels because these radionuclides are naturally present in background soil at concentrations associated with much higher risks. That is, because natural variability in background levels would also result in risks much higher than the target range, an increment that would represent a small fraction of this variability would be indistinguishable from the background risk level.

At the time EPA was developing target risk levels for NPL sites, hazardous chemicals from industry were the major concern, and risks could truly be considered incremental above background for many of these chemicals because they were typically anthropogenic (i.e., generated by man rather than occurring naturally). In contrast, the key contributors to risk at the Weldon Spring site occur naturally in soil. For this reason, the ALARA analysis was applied to the radionuclides at the site to determine how far below current levels they could be reduced toward background, considering technical practicability.

The issue for chemical risks is similar, although the magnitude of the background risk is lower. The risk associated with average concentrations of metals in soil at the uncontaminated off-site location exceeds 3×10^{-5}, which is considerably higher than the 1×10^{-6} "point of departure" identified by the EPA for NPL sites (EPA 1990a). Natural variability is inherent in the environmental levels of metals; the risk associated with the 95% upper confidence limits on the arithmetic average concentrations (the UL_{95} values) of metals at the background location is 5×10^{-5}, and the risk associated with the upper bound concentrations of these metals — i.e., the arithmetic mean plus two standard deviations — approaches the limit of EPA's target range. This background risk results primarily from exposures to arsenic. (The concentration of this metal in local soil is well within the range reported for agricultural soil in Missouri [Tidball 1984]). Thus, the natural presence of arsenic in soil interferes with the attempt to reduce incremental risks for the Weldon Spring site to levels within EPA's target range. This emphasizes the importance of considering background constraints in developing cleanup criteria for site soil; otherwise, areas targeted for excavation might be backfilled with soil for which associated risks could be even higher. For this reason, an ALARA analysis was also conducted for certain chemicals at the site to determine how far residual risks could be reduced below current levels toward background, considering technical practicability and the risks associated with the backfill material.

For noncarcinogens, the hazard index for a resident associated with average background concentrations of metals in the area of the Weldon Spring site is less than 1, but the hazard index associated with the upper bound concentrations exceeds 1. Therefore, it is possible that noncarcinogenic health effects could also be associated with local soil that would be used as backfill. To address this issue, an ALARA analysis was also conducted for the primary contributors to potential noncarcinogenic health effects.

2.3.5 Subsurface Contamination

Subsurface contamination was an additional factor considered in developing health-based cleanup criteria for the Weldon Spring site because contamination extends below the surface in certain areas. Analyses of surface and subsurface soil (up to 4.6 m [15 ft]) at the off-site background location did not identify any trends, indicating that the concentrations of naturally occurring metals do not generally differ with depth for the soil types common to the site area.

Results of the site-specific risk assessments for the resident and farmer were used as key input for developing soil cleanup criteria. These assessments generally focused on exposures to contaminants in (or dispersed from) surface soil, except for indoor radon. It was assumed that radon gas would be generated from subsurface radium and would enter a structure through the basement or foundation slab. Other subsurface contamination was addressed by separate analyses to ensure that levels remaining at the site would be reasonably protective under future scenarios that could involve exposure to contaminants that are currently buried.

The general issue of subsurface contamination was addressed by two different analyses. For the first analysis, a redistribution scenario was evaluated in which it was assumed that subsurface soil was excavated (e.g., for a basement) and then redistributed on the surface at that location, such that an individual (e.g., a resident) could be exposed to previously buried contaminants now present in surface soil. For the second analysis, screening-level calculations were conducted to estimate groundwater concentrations that could result from soil leaching and to assess potential health effects if that groundwater were ingested.

2.4 CLEANUP CRITERIA FOR SITE SOIL

2.4.1 Radioactive Contaminants

The radionuclides present at the Weldon Spring site belong to the uranium-238, uranium-235, and thorium-232 decay series. A radiological source term analysis was performed to determine the relative concentrations in site soil of the radionuclides in these three decay series (see Section 2.3.2.1 of the BA for additional discussion of this analysis). The results of the source term analysis indicated that soil cleanup criteria should be developed for five of these radionuclides — uranium-238, thorium-232, thorium-230, radium-228, and radium-226.

The source term analysis indicated that the concentrations of all radionuclides in the uranium-235 decay series are essentially equal to that of uranium-235 (the concentrations of the two major radioactive decay products in this series — actinium-227 and protactinium-231 — are actually lower than that of uranium-235 [see Table 2.3 of the BA]). The vast majority of uranium processed at the site was natural uranium, in which the activity concentration of uranium-238 to uranium-235 is 1.0 to 0.046. Hence developing a cleanup level for uranium-238 will indirectly establish levels for uranium-235, actinium-227, and protactinium-231. The doses associated with these radionuclides were incorporated in the development of potential cleanup criteria for uranium-238.

Of the remaining five major radionuclides (i.e., lead-210, radium-226, radium-228, thorium-230, and thorium-232), cleanup criteria were developed for all but lead-210. This approach is consistent with EPA guidance to apply the model that has been developed for lead to determine a site-specific cleanup concentration; this application is discussed in Section 2.4.2.3. The radiological dose associated with lead-210 was incorporated into the development of cleanup criteria for radium-226. This approach is supported by the results of the radiological source term analysis, which indicate that the concentrations of lead-210 are the same as those for radium-226 in site soil. For radium and thorium, the available ARARs and TBCs (Section 2.2.1.1) were considered the upper limits that would be met for residual levels in site soil. The preliminary ALARA analysis was then conducted to determine how far below those levels the residual concentrations could reasonably be reduced, considering technical practicability and site-specific conditions regarding the nature of the contamination. For radium-226, the risks associated with inhalation of radon-222 were also factored into the development of cleanup criteria.

From the rebaseline risk assessment (Appendix E), the estimated incremental radiological risks to a resident at the site in the absence of remedial action range from 1×10^{-6} to 9×10^{-2} (Table E.9); the median risk is 2×10^{-4}. This risk is largely due to the inhalation of radon-222 decay products and external gamma irradiation from radium-226 (Table E.10). Hence, the development of radiological cleanup criteria focused initially on this radionuclide. For comparison, the combined risk from external gamma irradiation, incidental ingestion, and inhalation for a resident at the background location is estimated to be 3×10^{-3}. Therefore, the development of radiological cleanup criteria for the site is less an issue of determining acceptable concentrations of radionuclides in soil than it is an issue of determining the ability to clean up the site to levels as low as reasonably achievable. These levels are based on considerations of cost, waste volumes, and sampling instrument sensitivities. To address overall protectiveness, a "post-cleanup" assessment was conducted to estimate radiological risks associated with the indicated cleanup criteria. The results of this assessment are discussed in Section 2.4.1.3.

Technical constraints, incremental exposures, and cost effectiveness were considered in developing the radiological cleanup criteria for site soil. That is, the ALARA analysis considered the ability of standard instruments to determine contaminant concentrations in the field and at what value the increased cost associated with further reducing the residual concentration would not be offset by a commensurate reduction in incremental risk.

Two key factors affect the ALARA analysis for the Weldon Spring site that would not necessarily be relevant for other sites. First, the levels of radionuclides in soil at most locations are relatively low, so the areas at which an iterative ALARA analysis would be applied to further reduce elevated concentrations are limited; also, most areas do not contain appreciable subsurface contamination, so the affected volumes are generally small. Second, the amount of contaminated soil at the site is a small fraction of the total volume of contaminated material being addressed by this remedial action, and the concentrations of radionuclides in the larger volume of other waste (especially the raffinate pit sludge) are much higher. This means that potential differences in health effects from exposures during the action period associated with excavating and handling the incremental volumes of soil to achieve alternative cleanup levels would be insignificant. (The same is true for chemical contaminants.) Therefore, the overall impact associated with excavating soil contaminated with relatively low levels of radionuclides (and chemicals) to attain the range of residual concentrations developed from an ALARA analysis would be minimal, considering factors such as time, cost, and worker exposures.

2.4.1.1 Radium and Thorium

The ARARs and TBCs available for radium and thorium translate to cleanup targets of 6.2 and 16.2 pCi/g for surface and subsurface soil, respectively, including background. Those levels are exceeded in site soil at 17 locations for radium-226, 15 locations for radium-228, and 21 locations for thorium-230. Having established the "starting points" for radium and thorium, a two-part ALARA evaluation was conducted to determine reasonably achievable risk-and-technology-based levels below those limits. The first part addressed the surface limit, and the major considerations for this evaluation were field- and laboratory-related technical issues — i.e., how limitations related to field sampling, verification, and instrumentation (counting error) would affect the ability to distinguish between a residual contaminant level and the background concentration, which would be the lowest level attainable. Also considered were the risks associated with the residual soil contamination and the costs associated with remediating the site to various levels.

This evaluation focused on radium-226 because related risks are the highest of the four isotopes (i.e., radium-226, radium-228, thorium-230, and thorium-232), primarily because of the risk associated with inhalation of radon-222 decay products. Computer simulations were performed to evaluate the ability to confirm that remediated areas were indeed clean, i.e., that the concentration averaged over a 100-m^2 (1,100-ft^2) area was below a predetermined level. Two errors can result from sampling an area to determine compliance with a concentration standard: (1) it can be incorrectly concluded that a clean area needs further remediation or (2) it can be incorrectly concluded that a contaminated area is clean. Obviously, the second error is much more significant and should be avoided. To minimize the likelihood of such an error, field activities can target a level below the actual standard to effectively ensure that this level would be met. The results of a statistical analysis for the Weldon Spring site indicate that targeting the field activities to a concentration of 1 pCi/g below the residual limit would ensure at a 95% confidence level that the limit would be achieved (MK-Ferguson Company and Jacobs Engineering Group 1991b).

A practical consideration in establishing cleanup levels is the cost associated with verifying that the standard has been met. Field instruments are able to reliably detect radium-226 concentrations of 5 pCi/g and possibly 4 pCi/g. Lower concentrations require the collection of field samples for analysis in a chemical laboratory. Such a procedure is costly because of the time and effort associated with the laboratory analysis and, more importantly, because cleanup activities would have to be delayed until the results of the analysis were received. Also, a cleanup level below 4 pCi/g would likely result in the removal of substantial amounts of clean soil because of the difficulty associated with distinguishing from the background level in the field, which would increase the cost of remediation without reducing risk. On the basis of these practical considerations, the field target for radium-226 was identified as 4 pCi/g including background.

The risk to human health associated with residual radium-226 at the site was evaluated by estimating the potential risk to an individual who would move on-site and establish a small farm at the Ash Pond area (MK-Ferguson Company and Jacobs Engineering Group 1991b). The ALARA goal for radium-226 determined from this analysis is 5 pCi/g including background. This level corresponds to the field target of 4 pCi/g including background, which would be applied during cleanup activities. That is, contaminated soil would be removed until the residual concentration was 4 pCi/g or less, as determined by field instruments. This would ensure at a 95% confidence level that the limit of 5 pCi/g was attained across the site.

The second part of the ALARA evaluation addressed subsurface contamination. The focus of this assessment was the volume of radium-contaminated soil at depth, which is very small because soil contamination at the site is primarily surficial. On the basis of this site-specific factor, it was determined that the surficial goal of 5 pCi/g could also reasonably be applied to subsurface contamination (MK-Ferguson Company and Jacobs Engineering Group 1991b). The ALARA goal of 5 pCi/g, including background, is also considered appropriate for the other three radionuclides because of the very low volumes of soil contaminated with radium-228, thorium-230, and thorium-232. This site-specific ALARA consideration would probably not be relevant at other sites.

2.4.1.2 Uranium

Uranium-238 is the primary radioactive contaminant in site soil. Characterization data indicate that low-level contamination with this radionuclide is widespread and is distributed predominantly in the upper 0.15 m (0.5 ft) of soil. A few localized areas of relatively high concentrations occur at greater depths, e.g., at the dump areas and around some of the chemical plant buildings. No ARAR or TBC is available for uranium, so the cleanup target was derived solely from the ALARA analysis. A range of residual levels for uranium-238 was considered to evaluate incremental risk reductions associated with excavation options, factoring in related excavation volumes and costs.

The RESRAD computer code, which implements the methodology prescribed in DOE Order 5400.5 for determining residual radioactive material guidelines (Gilbert et al. 1989), was used to evaluate residual concentration limits for uranium. Potential doses and risks from existing contamination and various residual levels were estimated on the basis of site-specific data. The Ash Pond area was selected for this evaluation on the basis of its relatively high levels of radioactive contamination, and potential risks were estimated for an individual who would move on-site and establish a small farm area. The pathways evaluated in this analysis were external gamma irradiation, inhalation of contaminated airborne particulates, ingestion of radioactively contaminated soil, ingestion of plant foods grown in radioactively contaminated soil, ingestion of meat and milk from livestock fed with radioactively contaminated fodder and water, and ingestion of drinking water from a nearby well.

Best-estimate values for the average uranium concentration in soil, and the associated area and thickness of the contaminated zone were estimated with the kriging method.* In kriging, radionuclide concentrations are estimated with a regular-spaced mesh, which is then contoured to obtain profiles of constant concentration. The radionuclide data were kriged and contoured in 0.3-m (1-ft) incremental layers to a depth of 1.5 m (5 ft). The results of this kriging assessment were refined to account for physical features at the site such as buildings, roads, topography, and drainages that would affect the distribution of uranium in site soil. The average uranium concentration in this area was then calculated by areal weighting; the average concentration estimated for uranium-238 by this method is 190 pCi/g, and the estimated average thickness of contamination is 1 m (3 ft). The maximum annual dose to a farmer from exposures associated with existing conditions at the Ash Pond area is estimated to be 42 mrem/yr. By applying the EPA risk factor of 6×10^{-7}/mrem (EPA 1989g), this dose corresponds to an annual risk of 3×10^{-5}/yr. External gamma irradiation contributes almost 60% of the total dose; inhalation of contaminated particulates and ingestion of contaminated garden produce contribute 16 and 12%, respectively. The contribution from ingestion of contaminated milk, meat, and soil together is less than 15%. This radiological dose is predicted to remain relatively constant over hundreds of years but, as material slowly erodes away, the dose will gradually decrease.

The RESRAD computer code was also used to calculate the reduction in dose associated with four residual concentration levels of 120, 60, 30, and 15 pCi/g for uranium-238. Estimated sitewide excavation volumes required to meet these levels were determined by the kriging method. Associated costs were calculated on the basis of an estimated \$72/m^3 (\$55/yd^3) of soil; this value includes the cost for excavation and disposal cell activities, including waste emplacement. To realistically address the means by which these concentration levels would be achieved in the field, it was assumed that contaminated soil would be excavated until the prescribed level was met, and the excavated area would then be backfilled with clean soil. This differs from the modeling approach used to evaluate residual concentration limits for radium-226 because the dose reduction attributable to backfill was not included in that analysis. Backfill would not significantly reduce the dose attributable to radium-226 to a someone living on-site because much of the dose would be associated with indoor radon that would enter the house from subsurface soil. This issue is not relevant to uranium-238.

Removing soil to achieve a residual concentration of 120 pCi/g for uranium-238 and backfilling the excavated areas with approximately 0.15 m (0.5 ft) of clean soil would decrease the maximum annual dose to about 20 mrem/yr. This maximum annual dose would occur about 400 years in the future after most of the clean cover soil had eroded away. To achieve this level of residual uranium, about 8,100 m^3 (11,000 yd^3) of soil would require excavation at a cost of \$580,000. Without backfill, a residual concentration of 120 pCi/g would result in an annual dose of about 25 mrem/yr immediately following cleanup. Removing soil to achieve a residual concentration of 60 pCi/g and backfilling with 0.3 m (1 ft) of clean soil would result in a maximum annual dose of 6.7 mrem/yr, which would occur about 800 years in the future.

*Kriging provides a best-estimate statistical representation of the data. Soil concentrations were interpolated onto grid intersections with the kriging algorithm, which applies a weighting scheme that minimizes error and variance, to provide an estimate of the concentration at unmeasured locations.

Approximately 20,000 m^3 (26,000 yd^3) of soil would have to be removed to achieve this level, and the cost would be about \$1.4 million. Further excavation to achieve a residual concentration of 30 pCi/g and backfilling the excavated areas with 0.6 m (2 ft) of clean soil would reduce the maximum annual dose to 1.5 mrem/yr, which would occur 10,000 years in the future after most of the contamination would have leached to groundwater. For comparison, a residual concentration of 30 pCi/g, assuming no backfill, would result in an annual dose of 6.7 mrem/yr immediately following cleanup. To achieve this level, approximately 28,000 m^3 (37,000 yd^3) of soil would have to be removed, and the cost would be about \$2.0 million. Continuing cleanup to a level of 15 pCi/g would further reduce the maximum annual dose to about 0.38 mrem/yr, which would also occur 10,000 years in the future. In reducing the residual concentration from 30 to 15 pCi/g, the net reduction in dose is about 1.1 mrem/yr (which would occur in the distant future) but the total volume of soil removed and the resultant cost would increase by 50%.

The cost estimates provided in this analysis do not include the cost associated with verifying that the remediation standard is met. The cost of soil remediation would increase significantly if it were necessary to conduct laboratory analyses on soil samples. Field instruments are able to detect uranium-238 concentrations at a level of 30 pCi/g, but a level of 15 pCi/g would necessitate collection of soil samples for laboratory verification. This would increase the costs significantly above those presented. On the basis of this analysis, the cleanup target for uranium-238 is 120 pCi/g. Without backfill, this residual concentration would result in an annual dose of about 25 mrem/yr, which has been identified by the EPA as an acceptable dose limit for managing uranium and thorium by-product material. Considering the possible net reduction in dose, additional cost, and technical limitations associated with further reducing this residual level, a site-specific ALARA goal of 30 pCi/g was established for uranium-238.

2.4.1.3 Post-Remedial Action Radiological Assessment

To evaluate the protectiveness of the cleanup criteria developed for the site, both sitewide and location-specific analyses were conducted to assess potential risks for future receptors from exposures to residual radionuclides. The site-specific residual concentrations that are expected to be achieved were used for this post-cleanup assessment, i.e., it was assumed that the concentrations of radium-226, radium-228, thorium-230, and thorium-232 would not exceed 5 pCi/g (including background), and the concentration of uranium-238 would not exceed 30 pCi/g.

The location-specific analysis addresses the variability of radioactive contamination at the site, and it provides a realistic assessment of actual conditions. On-site locations that exceed the ALARA goals were assumed to be excavated and backfilled with uncontaminated soil from a local background area. The scenario assumptions for this analysis were the same as those used to estimate risks for each receptor in the rebaseline assessment. The exposure point concentrations used for this assessment were the new sitewide UL_{95} values for the recreational visitor and the new location-specific concentrations for the resident and ranger; these modified exposure point concentrations account for the changes associated with replacing contaminated soil with uncontaminated backfill at those areas for which excavation is indicated.

For the resident, the incremental risk following site cleanup would range from 0 (i.e., background) to 6×10^{-3}, with a median of 8×10^{-6} across the site. Locations at which the risk would exceed 1×10^{-4} are generally those areas at which the radium-226 concentration slightly exceeds the background concentration of 1.2 pCi/g. The fact that an incremental concentration of 0.075 pCi/g corresponds to a risk of 1×10^{-4} indicates the difficulty associated with meeting EPA's general target risk range for a residential scenario at the site.

For the recreational visitor, the incremental risk from sitewide exposures was estimated to be 7×10^{-6}. The incremental risk for the ranger varies from 2×10^{-5} to 2×10^{-4}, with a median of 2×10^{-5}; the median and low end of the range are the same because outdoor (sitewide) exposures dominate the combined risk from indoor and outdoor exposures at most locations.

Potential leaching from soil to groundwater was also assessed for radionuclides under post-cleanup conditions to provide a preliminary indication of the potential impact to future receptors in the event that groundwater in the shallow aquifer was used as drinking water. For this assessment, the new UL_{95} values for radionuclides in sitewide soil were used to estimate leaching to groundwater with the methodology described in Appendix E (Section E.4.1.3). The incremental risk estimated for a resident from drinking water ingestion, assuming an infiltration rate of 5 cm/yr (2 in./yr), is 2×10^{-5}; approximately 40% of this risk is from lead-210. For comparison, leaching was also modeled with background soil concentrations. The estimated risk from ingestion of drinking water at the off-site background location is 5×10^{-5}. Based on these results, the radiological cleanup criteria are expected to be protective of groundwater. Although this is a preliminary analysis, it is intended to be conservative (the uncertainty associated with this analysis is discussed in Appendix E). Additional analyses will be conducted to address groundwater as part of the future groundwater operable unit.

The results of the post-cleanup assessment for radionuclides were also used to assess compliance with the environmental standards and guidelines identified in Section 2.2.1. The annual dose limit of 25 mrem/yr above background identified by the EPA would be met for recreational use of the site but this limit would not be met for residential use at approximately 10% of the soil areas. The elevated risk estimates for those areas result almost entirely from exposures to the estimated levels of indoor radon, which would be generated by the residual radium in soil (entering through the basement or foundation slab). However, the EPA has separately identified an acceptable level for indoor radon of 4 pCi/L (EPA 1992), and the indoor radon concentrations associated with the cleanup target and goal for radium are expected to be at or below this level at all site locations. The incremental outdoor radon concentration is estimated be less than 0.1 pCi/L, and the estimated annual dose from inhalation of airborne particulates is less than 10 mrem/yr at all locations. Hence, standards for radiation exposure from the air pathway would be met by the cleanup criteria for all scenarios.

2.4.2 Chemical Contaminants

The estimated risks and hazard indexes presented in this section are for a hypothetical resident who was assumed to be equally likely to live at any one of the individual borehole locations on-site. The incremental (and total) risk for a resident exceeds 1×10^{-4} at about 20 site locations contaminated with arsenic, PAHs, or PCBs; individual cleanup criteria were developed for each of these contaminants. At most of the remaining locations, the total risk ranges from about 1×10^{-5} to 5×10^{-5} compared with an average background risk of 3×10^{-5}, so the incremental risk is within or below the target range at most locations. In general, the cumulative frequency distributions for metals in site soil parallel the corresponding distributions at the nearby background location. Because the total estimate is generally dominated by the contribution from naturally occurring metals, the incremental risk associated with many site locations is small. No measurable incremental risks are indicated for any metal other than arsenic (for which the background risk is comparable to that estimated at most site locations).

For noncarcinogens, four metals were identified as contributors to a segregated hazard index above 1 (this level was exceeded at 14 locations) — arsenic, chromium, thallium, and uranium. Specific criteria were developed for these contaminants to limit the potential for noncarcinogenic health effects. The protective levels for arsenic and uranium were determined in conjunction with the development of criteria on the basis of risk. Except for lead — for which a separate analysis was conducted — results of the site-specific health assessments indicated that individual cleanup criteria were not warranted for any other contaminants. For uranium, the hazard quotients associated with the range of cleanup criteria evaluated on the basis of radiological risks — 120, 60, 30, and 15 pCi/g — are well below the level of concern for noncarcinogenic effects. Therefore, no further consideration was indicated for this contaminant.

The development of cleanup criteria for the key chemical contaminants in surface soil is presented in Sections 2.4.2.1 through 2.4.2.7. In determining how to apply those criteria developed for surface soil to cleanup targets for subsurface soil, two major factors were considered: the nature of the contaminant relative to its potential for leaching to groundwater and the likelihood of the soil redistribution scenario.

Leaching is not a primary consideration for metals because site concentrations are generally similar to those at the nearby background location, except for lead. (Lead has been detected at high concentrations in subsurface soil at two locations. Because these levels were measured within 3 m [10 ft] of the surface, those locations were addressed as part of the soil redistribution scenario in that modeling analysis.) No trend is evident from a comparison of surface and subsurface concentrations either on-site or off-site, indicating that the distribution of metals on-site reflects natural variability. Results of the screening-level calculations for leaching of metals from sitewide soil are generally similar to those for the off-site background location, which were compared with available data for local and regional groundwater.

Of the organic compounds, PAHs and PCBs are generally immobile in soil and their persistence is controlled more by biodegradation or surface processes than by leaching (see Appendix E of the BA [DOE 1992a]). In addition, the levels reported for subsurface soil are relatively low, e.g., about 1 mg/kg or less. Screening-level leaching calculations for these compounds result in groundwater concentrations that are associated with a carcinogenic risk or hazard index lower than EPA's target levels from a daily intake of 2 L/d for a resident scenario. Therefore, no adverse health effects are expected from leaching of PAHs or PCBs to groundwater.

Nitroaromatic compounds are also subject to biodegradation, but leaching is considered a factor for the scattered pockets of subsurface contamination that remain at the site. Subsurface concentrations at most locations range from less than 1 to 3 mg/kg; TNT has been measured at about 30 mg/kg in two locations within 1.8 m (6 ft) of the surface. On the basis of screening-level calculations for leaching to groundwater, if an individual were to ingest 2 L of water from the shallow aquifer directly below those locations for 30 years beginning at that point in the future when the leached TNT reaches the aquifer, the carcinogenic risk and hazard index would exceed EPA's target levels (Appendix E, Tables E.19 and E.20). However, as the nitroaromatic compounds leach from the soil, the concentrations would decrease over time. To be conservative, no adjustment was made in these screening-level estimates to account for such attenuation. In addition, assuming an infiltration rate of either 5 or 13 cm/yr (2 or 5 in./yr), these compounds would be expected to undergo some biodegradation during the estimated time of vertical transport through the vadose zone. Also, once the contaminants reach the water table, they would be subject to three-dimensional dispersion and adsorption along the flow path, so the actual groundwater concentrations for a hypothetical future resident could be lower than those estimated from these preliminary calculations. Furthermore, uncertainty factors ranging from 100 to 3,000 have been incorporated into the reference doses used to estimate noncarcinogenic health effects from these compounds. Finally, for comparison, applying the same assumptions to background levels of arsenic would also result in a risk and hazard quotient (and index) above EPA's target levels. Nevertheless, the potential effect of leaching will be incorporated into the definition of target areas for nitroaromatic compounds for consideration during the field application of ALARA.

Additional characterization is planned for the physical and geochemical properties of the site subsurface to support the groundwater operable unit, and these new data will be used to refine the preliminary leaching calculations in this FS. Any significant change to the estimation of potential future health effects as a result of leaching will be incorporated into the RI/FS for the groundwater operable unit to be prepared within the next several years.

The soil redistribution scenario addresses the possibility that an individual might construct a house on-site some time in the extended future, excavating soil to a depth of 3 m (10 ft) for a basement and redistributing this soil on the surface for a yard. The concentrations assumed for soil contaminants in this analysis represented weighted averages from reported data that were often biased high, so the concentrations would probably be lower. In addition, it is not very likely that the excavated soil alone would represent the entire surface to which someone could be exposed. For example, it could be equally reasonable to assume that this soil would make up 10% of the yard surface, in which case the estimated health effects would decrease by a factor of 10.

An additional consideration that affects both surface and subsurface cleanup criteria is the conservative assumptions that have been incorporated into the general methodology for estimating health effects. The assumptions used for intake parameters and toxicity values in this assessment tend to overestimate potential health effects (see Section 5.6 of the BA [DOE 1992a]). Intake values generally represent the 95th percentile of the distribution for each parameter, and combining these values to assess a given scenario will result in an even higher percentile for the overall exposure. Similarly, the slope factor used to estimate a chemical carcinogenic risk is typically the upper 95% confidence limit of the probability of a response determined from laboratory experiments with animals, so the "true risk" to humans estimated from this conservative approach is likely to be lower. In parallel, the uncertainty factors that have been incorporated into the reference doses used to quantify potential noncarcinogenic effects probably result in an overestimation of the hazard quotients and indexes. These issues were considered in identifying cleanup criteria for soil from the results of the site risk assessments.

On the basis of the redundantly conservative factors used to estimate health effects, the subsurface cleanup criteria are taken to be 10 times the levels that were developed for surface soil, except as otherwise noted in the following discussion. The development of soil cleanup criteria for arsenic, chromium, lead, thallium, PAHs, PCBs, and nitroaromatic compounds is presented in Sections. 2.4.2.1 through 2.4.2.7.

2.4.2.1 Arsenic

Arsenic represents the limiting factor for determining appropriate residual levels for chemical risks at the site. That is, restoring excavated areas of the site with local borrow material could result in a new risk at the "remediated" location that exceeds 1×10^{-4}, considering the natural variability of arsenic in off-site soil.

The Missouri Department of Health (1992) recently proposed a level of 11 mg/kg for arsenic in soil at residential areas, which is slightly less than the arithmetic mean concentration in uncontaminated soil off-site. Arsenic concentrations at the background location range from 1 to 33 mg/kg, with an upper bound of 26 mg/kg. The concentrations reported for agricultural soil in Missouri range from 2.5 to 72 mg/kg (Tidball 1984). By applying the same assumptions made for the on-site resident to the off-site location, the risk associated with the upper end of the range for arsenic in background soil exceeds 9×10^{-5}, which is nearly at the upper limit of EPA's target range. Risks associated with natural levels of arsenic in similar soil throughout Missouri would probably exceed the target range.

A comparison of the cumulative lognormal frequency distributions for arsenic on-site and off-site are quite similar, with slight variances at each end (Figure 2.2). That is, arsenic levels at the site follow the same general distribution pattern as at the local background area except for a small number of elevated values. The maximum concentration of arsenic measured in surface soil at the site is 81 mg/kg, and the maximum measured at any depth (within 1.2 m [4 ft] of the surface) is 133 mg/kg; the concentration exceeds 45 mg/kg at several surface locations, one of which was indicated for cleanup on the basis of the radiological cleanup criteria.

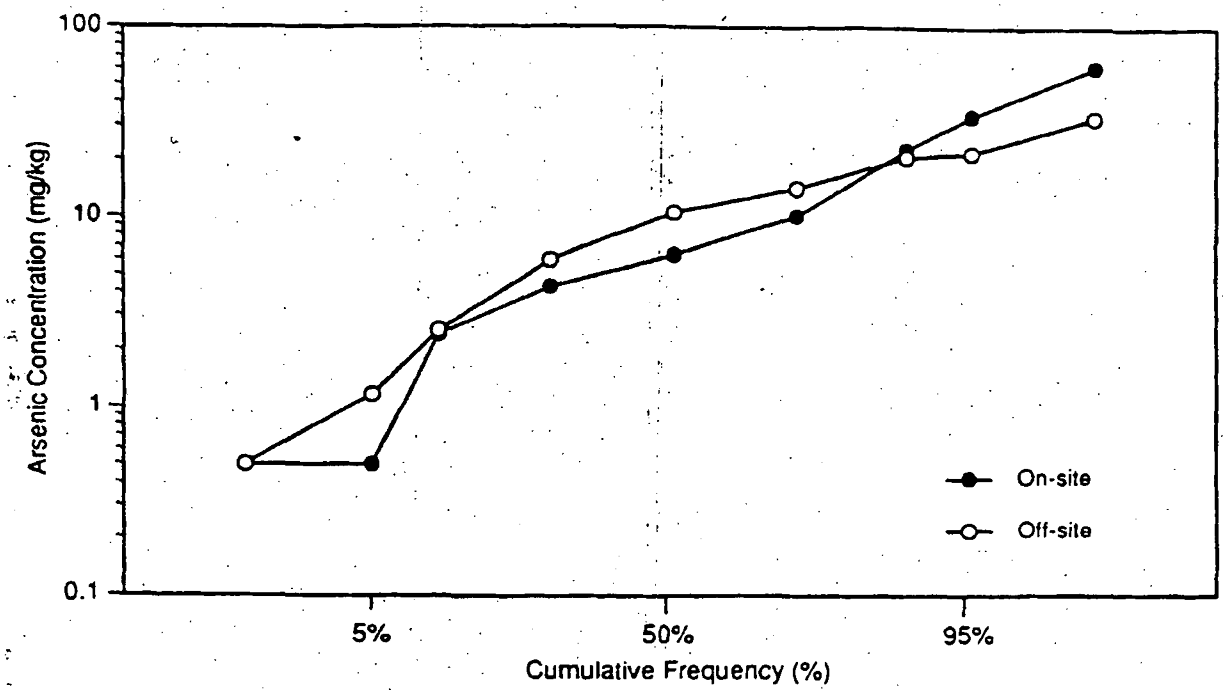


FIGURE 2.2 Cumulative Lognormal Frequency Distribution for Arsenic in Soil

From that point, the number of locations in subsequent concentration increments increases considerably, and no obvious break point is evident from the gradually decreasing values reported below that level.

On the basis of the site-specific risk analysis for a resident, a level of 45 mg/kg corresponds to a hazard quotient of less than 1 and a risk of 1×10^{-4}, which is slightly higher than the risk associated with the upper end of the distribution for arsenic in off-site soil. A level of 75 mg/kg corresponds to a hazard quotient of less than 1 and a risk of 2×10^{-4}; the incremental risk associated with this level would be about 1×10^{-4}.

The preliminary ALARA analysis for arsenic indicates that levels might be reduced to 45 mg/kg during field activities for a reasonable cost; however, further decreasing the residual level toward the background range would result in a substantial increase in excavation volume. Additional costs would result from the extensive verification needed to distinguish residual levels from the local background level. More importantly, the risk associated with the backfill soil could actually result in a net increase in risk on-site if the target levels were reduced much below this level because of the greater amount of borrow material that would be used to backfill excavated areas. From this information, a soil concentration of 75 mg/kg is identified as the cleanup target for arsenic, and a concentration of 45 mg/kg is the ALARA goal that would be targeted during field activities.

Concentrations reported for arsenic in subsurface soil are less than 10 times the cleanup target and ALARA goal at all locations, and the maximum 3-m [10-ft] weighted average concentration is 81 mg/kg. Therefore, soil removal is not indicated for any subsurface area.

2.4.2.2 Chromium

Results of the site-specific health assessment indicate that inhalation of chromium contributes significantly to the total hazard index at two locations, one in the South Dump/Ash Pond area and the other in the former coal storage area. (Cleanup has already been indicated for both of these locations, the first on the basis of radioactive contamination and the second on the basis of arsenic contamination.) The concentration of chromium at these locations is 120 mg/kg, which is the maximum value measured in surface soil on-site; the next highest measurement is 80 mg/kg.

Applying the assumptions for the on-site resident, a chromium concentration of 110 mg/kg corresponds to a hazard quotient of 1. This estimate applies for total chromium because the noncarcinogenic effects are the same for both chromium III and chromium VI. Considering the conservative approach applied to estimate the inhalation pathway (i.e., that airborne contaminants originated from a single borehole location), the actual hazard quotient would probably be much lower. On the basis of available data, the concentration of chromium VI at the site is expected to be about 10% of the total chromium concentration. Nevertheless, to be conservative, if it were assumed that all chromium was in the hexavalent form, a concentration of 100 mg/kg would correspond to a risk of 1×10^{-5}. From this information, a soil concentration of 110 mg/kg is identified as the cleanup target for total chromium, and a concentration of 100 mg/kg is the target for chromium VI.

The proposed state level for chromium is 280 mg/kg, for soil in which hexavalent chromium is likely or documented to exceed 4 mg/kg. Although the cleanup target for chromium is lower and is expected to be protective, a slightly lower concentration of 90 mg/kg is identified as the ALARA goal for both total and hexavalent chromium. For comparison, the upper end of the distribution for soil at the nearby off-site location ranges from 12 to 62 mg/kg, and levels in agricultural soil across Missouri range from to 10 to 150 mg/kg (Tidball 1984).

For chromium, concentrations reported in subsurface soil are less than 10 times the preliminary cleanup target at all locations except one. The 3-m (10-ft) weighted average concentration exceeds this value only at the location in the South Dump/Ash Pond area where the surface concentration is 120 mg/kg (this area is also radioactively contaminated and has been targeted for cleanup). Data are available only for the subsurface interval from 0.6 to 1.2 m (2 to 3 ft), and the concentration is about 30% lower than the surface measurement; thus, removing the surface soil at this location is expected to result in a 3-m (10-ft) average below 100 mg/kg. Therefore, no additional soil removal is indicated for any subsurface areas.

2.4.2.3 Lead

By inputting site-specific data to EPA's uptake/biokinetic model, three surface locations were identified in the vicinity of Ash Pond for which the estimated blood lead level would exceed the target of 10 µg/dL in greater than 5% of the population of children aged 0 to 72 months. The soil concentrations at these locations (750, 1,100, and 1,900 mg/kg) also exceed the lower limit of 500 mg/kg identified in EPA's interim guidance for residential settings and the state level of 240 mg/kg. For comparison, the concentrations in off-site background soil range from 6 to 76 mg/kg, and those in agricultural soil in Missouri range from 10 to 7,000 mg/kg (Tidball 11984).

Evaluating the state level in combination with the average concentration for lead from all site monitoring wells in which it has been detected results in an estimated blood level lower than 10 µg/dL. (The predicted future groundwater concentration estimated from leaching calculations with the sitewide UL_{95} value for lead in soil is lower than the concentration in groundwater used for the modeling analysis, so this level is expected to be protective.) The level of 240 mg/kg recently proposed by the Missouri Department of Health is exceeded at one additional surface location, between raffinate pits 2 and 4, where the reported concentration is 255 mg/kg. This concentration is considerably lower than the values identified in EPA's interim guidance, and the associated blood lead level is also lower than the level of concern.

To address subsurface lead contamination, those locations at which the 3-m (10-ft) average concentration exceeded 240 mg/kg were also evaluated with the EPA uptake/biokinetic model. Model predictions for two additional locations north of Ash Pond exceed the target blood lead level; the weighted average concentrations at this location were 14,000 mg/kg (from one high measurement of 43,000 mg/kg at a depth of 0.6 to 1.2 m [2 to 4 ft]) and 450 mg/kg (from one high measurement of 1,700 mg/kg at a depth of 0.15 to 0.6 m [0.5 to 2 ft]). Because the subsurface concentrations at the two locations are relatively high, the factor of 10 typically applied for subsurface versus surface concentrations was not included for those locations.

The upper limit identified in general EPA interim guidance for lead in surface soil at residential settings is 1,000 mg/kg. Two locations in the northern portion of the site contain lead exceeding this limit. Results of the site-specific uptake/biokinetic modeling for exposures to lead indicate that a value of about 450 mg/kg represents an appropriate cleanup level for site soil; this concentration is slightly less than the lower level of 500 mg/kg identified in EPA's interim guidance. Three surface locations and two subsurface locations in the northern portion of the site are indicated for potential cleanup on the basis of this modeled level.

The additional excavation associated with reducing the residual concentration of lead in site soil from EPA's upper guideline value of 1,000 mg/kg to the lower value of 500 mg/kg would be small, and that required to extend the excavation to areas above the health-based level of 450 mg/kg would be negligible. Further reducing the soil concentration to the state level of 240 mg/kg would involve a limited additional effort, which would not be expected to result in a measurable overall health benefit for potential future receptors. Nevertheless, to reduce the contribution from soil relative to other sources of lead exposure for a future receptor, the state-proposed level is considered a reasonable ALARA goal for field application. From this information, the modeled concentration of 450 mg/kg is considered the cleanup target for lead, and the state-proposed level of 240 mg/kg is considered the ALARA goal that would be applied during field activities.

2.4.2.4 Thallium

Concentrations reported for thallium in surface soil at many locations exceed the level of 3.9 mg/kg proposed by the Missouri Department of Health for statewide consideration for soil in residential settings, which is not unexpected given that the average concentration in local soil is 6 mg/kg. The thallium concentrations at three locations range from 10 to 12 mg/kg. Cleanup has already been indicated for one of these locations on the basis of arsenic and chromium contamination. The combined hazard index exceeds 1 for the location at which both thallium and arsenic are elevated, with both metals contributing about equally. Excavating surface soil from this location would reduce the thallium and arsenic concentrations to result in a combined hazard index of less than 1, which would remove the indicated potential for adverse noncarcinogenic effects. The results of the site-specific risk assessment indicate that no locations exist at which exposures to thallium alone would result in adverse health effects (i.e., the hazard quotient is less than 1 at all locations). Applying the assumptions for the on-site resident, a thallium concentration of 20 mg/kg corresponds to a hazard quotient of 1. The estimated potential for noncarcinogenic effects from thallium is probably overestimated because a very high uncertainty factor of 3,000 has been incorporated into the reference dose used to estimate these effects.

Relative to the concentration in local soil, the upper-bound concentration of thallium in soil at the nearby background location is 16 mg/kg, and the maximum concentration is 20 mg/kg. (No data were found for thallium in Missouri soil.) The hazard quotient associated with this upper end of the range for background soil is 1, as is the hazard index associated with the combined presence of thallium and arsenic at their respective upper-bound concentrations (mean plus two standard deviations) at the background location. Therefore, the feasibility of reducing the potential noncarcinogenic effects from thallium at the site is limited by the natural presence of this metal in local soil. From this information, a concentration of 20 mg/kg is considered the cleanup target and 16 mg/kg is considered the ALARA goal.

The average concentration of thallium in subsurface soil is 80 mg/kg at one location at a depth interval of 0.6 to 1.2 m (2 to 4 ft), the Ash Pond/South Dump area; the next highest average value is less than 25 mg/kg. Cleanup has already been indicated for this location on the basis of radioactive contamination, and no additional areas of subsurface contamination are indicated for removal.

2.4.2.5 PAHs

The six carcinogenic PAHs present at the site were detected together in the top 15 cm (6 in.) of soil adjacent to the concrete pad of a pilot plant building in the northern part of the former chemical plant. Results of the site-specific risk assessment indicate that exposures to these PAHs would result in a risk of 6×10^{-4} for a hypothetical resident, which exceeds the EPA target range. Because the PAHs were not detected in subsurface soil at that location, excavating the surface soil would effectively remediate this area. If the residual level for the combined PAHs was 5.6 mg/kg, the residual risk would be the same as the risk associated with the upper end of the range for arsenic in local soil that would be used as backfill, or about 9×10^{-5}. The level recently proposed by the Missouri Department of Health as safe for benzo(a)pyrene in residential settings is 0.44 mg/kg. Applying the assumptions used for a resident in the site-specific risk assessment to this concentration results in a risk estimate of 8×10^{-6}, which is much lower than the risk that could be associated with local soil used as backfill.

The concentration of benzo(a)pyrene in soil at the concrete pad location is about 5 mg/kg, and the concentrations of the other carcinogenic PAHs range from about 3 to 8 mg/kg. Excavating surficial soil from this location to achieve the state-proposed level of 0.44 mg/kg for benzo(a)pyrene would also reduce the levels of the other PAHs to protective levels. Applying this recommended concentration to each of the carcinogenic PAHs and conservatively assuming that each would be present at this residual level would result in a risk of about 5×10^{-5}. Because this estimate is similar to the average risk associated with local soil that would be used as backfill, further reduction in PAH concentrations would not result in any net risk reduction.

Two of the carcinogenic PAHs — benz(a)anthracene and chrysene — were detected in surface soil at one other location, the former coal storage area, at a concentration of about 0.4 mg/kg. This concentration is below the state-recommended level of 0.44 mg/kg for these two compounds, and the risk associated with exposures to these compounds is about 1×10^{-5}, which is less than the risk associated with arsenic in local soil that would be used as backfill. Therefore, no PAH removal is indicated for this location. No carcinogenic PAHs were detected in subsurface soil at any location (including the concrete pad). From this information, the cleanup target for carcinogenic PAHs in surface soil is 5.6 mg/kg; 0.44 mg/kg is considered the ALARA goal that could be applied during field activities.

Eight noncarcinogenic PAHs were detected in surface soil next to the concrete pad of the pilot plant, at concentrations ranging from about 2 to 20 mg/kg. These concentrations are well below the levels proposed by the state. Four of these PAHs have also been detected at the coal storage area at concentrations ranging from less than 1 to about 5 mg/kg. A single noncarcinogenic compound was measured at less than 1 mg/kg at two additional locations previously used as drum storage areas, one next to a building south of the raffinate pits that was used to store machine and motor parts and another next to a building in the southeastern area of the site that was used for spray painting. Only two noncarcinogenic PAHs have been detected in subsurface soil. These compounds were detected at a depth of 0.6 to 1.1 m (2 to 3.5 ft) in the former coal storage area, at a combined concentration of about 1 mg/kg.

These concentrations are orders of magnitude lower than those for which potential adverse noncarcinogenic health effects would be indicated, depending on the specific contaminant. Therefore, no site areas are indicated for the removal of noncarcinogenic PAHs on the basis of soil-related exposures, and no individual cleanup criteria are developed for these compounds. In addition, the PAHs are relatively immobile and the screening-level calculations conducted to assess leaching to groundwater do not indicate a potential for adverse risks or noncarcinogenic health effects from future drinking water ingestion. Therefore, no additional areas are indicated for removal on the basis of groundwater considerations.

2.4.2.6 PCBs

Concentrations of PCBs in surface soil at the site range from less than 1 to 12 mg/kg, and one recently identified location has a high concentration of about 650 mg/kg. For a residential scenario, the state-proposed concentration of 0.65 mg/kg corresponds to an estimated risk of 8×10^{-6}. This risk is less than 25% of the average risk associated with local soil that represents backfill material for the site. Thus, removing site soil to achieve this residual level and replacing it with local soil could result in a higher residual risk. A PCB concentration of 8 mg/kg corresponds to the upper end of the risk range associated with local backfill. The hazard index associated with this concentration is much less than 1 for all scenarios.

The excavation effort to reduce PCB concentrations in surface soil to 8 mg/kg would be reasonable relative to the limited contamination that has been detected and potential worker impacts; however, further decreasing this concentration would not be expected to reduce residual risks because the average risk associated with soil that would be used as backfill is similar. From this information, the cleanup target for PCBs in surface soil is 8 mg/kg. The level of 0.65 mg/kg is considered the ALARA goal that could be applied during field activities depending on the associated need for backfill.

During the site characterization effort, PCBs were detected in only three subsurface locations at concentrations ranging from about 0.2 to 1 mg/kg. Subsequent soil excavation to support interim actions has identified subsurface concentrations of 8 mg/kg in a few additional locations. The 3-m (10-ft) average concentration would not be expected to result in adverse health effects at any location. In addition, these compounds are relatively immobile because of their physicochemical properties, and the screening-level leaching calculations do not indicate a potential for adverse health effects from future groundwater ingestion. Therefore, no subsurface areas are indicated for removal.

2.4.2.7 Nitroaromatic Compounds

No adverse health effects are associated with the relatively low levels of scattered nitroaromatic contamination at the site, with the possible exception of future impacts from leaching to groundwater. None of these compounds are present in surface soil at levels above those recently proposed by the state, and concentrations of TNT reported for subsurface soil at two locations are slightly above the proposed level. Nevertheless, soil cleanup criteria were developed for these compounds to ensure that guidelines would be available in the event that higher concentrations were detected during field cleanup operations. This also ensures that criteria are available for each of the organic contaminants of concern at the site (i.e., PAHs, PCBs, and nitroaromatic compounds), for which any risk is an incremental risk because these compounds are not naturally present in the environment.

Nitroaromatic compounds have been detected in surface soil at only two locations on-site. The first is the spoils pile adjacent to the raffinate pits, which contains soil that was excavated to construct the pits more than 20 years ago. The concentrations of nitroaromatic compounds in the upper 1.2 m (4 ft) at this location range from about 0.6 mg/kg (TNB) to 1.6 mg/kg (2,6-DNT). The total hazard index estimated for a resident at this location from the site-specific health assessment is 0.2, which is well below the level of concern and indicates that no noncarcinogenic effects are expected. The total risk estimated for this location is 6×10^{-6}, which is well below the risk associated with local soil that would be used as backfill. The hazard quotient estimated for a hypothetical resident from exposure to the state-recommended level for 2,6-DNT is about 1/1,000 of the level of concern, and the risk is about 1/30 of the average risk associated with backfill material. Therefore, removal of soil from this location is not indicated on the basis of the site-specific health assessment.

The second location at which nitroaromatic compounds were detected in surface soil is near the drainage of a former Army TNT production line at the eastern boundary of the site. Only one nitroaromatic compound, TNB, was detected at this location; the concentration reported for the upper 0.6 m (2 ft) of soil was about 2 mg/kg. The Missouri Department of Health has not specified a value for TNB. The total hazard index estimated for a hypothetical resident at this location is less than 1 (the hazard quotient associated with TNB is less than 0.2). Therefore, no noncarcinogenic effects are expected, and no soil removal is indicated on the basis of the site-specific assessment.

Similarly, the concentrations of nitroaromatic compounds in subsurface soil are generally less than 3 mg/kg except at the two locations near Ash Pond for which concentrations in the two subsurface intervals are 30 mg/kg. The incremental excavation required to remove this contamination is considered reasonable because this action would reduce potential impacts from any future leaching to groundwater. The 3-m (10-ft) average concentrations are less than 1 mg/kg at all locations except these two, and no adverse health effects would be expected from any other locations. Thus, no additional subsurface areas are indicated for removal on the basis of surface exposures.

Although no areas are indicated for removal on the basis of the site-specific health assessment, it is possible that concentrations in locations for which borehole-specific data are not available might be higher than those reported for the sampled locations. The sampling strategy for nitroaromatic compounds was well conceived, and it is expected that the locations at which these compounds could be present have been addressed. Nevertheless, the information presented in Section 2.5 can be applied if these compounds are unexpectedly found at any location, to ensure that residual levels across the site will be protective of human health.

2.5 SCENARIO-SPECIFIC HEALTH EFFECTS AND AREAS TARGETED FOR REMOVAL

The cleanup criteria developed for the Weldon Spring site consist of different values (alternatives) associated with each key contaminant, with cleanup levels ranging between a target and an ALARA goal. Final remediation levels will be identified in the ROD for this cleanup action. Those final levels will be determined from the remedy selected for the site, coupled with a consideration of future land uses.

In order to facilitate selection of the final remediation levels, two separate analyses were conducted. For the first analysis, the cleanup targets developed on the basis of the resident and farmer were used to assess potential health risks for the three hypothetical receptors evaluated in the rebaseline assessment, i.e., the recreational visitor, ranger, and resident. The parameters and assumptions used to define these scenarios are discussed in the rebaseline assessment (Appendix E, Section E.4), and supporting detail is presented in the BA.

The results of the radiological and chemical assessments are presented in Tables 2.3 and 2.4, respectively. For comparison, the risks associated with background concentrations of radionuclides and metals were estimated for the three receptors using the same exposure parameters and assumptions. For the second analysis, the concentrations of radioactive and chemical contaminants in soil that correspond to different target levels of risks and hazard indexes were calculated with the same exposure scenarios and parameters as in the previous assessment; the results are shown in Tables 2.5 and 2.6. These tables identify contaminant levels in soil that correspond to incremental target levels of residual risk (for radionuclides and chemicals) and hazard index (for chemicals). Together, the results of these two assessments (Tables 2.3 through 2.6) provide information that will be used to select final remediation levels for soil contaminants. It is expected that the final levels will be selected from within the ranges identified for the appropriate land use, as indicated by the cleanup remedy for the site.

The information presented in these tables also provides the means for applying appropriate flexibility for individual contaminants at given locations while ensuring that overall protectiveness is maintained. One of the key objectives of the site-specific development of cleanup criteria was to address contaminant heterogeneity. That is, because the contaminants contributing significantly to health effects near or above target levels are not present together at all locations, the most restrictive combination of levels selected for individual contaminants need not be applied across the entire site to ensure protectiveness. Thus, adjustments can be made for specific locations at which several such contaminants are present together by combining the appropriate information from the tables.

To provide an indication of how these cleanup levels would be applied, the soil areas that could be excavated on the basis of the cleanup targets and ALARA goals are shown in Figure 2.3. The area of impact around a given borehole was estimated by considering site history and available data for the key contaminant(s) present at that location. For radioactive contaminants, the data were kriged and contoured, incorporating information for surface features. Data from forthcoming samples will be used to further define these areas (e.g., for PCBs). Subsurface contamination has been incorporated into the definition of these areas (e.g., for radionuclides, lead, and nitroaromatic compounds), as it would be after the final remediation levels are determined. The depth of excavation and backfill would be 0.15 m (0.5 ft) in most cases; for radionuclides, the depth would be lower in certain areas.

Excavating soil to meet the cleanup targets and ALARA goals for chemicals at the site would result in an incremental chemical risk at or below EPA's target range for all scenarios, and the hazard index would be well below the level of concern. However, this is not the case for the radiological cleanup criteria because incremental radiological risks exceed the target range at certain locations under a residential scenario. The results of the post-cleanup assessment for radionuclides indicate that except for exposures to indoor radon, environmental standards and guidelines would be met — including EPA's target range for incremental risk. For radon, the EPA has separately identified a level of 4 pCi/L as an acceptable concentration for indoor air. The indoor radon concentrations associated with the cleanup target and goal for radium are expected to be at or below this level at all site locations.

It is possible that different land uses could be associated with different areas of the Weldon Spring site in the future under any of the final alternatives. For those final alternatives under which the waste would be disposed of on-site, neither recreational nor residential scenarios would apply to a determination of residual soil contaminant levels in the disposal area for two reasons. First, surface and subsurface soil would be excavated from this area to construct the cell, and the new surface soil to which someone could be exposed would be the uncontaminated soil of the cell cover. Second, contaminants in subsurface soil beneath the disposal cell would be isolated from possible future migration because the cell would serve as the equivalent of an engineered multilayer cap, with the liner and compacted subgrade components acting to limit the potential for leaching of any subsurface material to groundwater. However, the cleanup criteria for site soil outside the disposal area could be determined from an assumption of future recreational or residential use.

For the alternatives under which waste would be disposed of off-site, recreational or residential scenarios might be reasonable for any area of the site in the extended future. The potential for adverse impacts from the levels proposed for residual contamination at the Weldon Spring site, including consideration of migration to groundwater, is expected to be low for all scenarios. Thus, it is expected that the proposed remediation of this site could result in the release of property for other uses, as appropriate to the remedy selected.

Both environmental standards and the results of the site-specific human health assessment for the receptors with the maximum potential risks have been used to focus the development of cleanup options for soil at the Weldon Spring site. Location-specific factors and the likelihood of specific future exposures under the appropriate land-use scenarios can be incorporated into upcoming decisions for the final disposition of the site by flexibly applying ranges indicated by the cleanup alternatives that have been presented here.

TABLE 2.3 Estimated Radiological Risks for the Recreational Visitor, Ranger, and Resident Associated with the Potential Cleanup Criteria[a]

Radionuclide/ Criterion	Soil Concentration (pCi/g)[b]	Risk to Hypothetical Receptor		
		Recreational Visitor	Ranger	Resident
Radium-226				
Cleanup target	6.2	5×10^{-5}	8×10^{-4}	2×10^{-2}
ALARA goal	5	4×10^{-5}	6×10^{-4}	8×10^{-3}
Field target	4	3×10^{-5}	5×10^{-4}	6×10^{-3}
Background	1.2	9×10^{-6}	2×10^{-4}	2×10^{-3}
Radium-228				
Cleanup target	6.2	2×10^{-5}	2×10^{-4}	1×10^{-3}
ALARA goal	5	1×10^{-5}	2×10^{-4}	8×10^{-4}
Background	1.2	3×10^{-6}	5×10^{-5}	2×10^{-4}
Thorium-230				
Cleanup target	6.2	3×10^{-7}	4×10^{-6}	8×10^{-6}
ALARA goal	5	2×10^{-7}	3×10^{-6}	6×10^{-6}
Background	1.2	6×10^{-8}	8×10^{-7}	2×10^{-6}
Thorium-232				
Cleanup target	6.2	2×10^{-6}	2×10^{-5}	4×10^{-5}
ALARA goal	5	1×10^{-6}	2×10^{-5}	3×10^{-5}
Background	1.2	3×10^{-7}	4×10^{-6}	7×10^{-6}
Uranium-238				
Cleanup target	120	2×10^{-5}	2×10^{-4}	5×10^{-4}
ALARA goal	30	4×10^{-6}	5×10^{-5}	1×10^{-4}
Background	1.2	2×10^{-7}	3×10^{-6}	8×10^{-6}

[a] The radiological risks reported for radium-226 include the contributions from radon-222 and lead-210; the radiological risks reported for uranium-238 include the contributions from uranium-235, protactinium-231, and actinium-227 (see text). Data for local background is presented for comparison; the background soil concentration of 1.2 pCi/g represents the average concentration measured for each of the listed radionuclides at off-site locations that have not been affected by site releases.

[b] The cleanup targets for radium and thorium represent surface concentrations; the subsurface concentration is 16.2 pCi/g. The ALARA goal of 5 pCi/g for radium and thorium applies to both surface and subsurface contamination. The listed cleanup targets and ALARA goals include the background concentration of 1.2 pCi/g. For radium-226, an additional field target was included to ensure that the ALARA goal would be achieved.

TABLE 2.4 Estimated Chemical Health Effects for the Recreational Visitor, Ranger, and Resident Associated with the Potential Cleanup Criteria

Chemical/ Criterion[a]	Soil Concentration (mg/kg)	Risk			Hazard Quotient[b]		
		Recreational Visitor	Ranger	Resident	Recreational Visitor	Ranger	Resident
Metals[c]							
Arsenic							
Cleanup target	75	6×10^{-6}	7×10^{-5}	2×10^{-4}	0.02	0.3	0.9
ALARA goal	45	3×10^{-6}	3×10^{-5}	1×10^{-4}	0.01	0.2	0.5
Background	26	2×10^{-6}	2×10^{-5}	7×10^{-5}	0.008	0.1	0.3
Chromium (total)							
Cleanup target	110	NA[d]	NA	NA	0.03	0.6	1
ALARA goal	90	NA	NA	NA	0.02	0.4	0.8
Background	36	NA	NA	NA	0.01	0.1	0.3
Chromium (VI)							
Cleanup target	100	3×10^{-7}	6×10^{-6}	1×10^{-5}	0.03	0.6	1
ALARA goal	90	3×10^{-7}	5×10^{-6}	9×10^{-6}	0.02	0.4	0.8
Thallium							
Cleanup target	20	NA	NA	NA	0.03	0.3	1
ALARA goal	16	NA	NA	NA	0.02	0.3	0.8
Background	16	NA	NA	NA	0.02	0.3	0.8
PAHs[e]							
Cleanup target	5.6	3×10^{-6}	3×10^{-5}	1×10^{-4}	0.00002	0.0002	0.0007
ALARA goal	0.44	2×10^{-7}	2×10^{-6}	8×10^{-6}	0.000001	0.00002	0.00005
PCBs[f]							
Cleanup target	8	2×10^{-6}	3×10^{-5}	1×10^{-4}	0.008	0.09	0.3
ALARA goal	0.65	2×10^{-7}	2×10^{-6}	8×10^{-6}	0.0006	0.008	0.02

TABLE 2.4 (Cont.)

Chemical/ Criterion[a]	Soil Concentration (mg/kg)	Risk			Hazard Quotient[b]		
		Recreational Visitor	Ranger	Resident	Recreational Visitor	Ranger	Resident
Nitroaromatic compounds[g]							
DNB							
Cleanup target	25	NA	NA	NA	0.02	0.3	0.9
ALARA goal	5.6	NA	NA	NA	0.005	0.07	0.2
2,4-DNT							
Cleanup target	55	2×10^{-6}	2×10^{-5}	6×10^{-5}	0.03	0.3	1
ALARA goal	7.4	2×10^{-7}	3×10^{-6}	8×10^{-6}	0.003	0.04	0.1
2,6-DNT							
Cleanup target	94	3×10^{-6}	3×10^{-5}	1×10^{-4}	0.002	0.03	0.06
ALARA goal	7.4	2×10^{-7}	3×10^{-6}	8×10^{-6}	0.0002	0.002	0.007
NB							
Cleanup target	140	NA	NA	NA	0.03	0.3	1
ALARA goal	28	NA	NA	NA	0.005	0.06	0.2
TNB							
Cleanup target	14	NA	NA	NA	0.03	0.3	1
ALARA goal	10	NA	NA	NA	0.02	0.2	0.7
TNT							
Cleanup target	140	2×10^{-7}	2×10^{-6}	7×10^{-6}	0.03	0.3	1
ALARA goal	14	2×10^{-8}	2×10^{-7}	7×10^{-7}	0.003	0.03	0.1

See next page for footnotes.

TABLE 2.4 (Cont.)

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[a] The listed criteria are for surface soil and include background; criteria for subsurface soil are 10 times the listed value. Data for local background are presented for comparison and to permit a determination of incremental risk for the listed criteria (for example, the incremental risk for the resident that corresponds to the arsenic cleanup target is 1×10^{-4}). For metals, the listed concentration represents the upper bound concentration (mean plus two standard deviations) measured at a nearby off-site area; no background concentration is listed for chromium (VI) because the soil samples were analyzed for total chromium (hexavalent chromium was assumed to be 10% of total chromium on the basis of limited site-specific data and general environmental data). No background concentration is listed for the organic compounds because they are not naturally present in soil. The cleanup targets were determined from the site-specific risk assessment. Most ALARA goals are the levels recently proposed for statewide consideration by the Missouri Department of Health (1992) for soil in residential settings; exceptions are chromium, arsenic, thallium, and trinitrobenzene (TNB) — for which the goals were determined from the site-specific risk assessment. For chromium, the concentrations in site soil are not expected to approach the state-proposed levels of 5,600 and 280 mg/kg for total and hexavalent chromium, respectively. The state-proposed levels for arsenic and thallium are 11 and 3.9 mg/kg, respectively, which are considerably below the local background concentrations; no level was proposed for TNB.

[b] The hazard quotient shown for each contaminant represents the sum of the contributions from the inhalation and ingestion pathways, where appropriate.

[c] Lead is not shown in this table because an EPA value is not available from which to quantify the risk or hazard quotient. The cleanup target is 450 mg/kg, as determined by applying site-specific input to EPA's model; the ALARA goal is 240 mg/kg, which is the general level proposed by the Missouri Department of Health (1992).

[d] NA indicates that the entry is not applicable because the contaminant is not a carcinogen.

[e] The carcinogenic PAHs detected at the Weldon Spring site are benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, and indeno(1,2,3-cd)pyrene. Represented by benzo(a)pyrene for carcinogenic effects for this presentation, assuming the oral reference dose for pyrene for noncarcinogenic effects. The listed concentration represents the objective for each individual compound; where present together, the individual concentrations would be adjusted accordingly.

[f] Aroclor 1248, Aroclor 1254, and Aroclor 1260.

[g] Notation: DNB, dinitrobenzene; 2,4-DNT, 2,4-dinitrotoluene; 2,6-DNT, 2,6-dinitrotoluene; NB, nitrobenzene; TNB, trinitrobenzene; TNT, trinitrotoluene.

TABLE 2.5 Soil Concentrations of Radionuclides Associated with Target Levels for Residual Risk for the Recreational Visitor, Ranger, and Resident

Receptor/ Radionuclide[a]	Soil Concentration (pCi/kg) Relative to Risk 1×10^{-4}	1×10^{-5}	1×10^{-6}
Recreational visitor			
Radium-226	23	2.3	0.23
Radium-228	46	4.6	0.46
Thorium-230	2,100	210	21
Thorium-232	430	43	4.3
Uranium-238	810	81	8.1
Ranger[b]			
Radium-226	0.81	0.081	0.0081
Radium-228	2.6	0.26	0.026
Thorium-230	160	16	1.6
Thorium-232	31	3.1	0.31
Uranium-238	95	9.5	0.95
Resident			
Radium-226	0.075	0.0075	0.00075
Radium-228	0.62	0.062	0.0062
Thorium-230	81	8.1	0.81
Thorium-232	16	1.6	0.16
Uranium-238	23	2.3	0.23

[a] The value for radium-226 includes the contribution from radon-222 and lead-210; the value for uranium-238 includes the contribution from uranium-235, protactinium-231, and actinium-227 (see text).

[b] For the ranger, risks from outdoor exposures are estimated from sitewide UL_{95} values, and those from indoor exposures are estimated from location-specific values. Although the relationship between the UL_{95} and location-specific values varies by location, outdoor exposures generally dominate the total risks. On this basis, representative concentrations were calculated for this receptor.

TABLE 2.6 Soil Concentrations of Chemicals Associated with Target Levels of Residual Risks and Hazard Quotients for the Recreational Visitor and Resident[a]

Receptor/ Contaminant	Soil Concentration (mg/kg) Relative to Risk			Soil Concentration (mg/kg) Relative to Hazard Quotient		
	1×10^{-4}	1×10^{-5}	1×10^{-6}	1	0.5	0.1
Recreational visitor						
Metals						
Arsenic	1,400	140	14	3,200	1,600	320
Chromium III	NA[b]	NA	NA	3,700	1,800	370
Chromium VI	35,000	3,500	350	3,400	1,700	340
Thallium	NA	NA	NA	750	380	75
PAHs[c]	220	22	2.2	320,000	160,000	32,000
PCBs[d]	320	32	3.2	1,100	530	110
Nitroaromatic compounds						
DNB	NA	NA	NA	1,100	530	110
2,4-DNT	3,600	360	36	2,100	1,100	210
2,6-DNT	3,600	360	36	43,000	21,000	4,300
NB	NA	NA	NA	5,300	2,700	530
TNB	NA	NA	NA	530	270	53
TNT	83,000	8,300	830	5,300	2,700	530
Resident						
Metals						
Arsenic	35	3.5	0.35	82	41	8.2
Chromium III	NA	NA	NA	110	54	11
Chromium VI	1,000	100	10	100	50	10
Thallium	NA	NA	NA	20	10	2
PAHs[c]	5.6	0.56	0.056	8,300	4,100	830
PCBs[d]	8.3	0.83	0.083	27	14	2.7
Nitroaromatic compounds						
DNB	NA	NA	NA	27	14	2.7
2,4-DNT	94	9.4	0.94	55	27	5.5
2,6-DNT	94	9.4	0.94	1,100	550	110
NB	NA	NA	NA	140	69	14
TNB	NA	NA	NA	14	6.9	1.4
TNT	2,100	210	21	140	69	14

[a] Estimates for the ranger are not shown because both sitewide UL_{95} values and location-specific values are used to estimate the health effects for this receptor from combined outdoor (sitewide) and indoor exposures. Because the relationship between the UL_{95} and location-specific values varies by location, back-calculation to a single soil concentration would not be representative of exposure conditions.

[b] NA indicates that the entry is not applicable because the contaminant is not a carcinogen.

[c] The carcinogenic PAHs detected at the Weldon Spring site are benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, and indeno(1,2,3-cd)pyrene. Represented by benzo(a)pyrene for carcinogenic effects for this presentation, assuming the oral reference dose for pyrene for noncarcinogenic effects.

[d] Aroclor 1248, Aroclor 1254, and Aroclor 1260.

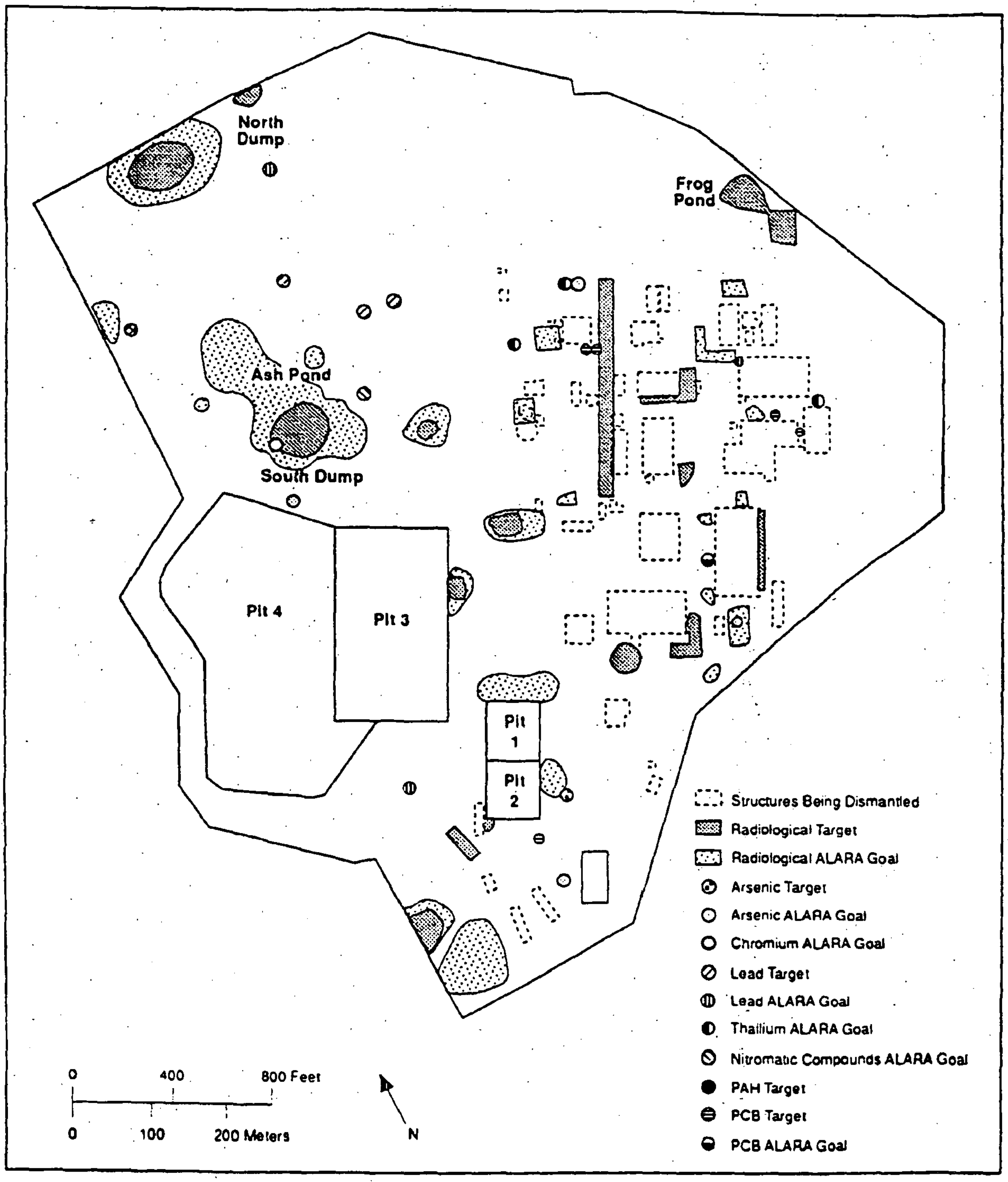

FIGURE 2.3 Areas of Soil Targeted for Removal under the Potential Cleanup Criteria

3. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Alternative remedial actions for the Weldon Spring site were developed by identifying remedial technologies and process options that are potentially applicable to the various contaminated media at the site. These media include soil, sludge, sediment, surface water, groundwater, structural material, process chemicals (including process wastes from the project's two water treatment plants), and vegetation. The technologies considered in selecting remedial action alternatives for these media include those identified in the NCP (EPA 1990a). Additional technologies were considered on the basis of experience and information gained as a result of remedial action planning and implementation at similar sites. These technology types and process options were screened for applicability to the site in accordance with EPA guidance (EPA 1988a).

3.1 CRITERIA FOR IDENTIFYING AND SCREENING TECHNOLOGIES

Evaluation of potentially applicable technology types and process options is a key step in the FS process. The criteria for identifying potentially applicable technologies are provided in EPA guidance (EPA 1988a) and in the NCP (EPA 1990a). A strong statutory preference for remedies that are reliable and provide long-term protection is identified in Section 121 of CERCLA, as amended. The primary requirements for a final remedy are that it be both protective of human health and the environment and cost effective. Hence, technology screening focuses on these two factors. Additional selection criteria include the following:

- Preferred remedies are those in which the principal element is treatment to permanently or significantly reduce the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants;
- Where practical treatment technologies are available, off-site transport and disposal without treatment is the least preferred alternative; and
- Permanent solutions and alternative treatment technologies or recycle/resource recovery technologies should be assessed and used to the maximum extent practicable.

These criteria have been considered in identifying and screening technologies to determine the appropriate components of remedial action alternatives for the Weldon Spring site. Protection of human health and the environment was the primary consideration for determining how the contaminated material should be managed.

The remedial action objectives and goals for the Weldon Spring site are described in Chapter 2. On the basis of the current understanding of contaminants and environmental conditions at the site, general response actions that could be implemented to achieve these objectives and goals are institutional controls, in-situ containment, removal, treatment, short-term storage, and disposal. Technology types and process options that could be used to implement these actions have been identified for each general response and are listed in Appendix B. Specific application of these technology types and process options to site conditions was evaluated to determine which would be most appropriate for site remediation. These technologies were screened on the basis of effectiveness, implementability, and cost, as defined by the following factors:

- Effectiveness — in terms of protecting human health and the environment in both the short term and the long term;
- Implementability — in terms of technical feasibility, resource availability, and administrative feasibility; and
- Cost — in a comparative manner (i.e., low, moderate, or high) for technologies of similar performance and/or implementability.

These screening criteria were applied only to the technologies and general response actions being evaluated and not to the site as a whole (i.e., combined site problems). This comprehensive evaluation is applied only after alternatives have been assembled from the appropriate technologies (in Chapter 4). Effectiveness was the major emphasis of this screening evaluation. Additional discussion of these criteria is provided in Section 4.3.

The no-action response (i.e., no further action beyond ongoing interim actions) was also included in this evaluation to provide a baseline for comparison, and it is evaluated as an alternative in Chapters 4 through 7. The technology types and process options identified for the other response actions (Appendix B) were screened for applicability to the various media at the site. Potentially applicable technologies are discussed and the results of the screening process are presented in Section 3.2.

3.2 TECHNOLOGY IDENTIFICATION AND SCREENING

3.2.1 Institutional Controls

Institutional controls are measures that preclude or minimize public exposure by limiting access to or use of contaminated areas. Institutional controls include measures to restrict access, such as security guards, ownership and use or deed restrictions, and monitoring; these measures could be applied to each of the contaminated media at the site. Institutional controls do not reduce contaminant toxicity, mobility, or volume, but they can reduce the potential for exposure to contaminated material. Institutional control measures that apply solely to groundwater, such as groundwater restrictions, may be used to prohibit or limit the drilling of new wells or prohibit the temporary use of existing wells. Groundwater response actions will be evaluated in detail as part of the future groundwater operable unit for the site. These and other institutional controls are described in this FS as they may relate to an interim or contingency response for groundwater, e.g., in the event of failure of a containment system.

The screening analysis for institutional controls is summarized in Table 3.1. On the basis of effectiveness, implementability and cost, all institutional controls have been retained. The most significant control at the site is land ownership. As long as DOE maintains custody of the Weldon Spring site and the U.S. Department of the Army and the state of Missouri own the surrounding areas, the potential for significant public exposure will remain low because land use can be controlled and access to contaminated areas can be restricted.

3.2.2 In-Situ Containment

In-situ containment consists of technologies that confine contaminated media at their current locations. These technologies reduce contaminant mobility and the associated potential for exposure, but they do not reduce contaminant toxicity or volume. In-situ containment technologies include surface controls/diversions, caps and other surface seals, lateral barriers, and bottom seals.

Surface controls/diversions are used to divert surface runoff around contaminated areas to minimize the potential for contaminant resuspension. Graded contours, swales, and berms can effectively control surface water runon and runoff and can limit the mobility of contaminants. These measures have been effectively used on-site (e.g., at the Ash Pond area). Sedimentation basins could also be used in conjunction with surface controls/diversions for surface water control. These measures would not, however, be effective for the off-site surface waters (lakes) that are hydrologically connected to each other and to the local groundwater system.

A contaminated area can be encapsulated by placing barriers on top (caps), on the sides (lateral barriers), and beneath (bottom seals). 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 prior to cap placement. In-situ capping of the raffinate pit sludge would be extremely difficult and, prior to capping, would necessitate dewatering of the sludge after the ponded water was removed to increase its weight-bearing capacity. Subsurface contamination can be isolated through the use of lateral barriers and bottom seals such as slurry walls or grout curtains. The effectiveness of lateral barriers and bottom seals would be constrained by the large size of the affected area (more than 10 ha [25 acres]) and the nature of the site-specific hydrogeological conditions (i.e., weathered limestone in the upper zone of the bedrock).

In-situ containment technologies applicable to structural material and debris include application of paint, foam, or emulsions. Such applications can effectively control releases from contaminated surfaces.

The screening analysis for in-situ containment is summarized in Table 3.2. All in-situ containment technologies have been retained for on-site activities. However, these technologies are not applicable to off-site surface water impoundments (i.e., Lakes 34, 35, and 36).

TABLE 3.1 Summary of Screening Analysis for Institutional Controls

Institutional Control Measure	Affected Medium[a]	Effectiveness	Implementability	Cost
Access restrictions	All	The site is fenced, and entry is controlled by security guards; these measures mitigate potential public exposure to contamination on-site by restricting entry. The adjacent Army property is also fenced, and public access is restricted; these measures mitigate potential public exposure to localized areas of vicinity property contamination. In addition, worker access to contaminated areas within the perimeter fence is restricted by an access control station, internal fences, ropes, and signs; these measures mitigate potential worker exposure to contamination on-site.	Fences, guards, and other such measures are easy to implement, and resources are readily available.	Low
Ownership and use or deed restrictions	All	The DOE has custody of the site and is expected to maintain this custody and accountability for as long as waste remains there. This measure permits the control of public exposures to on-site contamination by restricting access and use. The Army owns land adjacent to the site, which mitigates potential public exposure to localized areas of radioactive contamination on that property. The state owns the surrounding wildlife areas, and recreational use limits the extent of exposures; swimming is not allowed in the affected lakes because of physical hazards such as submerged stumps.	Ownership and use or deed restrictions are easy to implement, and resources are readily available.	Low
Monitoring	All	An extensive environmental monitoring program is in place at the site, and additional monitors will be employed during upcoming response actions, e.g., during quarry bulk waste activities and building dismantlement. This measure can support the mitigation of potential exposures by providing data on the nature and extent of contamination and the effectiveness of primary control measures such as containment or removal.	Monitoring is easy to implement, and resources (e.g., air, surface water, and soil sampling equipment and groundwater monitoring wells) are readily available.	Moderate
Groundwater restrictions	Groundwater	Fences or other barriers such as well caps can control exposures to contaminated groundwater. Groundwater response actions will be evaluated in detail as part of the groundwater operable unit.	These measures can be easy to implement, and resources are readily available.	Low

[a] Potentially affected media include soil, sludge, sediment, surface water, groundwater, structural material, process chemicals, and vegetation.

TABLE 3.2 Summary of Screening Analysis for Containment

In-Situ Containment Measure	Affected Medium	Effectiveness	Implementability	Cost
Surface controls/ diversions	Soil, sludge, sediment, surface water	Diversions — such as graded contours, swales, or berms — can effectively reduce contaminant mobility at the site. A diversion system is currently in place at the Ash Pond area. Frog Pond currently serves as a siltation pond, and the TSA and MSA each include a retention pond to mitigate contaminant release via overland flow. Such measures would not be effective for containing off-site surface water due to the interconnected hydrology of that area.	Can be implemented with conventional equipment and procedures, and resources are readily available.	Low
Caps and covers	Soil, sludge, sediment, process chemicals	Caps and covers can effectively limit airborne emissions (including radon) and external gamma radiation, and they can also reduce precipitation-enhanced percolation and leaching. Consolidated chemicals and asbestos-containing material are currently containerized and covered in enclosed systems for short-term storage, and materials stored at the TSA and the MSA that are susceptible to erosion will be covered as needed (e.g., with tarps), as an interim measure pending final disposition.	Can be implemented with conventional equipment and procedures, and resources are readily available. Dewatering the raffinate pit sludge would be required prior to capping, and capping the sludge would be extremely difficult.	Low to moderate
Lateral barriers	Soil, sludge, sediment, surface water	A lateral barrier — such as a slurry wall, grout curtain, or sheet piling — can reduce lateral migration, provided the barrier can be properly installed. The effectiveness of this measure would be constrained by the size of the target area and by hydrogeological conditions at the site, such as weathering in the upper zone of the bedrock and depth to bedrock.	Can be implemented with conventional equipment but could be constrained by site-specific conditions. It is difficult to obtain very low permeabilities in barriers constructed in unconsolidated material.	Moderate to high
Bottom seals	Soil, sludge, sediment, surface water	Bottom seals have been incorporated in the construction of the new equalization basin for the site water treatment plant to preclude downward contaminant migration. For the existing impoundments, a subsurface bottom seal such as an injected grout layer can effectively reduce downward contaminant migration, provided the seal can be properly installed. The effectiveness of this measure would be constrained by the size of the target area and by site-specific hydrogeological conditions, such as weathering and depth to bedrock.	Can be implemented with conventional equipment but could be constrained by site-specific conditions. It is difficult to obtain sufficiently low permeabilities in seals constructed in unconsolidated material.	Moderate to high
Surface seals	Structural material	Surface sprays, sealants and emulsions can effectively control releases from contaminated surfaces for at least the short term. Surface seals have previously been used in the chemical plant buildings to mitigate potential releases and worker exposures.	Can be implemented with conventional equipment and procedures, and resources are readily available.	Low

3.2.3 Removal

Removal of contaminated material can limit contaminant mobility and volume at the affected source area and can facilitate treatment and disposal that could reduce contaminant toxicity, mobility, and volume. Removal measures can be applied to all affected media at the site, and the appropriate technology and process option is a function of the physical properties of the medium.

Removal of surface water at the site has been addressed as part of a previous response action (MacDonell et al. 1990), and removal of groundwater is beyond the scope of this action (Section 1.5.3). However, two types of groundwater removal technologies are briefly described here as they pertain to the ability to capture groundwater as a contingency, e.g., in the event of the failure of an on-site waste containment or disposal technology. Groundwater removal technologies will be evaluated in detail as part of the environmental documentation that will be prepared for the separate groundwater operable unit.

Technologies to remove contaminated groundwater include passive interceptor systems and pumping well systems. Passive interceptor systems consist of trenches or drains excavated to a depth below the water table and a collection pipe placed in the bottom of the trench. Interceptor drains are generally used either to lower the water table beneath a contamination source or to collect groundwater from an upgradient source in order to prevent further contamination of groundwater or surface water. Interceptor systems are generally very effective and can be relatively inexpensive to operate, but they may be difficult to install depending on the depths required (EPA 1987a). Such a system could be used effectively at the raffinate pits to collect perched water from beneath the pits. (A trench constructed during site preparation activities for the TSA, as part of the quarry bulk waste interim action, is currently intercepting this perched water.) Pumping well systems are used for hydrodynamic control of contaminated groundwater by manipulating the hydraulic gradient of groundwater through injection and/or withdrawal of water. Well systems require the installation of several wells at selected sites. These systems can offer a high degree of design flexibility, but their applicability at the Weldon Spring site could be constrained by the hydrogeological conditions.

Excavation with conventional earth-moving equipment (e.g., bulldozers, backhoes, and front-end loaders) can effectively remove bulk material such as soil, sludge, sediment, and material stored in the TSA and MSA. However, hydraulic dredges and pumps would be much more effective for the raffinate pit sludge because of its high water content. Hydraulic dredging of the raffinate pit sludge would allow for removal of the sludge while maintaining a water cover on the surface of the sludge to control airborne releases of fine-grained material and radon gas (MK-Ferguson Company and Jacobs Engineering Group 1992a). Following dredging of the raffinate pit sludge and removal of the remaining water, contaminated clay and other soil underlying the pits could be excavated with conventional earth-moving equipment. The water content of the underlying material would determine the specific removal method selected (e.g., draglines and backhoes).

The Missouri Department of Conservation plans to drain Lakes 34, 35, and 36 within the next several years in order to remove collected sediments under its routine sedimentation management program. After the lakes are drained, DOE would remove the contaminated sediment with standard earth-moving equipment; contaminated vegetation, if present, would be removed with standard clearing and grubbing techniques. This would limit the mobility of contaminants at those locations and reduce related exposures (e.g., via biouptake).

Decontamination is an effective removal technology for structural material, which for this discussion is the general representation for material associated with chemical plant structures, including metal, concrete, roofing material, equipment, tanks, and decontamination debris. Site structures are being decontaminated and dismantled as part of an interim action (Section 1.5.1). Further decontamination of the structural material following dismantlement could be an effective means of reducing the mobility and volume of contaminated material and supporting potential recycle and resource recovery for surficially contaminated structural steel. Decontamination could be accomplished by process options such as vacuuming, wiping, or washing contaminated surfaces, or by more aggressive techniques such as liquid abrasive blasting or hydrolasing (use of a high-speed water jet). Decontamination to meet site release criteria might be possible for concrete slabs or structural steel. A semiautomatic hydrolasing system is considered a potential in-situ technology for decontaminating concrete slabs at the Weldon Spring site. This method would not be implemented for concrete slabs with deep cracks (>2.5 cm [>1 in.]) or volumetric contamination. In addition, in order for the concrete to be releasable following excavation, the soil surrounding the slabs would have to be free of contamination. Hydrolasing would not be used on excavated concrete pieces because separate chunks could be susceptible to disintegration and fugitive emissions.

Liquid abrasive blasting could be used to decontaminate the structural steel at the Weldon Spring site. This method is not effective for use on steel with microcracking or with large areas that are inaccessible. Decontamination of accessible structural steel surfaces has been retained as a potential means of reducing waste volume and possibly allowing for material reuse.

The screening analysis for removal is summarized in Table 3.3. On the basis of this evaluation, the technologies of excavation, dredging, pumping, and decontamination have been retained as potentially applicable to site cleanup.

3.2.4 Treatment

Treatment encompasses a wide range of chemical, physical, and biological technologies that address various types of contamination in different media. Treatment can result in the permanent and significant reduction of contaminant toxicity, mobility, and/or volume. The specific reduction depends on the type of material and contamination being treated; the toxicity of radiation from site waste would not be affected by any treatment method. A wide variety of treatment technologies was considered for applicability to the Weldon Spring site (see Appendix B). The applicability of these technologies has been evaluated in detail in supporting documents (MK-Ferguson Company and Jacobs Engineering Group 1992a, 1992b, and the references cited therein). Potential chemical, physical, and biological treatment technologies were screened in this evaluation in terms of effectiveness, implementability, and cost. Treatment

TABLE 3.3 Summary of Screening Analysis for Removal

Removal Measure	Affected Medium	Effectiveness	Implementability	Cost
Excavation	Soil, sludge, sediment	Can effectively remove the source of contamination to limit contaminant mobility and volume at the affected area and reduce related exposures. Soil has been excavated successfully at contaminated vicinity properties under interim actions.	Can be implemented with conventional equipment and procedures, and resources are readily available.	Moderate
Dredging and pumping	Sludge, sediment	Can effectively remove the source of contamination to limit contaminant mobility and volume at the affected area and reduce related exposures.	Can be implemented with conventional equipment and procedures, and resources are readily available.	Moderate
Interception and pumping	Surface water, groundwater	Can effectively remove the source of contamination to limit contaminant mobility and volume at the affected area and reduce related exposures. On-site surface water will be pumped from various impoundments for on-site treatment under an interim action. Perched groundwater beneath the raffinate pits is currently being intercepted by a trench constructed as part of site preparation activities for the TSA, under the quarry bulk waste interim action.	Can be readily implemented with conventional equipment and procedures for surface water. Pumping or interception of groundwater can be constrained by site-specific conditions.	Low to moderate
Decontamination	Structural material	Can effectively remove contaminants from structural material to limit related exposures; such material is currently being decontaminated under the interim actions for site structures, which include asbestos and PCB removal activities.	Relatively straightforward to implement with conventional equipment and procedures. Secondary waste generated during decontamination must be managed.	Low to moderate
Dismantlement	Structural material (short-term storage and treatment facilities)	Can effectively remove contaminated structures to limit related exposures. Chemical plant buildings are currently being dismantled under interim actions, and facilities associated with site cleanup activities will also be dismantled after their purposes have been served.	Can be implemented with conventional equipment and procedures, and resources are readily available.	Moderate
Clearing and grubbing	Vegetation	Can effectively remove vegetation from site surfaces to limit contaminant mobility and volume at the affected area and reduce related exposures (e.g., via biouptake). Vegetation has been effectively removed by these measures to support interim actions, e.g., to construct the water treatment plant, MSA, and TSA.	Can be implemented with conventional equipment and procedures, and resources are readily available.	Low

of impounded surface water has been addressed as part of a previous response action (MacDonell et al. 1990), and treatment of groundwater is beyond the scope of this action (Section 1.5.3); groundwater will be addressed in detail as part of a separate operable unit. As part of a contingency response for groundwater in the upper aquifer, or to address perched groundwater beneath the raffinate pits, the water could be pumped to the treatment plant adjacent to the pits for treatment. Effluent from the treatment plant would be discharged to the Missouri River, in compliance with an existing permit from the state of Missouri. The site water treatment system has been designed with the capability to treat a variety of contaminants over a range of concentrations, including those present in the groundwater. Therefore, the facility would be available to treat such water, if it were deemed appropriate during the overall remedial action period.

3.2.4.1 Chemical Treatment Technologies

Several chemical treatment technologies are available for treating contaminated soil, sludge, sediment, water, and structural material (Appendix B). These technologies could be implemented in situ or following removal of the contaminated media. Process chemicals such as the process wastes from the project's two water treatment plants could also be chemically treated. The evaluation of potential technologies for site application in terms of effectiveness, implementability, and cost is summarized in Table 3.4.

Stabilization/Solidification. Stabilization/solidification technologies are those in which a fixing or stabilizing agent is mixed into the waste medium to create a product that is stable and resistant to leaching. Chemical stabilization/solidification could be applied in situ to fix contaminated material and limit the mobility of waste constituents, e.g., at the raffinate pits and at scattered soil locations across the site. In this process, additives are mixed directly into contaminated material by conventional backhoes or dragline cranes or equipment specifically designed for in-situ chemical injection and mixing. The chemical stabilization/solidification process can also be implemented following waste removal. This process involves mixing reagents with contaminated material in a mixing vessel, such as a pug mill, to immobilize the contaminants and solidify the waste.

The predominant fixing agents currently in use are Portland cement, lime/fly ash, Portland cement/fly ash, Portland cement/lime, and Portland cement/sodium silicate. Gypsum, bentonite, and zeolites could also be used, as could a number of proprietary agents. Chemical stabilization with cement and fly ash is an established practice for treating low-level radioactive and chemically hazardous waste. Gilliam and Francis (1989) have studied the use of Portland cement/fly ash to stabilize the raffinate pit sludge. Their study indicated that a blend of Type II Portland cement and ASTM* Class F fly ash combined with the sludge at a ratio of 0.6 g of reagent blend per gram of sludge produced a product passing the study design restrictions for

*ASTM = American Society for Testing and Materials.

TABLE 3.4 Summary of Screening Analysis for Chemical Treatment Technologies

Treatment Measure	Affected Medium	Effectiveness	Implementability	Cost
In-situ soil flushing, chemical addition/ detoxification	Soil, sludge, sediment	Soil flushing might reduce contaminant toxicity, mobility, and volume in certain applications by desorptive reactions in which a contaminant-specific reagent is sprayed or ponded over the contaminated area for treatment in situ. Chemical addition/detoxification might reduce the toxicity and mobility of certain contaminants via chemical reactions such as oxidation/reduction reactions that can alter a specific toxicity or solidify the material to limit mobility. However, these reactions can increase volume (e.g., through a precipitation reaction), and undesirable chemicals may remain following treatment. Soil flushing is typically ineffective for metals and radionuclides, which predominate at the site, and it would not alter the toxicity of metals or radiation from site waste.	Difficult to implement in situ because of variable soil conditions and low-permeability material that could impede percolation and contact with reagents. Certain processes would require special equipment and expensive reagents.	High
Leaching/contact extraction (including reprocessing)	Soil, sludge, sediment	Might reduce contaminant toxicity, mobility, and volume in certain applications by desorptive reactions in which a leaching reagent is applied to the contaminated media for treatment in situ or following removal. Typically used to remove organic contaminants, but can be used to remove some inorganic contaminants. In-situ applications could result in groundwater contamination from the leached reagents. Reprocessing of the raffinate pit sludge could potentially reduce the volume of material requiring disposal if the radionuclides were recovered from the sludge and a nonradioactive residue were generated. However, the effectiveness of this process is constrained by the generation of large quantities of secondary waste (radium-bearing gypsum) and the inability of the method to achieve the recovery efficiencies required to generate a releasable residual. The toxicity of metals or radiation from site waste would not be altered.	Difficult to implement for soil because of scattered contamination, variable physical conditions, and low permeability that could impede percolation and contact with reagents. Certain processes would require special equipment and expensive reagents. Leaching within the vadose zone would result in uncontrolled movement of leached reagents. Reprocessing the raffinate pit sludge following removal would be extremely difficult because filters, pipes, and screens would be plugged by gypsum, the suspended particle load would be high (which would impede the solvent extraction process), and additional waste would be generated; nitrate, ammonia, and chloride contamination and unrecovered metals and metalloids within the reprocessed residual would render the recovered material unreleasable.	High

TABLE 3.4 (Cont.)

Treatment Measure	Affected Medium	Effectiveness	Implementability	Cost
In-situ stabilization/solidification	Soil, sludge, sediment	Might limit the mobility of metals and radionuclides. The in-situ process is constrained by the size of the target area, the nature of the waste material, and the physical conditions of the contaminated areas. Contaminant mobility would be reduced but contaminant toxicity would not, and final waste volume would increase.	Somewhat difficult to implement because of the considerable areal extent and depth of the raffinate pit sludge and the scattered nature of soil contamination.	High
Stabilization/solidification following removal	Soil, sludge, sediment, process chemicals	Can effectively limit the mobility of metals, radionuclides, and chemical contaminants. The constraints of the in-situ process are eliminated by treating the materials in an engineered system. Contaminant mobility would be reduced but contaminant toxicity would not. Final waste volume would increase.	Can be easily implemented with readily available equipment and materials, such as a pug mill mixer and cement and fly ash.	High
Chemical addition following removal (e.g., lime addition, neutralization)	Surface water, groundwater	Can effectively reduce the toxicity, mobility, and volume of contaminated water by removing the contaminants from solution. A water treatment plant will be available to treat contaminated surface water at the site under an interim action. This system could also be used to treat groundwater, as appropriate, e.g., the perched groundwater intercepted from beneath the raffinate pits.	Can be easily implemented with readily available resources. A water treatment plant that includes chemical treatment components is being constructed at the site under an interim action.	Moderate

strength and free liquids. Type I Portland cement and ASTM Class C fly ash resulted in a product that decreased in compressive strength over time due to deterioration in the waste form structure; this deterioration was the result of the formation of ettringite (a hydrous basic sulfate of calcium and aluminum), which can reduce the strength of the treated product. A blend of ASTM Class C fly ash, lime, and Type I Portland cement can also result in the formation of ettringite and was therefore rejected for use as chemical stabilization/solidification agents for the Weldon Spring sludge and soil. Fixing agents containing only soluble silicates tend to result in a solidified product containing excess free water, which could leach the solid product. Other blends, e.g., cement/silicate, are widely used and can stabilize wastes containing metals, solvents, and oils. These fixing agents could also be used for the raffinate pit sludge. Additional bench-scale and pilot-scale tests would be required to determine the best reagent and reagent/waste blend.

Other fixing agents that have been used to stabilize/solidify wastes include thermoplastic agents such as bitumen and polymerization agents such as urea formaldehyde. Both of these reagent types are used mainly for stabilization of radioactive waste from nuclear power plants; in this process, the dewatered waste is coated with a resin, such as an organic polymer, and the entire mass is thermoset to form a waste-binder block. Because certain organic compounds diffuse quite rapidly through this type of material, thermoplastic encapsulation of the nitroaromatic-contaminated soil at the Weldon Spring site would not be as effective as other methods (MK-Ferguson Company and Jacobs Engineering Group 1992a). Swelling and cracking of the encapsulated surface could be caused by rehydration of the dehydrated salts that might form in the sulfate-rich, dewatered raffinate pit sludge. The main disadvantage of thermoplastic and polymerization systems is the potential for long-term degradation of some waste forms. High equipment and energy costs are also associated with these processes. Because of these factors, thermoplastic and polymerization systems were rejected from further consideration for the Weldon Spring waste. Chemical stabilization/solidification with a Type II Portland cement and Class F fly ash blend was retained.

Chemical Addition/Detoxification. Chemical addition/detoxification technologies encompass a wide range of processes in which chemical reagents are added to a waste matrix, and the resulting chemical reactions reduce the toxicity or mobility of certain contaminants or remove contaminants from the waste matrix for further treatment or disposal. These technologies, e.g., precipitation and oxidation/reduction, are highly contaminant specific and would not be effective for treating the various contaminants of concern at the Weldon Spring site because of the variable types and concentrations of site contaminants, the differing waste matrix properties, and the potential for interferences due to the presence of several contaminants within one medium. Another complicating factor relative to the Weldon Spring waste is the wide variability of waste composition over the media of concern at the site. Therefore, this technology type is rejected from further consideration for site waste.

Extraction. Extraction technologies include leaching, solvent flushing, and reprocessing. Leaching and nonaqueous soil flushing are typically used for treating single contaminant classes (e.g., volatile organic compounds), and each contaminant requires a specific treatment method. Contaminant-specific processes would, in general, be ineffective for treating the complex mixture of contaminants in the soil, sludge, and sediment at the chemical plant area. The variable chemical and physical soil conditions and the presence of low-permeability material would interfere with these processes and reduce percolation or contact with the surfactant (Holden et al. 1989). In addition, some of these processes would require special equipment and high-cost reagents, and could result in undesirable chemicals being left in the treated material.

In-situ leaching can be applied to unexcavated soil or other material to mobilize contaminants for subsequent recovery via groundwater extraction. This process is typically applied to remove organic contaminants; however, depending on site conditions, inorganic constituents might also be removable. To be effective, in-situ leaching generally requires that the contaminated zones occur within the water table, preferably within an aquifer that is situated between aquitards or aquicludes. The nature of the contaminants and the hydrogeological conditions at the Weldon Spring site are not conducive to this technology. The locations of contaminated soil and sediment at the site are scattered, and the contaminants are not generally within the water table. Attempted in-situ leaching of vadose zone contamination would probably result in the uncontrolled movement of the leaching reagents. Those reagents that were recovered, such as ammonium carbonate, would have to be removed from the extracted groundwater along with the leached contaminants to achieve acceptable concentrations for release or reinjection. Leaching reagents are difficult to remove from in-situ leached aquifers (MK-Ferguson Company and Jacobs Engineering Group 1992a), and in-situ leaching of on-site soil could result in groundwater contamination. Treatment of excavated soil by this technology might be effective for sandy or silty soil, depending on the contaminants, but the technology has not been demonstrated on finely divided soils such as clay because of difficulty in separating the extractant from the soil (MK-Ferguson Company and Jacobs Engineering Group 1992a).

In-situ leaching/extraction of the raffinate pit sludge would be similarly difficult because the sludge contains a complex mixture of contaminants that vary both laterally and vertically within each pit. In addition, the sludge is very fine grained and would impede circulation of the leaching solution.

An extraction process could also be applied to the sludge following its removal from the raffinate pits. Reprocessing the sludge would involve acid- or alkaline-based dissolution of uranium, thorium, and radium and their sequential recovery by solvent extraction and precipitation techniques. The objective of this treatment method would be to generate potentially usable products in which the radioactive material would be concentrated and a nonradioactive residual that could be disposed of without restrictions. Application of this technology to the raffinate pit sludge is constrained by the chemical processes involved and the recovery efficiencies required to generate a releasable residual and thus reduce the volume of material requiring disposal. Such a process has never been successfully employed in the hazardous waste, mining, or uranium/thorium concentrate-processing industries (MK-Ferguson Company and Jacobs Engineering Group 1992a).

Four techniques commonly used to process uranium and thorium ores or concentrates could potentially be used to reprocess the raffinate pit sludge: (1) nitric acid leach/tributyl phosphate solvent extraction, (2) sulfuric acid leach/organic amine solvent extraction, (3) hydrochloric acid leach/solvent extraction, and (4) sodium carbonate-ammonium hydroxide leach/solvent extraction. However, these techniques are used to recover only uranium or thorium, not both metals sequentially, and they are inappropriate for reprocessing the fine-grained, calcium-rich raffinate sludge. A nitric acid leach/tributyl phosphate solvent extraction method was formerly used at the Weldon Spring site to process uranium and thorium concentrates, and it was neutralization of the resultant waste streams with lime that originally generated the raffinate sludge. The calcium-rich raffinate sludge cannot now be effectively releached with sulfuric acid because reaction between the sulfuric acid and calcium would cause the formation of large amounts of radium-bearing gypsum, and this gypsum would plug screens, filters, and pipes (MK-Ferguson Company and Jacobs Engineering Group 1992a).

It is also unlikely that the other techniques commonly employed to process uranium and thorium ores or concentrates could achieve the required treatment efficiency. Although an alkaline-leach process would be more appropriate for the raffinate sludge (which is high in calcium carbonate), such a process is usually relatively inefficient, with recoveries ranging from 75 to 85%. Moreover, nitrate, ammonia, or chloride contamination caused by the leaching reagents, as well as unrecovered metals and metalloids within the reprocessed residual, would render the residuals unreleasable (MK-Ferguson Company and Jacobs Engineering Group 1992a). Thus, the waste volume would increase by this treatment, without an offsetting benefit.

Reprocessing methods used in acid-leach uranium mills, which are carefully designed to maximize uranium recovery from ore, typically extract 85 to 95% of the uranium in the leach cycle. Solvent extraction efficiencies of more than 99% would be needed for uranium, thorium, and radium recovery to produce a releasable residual from the raffinate pit sludge, and none of the available reprocessing methods are likely to achieve such efficiencies. A relatively suspension-free aqueous liquor is required to react with the extracting organic reagent in solvent extraction systems. The raffinate sludge, which is fine grained, would be difficult to remove from suspension. Consequently, the effective solvent extraction of uranium, thorium, and radium would be unlikely (MK-Ferguson Company and Jacobs Engineering Group 1992a). Reprocessing of the raffinate pit sludge was evaluated for both resource recovery and waste reduction. Although the cost of constructing such a reprocessing plant at the Weldon Spring site (estimated at $55 million [MK-Ferguson Company and Jacobs Engineering Group 1992a]) would far outweigh any potential economic benefits associated with recovering uranium and thorium from this material, the reprocessing technology was eliminated not because of cost but because existing technology cannot be applied to the Weldon Spring waste to meet the objective of either resource recovery or volume reduction. Reprocessing and other chemical extraction methods were therefore eliminated from further consideration.

3.2.4.2 Physical Treatment Technologies

Several physical treatment technologies are available for treating contaminated soil, sludge, sediment, water, and structural material (Appendix B). These technologies could be implemented in situ or following removal of the contaminated media. Process chemicals such as the process wastes from the project's two water treatment plants could also be treated by certain physical technologies (e.g., thermal treatment). The evaluation of potential technologies for site application in terms of effectiveness, implementability, and cost is summarized in Table 3.5.

Dewatering. Dewatering could be effective for treating the raffinate pit sludge to reduce waste volume or as a pretreatment step to facilitate the implementation of additional treatment processes (such as vitrification). The water removed by dewatering could be treated in the water treatment plant at the site. The sludge could be dewatered in situ by pumping or by installing gravity drainage trenches. However, the implementation of these processes would be constrained by the low permeability of the fine-grained sludge, and operational difficulties would result. Dewatering of the sludge following removal (e.g., by dredging) could be accomplished with centrifuges, cyclones, filters, or presses or a combination of these techniques. Solids contents of about 85 and 75%, respectively, are commonly achieved in industry through the use of (1) cyclones, plate thickeners, and filter tables or (2) a belt press, screen, and flocculation (MK-Ferguson Company and Jacobs Engineering Group 1992a). Dewatering treatability tests are being conducted to determine expected solids contents for the raffinate pit sludge. If these systems would not adequately remove excess water, thermal drying might be required as a pretreatment process step.

Dewatering is considered applicable to site cleanup activities and was retained as a treatment/pretreatment technology. It could be used as a support process to improve the subsequent treatment of certain site waste (e.g., for raffinate pit sludge and sediment if thermal treatment were selected).

Solids Separation. Technologies for solids separation include screening, hydraulic or spiral classification, and cyclone centrifugation. Such techniques have been used in the mining industry to segregate minerals that have significantly different densities and settling velocities than the host sediment — e.g., to separate gold, platinum, chromium, and tin from quartz sand. These techniques are only developmental for waste treatment applications. Significant volume reduction by physical separation methods requires the contaminant to be concentrated within, or adhered to, a volumetrically small fraction with a specific grain size, which must then be removed from the host material. It is very unlikely that any separation technology could meet the high separation efficiencies required to significantly reduce the volume of contaminated material at the Weldon Spring site. Contaminants in the soil, sludge, and sediment are not concentrated on a specific grain size that could be easily removed by separation techniques. Solids separation would, therefore, be generally ineffective for the site waste. Furthermore, technologies such as wet screening or classification would probably mobilize considerable amounts of certain contaminants, thereby further distributing the contamination instead of separating out an uncontaminated fraction (MK-Ferguson Company and Jacobs Engineering Group 1992a). Therefore solids separation has been rejected from further consideration for the site.

TABLE 3.5 Summary of Screening Analysis for Physical Treatment Technologies

Treatment Measure	Affected Medium	Effectiveness	Implementability	Cost
In-situ dewatering	Sludge, sediment	Could effectively reduce contaminant volume and solution mobility, but toxicity would remain unchanged. Solar evaporation would be less effective than energy-intensive processes. The effectiveness of in-situ dewatering is constrained by the drainage characteristics of the fine-grained sludge and sediment.	Standard processes such as gravity drainage trenches and in-situ pumping would be somewhat difficult to implement because of the physical characteristics of the sludge and sediment, i.e., the low permeability and small particle size.	Moderate to high
Dewatering following removal	Sludge, sediment	Could effectively reduce contaminant volume and solution mobility, but contaminant toxicity would remain unchanged. Process waste from the water treatment plants will be dewatered under an interim action.	Can be implemented with standard equipment and procedures. A dewatering system is being constructed as part of the site water treatment plant to treat the process waste.	Moderate
Nonthermal extraction (e.g., soil washing) and thermal extraction (e.g., steam extraction) in situ and following removal	Soil, sludge, sediment	The toxicity, mobility, or volume of contaminants might be reduced in certain applications by a physical sweeping process that mobilizes and separates contaminants from the matrix. This separation would result from either injecting or spraying/ponding water on the contaminated area in situ or mixing the matrix with water in a vessel following excavation. However, this process is typically ineffective for separating contaminants from fine-grained materials such as those present at the site.	Difficult to implement because the low-permeability clay layers and the fine-grained nature of the sludge would limit effective contact and mobilization.	Moderate
In-situ vitrification	Soil, sludge, sediment	Could reduce contaminant toxicity, mobility, and volume in certain applications. Off gas produced by the process would require collection and treatment. This in situ process is constrained by the nature of the waste and the physical conditions at the contaminated areas. The poor quality of the raffinate pit sludge (e.g., low silicate levels) would adversely impact process effectiveness. Additives would be required, and treatment optimization would be difficult. The toxicity of certain limited contaminants (e.g., nitroaromatic compounds) would be reduced, but the toxicity of retained metals and radiation from the site waste would not.	Difficult to implement because of the insufficient glass-forming material in the raffinate pit sludge and the considerable areal extent and depth of contamination. In addition, monitoring and verification would be very difficult.	High

TABLE 3.5 (Cont.)

Treatment Measure	Affected Medium	Effectiveness	Implementability	Cost
Vitrification following removal				
Joule-heated ceramic melter	Soil, sludge, sediment, process chemicals	Generally similar to in-situ vitrification but with fewer constraints. A bench-scale study of this vitrification method has been conducted for raffinate pit sludge; additives were required to produce a glassy product, and the need for considerable optimization was apparent.	Somewhat difficult to implement because of the innovative nature of this technology for most waste treatment applications. Joule-heated ceramic melting requires melt-modifying additives and material sizing prior to treatment, and the system is difficult to adjust for variations in feed parameters. This process is currently being used to treat high-level radioactive waste, but the availability of equipment is somewhat limited. Energy requirements are substantial, and off-gas emissions and operational safety are considerations.	High
Fossil fuel-heated ceramic melter	Soil, sludge, sediment, some metal debris, process chemicals	Generally similar to the joule-heated ceramic melter, with additional applicability for treating sized metal material such as steel pipes and beams.	Generally similar to the joule-heated ceramic melter but more amenable to variations in feed characteristics. This process has been adapted from the commercial glass-making industry for application to contaminated material, but it is developmental for waste applications. Equipment for glass making is widely available.	High
Plasma arc furnace	Soil, sludge, sediment, some metal debris, process chemicals	Generally similar to the fossil fuel-heated ceramic melter.	Generally similar to the fossil fuel-heated ceramic melter. The plasma arc torch process has been adapted from the commercial metal-melting industry for application to contaminated material, but it is developmental for waste applications.	High
Incineration following removal				
Rotary kiln incineration	Soil, sludge, sediment, vegetation, process chemicals	Typically used for treating organic waste, this process reduces waste volume and the toxicity of some contaminants. It oxidizes combustible wastes to gases and generates an ash residue that is susceptible to leaching and typically requires treatment or restrictive disposal. The presence of volatile metals such as mercury in the raffinate pit sludge would result in an off gas requiring treatment.	Implementation would be difficult because of the effects of various site-specific waste characteristics on the treatment system. Sodium would cause slagging and impede solids removal, the high moisture content of sediment and sludge would make incineration inefficient, and the fine-grained particle size of this material would tax an off-gas treatment system.	High

TABLE 3.5 (Cont.)

Treatment Measure	Affected Medium	Effectiveness	Implementability	Cost
Incineration following removal (cont.)				
Fluidized bed incineration	Soil, sludge, sediment, vegetation, process chemicals	Generally similar to rotary kiln incineration.	Generally similar to rotary kiln incineration, with additional constraints associated with the low operating throughput rate and the need to remove residuals and ash from the bed.	High
Slagging incineration	Soil, sludge, sediment, vegetation, process chemicals	Could destroy organic contaminants, reduce waste volume, and limit the mobility of inorganic contaminants by incorporation into a solid slag. Combustible wastes are oxidized or pyrolyzed, and nonvolatile, noncombustible contaminants are contained within the granular vitrified product or slag. The spent refractory would be contaminated with radionuclides and metals if this process were applied at the site. The toxicity of retained metals and radiation from the site waste would not change.	Generally similar to rotary kiln incineration, with the additional constraint of susceptibility to acid and metal halide attack and abrasion. This would necessitate frequent replacement of the refractory, which would result in processing delays.	High
Liquid injection incineration	Liquid process chemicals	Can effectively destroy organic contaminants; this process would require an emission control system.	The consolidated liquid process chemicals could be incinerated at an approved incinerator.	Moderate
Metal-melt refining	Structural material	Could reduce contaminated waste volume by partitioning structural material into a slag phase containing higher concentrations of radionuclides and a metal phase with reduced concentrations of radionuclides. However, this process would generate an off gas requiring treatment. Radiation toxicity would not be altered.	Administrative feasibility could be low because this process produces a volumetrically contaminated material, for which no standards have been established for unrestricted release. Waste treatment applications are limited, and decontaminating structural debris contaminated with radionuclides by this energy-intensive process has only been demonstrated on a limited basis. Resource availability is limited, and off-site transport would be required if the commercial facility near Oak Ridge, Tennessee, were used.	High

TABLE 3.5 (Cont.)

Treatment Measure	Affected Medium	Effectiveness	Implementability	Cost
Other thermal treatment following removal (e.g., molten salt process, flaring, wet-air oxidation, supercritical water oxidation, and infrared incineration)	Soil, sludge, sediment, structural material, process chemicals	Could destroy organic contaminants but is generally ineffective for treating radionuclides and inorganics, which predominate at the site. The toxicity of radiation from site waste would not be altered.	Would be very difficult to implement; these technologies would be innovative for application to the site waste, and resources are not readily available.	High
Solids separation following removal	Soil, sludge, sediment	Might achieve separation in certain applications, e.g., for separating radionuclides from the original ores, but would be generally ineffective for separating relatively low concentrations of contaminants from solid particles distributed throughout various grain sizes in the soil, sludge, and sediment at the site. Also, applying separation technologies to the site waste might mobilize and further distribute rather than segregate contaminants.	Could be implemented with available equipment. This technology has been applied in the mining industry (for ore separation processes), but it is only developmental for waste application.	Low
Volume reduction by crushing, compacting, shredding	Structural material, vegetation	Can effectively reduce the volume of structural material and vegetation following removal, but would not reduce contaminant toxicity or mobility. Often used effectively as a pretreatment step prior to additional treatment or disposal.	Can be implemented with readily available resources.	Moderate
Physical treatment following removal (e.g., filtration, centrifugation)	Surface water, groundwater	Can effectively reduce the toxicity, mobility, and volume of contaminated water by removing contaminants from solution. A water treatment plant will be available to treat contaminated water at the site under an interim action. This system would also be available to treat groundwater as appropriate, e.g., the perched groundwater intercepted from beneath the raffinate pits.	Can be implemented with readily available resources. A water treatment plant that includes physical treatment components is being constructed at the site under an interim action.	Moderate

Extraction. Water and steam extraction technologies can reduce contaminant toxicity, mobility, or volume in certain cases by physically "sweeping" contaminated material to accelerate the migration of contaminants through either injection or surface application of water on a contaminated area, in situ or within a vessel following removal. These processes are typically used to treat organic contaminants or highly mobile inorganic contaminants that can be physically removed from the waste matrix. Such contaminants are not present in significant quantities at the Weldon Spring site. Thermal or nonthermal physical extraction technologies would not remove the contaminants that are predominant at the site, i.e., radionuclides and metals. Therefore, they are rejected from further consideration.

Vitrification. Vitrification involves electrically heating contaminated material to temperatures high enough to cause it to melt. Organic contaminants are destroyed in this process, and other contaminants can be volatilized from the melt. The solids are formed into a chemically inert, leach-resistant, glass-like product that traps the inorganic contaminants. Vitrification can be applied in situ or following removal to reduce the toxicity, mobility, and volume of waste. The in-situ application of this technology is considered innovative for waste treatment, and it has not yet been demonstrated on the type of waste present at the Weldon Spring site or on as large a scale as would be required. It involves placing electrodes in the soil or waste over relatively small, incremental areas, and its effectiveness would be difficult to verify.

Following the removal of contaminated material, vitrification could be implemented with a joule-heated ceramic melter, fossil fuel-heated ceramic melter, or plasma arc torch furnace. In these processes, material is heated to temperatures high enough to melt the inorganic portions of the waste and, upon cooling, the nonvolatile components are incorporated into a vitrified solid. Ceramic melters are ceramic refractory-lined furnaces used for producing glass or vitreous material. Operating temperatures reach 1,200°C (2,190°F) for the joule-heated ceramic melter and up to 1,900°C (3,450°F) for the fossil fuel-heated ceramic melter. In joule-heated melters, heat is produced by passing an alternating current between electrodes submerged in the material to be melted; these melters are currently being used to vitrify liquid high-level radioactive waste. In fossil fuel-heated melters, fossil fuel such as natural gas is burned to heat the material; these melters are an adaptation of commercial glass-making technology and are currently in the pilot stage for application to treatment of radioactive and chemically hazardous waste.

Plasma arc torch furnaces generate a plasma in a gas as a heat source. Heat from the plasma is transferred to the material to be melted either by injecting the waste into the plasma plume or by using the plasma to generate a melt to which the waste is added. Melt temperatures in these systems can reach 2,000°C (3,630°F) (MK-Ferguson Company and Jacobs Engineering Group 1992a). Plasma arc torch furnaces are used in the steel industry, and adaptation to radioactive and chemically hazardous waste treatment is in the bench-scale and demonstration stage. The high melt temperatures achieved in the plasma arc torch process increase corrosion of the melter, which requires more expensive and complex alloys for construction compared with the other technologies. High-pressure water is also required for cooling the electrodes.

Joule-heated ceramic melters, fossil fuel-heated ceramic melters, and plasma arc torch furnaces are all potentially viable vitrification technologies. Joule-heated ceramic melters are more susceptible to refractory corrosion and require a more uniform feed composition than fossil fuel-heated ceramic melters. Fossil fuel-heated ceramic melters are more tolerant of changes in melt viscosity, conductivity, and metal phase immiscibility than joule-heated ceramic melters. The plasma arc torch furnace is a more complex developmental technology for treating radioactive and hazardous waste, and it would require significant development for use at the Weldon Spring site. Therefore, the fossil fuel-heated ceramic melter was identified as the representative technology for evaluating vitrification for the Weldon Spring waste in this FS. These vitrification process options are being further evaluated and tested to determine the optimal technology.

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. These technologies do not reduce the toxicity or mobility of radionuclides or inorganic constituents; they do reduce the total waste volume, but both processes produce an ash residue.

For rotary kiln incineration, the presence of elevated levels of alkali metal sulfates can cause refractory attack and slagging at high temperatures, which can impede solids removal. Fine particle size in the feed material results in a high particulate loading of the flue gases. Both of these conditions are characteristic of the Weldon Spring soil, sludge, and sediment. Fluidized bed incinerators require a fairly uniform size feed, and the presence of fine-grained material would result in high particulate loading of the flue gases. The ash produced from these technologies might be determined to be hazardous if it failed leach-testing criteria. If this were the case, the ash would require further treatment before disposal.

Rotary kiln and fluidized bed incineration technologies were not retained for further consideration because incineration would not reduce the toxicity or volume of most contaminants at the site and because potential problems exist relative to flue gas loading with fine particulates, possible refractory attack and ash fusion, and the need to further manage the ash residue produced. Incineration of organic debris and wood at the site was also screened from further consideration because the extensive engineering and time required for implementation and the expense of incineration are not justifiable for the small quantity of vegetation and wooden debris that might be contaminated and could be treated as effectively by other processes. For example, composting can achieve similar reductions in volume without the added air emissions and ash residual resulting from incineration (Section 3.2.4.3).

In a slagging mode, rotary kiln incinerators are operated at higher temperatures than otherwise used. Some ash and a glass frit similar to a vitrified product are produced. Refractory attack is a significant problem for incinerators operating in the slagging mode. Replacement of the refractory can be required as frequently as once or twice per year (MK-Ferguson Company and Jacobs Engineering Group 1992a). Slagging incinerators are also subject to the same constraints as rotary kiln and fluidized bed incinerators and were therefore also screened from further consideration.

Liquid injection incineration could be used to treat the liquid process chemicals present at the Weldon Spring site. These chemicals have been consolidated and are currently in storage in Building 434, and they include paints, solvents, and oils. The process chemicals at the Weldon Spring site are contaminated in excess of specific threshold levels of hazardous constituents and/or PCBs, as defined by the Resource Conservation and Recovery Act (RCRA) and the Toxic Substances Control Act (TSCA), and are therefore classified as a hazardous waste under RCRA and as a hazardous substance under TSCA; they are also restricted from land disposal under RCRA. Additionally, two tanks adjacent to the MSA are being used to store liquid tributyl phosphate contaminated with uranium, mercury, and PCBs. At present, the disposal method of choice for these types of wastes is destruction in an approved mixed waste incinerator (Radcliffe 1991). (As an example, the K-1435 incinerator at the Oak Ridge Gaseous Diffusion Plant near Oak Ridge, Tennessee, holds permits under TSCA and RCRA. The incinerator was permitted to receive TSCA waste on September 28, 1987, and a RCRA permit was received on March 20, 1989; the latter was written to accept qualified waste from any DOE site operated by Oak Ridge Operations [Radcliffe 1991]. Full-scale operation of the Oak Ridge incinerator began in the summer of 1991.) Because the site wastes consist of liquids with minimal entrained solids, the small amount of ash could probably be managed at the incinerator to which the material was sent.

Other Thermal Technologies. Other high-temperature technologies include the molten salt process, flaring, wet air oxidation, supercritical water oxidation, and infrared incineration. The molten salt process is used for the destruction of organic hazardous waste, particularly chlorinated hydrocarbons and chlorinated solvents. Organic waste undergoes catalytic destruction upon contacting molten salt maintained at a temperature between 760 and 1,040°C (1,400 and 1,900°F). This treatment technology cannot process material containing a high ash content, such as the soil, sediment, and sludge at the Weldon Spring site. In addition, the treatment process would not decrease the toxicity, mobility, or volume of the contaminants that predominate at the site. The same restrictions are also true for infrared incineration, which involves placement of the waste on a moving belt that passes under silicon carbide irradiators (MK-Ferguson Company and Jacobs Engineering Group 1992a; EPA 1988b, 1988c, 1989f).

Flaring is a special category of combustion under which waste is exposed to an open flame. This process does not apply for the site because it is only appropriate for gaseous waste streams consisting of relatively simple hydrocarbons such as fuel tank emissions and landfill methane gas (MK-Ferguson Company and Jacobs Engineering Group 1992a). Wet air oxidation involves aqueous phase oxidation of dissolved or suspended organic substances at relatively low temperatures (180 to 320°C [350 to 600°F]). Supercritical water oxidation relies on the physico-chemical properties of water when it is heated to its critical temperature (Rich and Cherry 1987).

When maintained above 374°C (705°F) and 22,000 kPa (3,200 psi), water is an excellent solvent for organic compounds. Both wet air oxidation and supercritical water oxidation are inappropriate for the largely inorganic and radioactive contaminants at the Weldon Spring site (MK-Ferguson Company and Jacobs Engineering Group 1992a). Because these processes have not been demonstrated for large-scale waste treatment applications and are not as effective as other processes for the contaminated media present at the site, they are rejected from further consideration.

Metal-Melt Refining. In metal-melt refining, induction furnaces are used to melt contaminated metal debris and capture radioactive contamination in the slag phase while producing a less contaminated metal. This process has been demonstrated on a limited basis. The Scientific Ecology Group, Inc., has constructed an 18-t (20-ton) induction melt furnace at its facility near Oak Ridge, Tennessee, and this facility has recently become operational (Large 1992). Metal-melt refining could potentially be used to remove some of the radioactive contaminants from steel; however, the feasibility of generating a radiologically releasable product is questionable and considerable energy is required.

Metal-melt refining has been used for industrial applications, but its use for decontaminating structural debris contaminated with radionuclides has been limited (MK-Ferguson Company and Jacobs Engineering Group 1992a). Bench-scale studies with material from DOE uranium-processing facilities have demonstrated a significant reduction in radioactivity in contaminated copper, iron, nickel, and steel through the partitioning of radionuclides into the slag phase, but the process was less effective with contaminated aluminum (Bechtel National 1988). No standards are currently available for unrestricted release of the volumetrically contaminated material that would result from this process. Therefore, partitioning could not be used to decontaminate structural material at the site for subsequent release without radiological restrictions.

Metal-melt refining could be used as a volume reduction technology, as discussed below. An additional variation of the metal-melting process is to melt the metal and mold it into products for limited use in the nuclear industry, e.g., for shielding components. In this process, the radioactive contaminants are not removed but become incorporated into the metal, thereby reducing hazards. This restricted-use recycle option could be considered as part of remedial design.

Volume Reduction. Reduction of waste volume or size by shredding, pulverizing, and/or compacting is considered potentially applicable to the management of rock and structural material, and it could be achieved with conventional equipment. Shredders can process both concrete and metal, concrete can be crushed or pulverized to reduce particle size and facilitate compaction, and metal debris can be smashed or flattened to facilitate compact placement in a disposal facility. These technologies are all retained for site application. The volume of structural metal can also be reduced by melting. The Scientific Ecology Group facility at Oak Ridge could be used for this purpose; however, this technology would have significant energy requirements.

3.2.4.3 Biological Treatment Technologies

Several biological treatment technologies are available for treating contaminated soil, sludge, sediment, water, and structural material (Appendix B). Biological treatment technologies use living organisms such as bacteria or fungi to detoxify or immobilize contaminants in waste. These technologies are applied primarily for converting organic contaminants into nontoxic products. Bioremediation has also been used to degrade inorganic contaminants such as nitrates, and it can be used to detoxify or immobilize certain metals by changing their oxidation state. The organically contaminated waste and organic material that are candidates for bioremediation at the Weldon Spring site include the nitroaromatic-contaminated soil fraction from the quarry (in storage at the TSA), the nitrate contamination in the raffinate pit sludge, and the vegetation and wooden debris.

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 (Wagner et al. 1986). 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 the introduction of 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 in order to stimulate or accelerate naturally occurring processes. Bioremediation technologies for soil, sludge, and other material contaminated with organic compounds (such as vegetation) include composting, suspended and attached growth (slurry and solid phase) biodegradation, and land application (land farming). The evaluation of these technologies in terms of effectiveness, implementability, and cost is summarized in Table 3.6.

Composting. Composting is accomplished by mixing the waste with a carbon source such as hay or manure, as required, to enhance the degradation of the organic material. Other nutrients and active cultures can also be added to promote biodegradation. Process options for composting include open and static windrows. The open windrow system consists of placing the mixture in long open piles and aerating them with periodic mixing. The static windrow system consists of placing long piles over a grid of perforated pipes through which air is forced. The static windrow system is generally faster than the open window system and allows for better control of the composting process. Compost can also be aged in a reactor vessel that is aerated by tumbling, stirring, and forced aeration. However, the energy requirements for this system are much larger.

Composting is applicable to the vegetation and wooden debris present at the Weldon Spring site and is retained for cleanup applications. The DOE is currently considering on-site biodegradation of wooden debris as a treatability study (separate documentation is being prepared for these activities). Composting can result in a volume reduction of 80 to 90% in 1 to 2 years, depending upon the compost content (MK-Ferguson Company and Jacobs Engineering Group 1992a). Composting would not reduce the toxicity of radioactive or metal contaminants.

TABLE 3.6 Summary of Screening Analysis for Biological Treatment Technologies

Treatment Measure	Affected Medium	Effectiveness	Implementability	Cost
Composting	Soil, sludge, and sediment contaminated with organic compounds; vegetation and wooden debris	Can reduce the toxicity, mobility, and volume of contaminated organic material; vegetation that has been removed from the area adjacent to the quarry is currently being composted in a mulch pile.	Can be implemented with conventional equipment and procedures.	Low
Suspended and attached growth biodegradation	Soil, sludge, and sediment contaminated with organic compounds and nitrate	Can reduce the toxicity, mobility, and volume of contaminated organic material. Not generally effective for metals and radioactive contaminants, but certain bacteria in the absence of oxygen can transform nitrate to nitrogen and remove uranium from solution by precipitation or adsorption.	May require pretreatment to remove toxic metals or other contaminants that can interfere with biological processes. Would require control of temperature, pH, oxygen, and water content.	Moderate
Land farming	Soil, sludge, and sediment contaminated with organic compounds and nitrate	Can reduce the toxicity, mobility, and volume of contaminated organic material. Protection of surface water and groundwater would be required.	Straightforward to implement but requires a large land area and intensive management and monitoring.	Moderate

The U.S. Department of the Army has studied composting of soil contaminated with nitroaromatic compounds. Field-scale studies and research have indicated that extractable nitroaromatic concentrations might be reduced by composting, depending on experimental conditions such as temperature, aeration, and quantity of amendments (Williams et al. 1988; U.S. Army Toxic and Hazardous Materials Agency 1989). This reduction appears to result from the metabolic utilization of the nitroaromatic compounds by microbes. The composting of site soil contaminated with these compounds is being considered as a pretreatment step to reduce concentrations prior to further treatment or disposal. Additional studies are being conducted to identify the appropriate inoculation, fertilization, and moisture requirements.

Suspended and Attached Growth Biodegradation. Suspended growth treatment could involve adding water to contaminated soil or sludge to create a slurry containing at least 50% water and mechanically aerating and mixing the slurry with nutrients and a microbial culture in a large reactor vessel or surface impoundment. Conducting this process in a reactor vessel allows better optimization of operating conditions and the collection and treatment of any emissions. Pretreatment of soil or sludge is often required to remove elevated concentrations of toxic metals or other inhibitors that could slow or halt biological activity. Strict control of temperature, pH, and oxygen are often critical to the success of these processes. This type of treatment would not be as effective as composting for the nitroaromatic-contaminated soil because of the presence of other contaminants.

Attached growth treatment can be used to treat soil and sludge in a reactor vessel or on a filter bed. For the latter, soil can be placed on a bed of clean sand underlain by a leachate collection system and a synthetic liner. Plastic coverings and a sprinkler system can then be used to create an environment conducive to biodegradation. This type of system is subject to the same constraints as a suspended growth system and would not be as effective as composting for treating nitroaromatic-contaminated soil at the Weldon Spring site because of the presence of other contaminants.

Biotransformation and biodenitrification can be conducted in both suspended and attached growth systems. Biotransformation involves the microbial alteration of a chemical substance into a less toxic or less mobile form. For example, certain strains of chemo-organotrophic bacteria (e.g., the obligate anaerobe, *Thiobacillus ferrooxidans* and the strict anaerobe *Desulfovibrio desulfuricans*) can reduce water concentrations of uranium by reducing the soluble hexavalent form to the insoluble trivalent form and causing it to precipitate into a sludge in the absence of oxygen (Agency for Toxic Substances and Disease Registry 1990; Lovley et al. 1991). Biodenitrification involves the transformation of nitrate and nitrite to nitrogen under anoxic conditions. These processes can be inhibited by the presence of metals or other contaminants that can slow or stop metabolic activities. Low-permeability soil or sludge can also interfere with microbial processes. Temperature, pH, and water and oxygen content are important variables that must be controlled.

Laboratory studies of biodenitrification of the raffinate pit sludge have indicated that this technology could potentially be used to enhance the removal of nitrate and nitrite from sludge solution and to reduce the concentrations of radium, uranium, and thorium in solution by adsorption onto the microbial mass, thereby generating another waste sludge (Taylor et al. 1979; Taylor 1980a, 1980b). Biodenitrification has been performed in a continuous-flow, stirred-tank reactor at the Oak Ridge Y-12 plant to treat waste streams averaging 25% nitrate (Johnson and Arnold 1986). Biotransformation and biodenitrification were screened from further consideration for waste at the Weldon Spring site because only limited contamination (primarily nitrates) would be addressed, the nitrate concentrations are variable, raffinate sludge represents a large volume of material, an additional waste sludge would be generated from the microbial growth, inhibitory contaminants are present, and maintaining appropriate temperature, pH, and low oxygen conditions in the system would be difficult. For these reasons, suspended and attached growth processes were rejected from further consideration.

Land Farming. In land farming, waste is typically spread out on and mixed with uncontaminated soil so indigenous bacterial and fungal agents can degrade the organic contaminants. Regular plowing and addition of water and nutrients are used to increase the rate of biodegradation. This process requires a large land area and is difficult to optimize and control; measures to protect groundwater, surface water, and air from potential contaminant releases are often required. On the basis of these constraints, land farming was rejected from further consideration.

3.2.5 Short-Term Storage

Short-term storage involves isolating contaminated material to protect human health and the environment until the material can be treated and/or permanently disposed of. This technology typically involves the construction of an engineered facility to minimize the potential for contaminant migration. Short-term storage would not reduce contaminant toxicity or volume, but it could reduce contaminant mobility and potential exposures. This technology could be applied for all contaminated media within the scope of this action. Depending on the material to be stored, the facility could be an enclosed structure (such as Building 434), a tank system (such as the tributyl phosphate tank system with bermed containment), or an outdoor area with a gravel pad or other base (such as the MSA and TSA) and covers such as tarpaulins. These options could be applied either on-site or at an off-site permitted facility.

The screening evaluation of short-term storage options is summarized in Table 3.7. Use of an off-site facility would require that the material be transported off-site and that an appropriate facility be available. Waste transport would result in an increased risk of transportation accidents and related impacts, the magnitude of which would depend on the waste volume and type, mode of transportation, and facility location. No suitable off-site facility exists for short-term storage of site waste, and none is likely to become available in the near future. Therefore, the off-site application was rejected from further consideration.

Short-term storage on-site is a viable option that is currently being used to support various interim actions, pending the forthcoming disposal decision. The TSA, MSA, and asbestos container staging area were recently constructed and Building 434 was renovated to serve as

TABLE 3.7 Summary of Screening Analysis for Short-Term Storage

Short-Term Storage Facility[a]	Affected Medium	Effectiveness	Implementability	Cost
Open and enclosed structures	Soil, rock, sludge, sediment, drummed process chemicals, containerized asbestos-containing material and other structural material, vegetation	Can effectively protect human health and the environment in the short term by reducing contaminant mobility and limiting exposures. The TSA, MSA, asbestos container staging area, and Building 434 are currently being used to support various interim actions. These facilities could be expanded/modified to store additional material. For the off-site application, transportation of the waste would increase risks to workers and the general public due to the increased likelihood of accidents and potential exposures.	The on-site application can be easily implemented with readily available resources. Such facilities have been and will continue to be developed on-site to support cleanup activities. An appropriate storage facility is not currently available off-site, and it is unlikely that such a facility would become available in the near future.	Low to moderate
Tanks and retention ponds	Surface water, groundwater (intercepted/collected), liquid waste	Effectiveness is the same as described above. Tributyl phosphate is currently being stored in a tank system, and surface water and intercepted groundwater are currently being stored in retention ponds.	Implementability is the same as described above.	Low to moderate

[a] The listed facility options would be land-based and could be located either on-site or off-site.

on-site storage facilities. These facilities could be expanded or modified, as needed, to support the current remedial action. In addition, retention ponds currently store surface water on-site, pending treatment under an interim action. Therefore, short-term storage continues to be considered applicable for site cleanup activities.

3.2.6 Disposal

Disposal options evaluated herein are limited to contaminated solids. Although contaminated surface water could be directly disposed of (i.e., without treatment) by discharging to land or surface water bodies or discharging to a publicly owned treatment works, such disposal is not necessary because a water treatment plant is being constructed at the site as part of an interim action. Any surface water requiring treatment would be transferred to this plant, and the resultant treated water would be managed in accordance with the existing discharge permit from the state of Missouri. The only related material that would require disposal is the process waste resulting from plant operations, and this material is being addressed under the current action. Hence, disposal options for surface water are not addressed further in this FS, and the discussion of disposal generally focuses on soil, sludge, and structural material. Management of contaminated groundwater will be evaluated in documentation for the groundwater operable unit to be prepared within the next several years.

Disposal of contaminated solid material involves confinement for permanent disposition. Disposal options considered for the waste resulting from site remediation include a land-based facility on-site, a land-based facility off-site, and ocean disposal. Ocean disposal was rejected from further consideration because this method for disposing of radioactive and chemically hazardous substances has not been approved by the EPA, and it is highly unlikely that such approval will be obtained in the near future. Hence, the disposal options considered in this FS are land-based facilities, both on-site or off-site. Nonradioactively contaminated process chemicals could be disposed of off-site at a commercial facility. Material determined to be hazardous under RCRA could be shipped to a permitted facility, and nonhazardous material could be shipped to a sanitary or demolition landfill. Related requirements are presented in Appendix G (Table G.3).

Several process options are available for a land-based facility, including a concrete vault and several design variations for an engineered cell. These facilities would be designed to minimize exposure of the waste to surface water, groundwater, wind, and other environmental forces — thereby minimizing exposure to and the migration of contaminants. Disposal facilities can be constructed out of naturally occurring material such as clay, soil, and gravel, or out of manufactured material such as concrete and geomembrane liners.

Concrete vaults are typically used to dispose of containerized waste. Although vaults are very 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, the capability of 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. Because it would not add significant protection for the disposal of weight-bearing waste (such as soil or sediment) and there is less design and operational flexibility compared with an engineered cell, a concrete vault was not considered further.

An engineered cell is often used to dispose of contaminated solids. This type of cell typically consists of a liner (or liners) below the waste and a cover over the waste. Side covers or embankments are also utilized to completely encapsulate the waste. Engineered cells are constructed to satisfy the design requirements appropriate to the type of waste they would contain. The radioactive waste associated with cleanup of the Weldon Spring site is classified as by-product material, as defined in Section 11e(2) of the Atomic Energy Act; such material is typically disposed of in accordance with the requirements in 40 CFR 192 (Appendix G, Table G.3). 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 a bottom clay layer 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.

Under RCRA regulations (40 CFR 261), a solid waste is considered to be a regulated hazardous waste if it is not otherwise excluded from regulation as a hazardous waste and either exhibits any of the characteristics identified in Subpart C of this regulation — in which case it is termed a "characteristic hazardous waste" — or is listed in Subpart D of the regulation — in which case it is termed a "listed hazardous waste." Waste determined to be hazardous as defined by RCRA is disposed of according to the requirements of 40 CFR 264 and 40 CFR 268; more stringent state requirements may also be pertinent, as indicated by the regulated conditions (Appendix G, Table G.3). In a cell with design components similar to those specified in 40 CFR 264, the waste is placed on a bottom liner system consisting of an upper membrane liner, a composite bottom liner (flexible membrane and clay layer), and a leachate collection and removal system. The leachate collection and removal system is designed to collect and remove any leachate or infiltrate from the cell. The cover on this type of cell includes an infiltration barrier, a drain layer, a frost protection layer, and an erosion protection barrier to limit erosion, infiltration of water, frost penetration, and biotic intrusion into the cell. A cell designed to accommodate both 11e(2) by-product material and chemically hazardous waste would incorporate elements of both cell designs, including a radon barrier in the cover, a composite liner, and a leachate collection and removal system in the bottom liner.

A third type of engineered disposal cell, the sanitary or demolition landfill, is designed to contain inert waste or waste that was initially characteristic hazardous waste but that has been treated so that it no longer exhibits the defined conditions. Requirements for this type of disposal cell are given in 40 CFR 258 (Appendix G, Table G.3). The cover system consists of a compacted soil cap and vegetative cover. The bottom liner system includes a composite liner and a leachate collection and removal system. This type of cell could be modified to contain both 11e(2) by-product and nonhazardous waste by including the relevant cover design requirements for a by-product waste disposal cell.

In addition to these design considerations, the land disposal restrictions promulgated by the EPA in 40 CFR 268 preclude the disposal of certain contaminants without prior treatment (Appendix G, Table G.3). The land disposal restrictions would be applicable to any Weldon Spring waste regulated under 40 CFR 268, and land disposal of such waste would require that appropriate treatment standards be met. The treatment standards are based on contaminant concentrations in the waste, the treatment technology utilized, or waste characteristics after treatment. No waste determined to be listed hazardous waste as defined by RCRA has been identified at the Weldon Spring site. Characteristic hazardous waste would be treated prior to disposal so that it no longer exhibits the characteristic condition. If any listed waste were identified as site cleanup progressed, it would be managed in accordance with the land disposal restrictions.

The implementability of land disposal at an off-site facility is affected by the availability of suitable sites for disposal of the Weldon Spring waste. In addition, the increased risk of accidents and exposures associated with off-site transport of the waste (Appendix F, Section F.7) and the increased cost for off-site transport and disposal would have to be balanced by an increased effectiveness compared with on-site disposal. No commercial facilities are currently authorized to accept 11e(2) by-product material for disposal. One facility, located near Clive in Tooele County, Utah, is authorized to accept naturally occurring radioactive material. The operator of this facility (Envirocare of Utah, Inc.) has applied to the U.S. Nuclear Regulatory Commission (NRC) for a license to dispose of 11e(2) by-product material, but such permission has not yet been received. However, because it is possible that this facility could receive permission to dispose of 11e(2) by-product material in the future, it was included in the evaluation of potential off-site disposal facilities. In accordance with the requirements of CERCLA, as amended, hazardous substances can be transferred off-site only to facilities that are operating in compliance with applicable federal laws and state requirements. In addition, the disposal unit must not be releasing any hazardous waste into the groundwater, surface water, or soil, and all such releases from other units at the facility must be controlled by a corrective action program.

Other off-site disposal options are currently limited to facilities that are owned and operated by DOE. As identified in DOE Order 5820.2A, large quantities of 11e(2) by-product material should normally be disposed of in the state in which it is generated (Appendix G, Table G.3). 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; and the Savannah River site near Aiken, South Carolina. However, no DOE disposal facilities exist in the state of Missouri or in the surrounding states. The Hanford site was evaluated for potential off-site disposal in the draft EIS (DOE 1987) as a reasonable, representative DOE facility.

Sites in the semiarid regions of the United States (e.g., the Envirocare and Hanford sites) tend to have more favorable hydrogeological conditions and lower population densities than sites in the more humid regions (e.g., in Missouri). In the draft EIS, a hypothetical facility was assumed to be located in Missouri within 160 km (100 mi) of the Weldon Spring site to evaluate the potential impacts associated with a nearby off-site disposal option (DOE 1987). Use of such a facility for disposal would require that it be properly sited, which would involve investigation, evaluation, environmental documentation, and public review and comment. In addition, a nearby facility would need to address licensing requirements of the NRC for radioactive material and siting requirements of the state of Missouri for chemically contaminated material. Development of such a facility would likely be a very protracted activity.

On-site disposal would require the construction of an engineered facility at the Weldon Spring site to dispose of contaminated material generated by site remediation. Engineering evaluations conducted to date have demonstrated that the geological conditions at the site would be suitable for such a facility (MK-Ferguson Company and Jacobs Engineering Group 1991a). The results of constant head triaxial permeability tests and a geologic model using three overburden units indicate that the naturally occurring materials at the Weldon Spring site are sufficiently impermeable to meet certain state requirements for locating a disposal facility. The Missouri Department of Natural Resources has reviewed the results of the site suitability work and concluded that no significant potential for catastrophic collapse exists in the disposal facility study area (Garstang 1991). Additional testing continues to be performed to study the effect that macropore features within the overburden might have on overall permeability, as well as the effect that hypothetical leachate (rather than water) might have on the results of constant head triaxial permeability tests.

The screening evaluation of potential disposal options is summarized in Table 3.8. On the basis of this evaluation, the general option retained for further evaluation was disposal in a land-based engineered cell. Such a cell would be designed for the specific waste type(s) it would contain; it could be located on-site, at the commercial Envirocare site in Utah, at the representative off-site DOE facility (i.e., the Hanford site), or at a hypothetical nearby site in Missouri within 160 km (100 mi) of the Weldon Spring site.

3.3 POTENTIALLY APPLICABLE TECHNOLOGIES

Potentially applicable technologies for site remediation are summarized in Table 3.9. This summary is based on the screening analysis presented in Section 3.2. The technology types that have been retained through this analysis were used to develop preliminary remedial action alternatives for the site. These alternatives are identified in Chapter 4.

TABLE 3.8 Summary of Screening Analysis for Disposal

Disposal Option	Effectiveness	Implementability	Cost
Land-based facility[a]			
Concrete vault	Typically used for the disposal of containerized waste because it is structurally stable and it allows for waste retrieval. Provides protection of the environment and reduces exposures. Provides some control of exposures and contaminant mobility relative to migration, but would require an additional clay layer for site application because of the permeability of concrete. Not appropriate for weight-bearing waste, and design flexibility is limited. Off-site disposal would increase risks to workers and the general public due to the increased likelihood of transportation accidents and potential exposures.	Construction requirements could result in longer completion schedules compared with an engineered cell. The capability to incorporate design changes such as an increase or decrease in size would be limited. Material placement within the vault would be hampered by equipment maneuverability constraints imposed by the structure. An off-site facility is not currently available for the Weldon Spring waste.	High
Engineered cell	Can be very effective for containment of weight-bearing waste. Provides protection of the environment and reduces exposures. Cover and liner systems limit exposures and contaminant mobility relative to migration. Allows design flexibility to accommodate specific waste types. Off-site disposal would increase risks to workers and the general public due to the increased likelihood of transportation accidents and potential exposures.	Straightforward to construct with established methods and readily available resources. Administrative constraints impact the availability of off-site applications for the Weldon Spring waste.	Moderate
Ocean disposal	Not an approved method of disposal for radioactive or chemically hazardous waste.	Not currently available because of regulatory restrictions and environmental concerns.	High

[a] Land-based disposal options could be implemented either on-site or off-site at a commercial facility (Envirocare), an existing DOE facility (Hanford), or a new facility constructed in Missouri (hypothetical nearby site).

TABLE 3.9 Screening of Potentially Applicable Technologies

General Response Action	Technology Type	Affected Media	Evaluation Result	Comments
No action	Not applicable	All	Retained	Provides a baseline for comparison with action alternatives.
Institutional control	Access restrictions	All	Retained	Can effectively limit entry to contaminated areas and can be used to support other response actions.
	Ownership and use or deed restrictions	All	Retained	Can minimize exposures to site contaminants by limiting use of contaminated areas and can be used to support other response actions.
	Monitoring	All	Retained	Can provide data useful for minimizing exposures and can be used to support other response actions.
	Groundwater restrictions	Groundwater	Retained	Can provide the means for a contingency response, as needed, pending the implementation of source control measures at the site.
In-situ containment	Surface controls/ diversions	Soil, sludge, sediment, surface water	Retained	Can limit contaminant mobility by directing surface runoff around contaminated areas on-site.
	Caps and covers	Soil, sludge, sediment, process chemicals	Retained	Can limit airborne emissions, attenuate gamma radiation, and reduce precipitation-enhanced percolation and leaching.
	Lateral barriers	Soil, sludge, sediment, surface water	Retained	Can limit lateral migration of contaminants.
	Bottom seals	Soil, sludge, sediment, surface water	Retained	Can limit vertical migration of contaminants.
	Surface seals	Structural material	Retained	Can effectively control releases from contaminated structural surfaces.

TABLE 3.9 (Cont.)

General Response Action	Technology Type	Affected Media	Evaluation Result	Comments
Removal	Excavation	Soil, sludge, sediment	Retained	Can effectively remove the source of contamination and can be readily implemented.
	Dredging and pumping	Sludge, sediment	Retained	Can effectively remove sludge from the raffinate pits and can be readily implemented.
	Interception and pumping	Surface water, groundwater	Retained	Can effectively remove water (e.g., from beneath raffinate pits) and provides the means for a contingency response.
	Decontamination	Structural material	Retained	Can effectively remove contaminants from structural material to limit related exposures.
	Dismantlement	Structural material	Retained	Can effectively remove contaminated structures (such as the temporary facilities constructed to support site cleanup activities) to limit related exposures.
	Clearing and grubbing	Vegetation	Retained	Can effectively remove vegetation from the site to support overall cleanup activities.
Treatment (chemical)	Soil flushing	Soil, sludge, sediment	Rejected	Difficult to implement because of limitations in selecting suitable flushing fluids for complex waste; generally ineffective for site conditions.
	Leaching/contact extraction (including reprocessing)	Soil, sludge, sediment	Rejected	Ineffective for treating radionuclides, metals, and other inorganic contaminants in site waste. Sludge reprocessing would be ineffective primarily because of the presence of calcium and the fine-grained nature of the sludge.
	Chemical addition/ detoxification	Soil, sludge, sediment	Rejected	Difficult to implement and to control chemical-specific reactions for a complex waste; generally ineffective for site conditions.

TABLE 3.9 (Cont.)

General Response Action	Technology Type	Affected Media	Evaluation Result	Comments
Treatment (chemical) (cont.)	In-situ stabilization/ solidification	Soil, sludge, sediment	Retained	Can reduce contaminant mobility but increases volume; process effectiveness is constrained by the nature of the waste and the physical conditions of the site.
	Stabilization/ solidification following removal	Soil, sludge, sediment, process chemicals	Retained	Can reduce contaminant mobility but increases volume; requires an engineered treatment facility.
	Chemical addition following removal	Surface water, groundwater	Retained	Can effectively treat contaminated water at the site to reduce its toxicity, mobility, and volume by removing contaminants from solution. The water treatment plant being constructed on-site under an interim action could also be used to treat groundwater, e.g., the perched water intercepted from beneath the raffinate pits.
Treatment (physical)	In-situ dewatering	Sludge, sediment	Retained	Could be difficult to fully implement because of drainage characteristics of the fine-grained sludge and associated operational difficulties (e.g., maintaining pump rates), but could be used to partially dewater the sludge to support its removal.
	Dewatering following removal	Sludge, sediment	Retained	Can reduce the mobility and/or volume of contaminated material with high moisture content such as the raffinate pit sludge.
	Nonthermal and thermal extraction	Soil, sludge, sediment	Rejected	Generally ineffective because of the nature of the material present. Low-permeability materials would limit contact and mobilization.
	In-situ vitrification	Soil, sludge, sediment	Retained	Can reduce contaminant mobility and volume and the toxicity of limited contaminants (e.g., nitroaromatic compounds); would produce off gas requiring collection and treatment. Process effectiveness is constrained by the nature of the waste and the physical conditions of the site.
	Vitrification following removal	Soil, sludge, sediment, process chemicals	Retained	Can reduce contaminant mobility and volume and the toxicity of limited contaminants (e.g., nitroaromatic compounds); would produce off gas requiring collection and treatment. Process would require an engineered treatment facility.

TABLE 3.9 (Cont.)

General Response Action	Technology Type	Affected Media	Evaluation Result	Comments
Treatment (physical) (cont.)	Rotary kiln incineration	Soil, sludge, sediment, vegetation, process chemicals	Rejected	Difficult to implement because of the presence of certain contaminants such as volatile metals and sodium and the fine-grained particle size of the contaminated media; generates air emissions and an ash residue that could be susceptible to leaching.
	Fluidized bed incineration	Soil, sludge, sediment, vegetation, process chemicals	Rejected	Same difficulties as rotary kiln incineration.
	Slagging incineration	Soil, sludge, sediment, vegetation, process chemicals	Rejected	Same difficulties as rotary kiln incineration, except the residue is a glass-like slag and the process is subject to refractory failure.
	Liquid injection incineration	Liquid process chemicals	Retained	The consolidated liquid process chemicals could be incinerated at an approved facility.
	Metal-melt refining	Structural material	Retained	Ineffective for generating a product that could be released for reuse without radiological restrictions. However, a restricted-use recycle option could be considered as part of remedial design.
	Other thermal treatment (e.g., molten salt process, microwaving, flaring, wet-air oxidation, supercritical water oxidation, and infrared incineration)	Soil, sludge, sediment, structural material, process chemicals	Rejected	Generally ineffective for site waste, would be very difficult to implement, and required resources are not readily available.
	Solids separation following removal	Soil, sludge, sediment	Rejected	Ineffective for separating relatively low concentrations of contaminants from soil, sludge, and sediment.

TABLE 3.9 (Cont.)

General Response Action	Technology Type	Affected Media	Evaluation Result	Comments
Treatment (physical) (cont.)	Volume reduction by crushing, compacting, shredding	Structural material, vegetation	Retained	Can effectively reduce the volume of structural material and vegetation.
	Physical treatment following removal	Surface water, groundwater	Retained	Can effectively treat contaminated water to reduce its toxicity, mobility, and volume by removing contaminants from solution. The treatment plant being constructed for contaminated surface water under an interim action could also be used to treat groundwater, e.g., the perched water intercepted from beneath the raffinate pits.
Treatment (biological)	Composting	Soil, sludge, and sediment contaminated with organic compounds; vegetation and wooden debris	Retained	Can effectively reduce volume of contaminated organic material at the site and could easily be expanded.
	Suspended and attached growth biodegradation	Soil, sludge, and sediment contaminated with organic compounds and nitrate	Rejected	Ineffective for complex waste and very difficult to implement because of the need to control temperature, pH, oxygen, water content, and other factors; would only address limited contaminants and would generate a secondary waste sludge.
	Land farming	Soil, sludge, and sediment contaminated with organic compounds and nitrate	Rejected	Ineffective for complex waste; would require a large land area and intensive management and monitoring.

TABLE 3.9 (Cont.)

General Response Action	Technology Type	Affected Media	Evaluation Result	Comments
Short-term storage	Open and enclosed structures	Soil, rock, sludge, sediment, drummed process chemicals, containerized asbestos-containing material and other structural material, vegetation	Retained	Can effectively reduce contaminant mobility in the short term; currently being used at the site, e.g., with the TSA, MSA, Building 434, and asbestos container staging area.
	Tanks and retention ponds	Surface water, groundwater (intercepted/ collected), liquid chemicals	Retained	Can effectively reduce contaminant mobility in the short-term; currently being used at the site.
Disposal	Land-based facility Concrete vault	Soil, sludge, sediment, structural material, vegetation, process chemicals	Rejected	Ineffective for weight-bearing waste and difficult to accommodate design changes.
	Engineered cell	Soil, sludge, sediment, structural material, vegetation, process chemicals	Retained	Can effectively contain weight-bearing waste to reduce containment mobility; can be designed to accommodate specific waste types and quantities.
	Ocean disposal	Soil, sludge, sediment, structural material, vegetation, process chemicals	Rejected	Not currently available due to regulatory restrictions and other acceptance issues.

4 DEVELOPMENT AND SCREENING OF PRELIMINARY ALTERNATIVES

Preliminary alternatives for remediating the Weldon Spring site were developed and screened in accordance with CERCLA, as amended, EPA guidance (EPA 1988a), and the NCP (EPA 1990a). Seven broad alternatives were developed on the basis of the criteria presented in Section 4.1. The preliminary alternatives, which are identified and described in Section 4.2, were then screened on the basis of the criteria presented in Section 4.3. Five final alternatives were selected from the results of the screening analysis, which is presented in Section 4.4. These final alternatives are identified in Section 4.5, described in Chapter 5, and evaluated in detail in Chapter 6. A comparative analysis of the final alternatives is presented in Chapter 7. The preferred alternative is identified in the proposed plan for this remedial action (DOE 1992b).

4.1 CRITERIA FOR DEVELOPING ALTERNATIVES

The EPA has established an approach for developing remedial action alternatives that are appropriate to the specific conditions at a site (EPA 1988a, 1990a). 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. This protection can be achieved by eliminating, reducing, and/or controlling risks posed by each pathway at a site. Two major categories of response are considered in developing remedial action alternatives:

- Containment — involving little or no treatment but protective of human health and the environment by preventing or controlling exposures to contaminants through engineering measures and by using institutional controls as necessary to ensure the continued effectiveness of a response; and

- Treatment — ranging from alternatives that use treatment as the primary element of the response to address the principal threat(s) posed by a site (this may not involve the highest degree of treatment or the treatment of all waste) to alternatives that use treatment to reduce the toxicity, mobility, or volume of contaminated material to the maximum extent feasible, minimizing the need for long-term management.

As stated in Section 121(b) of CERCLA, as amended, the most preferred alternatives are those that represent permanent and cost-effective solutions for protecting human health and the environment; permanently and significantly reduce the toxicity, mobility, or volume of contaminated material; and apply alternative treatment or resource recovery technologies to the extent possible. Least preferred are those alternatives involving the transport and disposal of waste off-site without treatment.

A no-action alternative — or no further action where a remedial action is preceded by interim response actions at a site — is also included to provide a baseline for comparison with other alternatives. For the analysis in this FS, the baseline condition of the Weldon Spring site reflects the removal actions and interim remedial actions that have already been finalized for the project (Section 1.5.1).

4.2 IDENTIFICATION OF PRELIMINARY ALTERNATIVES

Technologies potentially applicable to the management of contaminated media at the Weldon Spring site are identified and screened in Chapter 3 (Table 3.9). On the basis of this screening, various control technologies were identified as potential components of remedial action alternatives for the site. These technologies have been incorporated into seven preliminary alternatives:

- Alternative 1: No Action;
- Alternative 2: In-Situ Containment and Limited Disposal;
- Alternative 3: In-Situ Chemical Stabilization/Solidification and Limited Disposal;
- Alternative 4: In-Situ Vitrification and Limited Disposal;
- Alternative 5: Removal, Minimal Treatment, and Disposal;
- Alternative 6: Removal, Chemical Stabilization/Solidification, and Disposal; and
- Alternative 7: Removal, Vitrification, and Disposal.

All of the action alternatives (Alternatives 2 through 7) are further divided into alternative disposal options: disposal in an engineered cell on-site (Alternatives 2a, 3a, 4a, 5a, 6a, and 7a); disposal at the Envirocare site near Clive, Utah (Alternatives 2b, 3b, 4b, 5b, 6b, and 7b); disposal at the DOE Hanford site near Richland, Washington (Alternatives 2c, 3c, 4c, 5c, 6c, and 7c); and disposal at a hypothetical nearby site in Missouri (Alternatives 2d, 3d, 4d, 5d, 6d, and 7d). In-situ containment is the primary emphasis of Alternatives 2, 3, and 4; and source control via removal, with varying degrees of treatment, is the primary emphasis of Alternatives 5, 6, and 7.

Two separate engineering support studies were prepared to provide information for the screening analysis and detailed evaluation of site cleanup alternatives in this FS. The first report (MK-Ferguson and Jacobs Engineering Group 1992a) was prepared in 1990 and 1991 on the basis of screening-level information for the preliminary alternatives, and it is the source of much of the engineering and cost data used to analyze the alternatives in this chapter. In accordance with the NCP, the alternatives retained through the screening stage were subsequently evaluated in greater detail. To provide the more extensive engineering and cost analyses needed for that evaluation, a second engineering report was prepared (MK-Ferguson and Jacobs Engineering Group 1992b). This report was the source of much of the engineering and cost data used to evaluate the final alternatives in Chapters 6 and 7. Because the objective of the first study was to provide screening-level information for the preliminary analysis and because it was prepared at an early stage of the assessment process, some of the data in that report differ from the data provided in the second report. Therefore, in some cases, the values shown for certain parameters such as cost and waste volume in Chapters 6 and 7 differ from those shown in this chapter. However, these differences simply reflect the refinement of preliminary estimates, they are generally minor, and they do not affect the results of the analyses presented in this FS.

The site would remain fenced and existing institutional controls such as DOE custody, security guards, and monitoring are implicitly included in each of the action alternatives for the cleanup period. These controls are also included for the no-action alternative. Controls such as monitoring would be increased as needed. Each action alternative would require various support activities prior to implementation. These activities include the design and construction of staging areas, procurement of appropriate equipment, and development of contingency plans and operational controls to minimize contaminant releases. Site preparation activities would include clearing and grubbing contaminated areas on-site and at vicinity properties, constructing haul roads, and emplacing site perimeter dikes and siltation basins for surface water runoff/runon control. Other factors common to all preliminary action alternatives are discussed in Section 4.2.1; factors specific to each alternative are discussed in Section 4.2.2.

4.2.1 Factors Common to All Preliminary Action Alternatives

The preliminary action alternatives address contaminated media both on-site and in the vicinity. The approach for certain media is the same under each alternative; the common strategies for these media are identified in Sections 4.2.1.1 through 4.2.1.7.

4.2.1.1 Structural Material

As part of interim actions at the site, all chemical plant buildings and structures except the project office building will be dismantled and the resultant structural and equipment debris will be placed in storage at the debris staging area of the MSA (Section 1.5.1). For the discussions in this FS, the material resulting from the dismantlement of these structures — including building rubble, tanks, equipment, and asbestos — is referred to as structural material. The dismantlement of two buildings would be delayed until the material currently being stored inside is transferred to another appropriate storage area or to a disposal facility. Building 434 would continue to be used to store chemically hazardous material until the final disposal of this material. About 1,100 m^3 (1,500 yd^3) of friable asbestos-containing material has been double bagged and is currently stored in Building 103. Before this building is dismantled, the bags will be removed and relocated to the asbestos container staging area located in the northeastern portion of the site (Figure 1.3). An additional 2,400 m^3 (3,200 yd^3) of friable asbestos-containing material and 3,900 m^3 (5,100 yd^3) of nonfriable asbestos-containing material will be removed from the site buildings prior to building dismantlement; the friable asbestos will be double bagged and stored in the asbestos container staging area along with the friable asbestos relocated from Building 103. Nonfriable asbestos will be stored in the debris staging area of the MSA. As a contingency, containerized asbestos might be temporarily stored in Building 108. If

Building 108 were used for such short-term storage, the building would be dismantled after that material was transferred to the dedicated staging area.

Under the current remedial action, structural material and used personal protective equipment in short-term storage on-site (in the MSA debris staging area, TSA, asbestos container staging area, and the specified buildings) would be removed and transported to the volume reduction facility or the disposal cell, as appropriate. The volume reduction facility would be located near the largest quantity of structural material and rubble, i.e., next to the MSA, to facilitate transport. At this facility, the material would be reduced in size and/or volume by impact crushing, rotary shearing, or in-drum compaction. These processes are expected to achieve a typical volume reduction of between 10 and 50%. Approximately 130,000 m^3 (170,000 yd^3) of contaminated structural material would require treatment and/or disposal. Depending on the alternative selected, the treated debris would be placed in loading bins for subsequent transport to an on-site disposal cell or placed in containers and covered for transport to the off-site disposal locations. Metal debris at the MSA and similar debris at the TSA would be evaluated for resource recovery. Potentially reusable material, such as regular shaped structural beams and sheet metal siding, would be released for off-site salvage if it could be decontaminated to meet release criteria (Section 2.1 and Appendix G). The potential for recycling metal for restricted use, e.g., as shielding components, would also be considered as part of remedial design.

4.2.1.2 Process Chemicals

Chemicals from various locations on-site are being collected, characterized, consolidated, and containerized as part of an ongoing interim action; process waste that will be generated by the two water treatment plants under additional interim actions is also included in this category (Section 1.5.1). The nonradioactively contaminated chemicals would be transported off-site to a permitted treatment and/or disposal facility. The radioactively contaminated liquid chemicals that are suitable for incineration would be transported to an approved incinerator. Approximately 85 m^3 (111 yd^3) of containerized liquids from Building 434 and 28 m^3 (37 yd^3) of tributyl phosphate in two exterior tanks near the MSA would be packaged in accordance with applicable U.S. Department of Transportation (DOT) regulations and transported off-site by truck to the incinerator. Applicable requirements for shipping to and incineration at that facility would be met (Appendix G, Table G.3). A representative incinerator was selected for analysis of related transportation impacts in this FS; this incinerator was assumed to be the K-1435 incinerator located at the Oak Ridge Gaseous Diffusion Plant near Oak Ridge, Tennessee. That facility holds permits to incinerate waste under both TSCA and RCRA (Section 3.2.4.2). Transport of the chemicals from Building 434 to this representative incinerator would require about five haul trips (88 drums per trip), assuming that all waste was packaged in drums; the tributyl phosphate would require three tanker trucks. If the K-1435 incinerator were not available to treat contaminated liquids from the Weldon Spring site, they would be transported to and incinerated at an alternate permitted facility or treated on-site e.g., by chemical neutralization or stabilization.

The 2,800 m^3 (3,600 yd^3) of containerized process waste from the water treatment plants at the site and the quarry would be managed in the same manner as described for the raffinate pit sludge under each alternative in Section 4.2.2. An additional 22 m^3 (28 yd^3) of radioactively contaminated chemicals for which incineration is inappropriate would be treated on-site, e.g., by chemical neutralization or stabilization, prior to disposal. These chemicals, which are stored in about one hundred 55-gallon drums in Building 434, include nitric acid, sulfuric acid, sodium hydroxide, flammable and reactive solids, and oxidizers.

4.2.1.3 Organic Material

Various wooden debris and organic material from clearing and grubbing activities conducted to support site cleanup activities would be chipped and composted on-site to reduce waste volume. Potentially contaminated material would be composted separately from uncontaminated material. A total of about 23,400 m^3 (30,700 yd^3) of chipped vegetation would be composted in a mulch pile located in the northern portion of the site in an area that is not occupied by other facilities and is close to the largest amount of vegetation to be composted. Following volume reduction through decomposition, the contaminated material would be placed in an on-site disposal cell or transported to an off-site disposal facility, depending on the alternative. As indicated by the results of ongoing treatability tests, the nitroaromatic-contaminated soil from the quarry in storage at the TSA might also be composted as a pretreatment step prior to further treatment or disposal.

4.2.1.4 Off-Site Surface Water and Soil/Sediment

The Missouri Department of Conservation is planning to drain the surface water from Lakes 34, 35, and 36 in the Busch Wildlife Area and remove collected sediment as part of the routine sedimentation management program for the wildlife area. The total risks associated with exposures to the surface water in these lakes under conservative scenarios are at the low end of the target range identified by EPA (see Sections 5 and 6 of the BA [DOE 1992a] and Section 1.6 of this FS); hence, there is no need to remediate the water prior to the state's action. However, certain locations of shoreline soil and sediment contain elevated levels of radionuclides.

After the Missouri Department of Conservation has drained the lakes, DOE would remove the portion of sediment and shoreline soil that is contaminated in excess of soil cleanup criteria for the site (which are developed in Chapter 2). This material would be transported to the site for placement either in an on-site disposal cell or in short-term storage prior to transfer to containers for transport to an off-site disposal facility, depending on the alternative. The estimated volumes of sediment/soil that would be removed are 6,100 m^3 (8,000 yd^3) from Lake 34, 3,800 m^3 (5,000 yd^3) from Lake 35, and 5,400 m^3 (7,000 yd^3) from Lake 36 — for a total of about 15,300 m^3 (20,000 yd^3) (MK-Ferguson Company and Jacobs Engineering Group 1992a).

Before transporting the contaminated sediment from the lakes to the site, the haul trucks would be decontaminated at the lakes as necessary using portable facilities. The truckbeds would also be decontaminated on-site, if needed, before making the return trip to the lakes. The trucks would be lined and covered to prevent tracking or spillage of contaminated material. Haul routes from the lakes to the site are shown in Figure 4.1. One-way haul distances from Lakes 34, 35, and 36 are 4.0 km (2.5 mi), 4.3 km (2.7 mi), and 3.1 km (1.9 mi), respectively. Approximately 2,000 one-way trips, for a total haul distance of about 7,500 km (4,700 mi), would be required to transport the lake sediment to the site. Monitoring and mitigative measures that would be taken are described in Section 6.6. This activity would be coordinated with the Missouri Department of Conservation to ensure that schedules for sediment removal were consistent with the planned remedial action period for the site.

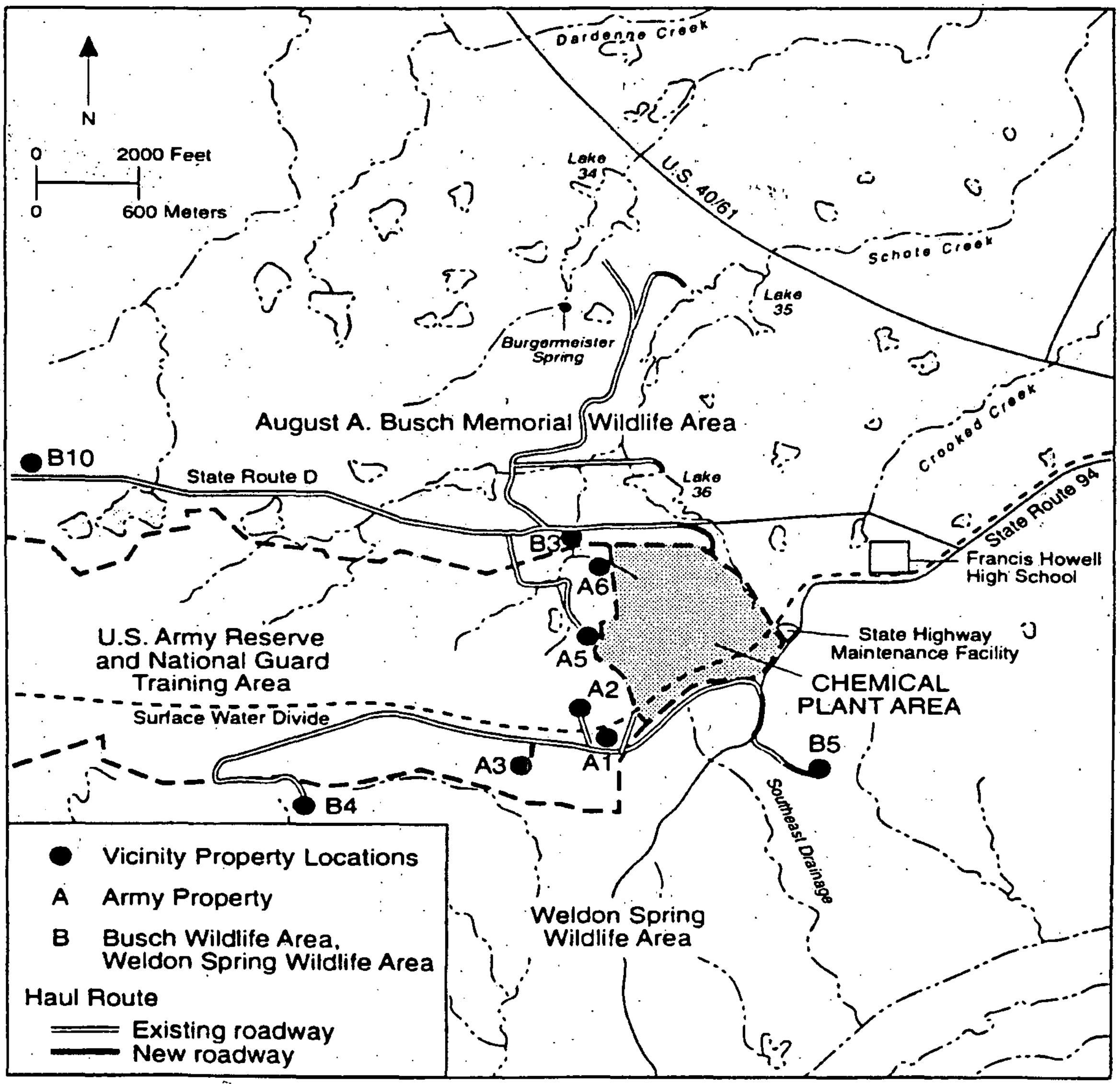

FIGURE 4.1 Off-Site Haul Routes for Transport of Contaminated Material from Lakes 34, 35, and 36 and Vicinity Properties to the Chemical Plant Area

4.2.1.5 Vicinity Property Soil

The vicinity properties are designated areas outside the site fence that are radioactively contaminated as a result of previous transport and storage activities (Figure 1.4). Although the contamination is variable, uranium is generally the predominant radionuclide; several of the properties also contain thorium and radium at levels above background. A detailed description of the radioactive contamination at these properties is provided in Section 5.2.3 of the RI (DOE 1992c). Decisions for the Southeast Drainage and vicinity properties at the quarry (e.g., Femme Osage Slough) are outside the scope of the current remedial action; those areas will be addressed under future actions for the project (Section 1.5.3). Contaminated soil at the remaining ten vicinity properties would be removed and transported to the site for management with other contaminated material as part of the current action.

Approximately 2,800 m^3 (3,600 yd^3) of contaminated soil is present at these ten vicinity properties. The soil would be excavated with hand-held shovels or earth-moving equipment, as appropriate to the size of the affected area (areas are shown in Table 3.6 of the BA). This soil would then be transported to the site for further management, as described for the material excavated from the lakes (Section 4.2.1.1). Haul routes for transport of the vicinity property soil to the site are identified in Figure 4.1. Not identified on Figure 4.1 is vicinity property B6 and the related haul route; this property is adjacent to the quarry, and excavated soil would be transported to the site along the haul road constructed as part of the interim action for the quarry bulk waste (DOE 1990b). Also not shown on the figure are vicinity properties already remediated as part of interim actions for the site (A7, B1, B2, and B8) and those outside the scope of the current action (A4, B7, and B9). Vicinity properties A4 and B7 (the Southeast Drainage) will be addressed as a separate action for the site after source control measures have been implemented and subsequent data collection is completed. Vicinity property B9 is the Femme Osage Slough, which will be addressed with the quarry residuals action.

Existing roads would be used where possible to move soil from the vicinity properties to the site; additional temporary haul roads would be constructed, as necessary. Before leaving a vicinity property, the haul truck would be decontaminated as necessary using portable facilities, and the truckbed would be lined and covered to prevent tracking or spillage of contaminated material. Assuming a maximum one-way distance of 4 km (2.5 mi), about 360 one-way haul trips, would be required to transport the vicinity property soil to the site, for a maximum total haul distance of 1,400 km (900 mi). Haul trucks would also be decontaminated at the site as necessary. Upon completion of removal activities, the excavated areas would be backfilled, covered with topsoil, and seeded. Reclamation of Army properties A5 and A6 (Figure 4.1) would include the placement of stone riprap in the drainage channel to prevent scour and downstream deposition of fine sediment. Monitoring and mitigative measures that would be applied at those vicinity properties are discussed in Section 6.6 and Appendix H.

4.2.1.6 Groundwater

Except for the perched water in the unsaturated zone beneath the raffinate pits, groundwater is being addressed as a separate operable unit of site cleanup. That is, it is not part of the scope of this RI/FS-EIS (Section 1.5.3). In the meantime, groundwater in the saturated zone is being addressed by implementing (1) source control measures, i.e., removing the contaminant sources; and (2) institutional controls such as monitoring, to determine the effectiveness of source control measures and to ensure the timely initiation of a response action, if needed. Thus, potential adverse impacts will be indirectly mitigated by actions taken prior to the decision for the groundwater operable unit. For example, the contaminated wetlands at the site (primarily the raffinate pits) represent sources of groundwater contamination. Surface water is being removed from these wetlands and treated in a newly constructed water treatment plant under an interim action (Section 1.5.1.4), and the contaminated sludge and sediment is being addressed under the current remedial action. A wetlands assessment prepared for these areas in accordance with 10 CFR 1022 is included in Appendix H. The control of this material will reduce the potential for future groundwater impacts at these locations.

The perched groundwater beneath the pits is being intercepted by a trench that was recently installed as part of adjacent site preparation for constructing the TSA, to support the interim action for quarry bulk waste. The intercepted water is being recirculated to the raffinate pits, and it will be treated in the water treatment plant that was recently constructed on-site for the interim action.

4.2.1.7 Quarry Residuals

Residual solid material that could result from future actions at the quarry includes rock, soil, sludge, and sediment (Section 1.5.3). This material would be managed in the same manner described in the alternatives for the current remedial action for similar material in storage at the TSA and MSA (Section 4.2.2).

4.2.2 Factors Specific to Each Preliminary Alternative

The remedial action alternatives for the Weldon Spring site primarily focus on soil, sludge, and sediment; structural material in short-term storage areas is also addressed. Decisions have already been made for other media, such as surface water, under interim actions and the common approaches identified in Section 4.2.1 address the remainder. Air is included indirectly with soil, sludge, and sediment because airborne contaminants are generated from the contaminants in these media. The specific components of the seven preliminary alternatives are described in Sections 4.2.2.1 through 4.2.2.7. The various treatment facilities and storage areas common to the action alternatives are shown in Figure 4.2.

4.2.2.1 Alternative 1: No Action

Under Alternative 1, no further action would be taken at the site. The following interim response actions for which decisions have already been finalized are assumed to be in effect as the baseline condition for this FS: (1) bulk waste from the quarry is assumed to be in short-term

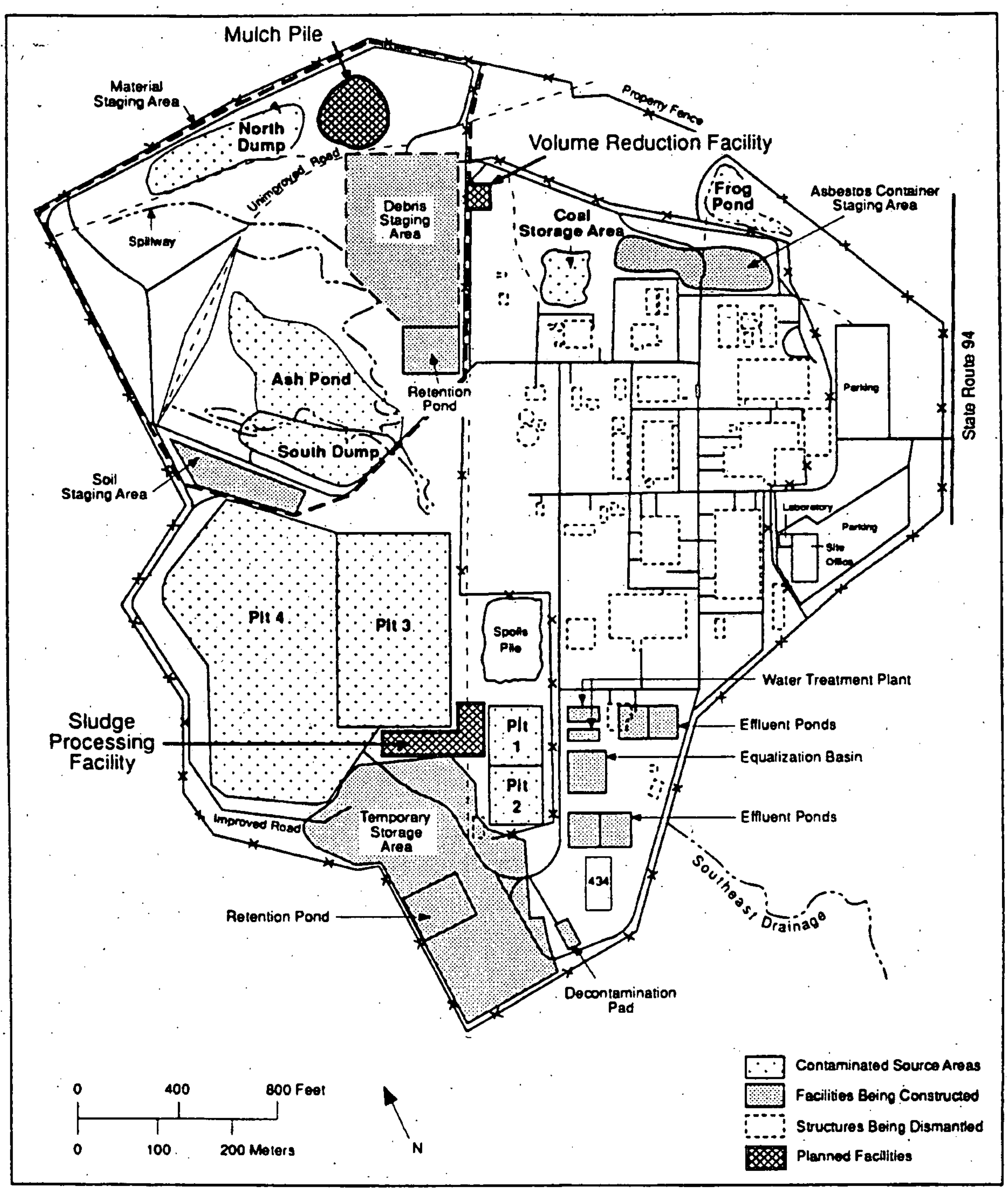

FIGURE 4.2 Location and Layout of Existing, Planned, and Proposed On-Site Storage and Treatment Facilities

storage at the TSA; (2) the water treatment plants at the quarry and the chemical plant area are assumed to be operational; (3) buildings and other structures are assumed to be dismantled, with the debris in short-term storage at the MSA; and (4) containerized chemicals remain in short-term storage at Building 434. For the no-action alternative, the current conditions of the contaminated soil, sludge, and sediment would continue.

4.2.2.2 Alternative 2: In-Situ Containment and Limited Disposal

Alternative 2 involves in-situ containment of some source areas at the site and limited disposal of material from others. The in-situ containment component would apply to the raffinate pits, Frog Pond, Ash Pond, North Dump, and South Dump. The remaining areas — i.e., the TSA, MSA, sitewide soil, and vicinity property soil and sediment — would not be amenable to containment in place because these are either short-term storage facilities that were not designed for long-term waste management or are scattered locations of soil contamination. Therefore, the limited disposal component of this alternative applies to these areas.

Under the in-situ containment component of Alternative 2, the contaminated material would be contained in place at the various source areas defined above. Soil would be capped with an earthen cover or synthetic geotextile fabric, and runoff from these areas would be diverted by surface grading controls. The raffinate pit sludge and pond sediment would be contained with a surface cap, lateral cutoff walls, and an underlying confining layer. The cap would be the same as that used to cap soil areas, and the subsurface component would involve the injection of a natural or polymeric grout material around the periphery of and beneath the pits and ponds. The total area requiring a surface cap and subsurface grout layer is approximately 17 ha (42 acres). Subsurface grout walls would also extend around the periphery of the various source areas over a combined distance of about 3,000 m (10,000 ft) and to a depth of up to 20 m (65 ft) at the raffinate pits. This in-situ containment system would encompass about 316,000 m^3 (413,000 yd^3) of contaminated soil, sludge, and sediment.

Under the limited disposal component of Alternative 2, the contaminated material not contained in situ would be removed with standard construction equipment and transported to an engineered disposal cell on-site (Alternative 2a), at the Envirocare site (Alternative 2b), at the Hanford site (Alternative 2c), or at the hypothetical nearby site (Alternative 2d). Approximately 154,000 m^3 (202,000 yd^3) of contaminated soil, organic material, and other waste would be removed from the TSA; the mulch pile; vicinity properties; Lakes 34, 35, and 36; and scattered sitewide soil areas. This material includes the contaminated soil excavated to construct the TSA and water treatment plant, which is being stored at the MSA (Figure 4.2). The 130,000 m^3 (170,000 yd^3) of existing structural material would bring the total volume of contaminated material requiring disposal under Alternative 2 to about 284,000 m^3 (372,000 yd^3). Because of the large quantity of waste requiring disposal and the relatively long haul distance (more than 2,400 km [1,500 mi]), waste would be shipped by rail for most of the distance to the western sites (Alternatives 2b and 2c); a small segment of the trip would be by truck, i.e., from the site to the rail siding in Wentzville, Missouri. Waste would be shipped by truck directly to the hypothetical nearby site (Alternative 2d).

The conceptual design of the engineered cell for on-site disposal includes a leachate collection and removal system and a cover system with an infiltration and radon attenuation barrier. This design incorporates features of a disposal cell for radium-contaminated waste, taken from the cell design for DOE's Uranium Mill Tailings Remedial Action (UMTRA) Program, with the addition of a leachate collection and removal system to retrieve any liquid such as rainwater that might accumulate during the construction and operation period and to support future monitoring of the effectiveness of the disposal cell. The cell design would provide sufficient capacity to accommodate the total waste volume from all source areas not contained in situ and all material (e.g., equipment) contaminated during implementation of site cleanup activities. The preliminary conceptual design of the on-site cell is described in more detail in Section 5.2.3; final design of the disposal cell would be developed during detailed remedial design, as determined by the remedy selected. For the representative analyses in this document, the disposal cell at the off-site locations was assumed to be similar to that evaluated for on-site disposal because the nature of the waste (e.g., radium-containing and therefore radon-generating) rather than the geographic location would be the key factor for cell design.

Off-site disposal under Alternative 2b or 2c would require the leasing or construction of a rail siding near the site for transfer of waste containers to railcars; some additional on-site stockpiling of material to coordinate with the off-site transportation schedule; and equipment and operations to load, transport, and transfer the waste containers at the site, at the siding, and at the disposal site. Rail access to both the Union Pacific and Burlington Northern lines is available in the area of Wentzville, Missouri. This area was therefore selected as the representative location for a rail siding on the basis of suitability and reasonable haul distance (24 km [15 mi]) from the site. Under Alternative 2d, waste would be trucked directly to the nearby site.

Limited disposal at an off-site facility under Alternative 2 would involve shipping about 284,000 m^3 (372,000 yd^3) of currently contaminated material plus about 76,000 m^3 (100,000 yd^3) of material that would become contaminated during remedial activities. Potential rail routes to the western sites (Alternatives 2b and 2c) are identified in Figure 4.3. The haul route to the hypothetical nearby site (Alternative 2d) would consist of existing roads and would depend on the location determined for this site. Off-site disposal of the 361,000 m^3 (472,000 yd^3) of site waste — which would weigh about 660,000 t (727,000 tons) — would require approximately 350 one-way rail trips assuming 25 railcars per train carrying three 25-t (28-ton) containers per car; this corresponds to 845,000 rail-km (525,000 rail-mi) for transport to the Envirocare site (Alternative 2b) and 1,180,000 rail-km (735,000 rail-mi) for transport to the Hanford site (Alternative 2c). For both alternatives, the initial transportation of waste by truck to the rail siding in Wentzville, Missouri, would require approximately 26,000 one-way trips, assuming one 25-t (28-ton) container per truck, for a total of 628,000 truck-km (390,000 truck-mi). Assuming a maximum distance of 160 km (100 mi) to the nearby site, off-site disposal under Alternative 2d would require approximately 26,000 one-way truck trips for a total of 4,180,000 truck-km (2,600,000 truck-mi).

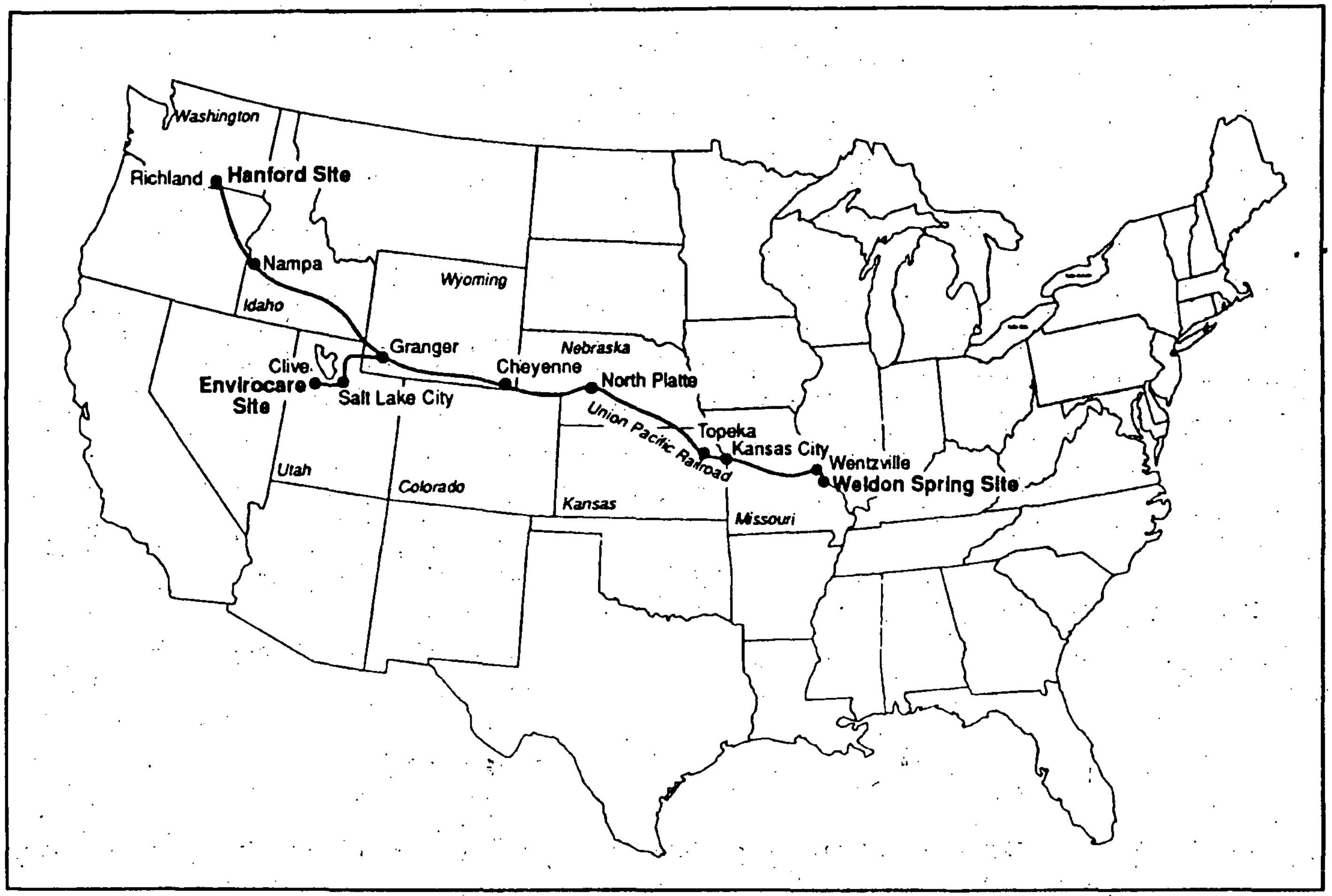

FIGURE 4.3 Potential Rail Routes to Clive, Utah, and Richland, Washington

4.2.2.3 Alternative 3: In-Situ Chemical Stabilization/Solidification and Limited Disposal

Alternative 3 involves in-situ chemical stabilization/solidification of the raffinate pits, Frog Pond, Ash Pond, North Dump, and South Dump and limited disposal of material from the remaining source areas — i.e., the TSA, MSA, sitewide soil, and vicinity property soil and sediment. The latter source areas could not be practicably stabilized/solidified in place for the same reasons identified for Alternative 2. Contaminated soil would be excavated from the North Dump and relocated to the Ash Pond/South Dump area for consolidated treatment in order to reduce the area required for capping. Process waste from the two water treatment plants and other process chemicals (expected to total about 2,800 m^3 [3,600 yd^3]) would be treated with the raffinate pit sludge.

Chemical stabilization/solidification is a process that immobilizes and solidifies contaminated material by reaction with chemical additives such as cement and fly ash to form insoluble compounds and/or by the entrapment of contaminants in the relatively impermeable, stable matrix that is formed during setting. For in-situ treatment, the reagents could be added directly to the soil or sludge and mixed in with standard construction equipment. Alternatively, mixing equipment specifically designed with drills, augers, and paddles for in-situ applications could be used to inject additives concurrent with mixing. In the latter process, reagents would be added to the waste pneumatically or by pumping, and a crane-mounted mixing system could be used in soft soil and sludge up to 9 m (30 ft) deep. However, the raffinate pit sludge at the Weldon Spring site could not be stabilized/solidified in this manner because its compressive strength is insufficient to support the crane-mounted equipment. Therefore, reagents would be mixed directly into the sludge with backhoes and draglines working along the perimeter. Once the mixture had set, the backhoe or dragline could move onto the stabilized zone and reach the untreated sludge to repeat the process until the entire area was treated. Some additional areas would require clearing and grading to accommodate the equipment and supplies needed for in-situ chemical stabilization/solidification compared with Alternative 2.

Bench-scale laboratory tests with the raffinate pit sludge indicate that the addition of a cement/fly ash mixture results in a solidified mass with properties similar to concrete. The study found that a blend of 40% (by weight) Type II Portland cement and 60% ASTM Class F fly ash mixed at ratio of 0.6:1 (by weight) cement/fly ash to raffinate sludge would stabilize and solidify the sludge (Gilliam and Francis 1989). This blend achieved initial set within 1 day and final set within 7 days. The solidified mass met the performance criteria of (1) no drainable water within 28 days, (2) unconfined compressive strength of at least 410 kPa (60 psi), and (3) resistance to thermal cycling. With this blend ratio, an in-situ application of chemical stabilization/solidification for the 259,000 t (286,000 tons) of material in the source areas identified above would necessitate the addition of about 156,000 t (172,000 tons) of chemical reagents, i.e., 62,600 t (68,800 tons) of cement and 93,400 t (103,000 tons) of fly ash. Those areas stabilized/solidified in situ would then be capped in the same manner described for Alternative 2.

The limited disposal component of Alternative 3 would be the same as that described for Alternative 2, except the water treatment plant process waste and certain other containerized chemicals would have been treated with the raffinate pit sludge. The 356,000 m^3 (466,000 yd^3) of material not chemically stabilized/solidified in situ would be removed and disposed of in an engineered disposal cell on-site (Alternative 3a), at the Envirocare site (Alternative 3b), at the Hanford site (Alternative 3c), or at the hypothetical nearby site (Alternative 3d). The conceptual design of the cell would be as described for Alternative 2.

4.2.2.4 Alternative 4: In-Situ Vitrification and Limited Disposal

Alternative 4 involves in-situ vitrification of the raffinate pits, Frog Pond, Ash Pond, North Dump, and South Dump, and limited disposal of material from the remaining source areas —i.e., the TSA, MSA, sitewide soil, and vicinity property soil and sediment. The latter source areas could not be practicably treated in place for the same reasons identified for Alternative 2. Other material would be managed as described for Alternative 3.

The in-situ vitrification process uses electrically applied heat to melt the waste material, simultaneously destroying organic contaminants while incorporating inorganic contaminants into the glass-like product that forms upon cooling. In-situ vitrification involves placing an array of electrodes in the material to be treated and applying an electric potential between the electrodes. The resulting current heats the material between the electrodes to temperatures above 1,600°C. With continued application of the electric potential, the molten volume grows downward and outward to encompass the desired treatment volume. With existing large-scale in-situ vitrification equipment, individual settings can reach a maximum width of about 9 m (30 ft) and depths of up to 9 m (30 ft) (MK-Ferguson Company and Jacobs Engineering Group 1992a). Site preparation would be similar to that identified for Alternative 3.

Bench-scale laboratory tests with the raffinate pit sludge and on-site soil indicate that a blend of 50% soil and 50% sludge (dry weight) is needed for effective in-situ vitrification of the sludge. When this sludge was processed separately — i.e., without added soil — a soft, granular, highly devitrified product formed upon cooling (Koegler et al. 1989). At the indicated blend ratio, about 54,000 t (60,000 tons) dry weight of soil would need to be added to the raffinate pits prior to the application of in-situ vitrification. Contaminated soil and sediment from the source areas not treated in place could be used for this material, and the consolidated treatment would reduce the volume requiring disposal in a cell. Those areas vitrified in situ would then be capped in the same manner described for Alternative 2.

The limited disposal component of Alternative 4 would be the same as described for Alternative 3. Effective in-situ vitrification of the raffinate pit sludge would require the addition of a large amount of soil. Some of this material could be excavated from the contaminated soil areas, which would reduce the total amount of material requiring disposal by about 38,000 m^3 (50,000 yd^3). The 318,000 m^3 (416,000 yd^3) of material not vitrified in situ would be removed and disposed of in an engineered disposal cell on-site (Alternative 4a), at the Envirocare site (Alternative 4b), at the Hanford site (Alternative 4c), or at the hypothetical nearby site (Alternative 4d). Transportation and handling requirements would be somewhat reduced under this alternative compared with Alternative 2 or 3 because of the decreased disposal volume. Approximately 40 fewer train trips (Alternative 4b or 4c) and 3,000 fewer truck trips

(Alternative 4b, 4c, or 4d) would be required. Conceptual cell design would be similar to that identified for Alternative 2.

4.2.2.5 Alternative 5: Removal, Minimal Treatment, and Disposal

Alternative 5 involves the removal, limited treatment, and disposal of contaminated material from each of the on-site source areas. Under Alternative 5, contaminated soil, sludge, and sediment that exceeded soil cleanup criteria would be removed, and the sludge and sediment would be dewatered to reduce its volume, facilitate waste handling, and minimize free liquid. Soil, sludge, sediment, and other material would be removed from the short-term storage areas (e.g., the TSA) and dewatered as appropriate. After this removal and treatment, contaminated material would be transported to an engineered disposal cell on-site (Alternative 5a), at the Envirocare site (Alternative 5b), at the Hanford site (Alternative 5c), or at the hypothetical nearby site (Alternative 5d).

Under the removal component of Alternative 5, soil and sediment would be excavated or dredged from the various source areas with standard construction equipment such as front-end loaders, scrapers, and backhoes. A total of approximately 302,000 m^3 (395,000 yd^3) of soil and sediment would be removed in this manner. The raffinate pit sludge would be removed by a dredge suspended in the ponded water and then pumped as a slurry to holding tanks at a newly constructed sludge processing facility for dewatering. This special removal method would be required because the sludge is a fine-grained material with a high moisture content (73% water by weight) and some water would have to be maintained in the pits to minimize radon and dust emissions. The sludge processing facility would be constructed adjacent to the raffinate pits (Figure 4.2) to minimize the distance over which the 168,000 m^3 (220,000 yd^3) of highly contaminated material would have to be transferred for dewatering. After the sludge was dredged, an estimated 117,400 m^3 (153,500 yd^3) of underlying soil would be excavated with standard construction equipment. More site preparation activities would be required to implement Alternative 5 compared with Alternative 4 because of the more extensive excavation activities under this alternative.

The treatment component of Alternative 5 consists of dewatering all of the high-moisture-content material. Water removed from the raffinate pit sludge would be pumped to the on-site water treatment plant or returned to the raffinate pits to provide sufficient water for dredge flotation. After dewatering, the sludge is expected to consist of 80% solids and have a bulk density of 1.98 t/m^3 (1.67 $tons/yd^3$); the total volume would be about 34,000 m^3 (45,000 yd^3), which represents a volume reduction of about 80% (MK-Ferguson Company and Jacobs Engineering Group 1992b). The dewatered sludge would be fed either to enclosed hoppers for transfer to an engineered disposal cell on-site (Alternative 5a) or to sealed containers for transport to an off-site disposal facility (Alternative 5b, 5c, or 5d).

An additional 94,000 m^3 (123,000 yd^3) of material, such as facility components and protective gear, is expected to become contaminated during remediation activities; this waste and excavated soil and sediment, structural material, and dewatered sludge would be loaded into end dump trucks for transport to the on-site disposal cell or placed in temporary storage prior to being loaded into containers for transport to an off-site disposal facility. Disposal would involve a total waste volume of about 557,000 m^3 (728,000 yd^3).

On-site disposal (Alternative 5a) would consist of placing the sludge, sediment, soil, rubble, and other waste in a disposal cell designed as described for Alternative 2a (Section 4.2.2.2). Off-site disposal under Alternative 5 would be similar to that identified for Alternative 2. However, because of the increased volume of material requiring disposal, off-site transport would require more railcars and truckloads and would increase the amount of waste handling. (About 1.5 times as many trips would be required for this alternative compared with Alternative 2, 3, or 4). Off-site disposal of the total waste volume — which would weigh about 1,020,000 t (1,130,000 tons) — would require about 540 one-way rail trips for a total of 1,300,000 rail-km (810,000 rail-mi) to the Envirocare site (Alternative 5b) and 1,820,000 rail-km (1,130,000 rail-mi) to the Hanford site (Alternative 5c). For both alternatives, the initial transportation of waste by truck to the rail siding in Wentzville, Missouri, would require about 40,400 one-way trips for a total of 975,000 truck-km (606,000 truck-mi). Assuming a maximum distance of 160 km (100 mi) to the nearby site, off-site disposal under Alternative 5d would require about 40,400 one-way truck trips for a total of 6,500,000 truck-km (4,040,000 truck-mi).

4.2.2.6 Alternative 6: Removal, Chemical Stabilization/Solidification, and Disposal

Alternative 6 involves the removal, chemical treatment as appropriate, and disposal of contaminated material from each of the on-site source areas. Under Alternative 6, contaminated soil, sludge, and sediment would be removed from the same areas stabilized in place under Alternatives 2, 3, and 4, and the raffinate pit sludge and the highly contaminated soil would be treated by chemical stabilization/solidification to reduce contaminant mobility, facilitate waste handling, and eliminate free liquid for the final waste form. The soil, sludge, sediment, and other contaminated material (e.g., process waste from the water treatment plants) would be removed from the short-term storage areas and treated, as appropriate. After removal and treatment, the material would be transported with all other site waste to an engineered disposal cell on-site (Alternative 6a), at the Envirocare site (Alternative 6b), at the Hanford site (Alternative 6c), or at the hypothetical nearby site (Alternative 6d).

The removal component of Alternative 6 would be similar to that of Alternative 5. However, the raffinate pit sludge and other more highly contaminated material would be transported to the sludge processing facility for chemical treatment; this facility would be constructed adjacent to the raffinate pits, as for Alternative 5. For the purpose of preliminary conceptual design, it was estimated that 76,000 m^3 (100,000 yd^3) of soil would be treated, including soil underlying the raffinate pit sludge and soil from the quarry in storage at the TSA. The sludge would be dredged from the raffinate pits and pumped to a holding tank for feed into the sludge processing facility. Soil from beneath the pits and at the TSA would be removed with standard construction equipment (e.g., front-end loaders) for transport to the processing facility. The total volume of material that would be treated — including raffinate pit sludge, soil, water treatment plant process waste, and other containerized waste — is estimated to be about 248,000 m^3 (324,000 yd^3). Site preparation would be similar to that identified for Alternative 5.

The treatment component of Alternative 6 consists of chemical stabilization/ solidification in an engineered treatment system. The application of this chemical treatment process following removal is similar to the in-situ process described for Alternative 3 (Section 4.2.2.3), except the contaminated material would be mixed with reagents in an engineered system such as a pug mill blender or high shear mixer. The reagents expected to be used for stabilizing/solidifying the raffinate pit sludge consist of a blend of 40% (by weight) Type II Portland cement and 60% ASTM Class F fly ash mixed at ratio of 0.6:1 (by weight) cement/fly ash to raffinate sludge as identified in laboratory testing (Gilliam and Francis 1989). Implementation of Alternative 6 would therefore require about 83,300 t (91,800 tons) of cement and 124,000 t (137,000 tons) of fly ash to stabilize the 248,000 m^3 (324,000 yd^3) of sludge, soil, and other material (MK-Ferguson Company and Jacobs Engineering Group 1992b). Because this process also requires water for the complete hydration of cement, water would have to be added to the soil material; the raffinate pit sludge could be treated without prior dewatering. The treatment facility is estimated to require an area of approximately 0.40 ha (1.0 acre) to accommodate the necessary equipment for chemical stabilization/solidification, including the blender, feed preparation circuits, and reagent addition equipment. Chemical treatment of the contaminated sludge, soil, and other material would result in about 327,000 m^3 (428,000 yd^3) of treated product, which would be a grout-like mixture that would be expected to achieve initial set within 1 day and final set within 7 days (Gilliam and Francis 1989). This treated volume represents an increase of about 32% over the initial untreated volume.

Volume-reduced and size-reduced structural material, excavated soil and sediment, and the chemically stabilized/solidified sludge, soil, and other material would be loaded into trucks for transport to an engineered disposal cell on-site (Alternative 6a) or placed in short-term storage prior to being loaded into containers for transport to the Envirocare site (Alternative 6b), the Hanford site (Alternative 6c), or the hypothetical nearby site (Alternative 6d). After trucking the waste to Wentzville, Missouri, railcars would be used to transport containers to the distant disposal sites (Alternatives 6b and 6c); containers would be transported by truck directly to the hypothetical nearby site (Alternative 6d).

On-site disposal (Alternative 6a) would consist of placing the treated product, soil, and rubble in a disposal cell having design components similar to that described for Alternative 2a. The cell would be designed to accommodate a larger volume of waste because of the increased volume of sludge and soil after treatment; the design capacity would be 960,000 m^3 (1,250,000 yd^3), including a 10% contingency, and the cell would cover a surface area of about 17 ha (42 acres). The preliminary conceptual design of this cell is described in more detail in Section 5.2.3; final design of the disposal cell would be developed during detailed remedial design after the site remedy is selected.

Off-site disposal under Alternative 6 would be similar to that identified for Alternative 5, but additional waste handling and trips would be required to address the increased waste volume resulting from chemical treatment. The contaminated material would be placed in transport containers and shipped by rail and truck to an off-site disposal facility, as described for Alternative 5b, 5c, or 5d. Off-site disposal of the 772,000 m^3 (1,010,000 yd^3) of site waste — which would weigh about 1,380,000 t (1,520,000 tons) — would require about 725 one-way train trips for a total of 1,750,000 rail-km (1,090,000 rail-mi) to the Envirocare site (Alternative 6b) and 2,450,000 rail-km (1,520,000 rail-mi) to the Hanford site (Alternative 6c). For both alternatives, the initial transportation of waste by truck to the rail siding in Wentzville, Missouri, would require about 54,300 one-way trips for a total of 1,300,000 truck-km (810,000 truck-mi). Assuming a maximum distance of 160 km (100 mi) to the nearby site, off-site transport under Alternative 6d would require about 54,300 one-way truck trips for a total of 8,740,000 truck-km (5,430,000 truck-mi). About 185 more trips would be required compared with Alternative 5 because of the increased volume and weight of the chemically stabilized/solidified product.

4.2.2.7 Alternative 7: Removal, Vitrification, and Disposal

Alternative 7 involves the removal, thermal treatment as appropriate, and disposal of contaminated material from each of the various on-site source areas. The removal component of Alternative 7 would be similar to that of Alternative 6, but the treatment component would differ. The vitrification system in the sludge processing facility would operate on a year-round schedule whereas excavation and dredging operations would require a winter shutdown; thus, removal operations would be conducted to accommodate the production rates required for vitrification. This would necessitate additional stockpiling of soil material at the TSA or MSA compared with Alternative 5, or, in the case of the dewatered raffinate pit sludge, in a contained storage area within the sludge processing facility. The raffinate pit sludge, soil, and other material would be transported to the sludge processing facility constructed adjacent to the raffinate pits as described for Alternative 6 (Figure 4.2). Site preparation would be similar to that identified for Alternative 5.

The treatment component of Alternative 7 consists of vitrifying the contaminated sludge, soil, and certain other waste in an engineered treatment system in a manner similar to that identified for in-situ vitrification (Section 4.2.2.4). For the analyses in this FS, a fossil fuel-heated system was evaluated as the representative vitrification technology. In this system, waste would be fed into an enclosed vessel and melted by heating with a fossil fuel-generated flame (Section 3.2.4). The vitrification system would consist of a feed preparation circuit and a melting circuit. As for in-situ vitrification, a blend of 50% soil and 50% sludge (dry weight) would be expected to result in effective vitrification of the raffinate pit sludge (Koegler et al. 1989); the vitrification system would be designed to blend soil and sludge at the required ratio during processing. The facility is estimated to require approximately 0.40 ha (1.0 acre) to accommodate the necessary treatment equipment, including the feed preparation and melter circuits. Vitrification of the sludge, soil, and other material is estimated to result in about 78,800 m^3 (103,000 yd^3) of treated product, which would be a fritted, noncohesive, glass-like material with a particle size of 0.32 to 0.64 cm (1/8 to 1/4 in.) (MK-Ferguson Company and Jacobs Engineering Group 1992a). This treated volume represents a decrease of about 68% over the initial, untreated volume.

Volume-reduced and size-reduced structural material, excavated soil and sediment, and the vitrified product would be loaded into trucks for transport to an on-site disposal cell (Alternative 7a) or placed in short-term storage prior to being loaded into containers for transport to the Envirocare site (Alternative 7b), the Hanford site (Alternative 7c), or the hypothetical nearby site (Alternative 7d). After trucking the waste to Wentzville, Missouri, railcars would be used to transport containers to the distant disposal sites (Alternatives 7b and 7c); containers would be transported by truck directly to the hypothetical nearby site (Alternative 7d).

On-site disposal was conceptually designed to include two separate disposal cells — one for vitrified material and another for the remaining soil, sediment, and structural material — so that each cell design would be appropriate for the waste type being contained. The vitrified material would be chemically inert but would retain its radiological characteristics, i.e., radiation toxicity would not be affected by the treatment; therefore, this material would be placed in a disposal cell designed with components similar to UMTRA disposal cells. This type of cell would include a cover with an infiltration and radon barrier and would also include a bottom foundation layer, but the lower portion of the cell would not include a liner and leachate collection system. The other (nonvitrified) site waste would consist of the less-contaminated fraction of soil and sediment (the more highly contaminated material would be vitrified with the raffinate pit sludge) and the structural material. This waste would be placed in a disposal cell designed with an infiltration and radon barrier as a component of the cell cover and a leachate collection and removal system, as described for Alternative 6 (Section 4.2.2.6). A preliminary conceptual design of these cells is described in more detail in Section 5.3.3; final design of the disposal facility would be developed during detailed remedial design, as determined by the remedy selected.

Off-site disposal under Alternative 7 would be similar to that identified for Alternative 5, but the total number of trips would be slightly lower because of the volume reduction associated with vitrification. The contaminated material would be placed in transport containers and shipped by rail and/or truck to the off-site disposal site. Off-site disposal of the 522,000 m^3 (683,000 yd^3) of site waste — which would weigh about 980,000 t (1,080,000 tons) — would require about 515 one-way train trips for a total of 1,240,000 rail-km (773,000 rail-mi) to the Envirocare site (Alternative 7b) and 1,740,000 rail-km (1,080,000 rail-mi) to the Hanford site (Alternative 7c). For both alternatives, the initial transportation of waste by truck to the rail siding in Wentzville, Missouri, would require about 38,600 one-way trips for a total of 930,000 truck-km (580,000 truck-mi). Assuming a maximum distance of 160 km (100 mi) to the nearby site, off-site disposal under Alternative 7d would require about 38,600 one-way truck trips for a total of 6,210,000 truck-km (3,860,000 truck-mi).

4.3 CRITERIA FOR SCREENING ALTERNATIVES

The seven preliminary alternatives were evaluated for applicability to remediating the Weldon Spring site on the basis of three general criteria: effectiveness, implementability, and cost. The effectiveness of an alternative is defined by its overall ability to protect human health and the environment in both the short term and long term. Measures of effectiveness include (1) reduction of potential long-term impacts to human health and the environment; (2) reduction of contaminant toxicity, mobility, or volume through treatment; (3) control of potential impacts to human health and the environment during the action period; (4) timeliness; and (5) attainment of regulatory requirements.

The implementability of an alternative is defined by its technical feasibility, resource availability, and administrative feasibility. Technical feasibility addresses the demonstrated performance, construction, operation, maintenance, replacement, and monitoring of an alternative's technical components. Potential constraints associated with the site environment are also considered. Availability addresses the resources required to implement specific components of an alternative and the ability to obtain them. Administrative feasibility addresses both the acceptability of an alternative by other agencies and groups and pertinent environmental requirements, including the need for permits, as appropriate.

The cost of an alternative is considered in a comparative manner at the screening stage by comparing general estimates for each alternative to evaluate relative costs. For example, for alternatives that are of similar effectiveness and implementability or that use similar treatment or engineering controls to achieve remedial action objectives, relative cost becomes an important screening criterion; if one of these similar alternatives is much more expensive than another, it can be screened from further consideration. In addition, if the cost of an alternative is inordinately excessive compared to the effectiveness it provides, that alternative can also be screened from further consideration.

4.4 SCREENING OF PRELIMINARY ALTERNATIVES

4.4.1 Alternative 1: No Action

Under Alternative 1, the site would remain unchanged except for conditions resulting from the completion of various interim actions that have already been approved. The quarry bulk wastes would be in storage at the TSA; structural material from building dismantlement would be in storage at the MSA and the asbestos container staging area; and the water treatment plant would be operational.

4.4.1.1 Effectiveness

Alternative 1 would not involve any further treatment beyond that achieved by the interim actions to reduce the toxicity, mobility, or volume of contaminated material at the site, and it would not provide for a timely or permanent response to site problems. In addition, certain regulatory requirements would not be met. The potential for exposures of wildlife, trespassers, and on-site workers would continue in the short term and could increase over time if contaminants were released to groundwater, surface water, soil, or air. In addition, if site controls were lost in the extended future, protection of human health and the environment at the site could not be ensured. Potential impacts to human health and the environment associated with no further action at the site are discussed in the BA (DOE 1992a) and in Appendix E and Section 6.11 of this FS.

4.4.1.2 Implementability

Minimum site operations, including monitoring and maintenance activities, would continue with readily available resources. Administrative feasibility related to time limitations for interim storage of hazardous waste could be an issue.

4.4.1.3 Cost

Costs associated with the no-action alternative (baseline conditions) include those for operating and maintaining existing facilities and continuing the general monitoring and maintenance of the site. Annual costs are estimated to be about $1.2 million (MK-Ferguson Company and Jacobs Engineering Group 1992b).

4.4.2 Alternative 2: In-Situ Containment and Limited Disposal

4.4.2.1 Effectiveness

Under the in-situ containment component of Alternative 2, exposures to humans and wildlife would initially be reduced. However, long-term protection over time would be uncertain because of difficulties associated with implementing an effective in-situ containment system at the most highly contaminated areas, i.e., the raffinate pits. The difficulties in ensuring waste isolation, determining the extent of maintenance requirements for the subsurface component of the containment system, and implementing such maintenance could also limit the effectiveness of this alternative. Alternative 2 does not satisfy the statutory preference for treatment as a principal element of remediation, and it would not reduce the toxicity, mobility, or volume of contaminants through treatment. Contaminants could be controlled through containment in the short term, but they might be mobilized over the long term if the containment system were to deteriorate. This alternative could probably be implemented in a timely manner except for the off-site disposal options, to varying degrees; for example, the implementation of Alternative 2d would probably be protracted because of siting issues. (Section 4.4.2.2).

The effectiveness of the limited disposal component of Alternative 2 would also be affected by the disposal option. On-site disposal in an engineered cell (Alternative 2a) could provide long-term protection of human health and the environment. This option would involve the dedication of an area of land at the site for permanent disposal and continued monitoring and maintenance. Containment of the contaminated soil and structural material in an engineered cell would reduce the potential for contaminant migration. If the in-situ containment system and/or the disposal cell were to fail over the long term without a maintenance response (e.g., if institutional controls were lost at the site), contamination of groundwater could result. In the short term, exposures of workers and potential adverse health effects could result from proximity to the highly contaminated material during the containment efforts, e.g., from external gamma irradiation at the raffinate pits.

Potential short-term environmental impacts associated with Alternative 2a include the disturbance of soil and increases in airborne emissions, and the displacement or loss of vegetation and wildlife due to noise and other impacts related to the grouting, construction, waste handling, and regrading activities. These activities might also increase concentrations of suspended solids in off-site surface water during the short term. Mitigative measures such as sediment barriers and surface wetting would be implemented to control potential releases via surface runoff and fugitive dust. No impacts to threatened or endangered species would be expected. Federal listed threatened and endangered terrestrial species such as the bald eagle and the peregrine falcon have been identified as transient visitors to areas near the site; however, the site does not provide critical habitat for these species and they are not expected to utilize the site. On-site impoundments might provide suitable habitat for some state listed species such as the wood frog and Blanding's turtle, but only the state rare pied-billed grebe has been reported from the site (at two of the raffinate pits).

Potential environmental impacts associated with Alternative 2b, 2c, or 2d include those identified for Alternative 2a plus impacts associated with off-site transport and disposal. These impacts could include short term disturbance of soil, increased airborne emissions, and short-term displacement or loss of vegetation and wildlife from construction of a rail siding for Alternatives 2b and 2c and construction and operation of a disposal site at the off-site locations. For Alternative 2b, 2c, or 2d, exposures would be higher in the short term than for Alternative 2a because more waste would be handled (i.e., some double handling would result from the necessary staging activities). The additional transportation requirements could also result in an increased potential for spills or accidents. The potential for truck accidents would be greater for Alternative 2d than Alternative 2b or 2c because of the higher accident rate associated with the highway haul distance required to truck the waste to a nearby disposal site. Potential health impacts during transportation of the contaminated material to the two other off-site disposal locations could result from train or truck accidents that injured workers or the public. An accident might also result in the contamination of soil or water as a result of a spill. A spill contingency plan would be prepared to minimize the possibility of such impacts prior to off-site disposal for Alternative 2b, 2c, or 2d.

4.4.2.2 Implementability

Alternative 2 could be implemented with readily available resources. However, the technical feasibility of the in-situ component would be quite low because it would be difficult to construct complete containment systems by capping and injecting a confining layer around and beneath each source area, creating multiple in-situ isolation units, given the areas and depths of contamination and the geological setting at the site. This installation would be very difficult because (1) perimeter grouting at the raffinate pits and two ponds and other scattered locations would require covering a linear distance of about 3,000 m (10,000 ft), and subsurface grouting would be required over a combined area of about 17 ha (42 acres); (2) the raffinate pits contain sludge with low compressive strength to depths of about 20 m (65 ft); (3) operations would be constrained by the proximity of the site boundary, which is within 15 m (50 ft) of the western edge of raffinate pit 4; and (4) the weathered nature of the upper zone of limestone bedrock could compromise the effectiveness of a comprehensive subsurface containment system constructed by in-situ injection. Grout injected into the subsurface might move into loosely bedded material and fail to create a contiguous seal. Although a number of potential pathways for contaminant migration could be sealed, failure of the confining layer to fully block all of these pathways would be sufficient to compromise the containment over time, and contaminant migration to groundwater could result. Because a seal failure would go unnoticed, waste isolation could not be ensured under Alternative 2. Identifying maintenance requirements for a subsurface containment system and maintaining and monitoring its integrity would be extremely difficult because of the area, depth, and type of material involved. In summary, a series of comprehensive in-situ containment systems would be very difficult to install, and the likelihood of achieving, verifying, and maintaining system integrity would be very low.

The acceptability of the in-situ containment component of Alternative 2 would be affected by the technical difficulties of implementation and the problems in ensuring effectiveness. In-situ containment does not represent a fully effective short-term or long-term solution to potential impacts associated with the contaminated material at the Weldon Spring site. Therefore, the administrative feasibility of this method could be somewhat low.

For the soil, sediment, and structural material that would not be contained in situ, disposal could be accomplished in a relatively straightforward manner using readily available resources under Alternative 2a. The material would be transported directly to an on-site disposal cell following removal for this alternative. The transportation component of off-site disposal (Alternative 2b, 2c, or 2d) could also be implemented in a straightforward manner using readily available resources. Trucks, containers for transport, and the equipment needed to transfer these containers are readily available. The Wentzville area is served by both the Union Pacific and Burlington Northern railroads; it currently has several rail sidings, and a new siding could be constructed there for the Weldon Spring waste.

The disposal component of Alternative 2b (disposal at the Envirocare site) or Alternative 2c (disposal at the Hanford site) would be relatively straightforward because those sites are currently used for waste management activities so necessary resources would be generally available. However, off-site disposal at the hypothetical nearby site would be constrained by the difficulties associated with siting a new disposal facility. Extensive characterization of several potential locations would be required to support siting requirements. Additionally, receipt of input from the public in potentially impacted communities would be part of the site selection process. Licensing by the NRC for the radiological component and permitting by the state of Missouri for the chemical component of such a site would require an additional level of assessment and development. Because these siting, licensing, permitting, and development activities would likely take a long time, waste could remain at the Weldon Spring site under essentially current conditions for a number of years.

The acceptability of Alternative 2b, 2c, or 2d would also be affected by the administrative requirements for transport and disposal. The DOT regulates the transport of most radioactive and chemically hazardous material, and some states also have their own special requirements. Transport of the contaminated material off-site would involve a great deal of agency coordination so, with regard to administrative feasibility, the implementation of Alternative 2b, 2c, or 2d could be somewhat difficult.

Relative to administrataive issues for off-site disposal, the Hanford site currently receives only small quantities of waste from outside sources, and the administrative procedures that would allow disposal of the large quantities of Weldon Spring waste at the Hanford site are not currently in place. The Envirocare site could accept the 361,000 m^3 (472,000 yd^3) of soil, sediment, and structural material from the site if a license were in place from the NRC to dispose of 11e(2) by-product material; the owner/operator of this facility has submitted an application for such a license, and the application is under acceptance review. An EIS addressing potential environmental impacts associated with disposal of 11(e)2 by-product material at the Envirocare site is being prepared by the NRC, and the environmental review process is currently projected to be completed in July 1993.

As an additional consideration, disposal at a commercial facility off-site might not eliminate future DOE responsibilities for this material, even though the waste would be under the physical control of that facility. That is, although the material would be appropriately transferred to that facility such that it would be the responsibility of its owner/operator and the facility is assumed to remain a viable operation with applicable permits, the possibility that the company might become insolvent at some time in the future must be considered. Although the likelihood of this scenario is expected to be low, long-term future conditions cannot be projected with certainty at this time; many current NPL sites are the result of just such commercial failures, and the original generators of waste contained in those abandoned facilities have been required to reassume responsibility for that material.

4.4.2.3 Cost

The estimated cost of in-situ containment is relatively high. The installation of a flexible membrane liner and 1.2 m (4 ft) of a stabilizing surface cover subsequent to removing the ponded water from the affected areas is estimated to cost $54/$m^2$ ($5/$ft^2$). Construction of a stabilized working surface on the raffinate pits alone could cost about $5.7 million. Placement of a cap over the entire 17 ha (42 acres) of contaminated source areas could cost approximately $7.1 million. The cost to completely grout the perimeter and subsurface at the contaminated areas was estimated to be approximately $200 million, considering economy of scale. Site preparation requirements and complicating factors resulting from the areal extent and depth of contamination could significantly increase the total cost above this estimate. Excavation, volume reduction, and support operations common to each of the options under Alternative 2 would cost about $35 million, and restoration of the site following completion of remedial action activities would cost about $2.1 million.

The cost associated with the limited disposal component of Alternative 2 depends on the disposal location. On-site disposal (Alternative 2a) would require the construction of an engineered cell to contain the contaminated soil, sediment, and structural material. A disposal cell designed to accommodate the 361,000 m^3 (472,000 yd^3) of contaminated material is estimated to cost about $16 million to construct (MK-Ferguson Company and Jacobs Engineering Group

1992a). Off-site disposal costs include transportation costs and disposal fees charged at the disposal site.

The estimated costs for waste loading, truck hauling, and container handling for Alternative 2b (disposal at the Envirocare site) and Alternative 2c (disposal at the Hanford site) are \$175/t (\$159/ton) and \$140/t (\$127/ton), respectively (MK-Ferguson Company and Jacobs Engineering Group 1992a). On the basis of preliminary estimates, rail transport to the Envirocare site would cost \$63/t (\$57/ton), and rail transport to the Hanford site would cost \$88/t (\$80/ton). Total truck transport costs (including waste loading and container handling) to the hypothetical nearby site (Alternative 2d) are estimated to be \$167/t (\$152/ton) (MK-Ferguson Company and Jacobs Engineering Group 1992a). Hence, the total costs for handling and transporting the 660,000 t (727,000 tons) of waste from the Weldon Spring site to the Envirocare site, the Hanford site, or the hypothetical nearby site would be \$157 million, \$150 million, or \$111 million, respectively. Alternative 2b or 2c could require an additional \$4.2 million for the construction of a rail siding.

A preliminary estimate of the disposal fee for the Envirocare site is \$106/t (\$96/ton), which corresponds to a disposal cost of about \$70 million for Alternative 2b (MK-Ferguson Company and Jacobs Engineering Group 1992a). A preliminary estimate of the disposal fee for the Hanford site is \$130/m^3 (\$100/yd^3) (Guercia 1992), which corresponds to a disposal cost of about \$47 million for Alternative 2c. The cost estimate for the Hanford site does not include the cost for long-term monitoring and maintenance. A detailed cost analysis would be performed to develop a firm price for the disposal fee if disposal at an off-site facility were a component of the selected alternative.

Combining the component costs, the estimated total cost of Alternative 2a (disposal on-site) is \$266 million, the cost of Alternative 2b (disposal at the Envirocare site) is \$481 million, and the cost of Alternative 2c (disposal at the Hanford site) is \$451 million. The total cost of Alternative 2d would start at about \$377 million. However, the siting, permitting, and construction of a nearby site would be very expensive; the time required to implement this alternative would also impact the costs, and delays in siting and permitting would greatly increase total disposal costs. Considering these factors, Alternative 2d is expected to be more expensive than either Alternative 2b or 2c.

4.4.3 Alternative 3: In-Situ Chemical Stabilization/Solidification and Limited Disposal

4.4.3.1 Effectiveness

Alternative 3 would be more protective of human health and the environment than Alternative 2 because the contaminated soil, sludge, and sediment at the source areas that would be managed in situ would be chemically stabilized/solidified to reduce contaminant mobility. No contaminants would be destroyed in the process, and the waste volume of the treated material would increase by about 32% at those areas because of the addition of cement and fly ash to form the solid product. In-situ chemical stabilization/solidification could be implemented in a timely manner and could constitute a long-term solution if a consistently high-quality product could be achieved.

Exposures to humans and wildlife to the contaminated material that was stabilized/solidified in place would be reduced. However, long-term protection would be uncertain because of difficulties in ensuring the successful implementation of this in-situ treatment process at the site. Incomplete stabilization/solidification would result in only a partial reduction in contaminant mobility, and areas that were not fully stabilized/solidified would still be susceptible to contaminant releases. Therefore, this option might not reliably protect human health and the environment over time.

Potential short-term environmental impacts are expected to be somewhat greater for Alternative 3 than Alternative 2 because of the additional impacts associated with treatment activities. Such activities would also result in additional short-term impacts to workers, e.g., from air emissions during mixing activities. The timeliness of the off-site disposal component of Alternative 3 would be the same as described for Alternative 2. The overall effectiveness of the limited disposal component of Alternative 3 would also be as described for Alternative 2.

4.4.3.2 Implementability

Implementing in-situ chemical stabilization/solidification at the Weldon Spring site would be technically difficult because of the area and type of material involved, especially at the raffinate pits. Although this in-situ treatment process is a proven technology and standard equipment and resources could be used, its implementation at the pits would have several drawbacks, including the following: uniform solidification could not be ensured, complete mixing of the reagents and contaminated material could not be verified during treatment, and the integrity of the final product could not be verified. In addition, the de-facto secondary containment provided by the natural clay layer underlying the raffinate pits would probably be disturbed and possibly destroyed by mixing activities, thereby increasing the potential for contaminant migration to the subsurface. Also, the compressive strength of the sludge is insufficient to support the mixing equipment, and the stabilizing reagents would have to be added in stages starting from the perimeter so work could progress from previously treated areas. However, the compressive strength of the sludge could be increased by mixing in contaminated soil and sediment excavated from other on-site areas; this excavated material would be transported to the raffinate pits by truck for mixing with standard construction equipment such as bulldozers, backhoes, and front-end loaders.

Additional concerns result from the waste heterogeneity in the pits. Studies of this chemical treatment process have documented a wide range of setting rates and compressive strengths of stabilized/solidified product resulting from different ratios of contaminated material (e.g., sludge with soil) to stabilizing agent (e.g., cement and fly ash) (Gilliam and Francis 1989). Mixing of the process reagents and the contaminated material with backhoes, draglines, and bulldozers would likely result in a wide range of blends, which might not allow adequate quality control to ensure that the waste was fully stabilized and solidified. In addition, this mixing would increase concerns regarding sufficient product quality control and the possibility for disruption of the clay layer underlying the raffinate pits.

In-situ chemical stabilization/solidification is generally inefficient for treating contamination at relatively shallow depths of 0.3 to 0.6 m (1 to 2 ft) (MK-Ferguson Company and Jacobs Engineering Group 1992a). Much of the soil in the North Dump and South Dump areas and the sediment in Ash Pond and Frog Pond represents this type of contamination, and although it might be possible to utilize in-situ chemical stabilization/solidification in these areas, maintaining quality control for the addition of reagents and water could be difficult because of matrix and contaminant differences.

Although not strictly an in-situ application, an additional treatment option considered under this alternative involves excavating the sludge, sediment, and soil and then treating the material within an excavated process area that would be specifically prepared for that purpose. The process area would be capped in place when treatment was completed. This method would potentially address the concern regarding engineered, subsurface containment of the treated waste because the treatment area would be designed to serve as a secondary containment system. However, other concerns would remain, such as the inability to verify the effectiveness of the treatment process and the potential for damaging the containment system during mixing. The raffinate pit sludge would require some dewatering for proper control at the process area, but water would then have to be added during the chemical treatment process. Also, the area available on-site for this purpose is limited, and it would probably be filled before all the material was treated.

In-situ treatment is affected by a number of technical difficulties including the inability to ensure complete treatment. Thus, administrative barriers to implementation would be expected to result from the uncertain effectiveness of this process. The implementability of the limited disposal component of Alternative 3 would be the same as identified for Alternative 2 (Section 4.4.2.2).

4.4.3.3 Cost

Because of the volume, nature, and areal extent of the contaminated source areas, in-situ chemical stabilization/solidification is expected to be somewhat expensive. The cost of treating the raffinate pit sludge and soil and the sediment and soil at Ash Pond, Frog Pond, the North Dump, and the South Dump (319,000 m^3 [417,000 yd^3]) is estimated to be about \$50 million, at a unit cost of about \$158/m^3 (\$121/yd^3) (MK-Ferguson Company and Jacobs Engineering Group 1992a). This value includes costs associated with chemical addition and capping. Additional costs for monitoring and maintaining the treated areas could be substantial because of the uncertain effectiveness of this alternative. The cost of the limited disposal component of Alternative 3 would be slightly less than that identified for Alternative 2 because the water treatment plant process waste and other containerized waste would have been treated with the raffinate pit sludge. The total costs of Alternative 3a (disposal on-site), Alternative 3b (disposal at the Envirocare site), and Alternative 3c (disposal at the Hanford site) are estimated to be \$101 million, \$309 million, and \$276 million, respectively (Guercia 1992; MK-Ferguson Company and Jacobs Engineering Group 1992a). For the analyses in this FS, the fees for off-site disposal at the Envirocare and Hanford sites were determined from preliminary estimates. If off-site disposal were a component of the selected alternative, a detailed cost analysis would be performed to develop the firm price for this activity. The total cost of Alternative 3d would be higher than Alternative 3b or 3c because of siting, licensing, and permitting requirements.

4.4.4 Alternative 4: In-Situ Vitrification and Limited Disposal

4.4.4.1 Effectiveness

Under the in-situ vitrification component of Alternative 4, exposures to humans and wildlife could continue in the short-term for a longer period than for Alternative 3 because it would take several years longer to implement this treatment process as a result of limitations in the size of individual treatment areas and the time required for cooling. In-situ vitrification could be more protective of human health and the environment in the long term than either in-situ containment or in-situ chemical stabilization/solidification because contaminated material would be treated to reduce toxicity, mobility, and volume as part of the vitrification process. The toxicity of some of the contaminants in a portion of the site waste would be reduced because organic contaminants (e.g., nitroaromatic compounds in soil from the quarry) and some inorganic contaminants (e.g., nitrate) are destroyed by the high temperatures used in the process. However, the toxicity of radiation — which represents the principal threat from the site waste — would not be reduced by this (or any other) treatment process. Waste volume would be reduced because the void spaces would be eliminated during in-situ vitrification, and some components (e.g., humus, organic contaminants, and carbonate of lime) would be released as gas and vapor; the volume of the vitrified material would be reduced by 68%. In-situ vitrification could constitute a long-term solution because the projected life of a high-quality vitrified product is thousands of years, so leachability is expected to be very low under optimal conditions (MK-Ferguson Company and Jacobs Engineering Group 1992a, 1992b).

As part of the initial engineering anlyses for this remedial action, bench-scale tests were conducted with vitrified samples of raffinate pit sludge combined with site soil to assess leachability; the results indicated that the levels of contaminants leached from the vitrified waste were much lower than the levels that would be considered hazardous on the basis of EPA's modified extraction procedure toxicity (EP-toxicity) test, as shown in Table 4.1. (Tests with EPA's current toxicity characteristic leachate procedure [TCLP], which is similar to the EP-toxicity test, were not performed for that study.) However, the effectiveness of this process over time is unknown because of the variable chemical and physical properties and the large volume of contaminated material requiring treatment. The long-term effectiveness of Alternative 4 would therefore be questionable because of uncertainties associated with the successful implementation of in-situ vitrification (Section 4.4.4.2). As for the in-situ chemical treatment process, any contaminants not incorporated in the solid waste matrix a result of incomplete vitrification could potentially be mobilized over time.

TABLE 4.1 Estimated Leachate Concentrations for Vitrified Sludge and Site Soil

	Estimated Leachate Concentration[a] (mg/L)		Maximum Leachate Concentration Allowed[b] (mg/L)
Contaminant	ISV Glass	JHCM Glass	
Arsenic	<1	<1	5.0
Barium	0.04	0.04	100.0
Cadmium	0.01	<0.01	1.0
Chromium	<1	<1	5.0
Lead	<1	<1	5.0
Mercury	<0.03	<0.03	0.2
Selenium	<0.01	<0.01	1.0
Silver	<0.1	<0.1	5.0

[a] Concentration determined from a previous study of raffinate pit sludge and site soil with a modified extraction procedure (EP) toxicity test; further testing (TCLP) of similar waste to be conducted at other DOE facilities within the next several years will provide additional leachability data for vitrification. ISV = in-situ vitrification; JHCM = joule-heated ceramic melting.

[b] TCLP limits; see Appendix G, Table G.3.

Source: Koegler et al. (1989).

Another consideration with in-situ vitrification is the off gas produced during the melting process. In-situ vitrification would result in the release of considerable amounts of radon, combustion gases, and steam. In addition, the retention of volatile metals decreases toward the surface of the melt and heavy metal oxides can be entrained in combustion-product gases that provide a path for escape from the surface (Holden et al. 1989), so volatile inorganic compounds would also be released. These emissions would need to be controlled, e.g., by placing a collection hood over the processing area. Effective collection of the off gas over the large affected area at the site would be difficult to achieve. Treatment of the off-gas stream would generate additional waste, e.g., a residual aqueous scrub solution, that could be recycled to the feed unit for subsequent vitrification. The effectiveness and timeliness of the limited disposal component of Alternative 4 would be the same as for Alternative 2 (Section 4.4.2.1).

Potential health and environmental impacts associated with Alternative 4 would be somewhat greater than those associated with Alternative 3 because of additional short-term impacts associated with treatment activities. Workers and air quality would be impacted by the increased emissions of the off gas (including radon) produced by the high-temperature process.

4.4.4.2 Implementability

Several difficulties are associated with implementing vitrification in situ at the Weldon Spring site. One difficulty is that the raffinate pit sludge results in a poor-quality, highly devitrified product upon cooling (Koegler et al. 1989). Another difficulty is related to the thickness typically required for effective in-situ vitrification, which is about 1.5 to 2.1 m (5 to 7 ft) (MK-Ferguson Company and Jacobs Engineering Group 1992a). The site soil that is contaminated generally consists of relatively thin, widely distributed surface zones that could not be efficiently treated by in-situ vitrification, and certain pits contain sludge to greater depths. Although mixing excavated soil in with the raffinate pit sludge might somewhat address these problems, incomplete mixing is likely and would reduce the process effectiveness. Also, the clay layer underlying the raffinate pits could be disturbed or destroyed by the required mixing of soil or sediment with the sludge, thereby increasing the potential for contaminants to migrate to the subsurface. The implementability of in-situ vitrification is also impacted by the numerous electrode applications the process would require. On the basis of a maximum spacing between electrodes of about 5.5 m (18 ft), which allows formation of a maximum melt width of about 8.5 m (28 ft) (MK-Ferguson Company and Jacobs Engineering Group 1992a), the raffinate pits area alone would require about 1,400 applications.

Additional concerns with in-situ vitrification are the inability to directly monitor the process during application and the inability to verify the integrity of the final product. Testing by Koegler et al. (1989) has demonstrated that soil must be thoroughly mixed with the raffinate pit sludge to produce a high-quality vitrified product. In addition, during the vitrification process, contaminants can partition into immiscible phases that are not entirely encapsulated within the silica melt — e.g., a sulfur phase would rise to the top or a metal phase would sink to the bottom of the melt. Contaminants could be more readily mobilized from these immiscible phases than from the silica glass. The ability to determine whether incomplete mixing had resulted in any excessively devitrified zones would be limited; if present, such zones could result in future contaminant mobilization. Thermocouples are used to monitor the temperature regime and melt geometry during in-situ vitrification; however, these thermocouples failed during the bench-scale in-situ vitrification tests with site waste (Koegler et al. 1989). Subsurface sonic measurements could be used after processing to help identify nonvitrified zones, but the required subsequent remediation of those zones would be very difficult (MK-Ferguson Company and Jacobs Engineering Group 1992a).

The in-situ vitrification process would have difficulty treating the raffinate pit sludge because of its high water content, as evidenced by a recent test failure at another site in which a steam explosion halted processing (MK-Ferguson Company and Jacobs Engineering Group 1992a). In-situ vitrification of this sludge would also tax the off-gas treatment system and would result in slow melting rates and excessive electricity consumption (vaporizing 1 kg [2.2 lb] of water requires as much electricity as melting 1 kg [2.2 lb] of soil) (MK-Ferguson Company and Jacobs Engineering Group 1992a). Thus, the sludge and sediment would require extensive dewatering prior to in-situ vitrification. The DOE recently suspended an application of the in-situ vitrification process at another site after a fire started during large-scale testing (Howson 1991; MK-Ferguson Company and Jacobs Engineering Group 1992a).

Implementation of in-situ vitrification would also be constrained by limitations in equipment availability, the heterogeneity and large extent of contamination at the site, and the time and energy requirements. With regard to equipment availability, in-situ vitrification is a developing technology, and only one vendor currently holds exclusive rights to the use of this technology for application to hazardous waste remediation. This vendor recently announced that it was ceasing to offer the technology at this time (Howson 1991). The extensive time and power commitments that would be required are related to the considerable extent of the affected area (a combined area of about 17 ha [42 acres]) and the large volume of material to be treated.

The additional treatment option described for "in-situ" chemical stabilization/ solidification, whereby sludge, sediment, and soil would be excavated for treatment within a process area specifically prepared for that purpose, was also considered for vitrification. Upon completion of treatment, the process area would be capped in place. This method would potentially address the concern regarding engineered, subsurface containment of the treated waste because the process area would be designed to serve as a secondary containment system. However, other concerns would remain, i.e., the inability to monitor the effectiveness of the treatment process and the potential to damage the containment system during mixing and vitrification activities. In addition, the area available for this purpose is limited, and it would probably fill before all the material was treated; the time required for this single-area application would also be much longer.

Although in-situ vitrification might seem relatively more acceptable than in-situ chemical stabilization/solidification because of a perceived potential for increased long-term protection, considerable institutional concerns could result from the same questionable effectiveness described for Alternative 3 (including the inability to ensure complete treatment) and greater difficulties regarding the technical feasibility of its application at the Weldon Spring site. In addition, increased air emissions might pose a concern relative to air quality and possible health impacts. The implementability of the limited disposal component of Alternative 4 would be the same as identified for Alternative 2 (Section 4.4.2.2).

4.4.4.3 Cost

A considerable volume and areal extent of contaminated material would require staged treatment with an innovative process for which resources are not readily available, so Alternative 4 is expected to be more expensive than Alternative 3. The implementation of in-situ vitrification in straightforward applications, e.g., for a relatively small area, is estimated to cost about $\$304/m^3$ ($\$232/yd^3$) (MK-Ferguson Company and Jacobs Engineering Group 1992a). Because of the excessive devitrification that resulted in tests with the raffinate pit sludge alone (Koegler et al. 1989), in-situ vitrification without additives is not considered viable. The cost of vitrifying the raffinate pit sludge after mixing with excavated soil and sediment, combined with the cost of capping and site restoration, is estimated to be about $69 million (MK-Ferguson Company and Jacobs Engineering Group 1992a). In-situ vitrification of the remaining source areas, including capping and restoration, would bring the cost of the in-situ vitrification component of Alternative 4 to about $118 million. Additional costs for monitoring and maintaining the treated areas would be substantial because of the uncertain effectiveness of the in-situ application of this process at the site.

The costs associated with the limited disposal component of Alternative 4 would be similar to those identified for Alternative 3 (Section 4.4.3.3). The total costs of Alternatives 4a, 4b, and 4c (disposal on-site, disposal at the Envirocare site, and disposal at the Hanford site) are estimated to be $168 million, $354 million, and $329 million, respectively (Guercia 1992; MK-Ferguson Company and Jacobs Engineering Group 1992a). The total cost of Alternative 4d would be higher than Alternative 4b or 4c because of siting, permitting, and licensing requirements.

4.4.5 Alternative 5: Removal, Minimal Treatment, and Disposal

4.4.5.1 Effectiveness

Excavating contaminated soil and sediment and dredging the raffinate pit sludge would reduce potential impacts to human health and the environment associated with contaminated source areas in a timely manner and would reduce the potential for contaminant migration from those areas. Subsequent isolation of the waste in an engineered disposal cell either on-site or off-site would control the potential for contaminants to migrate in the long term. The main treatment component of Alternative 5 (dewatering of the raffinate pit sludge) would reduce contaminant volume and might result in a limited reduction in solution mobility by reducing the amount of water available to mobilize contaminants, but this would be offset by the potential for increased dispersion, and contaminant toxicity would not be reduced. Thus, Alternative 5 does not adequately satisfy the statutory preference for treatment as a principal element of the remediation.

The short-term and long-term effectiveness of Alternative 5 would depend on the controlled transport to and containment in an engineered disposal cell, especially for the highly contaminated, fine-grained, dewatered raffinate pit sludge. Because this material would not have been treated to effectively reduce contaminant toxicity or mobility, accidents or failures associated with transport or disposal activities could result in contaminant dispersal and possible health effects. The effectiveness of Alternative 5 could also be constrained by the technical difficulties associated with implementing the disposal component (Section 4.4.5.2).

Potential environmental impacts would be greater for Alternative 5 than Alternative 2, 3, or 4 because of additional impacts associated with the more extensive excavation activities. Increased short-term exposures to airborne contaminants and possibly to contaminants migrating off-site via runoff from the larger area disturbed could occur during implementation. In addition, more extensive monitoring and maintenance would be required to minimize potential long-term impacts because the disposal cell would contain untreated raffinate pit sludge. Impacts associated with Alternative 5b, 5c, or 5d would also include those for off-site transport and disposal, as described for the parallel options of Alternative 2. Compared with the previous alternatives with an off-site disposal component, the magnitude of potential impacts associated with an accident during off-site transport under Alternative 5b, 5c, or 5d could be much higher because the material being transported would include the highly contaminated, dewatered raffinate pit sludge, which could be susceptible to dispersal if an accident occurred. The magnitude of possible impacts at the off-site disposal location would also be higher because of possible releases from the untreated sludge and because of the larger volume of contaminated material. The timeliness of the off-site disposal component for Alternative 5 would be the same as Alternative 2.

4.4.5.2 Implementability

Implementing the removal component of Alternative 5 with regard to the availability of resources would be relatively straightforward. The contaminated soil could be excavated and the raffinate pit sludge and pond sediment could be dredged with standard equipment and materials that are readily available. Implementing the treatment component of Alternative 5 would also be straightforward (Section 3.2.4.2). The raffinate pit sludge could be dewatered with standard cyclones and filter press systems (MK-Ferguson Company and Jacobs Engineering Group 1992a). For both of these activities, stringent emission-control measures would be required when handling the raffinate pit sludge.

Implementing the disposal component of Alternative 5 would be difficult. The estimated 34,000 m^3 (45,000 yd^3) of dewatered raffinate pit sludge would consist of very fine-grained, cohesionless particles. From available data, most of this sludge has a particle size of less than 0.075 mm (0.003 in.); i.e., 89 to 99.9% of the particles would pass a small-mesh (#200) sieve (MK-Ferguson Company and Jacobs Engineering Group 1989). Therefore, this material would be very difficult to control, and it also has essentially no weight-bearing capacity. Hence, waste loading, transport to, and placement in a disposal cell would be very difficult; construction of an adequate engineered cover over the cell would be even more difficult because the dewatered, unstabilized sludge might not be able to support the weight of the cover. In fact, subsidence of a disposal cell cover would be more likely under this alternative than any other because of the poor weight-bearing properties of this material (MK-Ferguson Company and Jacobs Engineering Group 1992a). Although the sludge could be mixed with soil to increase its weight-bearing capacity, this activity could result in increased air emissions and possibly adverse health impacts. Without corrective maintenance activities, subsidence damage to cell integrity could also result in the release of contaminants into the environment.

Off-site transport of the site waste would increase potential exposures from waste handling and airborne contaminant releases. The sludge would be dewatered prior to either transport to or placement in the disposal cell because transport of a high-water-content sludge would be difficult and dewatering before disposal would be necessary to meet restrictions on the free liquid content and requirements for compressive strength compaction in the cell. In addition, neither the Envirocare site nor the Hanford site currently has the required equipment or administrative capabilities to dedicate to the dewatering of the fine-grained sludge; these capabilities would also be required for the hypothetical nearby site. Under current disposal practices at the Envirocare site, the moisture content of waste is reduced by spreading and mixing the material in a storage area to promote evaporation (Envirocare of Utah 1991).

However, this might not be appropriate for the fine-grained raffinate pit sludge because of the potential for adverse health impacts from air emissions.

The administrative feasibility of Alternative 5 would probably be affected by the uncertainties associated with the short-term and long-term effectiveness of this alternative and the potential for much greater adverse impacts than Alternative 2, 3, or 4. Therefore, it is expected to be the most difficult to implement of the action alternatives relative to administrative concerns.

4.4.5.3 Cost

Implementing Alternative 5 would cost more than Alternative 3 or 4, except for the on-site disposal option (Alternative 5a). Long-term costs would probably be higher than Alternative 6 or 7 (chemical and thermal treatment alternatives) because the waste would retain all of its toxicity and its potential mobility; contaminants could be more readily mobilized if the containment component of transport or disposal failed and no corrective measures were taken. The total cost of Alternative 5a (on-site disposal) is estimated to be approximately $76 million (MK-Ferguson Company and Jacobs Engineering Group 1992a).

From preliminary estimates, the cost to dispose of 557,000 m^3 (728,000 yd^3) of contaminated soil, sediment, dewatered sludge, and structural material at the Envirocare site would be $108 million, and the cost for disposal at the Hanford site would be $73 million. The estimated costs for waste transport to the Envirocare site and the Hanford site are $64 million and $90 million, respectively. From these estimates, the total cost of Alternative 5b (disposal at the Envirocare site) would be $404 million, and the total cost of Alternative 5c (disposal at the Hanford site) would be $361 million (Guercia 1992; MK-Ferguson Company and Jacobs Engineering Group 1992a). The siting, permitting, and construction of a nearby site would be very expensive, and related delays would greatly increase the cost of this disposal option. Thus, the total cost of Alternative 5d would be higher than Alternative 5b or 5c.

4.4.6 Alternative 6: Removal, Chemical Stabilization/Solidification, and Disposal

4.4.6.1 Effectiveness

Alternative 6 would be more protective of human health and the environment than Alternative 5 (removal and disposal with minimal treatment) because Alternative 6 combines chemical treatment of contaminated sludge, soil, and other material to reduce mobility with containment in an engineered disposal cell. Alternative 6 would also be more protective of human health and the environment than Alternative 3 (in-situ chemical stabilization/solidification) for two reasons. First, the process can be monitored during operations to verify correct and complete mixing, and the quality and integrity of the final waste form can be ascertained prior to disposal. Second, the chemically stabilized/solidified waste would be placed in a disposal cell that would provide the engineered containment system absent from the in-situ application.

The effectiveness of the removal component would be the same as Alternative 5, and the treatment component would be much more effective because of the substantial reduction in contaminant mobility that would be achieved by chemical stabilization/solidification. Leachability tests have been conducted on chemically stabilized/solidified sludge from the raffinate pits and nitroaromatic-contaminated soil from the quarry (Waste Technologies Group 1992). Test results indicate that leachate from the treated sludge and soil would be much lower than the TCLP requirements for hazardous waste (Table 4.2). Leachability depends on the contaminant type, the mechanical and chemical properties of the cement-fly ash matrix, and the various reactions of the contaminants within that matrix — such as diffusion, dissolution, adsorption, and precipitation. Past studies of leaching from cement-based grouts indicate that the metals would be fairly immobile, the organic compounds and nitrates would be relatively more mobile, and the nitroaromatic compounds would be the most mobile of the contaminants of concern at the Weldon Spring site (Gilliam et al. 1985; Gilliam and Loflen 1986; Gilliam 1990); the mobility of radionuclides would be low, as for other metals. The combination of chemical stabilization/solidification and containment in an engineered cell would provide a timely response to the contamination problems at the site, with some possible exceptions associated with implementability for the off-site disposal options. The toxicity of the chemically treated material would not be reduced because the process binds but does not destroy any contaminants. The volume of the treated material would increase by about 32% because of the addition of cement and fly ash; this would correspond to an increase of about 12% in the overall disposal volume for treated and untreated material combined.

Combined with the treatment, the disposal component of this alternative would provide long-term protection of humans and the environment from exposures to site contaminants. Thus, with regard to long-term effectiveness, the treated and untreated waste would be contained in an engineered cell so only a breach in the cell integrity without corrective measures could result in the release of contaminants to the environment over time. Damage to the cell in the absence of maintenance could expose the waste inside, including the portion that had been chemically stabilized and solidified. If this were to happen, contaminants could be leached from all the material, but leaching from the treated material would be slow because the cement-like matrix would not deteriorate for a long time. Even without the engineered protection of the cell, the chemically treated product would be expected to last hundreds to thousands of years.

One indicator of longevity is the time required to increase the hydraulic conductivity through a cement waste form. Preliminary modeling results for changes in the hydraulic conductivity in cement grout over time suggest that acceptable performance is likely to extend for at least hundreds of years (Alcorn et al. 1990). The high buffering capacity of the chemically stabilized/solidified waste (estimated at 4×10^{-3} meq/g at a pH greater than or equal to 7) would neutralize infiltrating solutions and would maintain a neutral to alkaline (and therefore less corrosive) leachate with an expected pH of 7 or above over a 100-year exposure period to

TABLE 4.2 Estimated Leachate Concentrations for Chemically Stabilized/Solidified Sludge and Quarry Soil[a]

Contaminant	Estimated Leachate Concentration (mg/L): Raffinate Pit Sludge[b]	Estimated Leachate Concentration (mg/L): Quarry Soil	Maximum Leachate Concentration Allowed[c] (mg/L)
Arsenic	0.218	<0.013	5.0
Barium	10.9	0.669	100.0
Cadmium	0.003	<0.002	1.0
Chromium	0.126	0.082	5.0
Lead	<0.018	<0.018	5.0
Mercury	<0.0002	<0.0004	0.2
Selenium	0.061	<0.019	1.0
Silver	0.012	<0.004	5.0
NB	<0.020	0.813	2.0
2,4-DNT	<0.020	0.017	0.13

[a] Concentrations in leachate are based on TCLP testing of raffinate pit sludge spiked with the historical high concentrations of contaminants and quarry soil spiked with the historical high concentration of nitrobenzene (NB). Samples were stabilized/solidified using the blend formula determined by Gilliam and Francis (1989) and cured for 28 days. 2,4-DNT = 2,4-dinitrotoluene.

[b] Sludge samples were taken from each pit. The highest leachate concentration is reported here.

[c] TCLP limits; see Appendix G, Table G.3.

Source: Waste Technologies Group (1992).

acid rain conditions (MK-Ferguson Company and Jacobs Engineering Group 1992a). Thus, because the chemically stabilized/solidified waste would resist deterioration, uncorrected damage to the disposal cell containing the waste would result in only slow releases of contaminants from the treated material to the environment. In addition, the treated waste would have high weight-bearing capacity. Strength testing of stabilized/solidified raffinate pit sludge indicated a penetration resistance of up to 28 MPa (4,000 psi) and an unconfined compressive strength exceeding 1.4 MPa (200 psi), although a range of values was measured under various experimental conditions (Gilliam and Francis 1989). Therefore, the concern for long-term effectiveness associated with subsidence of the disposal cell cover under Alternative 5 would not be an issue for Alternative 6.

Potential health and environmental impacts are expected to be generally similar to those for Alternative 5. Short-term exposures from removal activities would be similar but treatment exposures would be lower because the material would be maintained in a wet condition until it was containerized for disposal off-site or directly placed in the cell on-site. Potential impacts associated with the transport and off-site disposal components would probably be similar to Alternative 5. Although the more highly contaminated material would have been treated so releases would be lower, this benefit would be offset by the increased number of trips required to transport the larger volume of material and the associated increase in worker exposures and accidents.

4.4.6.2 Implementability

The implementability of the removal component of Alternative 6 would be the same as Alternative 5; that is, the contaminated material could be removed in a straightforward manner with readily available resources. Implementation of the chemical stabilization/solidification process would also be straightforward. Cement- and silicate-based stabilization/solidification is a commonly used method for which resources are readily available. Its effectiveness and feasibility have been demonstrated in many full-scale waste treatment applications, and as of 1991, this technology had been selected as the treatment component for remedial action at 62 sites on the NPL (Chemical Engineering Progress 1991).

The implementability of the disposal component of Alternative 6 would depend on the location of the disposal site. On-site disposal (Alternative 6a) could be accomplished in a relatively straightforward manner. The chemically stabilized/solidified product would be trucked directly from the treatment facility to the disposal cell. The treated raffinate pit sludge would be in an unset grout-like form that could be used to fill in voids around large pieces of structural material within the disposal cell, thus eliminating the need for hand digging and compacting for those pieces. Handling the sludge in a wet form would also limit the releases of radon and other contaminants, thereby limiting worker exposures. A somewhat drier material would result from the treatment of the less contaminated soil, and this material could be placed and compacted in a conventional manner. The chemically stabilized/solidified waste would be placed in the disposal cell in a manner that would minimize the surface area of the treated product and facilitate compact placement. A small surface area-to-volume ratio would correspond to lower leach rates in the extended future, e.g., if the cell were to fail and no corrective measures were taken, because less surface area would be exposed for potential deterioration.

In contrast, off-site disposal of the chemically stabilized/solidified material would be difficult to implement. The site waste would be transferred to shipping containers at the treatment facility for off-site transport to the Envirocare site (Alternative 6b), the Hanford site (Alternative 6c), or the hypothetical nearby site (Alternative 6d). For Alternative 6b or 6c, this would necessitate trucking the containers to a rail siding in Wentzville, Missouri, and transferring the containers at the siding to railcars for transport to the final disposal location. For Alternative 6d, the waste containers would be trucked directly to the hypothetical nearby site. Because the stabilized/solidified material would be expected to achieve initial set within 1 day and final set within 7 days, the material would set within the containers during transport, and the resulting material would be a monolithic concrete-like product with an expected density of about 1.72 t/m^3 (1.45 tons/yd^3). It would be difficult to reuse the container because this set material would be hard to remove from the shipping containers for placement in the disposal cell. The monolithic waste form would probably have to be fractured to remove it from these containers, and this would increase the surface area of the waste and therefore the potential for future leaching. Alternatively, the solidified material could be disposed of while still in the containers, in which case the overall costs would be higher and those resources would be irretrievably committed. In addition, the higher volume and weight of the combined waste would increase the time and cost of transport. An alternative mix formula of sludge, soil, and reagent might be developed that would result in a more manageable soil-like product for off-site disposal; however, this material might be more subject to dispersal if released, with related potential health effects, and the total volume and weight would still be higher.

The acceptability of Alternative 6 would probably be higher than Alternatives 2 through 5 because of the limitations associated with in-situ containment, in-situ treatment, and removal and disposal with minimal treatment under those alternatives. However, the acceptability of off-site transport and disposal of the chemically stabilized/solidified material would be affected by the larger amount of material requiring transport and the greater amount of handling that would be required.

4.4.6.3 Cost

The cost of Alternative 6 is expected to be among the highest of all preliminary alternatives because it combines the cost of excavation with the cost of treatment, including the cost for chemical additives. The total cost of Alternative 6a (on-site disposal) is estimated to be about $157 million (MK-Ferguson Company and Jacobs Engineering Group 1992b). From preliminary estimates, the cost to dispose of the 772,000 m^3 (1,010,000 yd^3) of combined waste at the Envirocare site would be $146 million, and the cost for disposal at the Hanford site would be $101 million. The disposal costs could be somewhat higher than these estimates because increased handling would be required to dispose of the set chemical stabilization/solidification product. The estimated costs for waste transport to the Envirocare site and the Hanford site are $87 million and $122 million, respectively. Thus, the total cost of Alternative 6b (disposal at the Envirocare site) is estimated to be $541 million, and the total cost of Alternative 6c (disposal at the Hanford site) is estimated to be $482 million (Guercia 1992; MK-Ferguson Company and Jacobs Engineering Group 1992a). The total cost of Alternative 6d (disposal at the hypothetical nearby site) would be higher than Alternative 6b or 6c because of the siting, licensing, and permitting requirements.

4.4.7 Alternative 7: Removal, Vitrification, and Disposal

4.4.7.1 Effectiveness

Alternative 7 would be more protective of human health and the environment than Alternative 5 (removal, minimal treatment, and disposal) because contaminated material would be treated to reduce toxicity, mobility, and volume. Alternative 7 would also be more protective of human health and the environment than Alternative 4 (in-situ vitrification and limited disposal) for the same two reasons given for Alternative 6. That is, visual inspection and on-line management of the treatment process is possible so the quality and integrity of the final waste form could be ascertained prior to disposal, and the vitrified waste would be placed in a disposal cell that would provide the engineered containment system absent from the in-situ application.

The effectiveness of the removal component would be the same as Alternatives 5 and 6. Although the treatment component of Alternative 7 would be less timely than those alternatives because of technical limitations (Section 4.4.7.2), vitrification would reduce the toxicity, mobility, and volume of certain waste more effectively. The toxicity of certain contaminants would be reduced because the organic compounds and some inorganic contaminants in certain portions of the waste to be treated would be destroyed in the high-temperature process. The toxicity of radiation from the waste would not be reduced by this treatment method (or any other). The volume of the treated material would be reduced to an estimated 32% of the original volume, which corresponds to a reduction of about 52% by weight (MK-Ferguson Company and Jacobs Engineering Group 1992a). The mobility of contaminants would also be significantly reduced because the waste product would be a glass-like material that would resist leaching. Previous bench-scale leach tests with samples of vitrified raffinate pit sludge and site soil indicated that contaminant concentrations in the leachate were much lower than levels that would be considered hazardous on the basis of the modified EP-toxicity test, as shown in Table 4.1. Leach tests that are used to characterize vitrified high-level radioactive waste (i.e., Materials Characterization Center tests) were also performed on the vitrified sludge samples; results showed that the vitrified waste had leachate concentrations approximately 4 to 8 times lower than those resulting from similar testing of high-level radioactive waste glass (Koegler et al. 1989).

Combined with the treatment, the disposal component of this alternative would provide long-term protection of humans and the environment from exposures to site contaminants. Thus, with regard to long-term effectiveness, the treated and untreated waste would be contained in an engineered cell so only a breach in the cell integrity without corrective measures could result in the release of contaminants to the environment over time. In the absence of maintenance, damage to the cell could expose the waste inside, including the vitrified portion.

If this were to happen, contaminants could be leached from all the material, but leaching from the vitrified material would be very slow because the glassy matrix would not deteriorate for a long time. An effectively vitrified product would be expected to withstand environmental degradation for thousands of years (Hansen and Fitzpatrick 1989). Vitrified waste can also have high weight-bearing capacity. Strength testing of vitrified samples of the Weldon Spring waste indicated an average compressive strength of about 300 MPa (43,000 psi) and an average splitting tensile strength of about 28 MPa (4,000 psi) (Koegler et al. 1989). Therefore, the concern for long-term effectiveness associated with subsidence under Alternative 5 would not be an issue for Alternative 7.

Potential environmental impacts are expected to be generally similar to Alternative 6. To minimize potential health impacts from stack releases, the off gas produced during vitrification would have to be controlled by an efficient off-gas collection and treatment system for the volatile inorganic compounds, combustion gases, and steam generated during the process; controls for radon would also be included, as necessary. Treatment of the off-gas stream would generate additional waste, e.g., a residual aqueous scrub solution; portions of this waste could be recycled for subsequent vitrification, but some scrub solution might require further treatment (e.g., by chemical stabilization) prior to disposal. Short-term health effects would be slightly higher for Alternative 7 than Alternative 6, primarily because more workers would be needed to implement this complex process, and the high temperatures pose additional safety hazards. A considerable amount of energy would be required to implement this treatment process. Potential environmental impacts associated with the transport and off-site disposal components of Alternative 7 could be somewhat lower than those identified for Alternative 6 because fewer trips would be required.

4.4.7.2 Implementability

The implementability of the removal component of Alternative 7 would be similar to Alternative 5; that is, the contaminated material could be removed in a straightforward manner with readily available resources. Implementation of the vitrification component of Alternative 7 would be feasible but not as straightforward as the chemical treatment component of Alternative 6. The off-gas collection system of the facility would require considerable optimization to minimize the release of airborne contaminants from the stack. Also, ensuring a high-quality final product with the vitrification process would require more workers, including specially trained operators, and intensive monitoring of the feed stream and other process variables would be required during treatment. A process engineer would be required to oversee scheduling, optimization, maintenance, and monitoring activities. In addition, the vitrification technology has not been applied on the large scale that would be required for the Weldon Spring waste. Although industrial applications of fossil fuel-heated ceramic melters are available for many operating rates, units designed specifically for treating hazardous waste are currently available only for pilot-scale applications (Holden et al. 1989; Lee 1989). For this reason, the effectiveness of vitrification has only been demonstrated for hazardous waste treatment applications in small-scale, prototype units (Holden et al. 1989). Vitrification methods are being used to treat high-level radioactive waste at a few locations in total quantities of up to several hundred tons; the amount of waste to be vitrified at the Weldon Spring site under this alternative is about 160,000 t (180,000 tons) (MK-Ferguson Company and Jacobs Engineering Group 1992b).

The disposal component of Alternative 7 could be implemented in a relatively straightforward manner. For on-site disposal (Alternative 7a), the vitrified product would be trucked directly from the treatment facility to the disposal cell. Because the fritted glass-like product would be a cohesionless material, it could be placed in alternating layers or mixed with a binding material such as soil or clay to facilitate compaction within the cell. This placement could be accomplished with standard procedures and readily available resources. The transport of the vitrified material for off-site disposal under Alternative 7b, 7c, or 7d would also be straightforward. The fritted glass-like product could be easily containerized for shipment. Overall transportation requirements would be lower because of the decreased volume (by about 24%) and weight of the material to be transported.

The acceptability of Alternative 7 would probably be higher than for Alternatives 2 through 5, as described for Alternative 6. However, the administrative feasibility of Alternative 7 is expected to be less straightforward than Alternative 6 because the vitrification technology is more innovative than the chemical stabilization/solidification technology, i.e., its effectiveness has not been demonstrated on the appropriate scale with similar waste. In addition, the release of airborne contaminants from the stack of the vitrification facility could generate administrative concerns, e.g., with regard to permits.

4.4.7.3 Cost

Alternative 7 is expected to be among the most expensive of the preliminary alternatives because of the high cost of vitrification, which results from the considerable energy requirements and process sophistication. The total cost of Alternative 7a (on-site disposal) is estimated to be about $182 million, which is slightly higher than the cost for Alternative 6a (MK-Ferguson Company and Jacobs Engineering Group 1992b). From preliminary estimates, the cost to dispose of the 522,000 m^3 (683,000 yd^3) of combined waste from the Weldon Spring site at the Envirocare site would be $104 million, and the cost for the Hanford site would be $68 million. These costs are somewhat lower than the parallel options under Alternative 6 because the overall waste volume and weight would be smaller. The estimated cost for waste transport to the Envirocare site is $59 million, and the cost for transport to the Hanford site is $75 million. Thus, the total cost of Alternative 7b (disposal at the Envirocare site) is estimated to be $351 million, and the cost of Alternative 7c (disposal at the Hanford site) is estimated to be $304 million (MK-Ferguson Company and Jacobs Engineering Group 1992b). The total cost of Alternative 7d (disposal at the hypothetical nearby site) would be higher than Alternative 7b or 7c because of the siting, licensing, and permitting requirements.

4.5 SCREENING SUMMARY AND IDENTIFICATION OF FINAL ALTERNATIVES

The results of the screening analysis for the preliminary alternatives are summarized in Table 4.3. Information for each alternative was evaluated relative to EPA's screening criteria

TABLE 4.3 Screening of Preliminary Alternatives

Alternative	Effectiveness	Implementability	Cost
Alternative 1: No Action	Exposures of humans and wildlife at the contaminated areas would continue, and migration could result in increased exposures over time. Adverse health effects could occur if access were uncontrolled in the future. No treatment would be applied to reduce the toxicity, mobility, or volume of contaminated material; no permanent solution would be achieved; and certain environmental requirements would not be met.	Standard practices and equipment would be used to conduct general maintenance activities and maintain current institutional controls such as monitoring.	Annual costs are estimated to be $1.2 million. These baseline costs would probably increase with inflation.
Alternative 2: In-Situ Containment and Limited Disposal	More protective in the long term than Alternative 1 but least protective of the action alternatives. Short-term impacts to workers would be higher than Alternative 1 because of exposures during the containment and disposal activities. Containment of waste both in situ and in the engineered disposal cell would control site contaminants and reduce the potential for migration. However, overall protectiveness in the long term is uncertain because of the difficulty in ensuring and maintaining an effective subsurface containment system. This alternative would not reduce the toxicity, mobility, or volume of contaminated material by treatment. Accidents and exposures during waste transport would occur under Alternative 2b, 2c, or 2d; worker exposures would be higher than Alternative 2a because of increased waste handling.	Material not contained in situ could be removed with standard procedures and readily available resources, and a disposal cell could be readily constructed for this waste. Subsurface containment of the other waste would be difficult to implement and verify because of the large size of the contaminated areas and the geological setting of the site. In addition, it could be difficult to maintain an effective cover over the raffinate pits because of the low weight-bearing capacity of the sludge. For the off-site disposal options (Alternatives 2b, 2c, and 2d), waste transport could be implemented with readily available resources, but the extensive agency coordination required would affect administrative feasibility. Other administrative issues associated with disposal could delay the implementation of those alternatives. No facility is available in Missouri, so Alternative 2d would require protracted siting, licensing, permitting, and development activities. For Alternatives 2b and 2c, although waste management activities are ongoing at	More expensive than all the other alternatives except the off-site disposal options of Alternative 6. In-situ containment of the various source areas is estimated to cost about $200 million. The total estimated costs are $266 million for Alternative 2a (on-site disposal), $481 million for Alternative 2b (disposal at the Envirocare site), and $451 million for Alternative 2c (disposal at the Hanford site). Alternative 2d (disposal at the nearby site) would cost more than Alternative 2b or 2c because of siting, licensing, permitting, and development requirements.

TABLE 4.3 (Cont.)

Alternative	Effectiveness	Implementability	Cost
Alternative 2: In-Situ Containment and Limited Disposal (Cont.)		the Envirocare and Hanford sites, neither has developed a disposal facility and administrative procedures to receive waste from the Weldon Spring site. The owner of the Envirocare site has applied for an application to dispose of 11e(2) by-product material, so an administrative review process is underway for that site.	
Alternative 3: In-Situ Chemical Stabilization/Solidification and Limited Disposal	Similar to Alternative 2, except short-term impacts to workers would be higher because of increased emissions during treatment, and overall effectiveness would be somewhat better because the treatment would reduce the mobility of contaminants in the most highly contaminated material. Long-term effectiveness would be still be uncertain because of the difficulty in ensuring treatment and containment effectiveness.	The implementation and verification of in-situ mixing would be difficult because of the complex nature of most of the waste; for example, the raffinate pit sludge would not readily support the standard mixing equipment. In addition, maintaining the effectiveness of treatment and monitoring the quality of the final product would be difficult. The implementability of the removal and limited disposal components would be the same as for Alternative 2.	Less expensive in the short term than the other alternatives except Alternative 5a. In-situ chemical stabilization/solidification combined with capping and restoration is estimated to cost about $50 million. Additional costs related to monitoring and maintenance could be substantial. The cost of the disposal component would be similar to that of Alternative 2. The total estimated costs are $101 million for Alternative 3a (on-site disposal), $309 million for Alternative 3b (disposal at the Envirocare site), and $276 million for Alternative 3c (disposal at the Hanford site). Alternative 3d (disposal at the nearby site) would cost more than Alternative 3b or 3c because of siting, licensing, permitting, and development requirements.

TABLE 4.3 (Cont.)

Alternative	Effectiveness	Implementability	Cost
Alternative 4: In-Situ Vitrification and Limited Disposal	Generally similar to Alternative 3, except the waste volume would decrease because of the reduction in void space that would result from in-situ vitrification, and some contaminant toxicity would be reduced because of the destruction of organic and some inorganic compounds in portions of the waste. However, in-situ vitrification would generate an off-gas stream that could result in incremental short-term impacts to workers and would require an optimized treatment system.	Similar to Alternative 3, with additional constraints associated with the inability to vitrify the raffinate pit sludge without additives (such as soil or sediment) and the need for enough special equipment to support the large number of applications required to treat all the material.	More expensive than Alternative 3 because of process complexity, special equipment and personnel needs, and high energy costs. In-situ vitrification combined with capping and restoration is estimated to cost about $118 million. The cost of the disposal component would be similar to that of Alternative 2. The total estimated costs are $168 million for Alternative 4a (on-site disposal), $354 million for Alternative 4b (disposal at the Envirocare site), and $329 million for Alternative 4c (disposal at the Hanford site). Alternative 4d (disposal at the nearby site) would cost more than Alternative 4b or 4c because of siting, licensing, permitting, and development requirements.

TABLE 4.3 (Cont.)

Alternative	Effectiveness	Implementability	Cost
Alternative 5: Removal, Minimal Treatment, and Disposal	Could be more protective than Alternative 1, 2, 3, or 4 in the long term because contaminated material would be removed from source areas and placed in an engineered disposal cell to control exposures of humans and biota. The statutory preference for treatment as a principal element of remediation would not be addressed. Waste volume would be somewhat reduced (by dewatering), but toxicity and mobility would not. Potential contaminant migration would be reduced through containment in the disposal cell. Short-term impacts to workers would result from exposures to additional airborne releases compared with the other alternatives. Because of the potential loss of cover integrity due to subsidence, long-term effectiveness might be a problem. Contaminants could be more readily mobilized during transport and disposal activities (or following a future failure of the disposal cell in the absence of corrective measures) because the more highly contaminated and fine-grained raffinate pit sludge would be subject to dispersal. The effectiveness of off-site disposal for Alternatives 5b, 5c, and 5d would be similar to that identified for on-site disposal, but transportation risks could be significant. Potential worker exposures would be higher than for Alternative 5a (on-site disposal), because of increased waste handling and exposures during transportation. In addition, potential impacts to humans and biota could result from accidents along the transportation route.	Removal and treatment would be relatively straightforward and could be implemented with readily available resources and standard procedures. For disposal, it could be difficult to place and maintain the integrity of a cover because of weight-bearing problems associated with the unstabilized sludge. Transport of waste off-site would involve a great deal of agency coordination and would be constrained by administrative feasibility. The implementability of off-site disposal relative to other factors would be similar to Alternative 2, but additional controls would be needed to address the increased potential for air emissions during waste transport and placement.	More expensive than Alternative 3 or 4 except for the on-site option (Alternative 5a). Long-term monitoring and maintenance costs would probably be higher than Alternatives 6 and 7 because more intensive measures would be required. The total cost of Alternative 5a (on-site disposal) is estimated to be $76 million; the estimated costs of Alternative 5b (disposal at the Envirocare site) and Alternative 5c (disposal at the Hanford site) are $404 million and $361 million, respectively. Alternative 5d (disposal at the nearby site) would cost more than Alternative 5b or 5c because of siting, licensing, permitting, and development requirements.

TABLE 4.3 (Cont.)

Alternative	Effectiveness	Implementability	Cost
Alternative 6: Removal, Chemical Stabilization/Solidification, and Disposal	More protective than Alternatives 2 through 5 in the long term. Contaminant mobility of the treated material would be greatly reduced by treatment, but contaminant volume would increase from chemical addition; toxicity would not be reduced. Removal of waste from the various contaminated areas would minimize exposures to humans and biota at those areas. The effectiveness of the disposal component would be high. During transport, impacts from exposures due to accidents would be lower than Alternative 5 because the highly contaminated material would have been treated and would resist dispersal. Other potential transportation impacts from accidents and worker exposures would be somewhat higher than for the off-site disposal options of the other alternatives because the higher overall waste volume would increase the number of trips required.	Removal and treatment would be relatively straightforward and could be implemented with readily available resources and standard procedures. On-site disposal (Alternative 6a) could be accomplished in a relatively straightforward manner, but off-site disposal could be difficult. The stabilized/solidified product would set within the containers during transport, making it difficult to remove from the containers for placement in the disposal cell. The increased volume and weight of the material would increase the time and number of trips required for transport compared with Alternative 5 and Alternative 7. The implementability of off-site disposal relative to other factors would be the same as identified for Alternative 2.	More expensive than Alternatives 5 and 7 except Alternative 7a. The total cost of Alternative 6a (on-site disposal) is estimated to be $157 million; the estimated costs of Alternative 6b (disposal at the Envirocare site) and Alternative 6c (disposal at the Hanford site) are $541 million and $482 million, respectively. Alternative 6d (disposal at the nearby site) would cost more than Alternative 6b or 6c because of siting, licensing, permitting, and development requirements.
Alternative 7: Removal, Vitrification, and Disposal	Comparable to Alternative 6. Vitrification would be most effective in reducing the toxicity, mobility, and volume of contaminated material that was treated; radiation toxicity would not be reduced. The timeliness of this alternative would be less than Alternative 6 because of technical issues associated with implementing the vitrification process. Short-term impacts to workers would be higher than Alternative 6 because of the increased work force and hazards of the high-temperature process; airborne contaminants would be released from the facility stack. The effectiveness of removal and disposal would be high, as for Alternative 6a. For off-site disposal, transportation impacts from accidents and worker exposures would be somewhat lower than Alternative 6 because the lower overall waste volume would decrease the number of trips required.	Removal would be straightforward to implement, as for Alternative 6. However, treatment would be less straightforward to implement because of the complexity of the process, the heterogeneity of the waste to be treated, scale-up and optimization requirements, and the need for stringent safety measures and emission controls. Equipment is not readily available, and special operator training would be required. For disposal, the potential issue of stability would be addressed by alternating waste placement with clay or other binder material if a dedicated cell were used. Off-site disposal would be implemented with readily available resources.	More expensive than Alternative 3, 4, 5, or 6 for on-site disposal because of the complexity of the vitrification process, including equipment and personnel requirements and high energy costs. The costs for the off-site disposal options would be lower than those of Alternative 6 because fewer trips would be required to transport the smaller waste volume. The total cost of Alternative 7a (on-site disposal) is estimated to be $182 million. Estimated costs of Alternative 7b (disposal at the Envirocare site) and Alternative 7c (disposal at the Hanford site) are $351 million and $304 million, respectively. Alternative 7d (disposal at the nearby site) would cost more than Alternative 7b or 7c because of siting, licensing, permitting, and development requirements.

of effectiveness, implementability, and cost. On the basis of these results, the following alternatives were screened from further consideration:

- Alternative 2: In-Situ Containment and Limited Disposal;
- Alternative 3: In-Situ Chemical Stabilization/Solidification and Limited Disposal;
- Alternative 4: In-Situ Vitrification and Limited Disposal;
- Alternative 5: Removal, Minimal Treatment, and Disposal;
- Alternative 6b: Removal, Chemical Stabilization/Solidification, and Disposal at the Envirocare Site near Clive, Utah;
- Alternative 6c: Removal, Chemical Stabilization/Solidification, and Disposal at the Hanford Site near Richland, Washington;
- Alternative 6d: Removal, Chemical Stabilization/Solidification, and Disposal at the Hypothetical Nearby Site; and
- Alternative 7d: Removal, Vitrification, and Disposal at the Hypothetical Nearby Site.

Although it would not be protective of human health and the environment in the long term, the no-action alternative (Alternative 1) was retained through this screening to provide a basis for comparison with the remaining action alternatives during their subsequent detailed evaluation. The elimination of Alternatives 2, 3, 4, 5, 6b, and 6c from further consideration was based on lower effectiveness compared with other alternatives i.e., the inability of the alternatives to ensure long-term protection of human health and the environment at the Weldon Spring site — and/or difficulties in implementation — i.e., limitations in the technical and administrative feasibility of specific components of the alternatives. Alternatives 2, 3, and 4 were rejected from further consideration because of the lower effectiveness and implementation difficulties for the in-situ containment or treatment component of these alternatives compared with the alternatives that were retained. Alternative 5 was rejected from further consideration because of the implementation constraints associated with disposal of the dewatered sludge and related concerns about the short-term and long-term effectiveness of this alternative. Alternatives 6b and 6c were rejected from further consideration because of the lower effectiveness associated with off-site transport and disposal of the chemically stabilized/solidified waste, including the increased potential for accidents and exposures, and the substantial increase in costs without a relative benefit. Alternatives 6d and 7d were rejected from further consideration because of the implementation difficulties associated with siting, licensing, permitting, and developing a nearby disposal facility in Missouri and the increased transportation risk and cost compared with other alternatives that were more protective.

On the basis of the screening analysis for preliminary alternatives, the alternatives retained for detailed evaluation were:

- Alternative 1: No Action;
- Alternative 6a: Removal, Chemical Stabilization/Solidification, and Disposal On-Site;
- Alternative 7a: Removal, Vitrification, and Disposal On-Site;
- Alternative 7b: Removal, Vitrification, and Disposal at the Envirocare Site near Clive, Utah; and
- Alternative 7c: Removal, Vitrification, and Disposal at the Hanford Site near Richland, Washington.

These alternatives are discussed further in Chapters 5, 6, and 7.

5 DESCRIPTION OF FINAL ALTERNATIVES

Five remedial action alternatives for the Weldon Spring site were retained through the screening process:

Alternative 1: No Action;

Alternative 6a: Removal, Chemical Stabilization/ Solidification, and Disposal On-Site;

Alternative 7a: Removal, Vitrification, and Disposal On-Site;

Alternative 7b: Removal, Vitrification, and Disposal at the Envirocare Site near Clive, Utah; and

Alternative 7c: Removal, Vitrification, and Disposal at the Hanford Site near Richland, Washington.

The components of these alternatives are described in Sections 5.1 through 5.5. Under all final alternatives except no further action, contaminated material would be removed from various source areas, treated as appropriate, and then disposed of in an engineered disposal cell either on-site or off-site. The representative engineering procedures and equipment that are described for these alternatives are provided for purposes of comparing the feasibility of the alternatives and assessing potential impacts on human health and the environment. Final design components, procedures, and equipment selection would be developed during the remedial design phase and would incorporate optimization considerations and information developed during the course of detailed design.

5.1 ALTERNATIVE 1: NO ACTION

No action is included as a final alternative to provide a baseline for comparison with the action alternatives. Under this alternative, no further action would be taken and conditions at the various contaminated source areas would remain as they would exist after the ongoing interim actions are completed. These areas are described in detail in the RI report (DOE 1992c), and the information is summarized in Chapters 1 and 2 of this FS. The locations of the source areas are shown in Figure 1.3, and the areas and/or volumes of the material at on-site source areas, vicinity properties, and storage facilities are presented in Table 2.1. The following interim actions are assumed to be in effect as the baseline condition for this FS: (1) the bulk waste from the quarry is in short-term storage at the TSA; (2) the water treatment plants at the quarry and chemical plant area are operational; (3) the buildings and other structures have been dismantled, and the resulting material is in short-term storage at the MSA debris staging area and asbestos container staging area; and (4) the containerized chemicals remain in short-term storage at Building 434. The following activities would continue at the site under the no-action alternative: environmental monitoring of groundwater, surface water, and air; maintenance of all on-site storage facilities, including Building 434, the raffinate pit dikes, the Ash Pond dike, and perimeter fences; operation of the water treatment plants; and provision of site security.

5.2 ALTERNATIVE 6a: REMOVAL, CHEMICAL STABILIZATION/ SOLIDIFICATION,AND DISPOSAL ON-SITE

Alternative 6a involves the removal of contaminated material from each of the on-site source areas, treatment by chemical stabilization/solidification as appropriate, and disposal in an engineered disposal cell on-site. The volumes of wastes to be removed, treated, and disposed of are summarized in Table 5.1. Also summarized are the volumes of borrow material required, the total effort (in person-years) for implementation, and the potential land areas impacted (which would depend on the borrow area selected as part of detailed design).

5.2.1 Removal

Under Alternative 6a, contaminated material would be removed from the source areas and on-site storage facilities to achieve permanent source control and provide long-term protection of human health and the environment. Removal activities would be carried out with standard construction equipment and procedures. Conceptual procedures for removing contaminated material from the source areas are described in Sections 5.2.1.1 through 5.2.1.9.

5.2.1.1 Site Preparation

Removal activities at the site would begin with clearing and grubbing of vegetated areas and construction of haul roads and storage areas where necessary. Site preparation would require clearing and grubbing of an estimated 19 ha (48 acres) of vegetation. Construction of haul roads connecting the TSA, MSA debris staging area, and the raffinate pit area would require clearing of about 1.5 ha (3.6 acres). The vegetation would be removed from these areas, chipped, and transported to the mulch pile (Figure 4.3). The mulch pile is expected to be used to enhance biodegradation of approximately 23,500 m^3 (30,700 yd^3) of chipped vegetation under this alternative (MK-Ferguson Company and Jacobs Engineering Group 1992b). Following volume reduction through decomposition (estimated at up to 80 to 90%), the material would be transported from the mulch pile to the disposal cell. Construction of haul roads and laydown areas on-site and at the vicinity properties would include placing approximately 35,000 m^3 (45,800 yd^3) of fill and gravel base from off-site borrow areas. Several borrow areas are available locally; for the purposes of preliminary conceptual planning, it was assumed that the off-site borrow soil used to construct the cell and to backfill excavated areas would be taken from within an 8-km (5-mi) radius of the site (Section 5.2.1.10). Preparation for remediating Army vicinity properties A5 and A6 (Figure 1.4) would require clearing and grubbing of 1.2 ha (3.0 acres) of vegetation and construction of access roads. Site preparation might also include the construction of on-site perimeter water control dikes and siltation ponds (MK-Ferguson Company and Jacobs

TABLE 5.1 Summary of Waste Volumes, Borrow Material, Effort, and Impacted Land Areas for Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site

Parameter	Value
Volume removed (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	425,400
Quarry soil (stored in TSA)	52,000
Structural material[a]	203,000
Water treatment plant residuals	3,600
Total	904,000
Volume treated (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	50,000
Quarry soil (stored in TSA)	50,000
Structural material	123,000
Water treatment plant process waste	3,600
Total	447,000
Volume after treatment (yd^3)	
Raffinate pit sludge	290,400
Sediment/soil (includes roads and embankments)	66,000
Quarry soil (stored in TSA)	66,000
Structural material[b]	Variable
Water treatment plant process waste	4,800
Total disposal volume[c] (yd^3)	
Raffinate pit sludge	290,400
Sediment/soil (includes roads and embankments)	441,400
Quarry soil (stored in TSA)	68,000
Structural material	203,000
Water treatment plant process waste	4,800
Total	1,010,000
Volume of borrow material[d] (yd^3)	
Waste removal and reclamation (on-site and vicinity properties)	535,000
Disposal cell	982,000
Total	1,520,000

TABLE 5.1 (Cont.)

Parameter	Value
Effort (person-years)	
Excavation and on-site handling[e]	210
Treatment	90
Disposal	170
Transportation of supplies and fill	85
Total	560
Total on-site area impacted (acres)	137
Total off-site area impacted (acres)	85 (borrow material)

[a] The volume estimate for structural material includes the material contaminated by site cleanup activities, such as piping and equipment from the two water treatment plants.

[b] The volume reduction of structural material would be variable (see text) and could be offset by volume increases from size reduction (e.g., of concrete blocks).

[c] Does not include any contingency factors. Compaction within the disposal cell could reduce the overall volume of structural material.

[d] For the representative analysis in this FS, off-site borrow of 895,000 m^3 (1,171,000 yd^3) of clay-rich soil was assumed to be available from a 61-ha (150-acre) parcel of nearby land owned by the Missouri Department of Conservation (Section 5.2.1.10). Additional borrow material such as gravel, sand, fill, and topsoil would be supplied by local vendors.

[e] Includes worker requirements associated with removing soil from vicinity properties and sediment from the Busch Wildlife Area lakes, as well as restoring all excavated areas. Also includes the requirements associated with transporting chemicals off-site for incineration at a permitted facility.

Engineering Group 1992b). The construction of these structures would require clearing and grubbing of about 5.7 ha (14 acres) of land and placement of about 29,000 m^3 (37,900 yd^3) of soil embankments.

5.2.1.2 Building Foundations and Underground Piping and Sewers

Approximately 31,000 m^3 (40,600 yd^3) of concrete slabs, pads, and foundations remaining after building dismantlement would be removed, and this material would be hauled to the MSA debris staging area prior to transfer to the volume reduction facility or the disposal cell. Approximately 990 m^3 (1,300 yd^3) of underground piping and sewers would also be excavated and hauled to the MSA for staging. Contaminated soil around the pipes would be removed as described for on-site soil and sediment, and the resulting trenches would be backfilled.

5.2.1.3 Raffinate Pits

The water level at the raffinate pits would be lowered by pumping the ponded water to the adjacent water treatment plant under an interim action; some water cover would be maintained to minimize emissions of radon gas and contaminated particulates. Sludge would be removed from the pits under the current action with a dredge suspended in the remaining ponded water. After removal, the sludge would be pumped as a slurry into a holding tank located at the adjacent sludge processing facility (Figure 4.2). Following removal of the sludge and any residual surface water, the remaining contaminated soil — an estimated 117,400 m^3 (153,500 yd^3) of raffinate pit clay bottom and embankment material — would be excavated with conventional earth-moving equipment. It is estimated that about 38,000 m^3 (50,000 yd^3) of soil would contain fairly high levels of contaminants and would therefore be treated; this soil would be hauled to the chemical stabilization/solidification facility or staged at the TSA for later transfer to that facility. The remaining soil would be transported directly to the disposal cell. Excavation of soil from the raffinate pit area might require the placement of an aggregate base to stabilize the working surface. Such material would likely become contaminated during operations and subsequently require disposal along with the other on-site waste. Removal activities at the raffinate pits are expected to begin with pit 1, and the same sequence of activities would be repeated for pits 2, 3, and 4. Raffinate pit 4 also contains about 400 m^3 (500 yd^3) of debris that would be removed and transported to the disposal cell or to the volume reduction facility. The raffinate pits area would be restored following removal of the sludge and contaminated soil by filling and grading the pits and surrounding areas to achieve drainage consistent with the local topography. An estimated 85,000 m^3 (111,000 yd^3) of off-site borrow and 138,000 m^3 (180,000 yd^3) of uncontaminated material from the exteriors of the raffinate pit dikes would be used to restore the raffinate pits area. Topsoil would be placed following completion of basic site grading; the 38,000 m^3 (50,000 yd^3) of topsoil required to cover the pits is assumed to be available from on-site stockpiles, an off-site borrow area, or local vendors. The area would then be seeded with hardy native vegetation.

5.2.1.4 On-Site Soil and Sediment

Excavation and transport of the on-site soil and sediment could be accomplished with standard earth-moving equipment. After excavation, the soil and sediment would be placed into trucks for transportation to the disposal cell or to staging areas. The material removed by these procedures would include the contaminated sediment and soil in Ash Pond, Frog Pond, North Dump, South Dump, and other areas of the site, such as around the chemical plant buildings; the soil surrounding underground sewer lines, beneath building foundations, and in storage at the TSA and MSA; and the chipped organic material in the mulch pile.

Before the sediment was removed from Ash Pond and Frog Pond under this alternative, the water would have been pumped from the ponds to the water treatment plant under the interim action. After the water was removed, a gravel base would be placed in both ponds to stabilize the working surface for excavation of the sediment. The gravel base would likely become contaminated during removal activities and would then require disposal in the on-site cell. Contaminated soil surrounding underground sewer lines would be segregated during pipe removal activities and then transported to a staging area or directly to the disposal cell. Approximately 76,500 m^3 (100,000 yd^3) of contaminated soil from on-site areas or the TSA (e.g., the raffinate pit clay bottom and quarry soil) would be transported to the sludge processing facility adjacent to the raffinate pits for treatment. This material would be delivered to the treatment facility at the rate needed to meet the feed requirements for the chemical stabilization/solidification process (MK-Ferguson Company and Jacobs Engineering Group 1992b). After removal of contaminated soil from the chemical plant area and completion of the disposal cell, the excavated areas would be backfilled, regraded, and covered with topsoil recovered from clean stockpiles, an off-site borrow area, or local vendors, as required. The areas would then be seeded with hardy native vegetation.

5.2.1.5 Material Staging Area

Approximately 63,700 m^3 (83,300 yd^3) of building debris and foundation concrete in storage at the MSA would be removed and transported to the volume reduction facility (Figure 4.2). The remaining 27,300 m^3 (35,700 yd^3) of material in the MSA (which includes some nonfriable asbestos) would be removed and transported directly to the disposal cell. Restoration of the MSA would involve removal of the settling basin and foundations, approximately 11,100 m^3 (14,500 yd^3) of material, and placement of the contaminated material in the disposal cell. The area would then be backfilled, regraded, covered with topsoil, and seeded.

5.2.1.6 Temporary Storage Area

Approximately 115,000 m^3 (150,000 yd^3) of material would be stored at the TSA, and about 31,100 m^3 (40,700 yd^3) of this material would consist of debris and rock that, depending on its size, would be trucked to the volume reduction facility or directly to the disposal cell. Approximately 2,800 m^3 (3,600 yd^3) of containerized process waste from the water treatment plants in storage at the TSA would be transported to the sludge processing facility for chemical stabilization/solidification. Most of the remaining TSA material would be soil from the quarry, of which about 38,000 m^3 (50,000 yd^3) would also be transported to the sludge processing facility for treatment. Final closure of the TSA would involve excavation of the foundation, aggregate base, and related sediment (approximately 17,000 m^3 [22,000 yd^3]). The area would then be backfilled, regraded, covered with topsoil, and seeded.

5.2.1.7 Storage Building 434 and Asbestos Container Staging Area

About 3,600 m^3 (4,700 yd^3) of containerized friable asbestos in storage at the asbestos container staging area would be transported to the disposal cell, and an estimated 3,800 m^3 (5,000 yd^3) of contaminated personal protective equipment in storage at Building 434 would be transported to the volume reduction facility for in-drum compaction. Containerized liquid chemicals in storage at Building 434 would be placed in overpacks and loaded onto trucks for transport to a permitted facility for incineration; the contaminated tributyl phosphate would be transferred to tanker trucks for similar treatment (Section 4.2.1.2). Process chemicals for which incineration is inappropriate would be treated and disposed of in accordance with applicable requirements, such as Land Disposal Restrictions (40 CFR 268) (see Appendix G, Table G.3). Following the removal of all chemicals and personal protective equipment, Building 434 would be dismantled and the resulting material would be temporarily stored at the MSA debris staging area prior to volume reduction and/or disposal; the areas would then be restored as described for the MSA. Following removal of the asbestos, the asbestos container staging area would be similarly restored.

5.2.1.8 Contaminated Off-Site Sediment and Soil

Removal of sediment and shoreline soil from Lakes 34, 35, and 36 in the Busch Wildlife Area would be coordinated with the routine drainage and sediment removal program of the state of Missouri. After the Missouri Department of Conservation has drained the lakes, DOE would sample the sediment for contamination. It is estimated that DOE could remove about 15,300 m^3 (20,000 yd^3) of contaminated sediment from the combined lakes with a scraper, transporting the material to a transfer area located adjacent to each lake. The sediment would then be transported in covered trucks to the site for disposal. Locations of the potential haul routes are shown in Figure 4.1.

About 2,800 m^3 (3,600 yd^3) of contaminated soil on Army vicinity properties A1, A2, A3, A5, and A6 and vicinity properties B3, B4, B5, B6, and B10 in the Busch and Weldon Spring wildlife areas would be excavated and transported in covered trucks to the site for disposal (MK-Ferguson Company and Jacobs Engineering Group 1992b). Locations of the haul routes are shown in Figure 4.1. Remediation of Army properties A5 and A6 would involve the removal of contaminants that had migrated beyond the site fence as a result of runoff; therefore, to prevent possible recontamination of cleaned areas, the removal of soil from these two properties would be scheduled to follow remediation of the contaminated areas on-site that contribute drainage to those locations. The 10 vicinity properties would be reclaimed following excavation of the contaminated soil by placing clean backfill and topsoil. A gravel base or riprap would be used in drainage areas subject to water erosion, e.g., at Army vicinity properties A5 and A6.

5.2.1.9 Quarry Residuals

If residual material were removed from the quarry in the future on the basis of decisions to be made for the quarry residuals operable unit (Section 1.5.3), the material would be transported in containers or by covered truck along the haul road from the quarry to the site for disposal (DOE 1990b). This material could include soil from the cracks and fissures of the quarry walls and floor, sediment from Femme Osage Slough, and soil from the quarry water treatment plant staging area. Although the specific decision for what residual material might be removed and to what level is outside the scope of this FS, the decision on how to manage (dispose of) the contaminated material that could result from potential future cleanup activities will be part of the comprehensive disposal decision that will result from the current analyses.

5.2.1.10 Off-Site Borrow Soil

Approximately 895,000 m^3 (1,171,000 yd^3) of clay-rich soil would be excavated from an off-site borrow area in the vicinity of the Weldon Spring site to backfill and restore the on-site areas from which contaminated material is removed and to support construction of the disposal cell. A possible borrow area site under consideration is located southeast of State Route 94 on land owned by the Missouri Department of Conservation (Figure 5.1). The site occupies about 61 ha (150 acres), within which about 21 ha (52 acres) (not necessarily contiguous) might be excavated to an average depth of 4.3 m (14 ft) for borrow material. The total impacted area at this location would be about 34 ha (85 acres), which would include soil stockpile areas, access roads, and areas for equipment parking. Under current conceptual plans, a haul road about 1.6 to 2.4 km (1 to 1.5 mi) in length would be constructed for vehicle transport of the borrow material to the site.

The site of this potential borrow area is centered on a low irregular plateau, about 200 m (665 ft) above mean sea level (MSL), that is drained by shallow ravines along its margins. Several unpaved roads (earthen tracks without gravel bed) traverse the area, and a small pond is located in its east-central portion. Most of the borrow area site is covered with grasses and low shrubs, but stands of trees are situated along the western margin of the plateau and in the southern portion of that site. Other potential borrow area sites under consideration include sites on the adjacent U.S. Army property, the Busch Wildlife Area, and near the recently completed quarry haul road south of the Weldon Spring site in the Weldon Spring Wildlife Area.

Following removal of the borrow material, the area would be reclaimed in accordance with land use plans of the Missouri Department of Conservation. At a minimum, the area would be graded and revegetated. All reclamation activities would be undertaken in accordance with requests of the Missouri Department of Conservation.

5.2.1.11 Mitigation and Monitoring

During remediation activities, good engineering practices and mitigative measures would be implemented to control both contaminant releases and potential exposures to workers and the general public. All workers engaged in waste removal or handling would be required to wear an appropriate level of personal protective equipment. Workers and work areas would be monitored to ensure worker safety. Air and surface water are the primary environmental media that could be impacted by these activities. Monitoring and mitigative measures for Alternative 6a are summarized in Section 6.6. Dust control measures that would be implemented to minimize air impacts during the cleanup period are identified in Appendix C, Section C.3.5. These measures include spraying water, applying chemical dust suppressants, applying surface-stabilizing foam, covering stockpiles, and covering loads during transport.

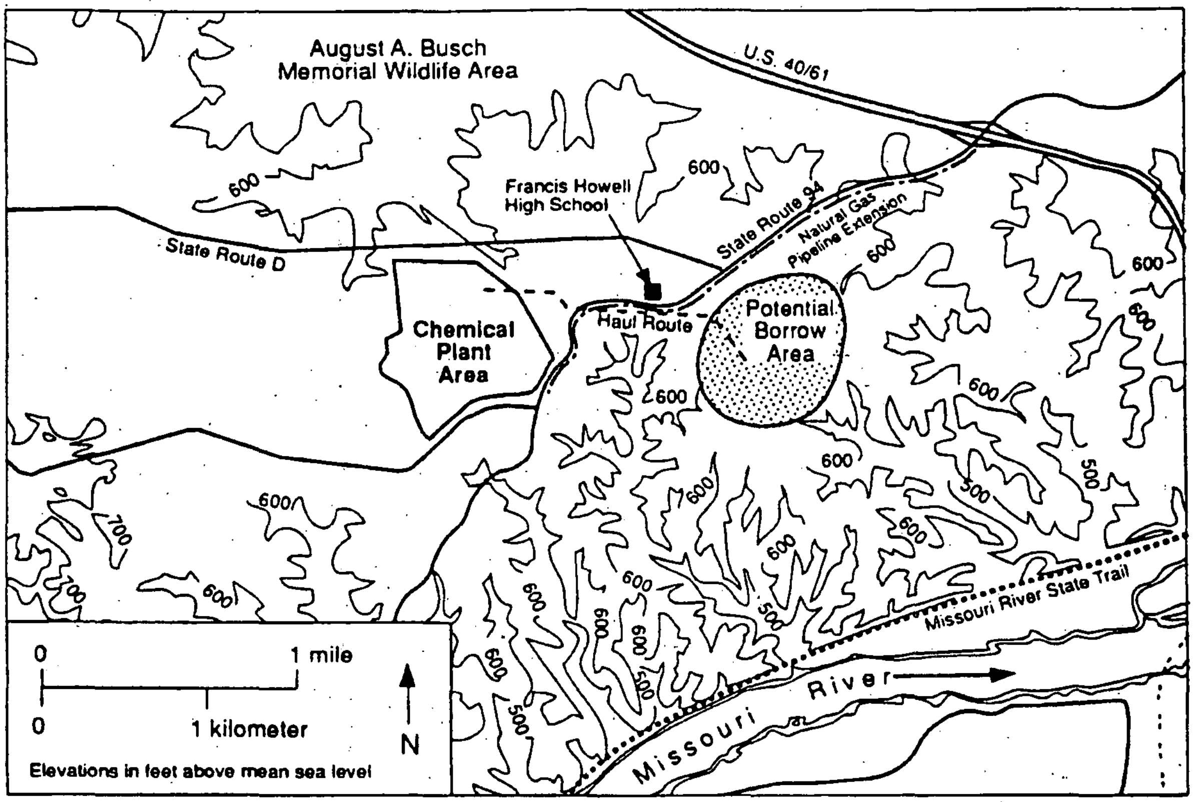

FIGURE 5.1 Location of Potential Borrow Area

Erosion control measures would be used to mitigate impacts to both air and surface water. For air, these measures include wetting loose material and minimizing construction stockpiles; for water, these measures include placing straw bales downstream of the work area, isolating work areas with berms, covering stockpiles, using temporary vegetative covers, and constructing siltation ponds to provide for settling of suspended solids from surface runoff prior to off-site transport (Figure 5.2).

Groundwater, surface water, and air would be monitored at the site and at specific off-site locations during remediation activities. The existing environmental monitoring program for the project would be expanded to include additional groundwater monitoring of both on-site and off-site wells. Under this expanded program, the number of wells sampled, the sampling frequency, and the number of analytes would all be increased. The locations of additional wells and information on the expanded groundwater monitoring plans are discussed in Section 6.2.3.3.

The current air monitoring program for airborne particulates, external gamma radiation, and radon would also be expanded. Under the existing environmental monitoring program, these parameters have been monitored continuously at the site perimeter and at several nearby locations for several years. Additional monitors (including state-of-the-art radon monitors) have

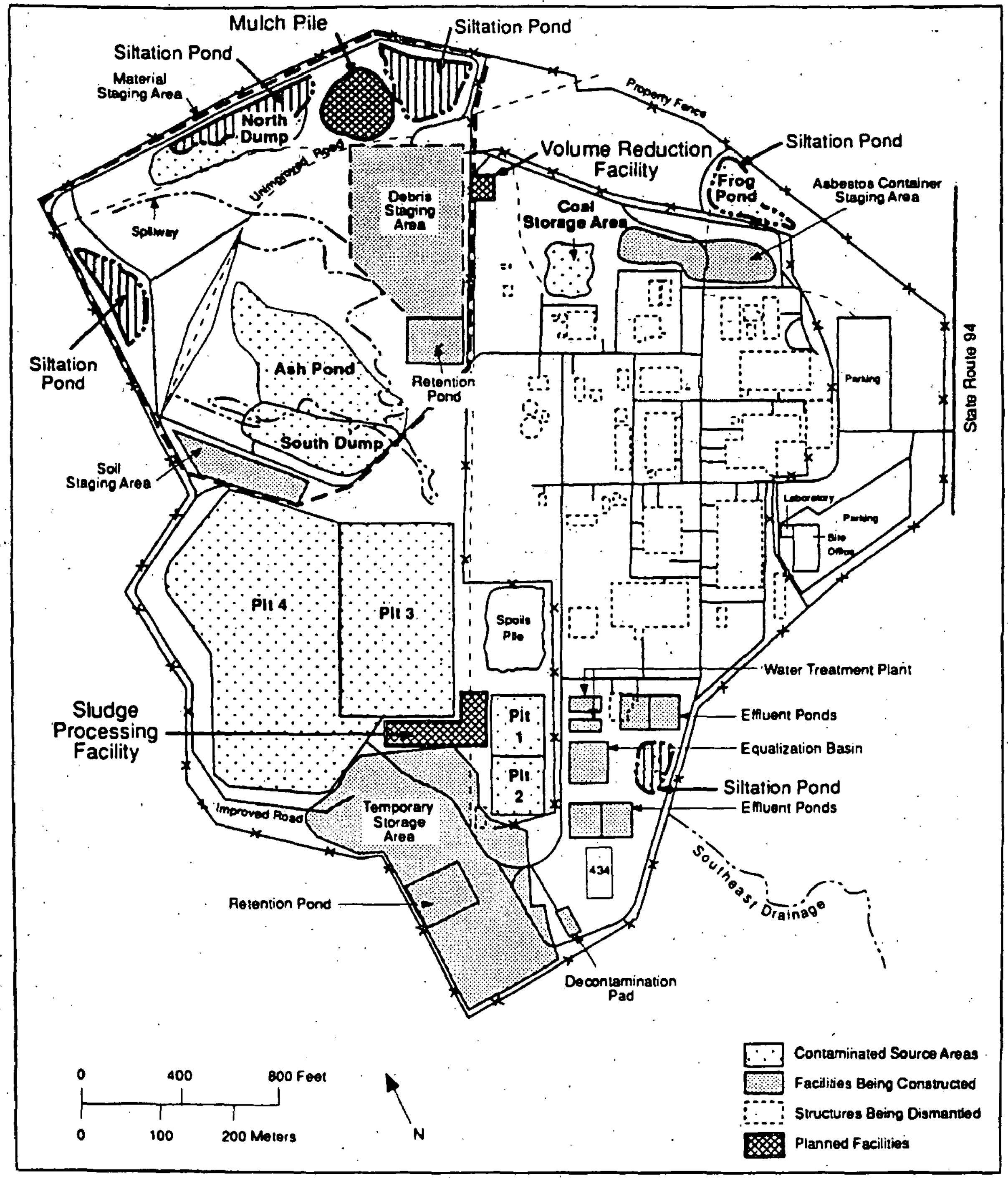

FIGURE 5.2 Location of Proposed Siltation Ponds

recently been installed on-site and at nearby locations, including Francis Howell High School. The current monitoring program, including the locations of detectors, is described in the site environmental monitoring plan (MK-Ferguson Company and Jacobs Engineering Group 1992c).

To address the concern regarding a potential increase in airborne radionuclide concentrations above natural background levels, air would be monitored at both the site perimeter and at nearby locations for the duration of site cleanup activities. In addition, mobile air samplers would be used in the work areas to ensure that airborne releases were maintained at low levels. If airborne concentrations were detected at above background levels at nearby receptor locations, contingency measures would be implemented to reduce contaminant emissions. For example, work could be stopped, exposed areas covered or otherwise controlled, and engineering measures could be increased prior to restarting work to ensure that nearby members of the general public would not be adversely impacted. Extensive monitoring would be applied in combination with stringent engineering controls to ensure the safety of workers and the general public.

The raffinate pit sludge and quarry material at the TSA are the primary sources of potential contaminant releases (especially radon) from the site. To minimize the possibility of releases from the raffinate pits, some water would be maintained in the pits during sludge dredging so that the surface water would continue to serve as a radon attenuation barrier during removal activities. Quarry material susceptible to airborne emissions at the TSA would be sprayed with dust suppressants or covered, as required, to minimize releases until it was transported to the sludge processing facility or the disposal cell; this material would be wetted during removal and transport to minimize radon and particulate emissions.

5.2.2 Treatment

Under Alternative 6a, two new facilities would be constructed on-site: (1) a chemical stabilization/solidification facility (i.e., the sludge processing facility), which would be used to treat sludge, sediment, soil, and water treatment plant process waste; and (2) a volume reduction facility, which would be used to treat rock, structural material, and containerized decontamination debris. Other on-site facilities include the water treatment plant and the decontamination pad that are being constructed as part of interim actions (Section 1.5.1). The locations of these facilities are shown in Figure 4.2. In addition, a mobile shredder would be used intermittently to reduce the volume and enhance the biodegradation of woody material, and the resultant chips would be placed in an on-site mulch pile.

The sludge processing facility located adjacent to the raffinate pits and the TSA would be used to chemically stabilize/solidify the highly contaminated sludge from the raffinate pits (approximately 168,000 m^3 [220,000 yd^3]) and soil from on-site areas, including clay underlying the raffinate pits and quarry soil at the TSA (totaling approximately 76,500 m^3 [100,000 yd^3]). Containerized (nonliquid) process chemicals in storage in Building 434 and approximately 2,800 m^3 (3,600 yd^3) of containerized process waste from the water treatment plants would also be treated in the sludge processing facility. The preliminary conceptual design of the sludge processing facility is based on use of the cement/fly ash mixture and waste blend ratio identified by Gilliam and Francis (1989), which would result in increasing the volume and weight of the material treated by about 32 and 60%, respectively.

The sludge processing facility would probably occupy an area of about 0.40 ha (1.0 acre). This area would require clearing and grading prior to installation of the foundation and necessary utilities, i.e., electricity and water. A single building would house the mixing equipment (e.g., a pug mill blender) and offices. The area surrounding the treatment facility would be surfaced with gravel to facilitate the delivery of process reagents and the transport of treated product to the disposal cell.

The various waste types that would be treated in the sludge processing facility have different characteristics and would generally be treated separately. However, because water would have to be added to the soil material (about 10% by weight) to achieve full hydration of the cement, nondewatered raffinate pit sludge could be blended with the relatively dry soil. Figure 5.3 illustrates the process flowchart for the chemical stabilization/solidification facility. The fine-grained raffinate sludge has a water content of about 73% by weight. This material would be dredged and pumped as a slurry directly to a holding tank within the sludge processing facility (Section 5.2.1.3). Some decanted water would be returned to the raffinate pits to minimize the introduction of additional water to the treatment facility and to help maintain sufficient water depth in the raffinate pits for the dredging operation and radon control. The raffinate pit sludge would be fed to the pug mill blender, and cement and fly ash would be simultaneously introduced through a screw conveyor in which they would be thoroughly mixed. Proper calibration, metering, and monitoring of the mixing of reagents and waste would be needed to ensure the specified waste-to-reagent blend. The metering devices would be calibrated and adjusted regularly. The reagents and raffinate pit sludge would be fed into a pug mill blender with a preliminary conceptual design capacity of about 127 t/h (140 tons/h) and a production rate of about 110 t/h (120 tons/h). The grout-like chemically treated product is expected to achieve initial set in 1 day and final set within 7 days (MK-Ferguson Company and Jacobs Engineering Group 1992b).

To minimize stockpiling, soil material would be transferred to the sludge processing facility from the excavation or storage areas at the rate needed to accommodate the feed requirements of the treatment plant. Any large rocks or cobbles would be removed by screening at the apron feeder and would be transported directly to the disposal cell. Some minor metal debris (e.g., nails and bolts) and some organic material (e.g., branches, twigs, and roots) would probably be present in the soil material feed. Most of the stray metal and woody debris would be removed by the screening process, and the small amount of debris that passed through the screen would not adversely affect the chemical stabilization/solidification process. Water would have to be added to the soil and clay to ensure full hydration of the cement. The water would be introduced at the screening stage to minimize dust generation. Water pumped from the adjacent water treatment plant (e.g., from the equalization basin) could provide the hydration requirements. The soil would then be screw fed to the pug mill blender for mixing with the cement and fly ash. A relatively drier, soil-like product would result from chemical stabilization of the soil material compared with the treated sludge product (MK-Ferguson Company and Jacobs Engineering Group 1992b).

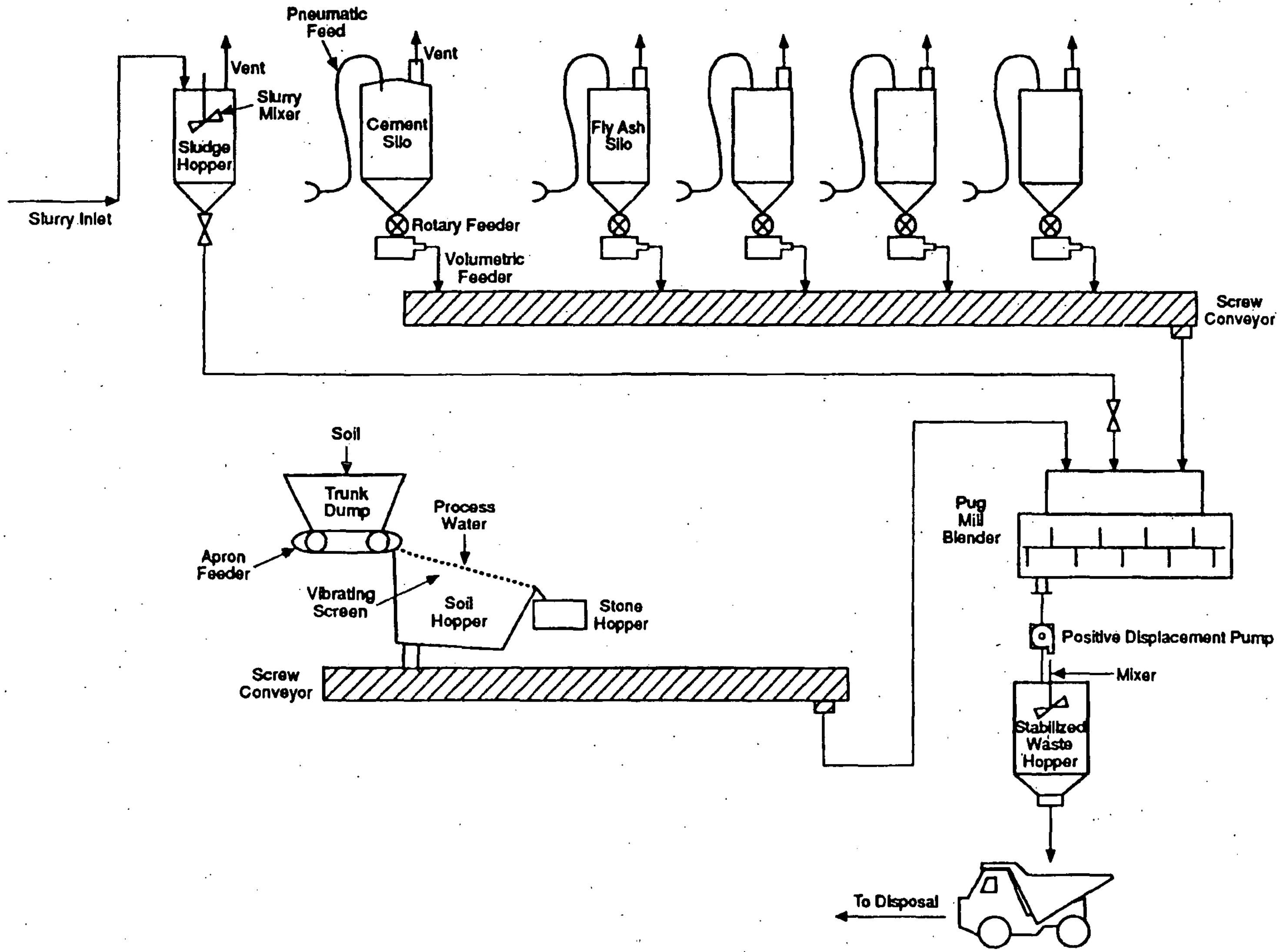

FIGURE 5.3 Process Flowchart for Chemical Stabilization/Solidification under Alternative 6a (Source: Modified from MK-Ferguson Company and Jacobs Engineering Group 1992b)

The treated soil product would be pumped to a hopper before transport to the disposal cell. The hopper would provide storage and would be continuously agitated to prevent setting. The treated product in the storage hopper would be visually monitored to identify the need for upstream system adjustment or water addition at the pug mill. Improperly formulated product could be recycled to the treatment system. If recycling of misformulated grout to the treatment system were delayed, a set inhibitor could be added to prevent setting prior to reprocessing.

Daily washdowns of the facility would be part of routine maintenance operations. Wash water would be routed to sumps and recycled as process water through the chemical stabilization/solidification system. Sediment generated during washdowns would be periodically removed and routed to the chemical stabilization/solidification soil feed system.

The leachability of the chemically stabilized/solidified product would be tested with the TCLP and other leach tests (MK-Ferguson Company and Jacobs Engineering Group 1992b). The stabilized waste is expected to pass the TCLP test on the basis of diffusion calculations, the concentrations of TCLP characteristic contaminants in the waste (MK-Ferguson Company and Jacobs Engineering Group 1992b), and bench-scale test results that indicated contaminant concentrations in the leachate of the chemically stabilized/solidified raffinate pit sludge were well below TCLP requirements (Waste Technologies Group 1992). The product would also be required to have an unconfined compressive strength adequate to support the overlying waste and help prevent subsidence of the disposal cell cover. The treated product would be tested to ensure that it met leach-resistance criteria. If a sample failed leachability tests, an analysis would be performed to determine potential causes and mitigative measures for correction in subsequent batches. Mitigative measures might include modifying the reagent blend or additive ratio, eliminating excess water, or adding contaminant-specific attenuating compounds. Use of such measures would be contingent upon further bench-scale and pilot-scale testing of the chemical stabilization/solidification process. The operating parameters for the treatment process would be optimized during pilot testing, and the treated product from start-up testing operations would be required to consistently pass the disposal criteria before full-scale operations would begin. The frequency of testing required to ensure product quality would be established during start-up testing.

On the basis of the waste/reagent blend identified in Gilliam and Francis (1989) and the estimated production rates used in the preliminary conceptual design, the chemical stabilization/solidification process would require about 83,000 t (91,000 tons) of cement and 123,000 t (136,000 tons) of fly ash over the project duration, at a rate of about 102 t (112 tons) of cement and 150 t (170 tons) of fly ash per day. This level of consumption would necessitate daily delivery of about five tankers of cement and seven tankers of fly ash. Cement and fly ash are available from local suppliers within 40 to 160 km (25 to 100 mi) of the Weldon Spring site (MK-Ferguson Company and Jacobs Engineering Group 1992b). Delivery trucks would travel on clean access roads to eliminate the need for vehicle decontamination. Vehicles would be scanned and decontaminated, as required, prior to leaving the site.

Operation of the chemical stabilization/solidification facility would require supervisors, laborers, and laboratory and maintenance personnel. The feed control system would be automated and computer controlled, minimizing the necessary labor force. No specialized, formal training would be required for workers. The sludge processing facility would operate for 4.5 years — assuming 9 months per year with a 3-month winter shutdown. The scheduled mechanical availability of the facility was assumed to be 90%, and the preliminary conceptual design was sized to include a production rate of 15% above the required throughput. Bench-scale testing of the chemical stabilization/solidification technology for applicability to the Weldon Spring waste is currently being conducted. Following the successful completion of this testing, pilot testing of the process with Weldon Spring waste would be carried out with equipment of the same type and function that would be used in full-scale operation; this testing would require about 12 months. Design, construction, and start-up of the full-scale chemical stabilization/solidification facility would probably require about 3.5 to 4.5 years.

Airborne emissions would be minimized as follows: the raffinate pit sludge would be delivered and maintained in a slurry or wet form until treatment began; reagents would be shipped in sealed tankers and transferred pneumatically to silos equipped with baghouses; the building would be equipped with an air filtration system; and, during processing, reagents would be transported to the mixing equipment by sealed screw conveyors. In addition, any stockpiled raffinate pit clay and other soil would be covered, and the haul routes from the TSA to the sludge processing facility would be sprayed with water or dust suppressants. Water for hydration would be added at the screening stage to minimize dust generation, and, after screening, the soil would be transported in sealed screw conveyors.

About 94,000 m^3 (123,000 yd^3) of structural material (e.g., metal, concrete, glass, piping/ductwork, tanks, equipment, and furniture), rock, and containerized decontamination material would be transported to the volume reduction facility for physical treatment (material sizing) to aid in waste placement and reduce waste volume, as necessary. The preliminary conceptual design of the volume reduction facility includes a shear, a pulverizer, an impact crusher, a rotary shear shredder, an in-drum compactor, and a decontamination unit. The actual equipment would be determined during detailed remedial design.

The volume reduction facility would be located in an 840-m^2 (9,000-ft^2) area appropriately situated to facilitate transfer from the staging area to the facility (Figure 4.2). Figure 5.4 illustrates the process flowchart for the preliminary conceptual design of the volume reduction facility. The impact crusher could process concrete rubble, cinder block, rock, glass, and ceramics into pieces smaller than 5 cm (2 in.). Although crushing would result in an initial volume increase, the crushed material would be compacted during placement in the disposal cell to eliminate voids. The rotary shear could cut and shred rebar, solid wooden material, metal siding, office and laboratory equipment, conduit, piping, and tank and equipment pieces into fragments of variable size, typically less than 15 cm (6 in.) maximum dimension. The volume reduction for debris, wood, and siding processed by rotary shear would be minimal, but the volume of conduit, piping, ductwork, tanks, and equipment pieces would probably be reduced from 10 to 50% (MK-Ferguson Company and Jacobs Engineering Group 1992b). The in-drum compactor could reduce the size of processed material by 10 to 50%. Large pieces of bulk metal, process equipment, railroad rails, and structural steel that could not be effectively

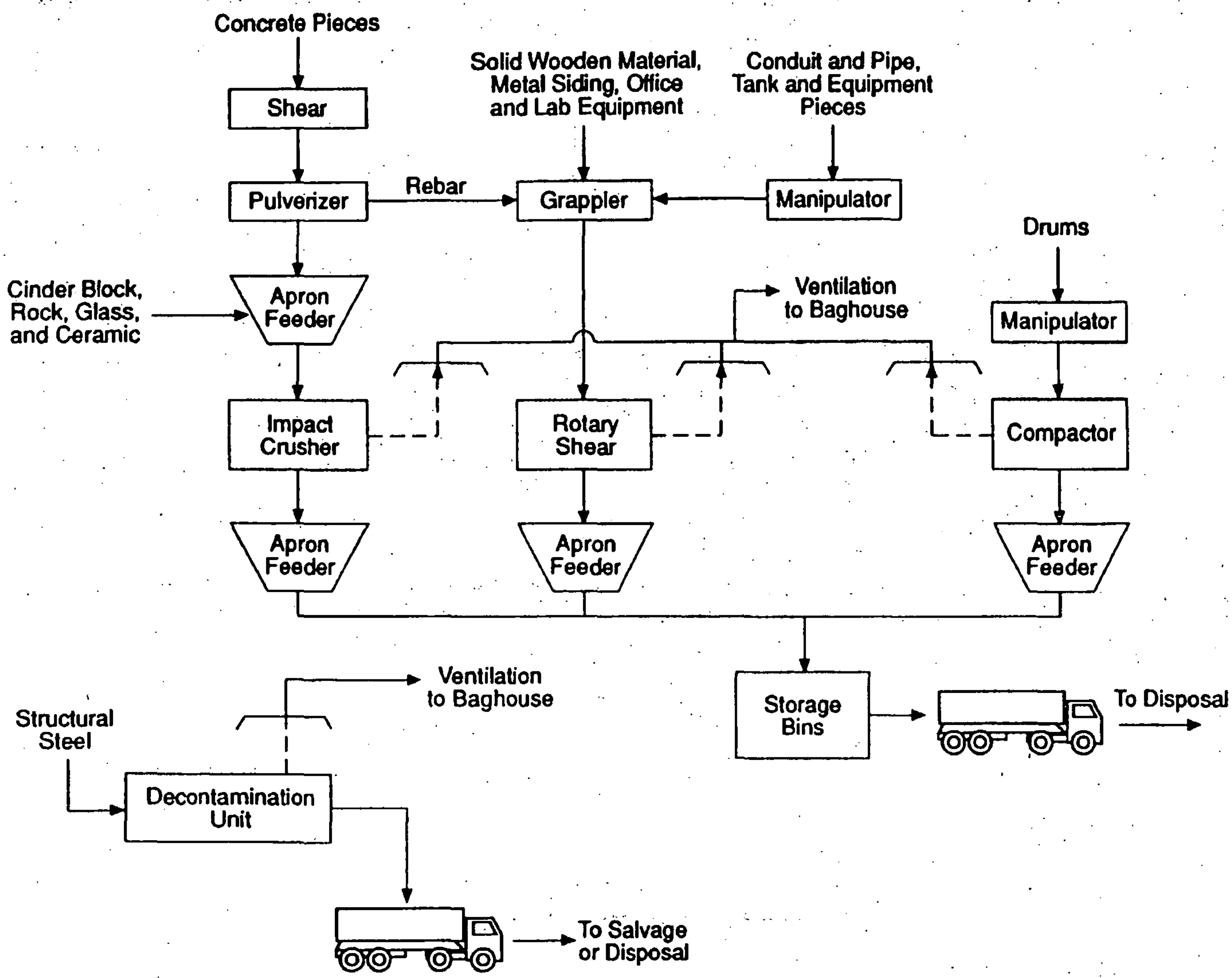

FIGURE 5.4 Process Flowchart for the Volume Reduction Facility (Source: Modified from MK-Ferguson Company and Jacobs Engineering Group 1992b)

decontaminated would be cut into manageable sizes for disposal. The material processed through the volume reduction facility would be staged in loading bins from which it could be retrieved for transport to the disposal cell.

A decontamination unit within the volume reduction facility could be used to treat structural material for which release and reuse would be practicable; the quantity of such material is estimated to be about 5,900 t (6,500 tons). This material could be treated with a wet abrasive blast process (hydrolasing), e.g., using high-pressure water with alumina or sand. The 5,900 t (6,500 tons) of structural steel would require about 3 years to decontaminate by liquid abrasive blasting at a cost of $1,180,000 ($182/ton), excluding costs associated with testing for release; the estimated effectiveness of decontamination after one application of liquid abrasive blasting is 95% (MK-Ferguson Company and Jacobs Engineering Group 1992a).

All processing equipment would be contained within the volume reduction facility area. Particulate emissions from the facility would be minimized, e.g., dust collection hoods would be positioned over each major piece of equipment and material transfer point. The facility could be enclosed within a building equipped with general ventilation hoods and a baghouse to control dust that escaped from the process equipment hoods. Dust suppressants would also be employed, and water sprays would be used during retrieval and transport of the volume-reduced material. Material collected from emission control devices would be transported to the disposal cell or to the sludge processing facility for treatment, as appropriate. Because of these engineering controls, airborne emissions from the volume reduction facility are expected to be very low.

Operation of the volume reduction facility would require a supervisor, equipment operators, and maintenance personnel. The facility would be designed to operate periodically over the remedial action period on an as-needed basis.

The volume of vegetation would be reduced and its biodegradation facilitated by chipping it in a mobile unit and placing the chipped material in a composting facility, termed the mulch pile, at the northern portion of the site (Figure 4.2). This pile would be maintained within an area of between 0.4 and 1.6 ha (1 and 4 acres) until material could begin to be placed in the disposal cell. The pile would be actively managed to enhance the biodegradation process (Section 4.2.1.4), and this composting could result in a volume reduction of 80 to 90% (MK-Ferguson Company and Jacobs Engineering Group 1992a). The end product of the process would be placed in the on-site disposal cell. Materials such as railroad ties and utility poles would probably not be composted because they would have been treated with chemicals to inhibit biodegradation. These materials would be chipped and placed in the disposal cell. In addition, some of the quarry soil in storage at the TSA contains elevated concentrations of nitroaromatic compounds. This soil could be composted in an area located within the TSA as a pretreatment step to reduce the concentrations of those compounds prior to further treatment by chemical stabilization/solidification, as required.

Support facilities would also be maintained on-site to provide electrical power, potable water, showers, portable sanitary facilities, offices for the construction management staff, and staging for excavation and construction activities. Most of these facilities are already in place, and they could be expanded to address incremental requirements associated with the increased activity on-site. Additional staging facilities would be constructed to support the heavy equipment used during the remedial action period and to provide for stockpiling of construction material for the disposal cell, such as borrow soil, gravel, piping, and liner material.

The various treatment and support facilities would be dismantled at the end of the remedial action period and either decontaminated for reuse (e.g., at another DOE facility) or treated by volume reduction and placed in the disposal cell. Following closure of the water treatment plant, a mobile water treatment unit could be brought on-site, if needed, to support final site closure activities.

5.2.3 Disposal

The preliminary conceptual cell design for disposal under Alternative 6a incorporates design features used in disposal cells for uranium mill tailings and solid/demolition waste (see Section 6.2.2). This disposal cell was conceptually designed to include a leachate collection and removal system and a cover system with an infiltration/radon attenuation barrier. It is referred to as the "combination" disposal cell because it combines the design features of cells used under two separate programs (uranium mill tailings and solid waste disposal) to minimize radon emissions, allow for the retrieval of liquids that might accumulate during cell construction and operation, and support monitoring of the disposal cell containment system. Final cell components would be determined during detailed remedial design. A contingency factor of 10% was applied to size the disposal cell for preliminary conceptual design. The resulting waste containment capacity that would be required under Alternative 6a is estimated to be 956,000 m^3 (1,250,000 yd^3). The chemically stabilized/solidified waste would be required to have sufficient strength to support the pressure of overlying waste and help prevent subsidence of the disposal cell cover. The data of Gilliam and Francis (1989) demonstrate that the strength of the chemically stabilized/solidified raffinate pit sludge would be adequate to support an effective cover.

A conceptual layout of the combination disposal cell with a waste capacity of 1,100,000 m^3 (1,500,000 yd^3) is shown in Figure 5.5, and a schematic section of the cell is shown in Figure 5.6. (For planning purposes, the disposal cell capacity was increased by 20% over that expected to be required.) The total area covered by the disposal cell would be about 17 ha (42 acres). Cell capacity could be increased by additional below-grade excavation and perimeter berms. Final design components would be determined during detailed design. The location of the disposal cell is constrained primarily by regulatory requirements that address overburden thickness and buffer zones.

On the basis of preliminary planning, the southern boundary of the study area for the conceptual cell coincides with the shallow groundwater divide. If the cell extended to the lower corner of this study area, the related groundwater monitoring system would surround the cell because groundwater could flow in both directions from beneath it — i.e., to the north toward Dardenne Creek and the Mississippi River and to the south toward the Missouri River. As part

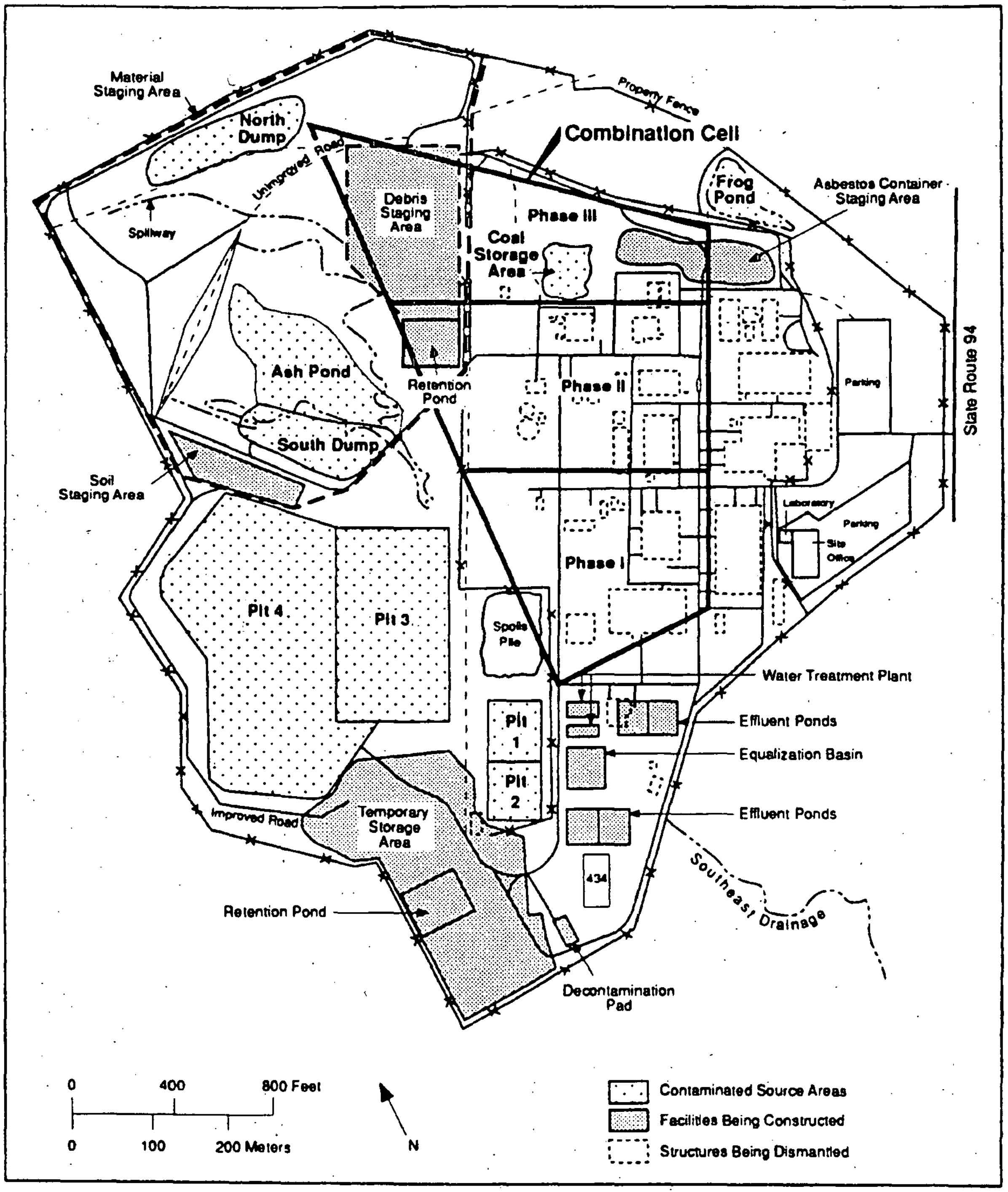

FIGURE 5.5 Conceptual Layout of the Combination Disposal Cell for Alternative 6a

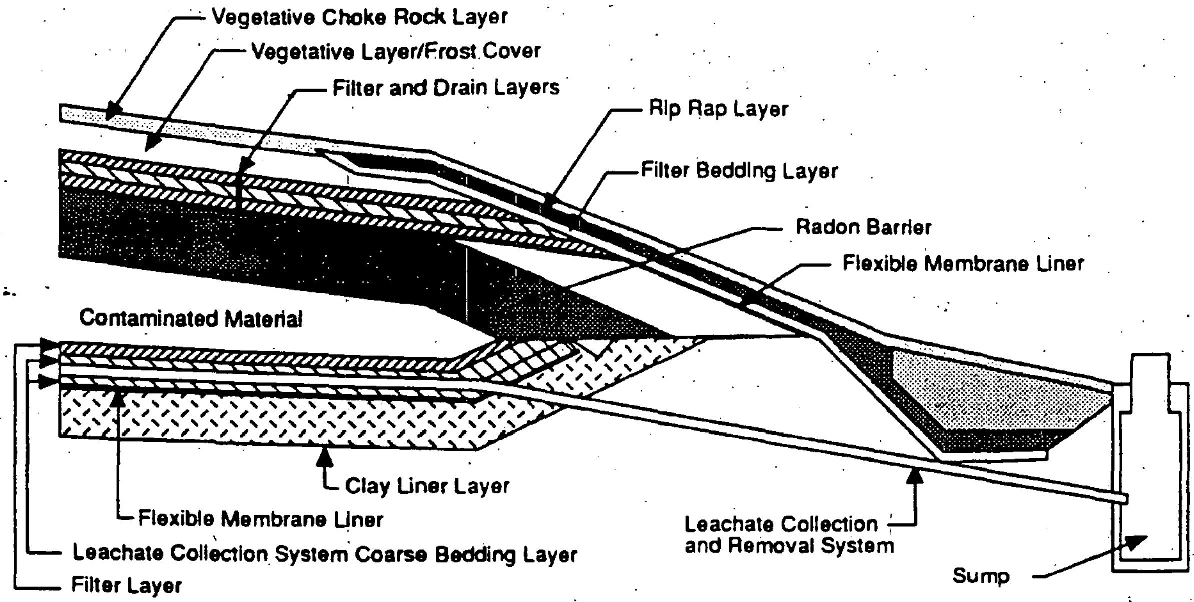

FIGURE 5.6 Typical Cross Section for the Combination Cell under Alternative 6a (Source: Modified from MK-Ferguson Company and Jacobs Engineering Group 1992b)

of further design planning, the specific location of the cell within the study area could be shifted slightly to the north such that groundwater would flow from beneath the cell in only that direction. This would reduce the total number of monitoring wells required on the south side of the divide.

Geological, geotechnical, and hydrogeological data have been collected, and studies of this type are continuing to assess the suitability of the Weldon Spring site for disposal. Previous and current studies have focused on two major aspects of site suitability: (1) suitability of the overburden as a foundation material for the proposed disposal cell and (2) suitability of the bedrock underlying the disposal cell relative to catastrophic collapse potential.

Characterization studies completed as part of the evaluation of overburden suitability include laboratory permeability tests and soil batch tests. The results of the laboratory permeability tests indicate that the condition of the overburden would provide adequate bearing and a sound foundation for a disposal cell, and the results of the soil batch tests indicate that the Ferrelview Formation and clay till (two of the overburden units) retard the migration of contaminants such as chromium, lead, uranium, and vanadium. Ongoing studies include further testing of the overburden units within the disposal area by field permeability tests and laboratory tests. The laboratory permeability studies are being conducted with both water and a synthetic leachate.

Most of the bedrock characterization studies have focused specifically on determining the presence of solution features or large voids that could increase the potential for catastrophic collapse and affect the integrity of the disposal cell. For example, bedrock studies conducted to date have included determinations of hydraulic conductivity from slug and pump tests, collection of core data from angle and vertical borings, examination of outcrops of the Burlington-Keokuk Limestone at nearby bluffs, and numerous water-level measurements. These studies have not identified any active groundwater conduits or closed depressions in the bedrock beneath the disposal cell. In addition, water-level measurements on and around the site reveal a well-developed groundwater divide, suggesting that the groundwater flow system is characterized by diffuse flow (porous media flow) with only minor components of discrete (fracture) flow (MK-Ferguson Company and Jacobs Engineering Group 1991a).

The state of Missouri continues to be consulted regarding the ongoing site studies. The applicability of state siting criteria for hazardous waste facilities are being evaluated in certain of these studies (see Appendix G, Table G.3, and Section 6.2.2). From the results obtained to date, the Weldon Spring site appears to be a suitable location for an on-site disposal cell. Following an approved demonstration of site suitability, initial cell construction activities would include grading and compacting of the ground surface to the finished subgrade elevation for the bottom liner and leachate collection and removal system. The preliminary conceptual design for the bottom liners and leachate collection and removal system consists of the following, in descending order from the waste contact: a filter zone; a leachate collection and removal system (a gravel drain-type material with perforated piping to collect and direct leachate to sumps or manholes located outside the cell perimeter); and a bottom composite liner consisting of a synthetic flexible membrane liner and a clay layer. The cover on the top of the cell embankment consists of the following, in ascending order from the waste contact: an infiltration/radon attenuation barrier, a flexible membrane liner, a filter-protected drain layer, a frost-protection/ vegetation bedding layer, and an erosion-protection layer consisting of choke rock and topsoil to support grass growth. The side slopes would consist of a radon/infiltration layer, a frost protection layer, a flexible membrane liner, a filter bedding layer, a riprap zone, and an erosion protection layer consisting of either rock alone or choke rock and topsoil to support grass growth.

Design considerations for an on-site disposal cell include potential effects from earthquakes, high winds and tornadoes, freeze-thaw cycles, heavy precipitation, plant and animal intrusion, and liner compatibility with the waste in the disposal cell. The severity of an earthquake and the resulting maximum potential horizontal acceleration would be incorporated into stability calculations used in designing the disposal cell embankment slopes. Disposal cell cover design would include consideration of wind damage, frost protection, and potential erosion from extreme precipitation events. The cell cover components would also be designed to deter intrusion by plant roots or burrowing animals. Liner materials would be chosen on the basis of their ability to contain the contaminants that would be in the disposal cell.

Construction operations would be performed in three phases (Figure 5.5), with two phases periodically overlapping. The construction area for each phase would be approximately one-third of the total cell area. Phased construction would allow for the staged removal of facilities that might be in the disposal cell footprint, i.e., the volume reduction facility and MSA debris staging area would no longer be needed after the structural material was treated and placed in the first and second phases of the disposal cell (MK-Ferguson Company and Jacobs

Engineering Group 1992b). Initial planning indicates that disposal cell construction would begin in the Phase I area (Figure 5.5) with foundation grading and construction of the leachate collection and removal system. After these activities were completed, waste would be placed in the Phase I area, and foundation grading and construction of the leachate collection and removal system would begin in the Phase II area. Construction for Phase III would begin when the waste in Phase I was enclosed within the radon attenuation barrier. This sequence of construction and waste placement would limit the disturbed area to only two-thirds of the entire cell area at any one time. Final adjustment of the cell size to accommodate the actual waste volume would be made in the Phase III area by adjusting the northern cell slope, adjusting the cell height (to a probable maximum height of 23 m [74 ft]), or a combination of both. The complete cover for all three phases of the disposal cell would be constructed following placement of all waste and the radon attenuation barriers for each phase of cell construction. Each construction phase would take approximately three consecutive construction seasons, and the entire cell would be completed in about 6.5 years.

The logistics of waste placement within the disposal cell under Alternative 6a would be governed by the physical properties of the waste. In general, the soil-like contaminated material (e.g., soil, sediment, crushed rock, and concrete) would be placed against the interior side of the cell cover on the outer perimeter of the cell and on the foundation, forming a perimeter zone adjacent to the cover (Figure 5.7). Rubble from the volume reduction facility, the MSA debris staging area, and the TSA would be placed inside the outer perimeter of soil-like waste. The grout-like material from chemical stabilization/solidification would then be placed on the rubble surface, and it would enter and fill the void spaces within and between the rubble. The drier material produced from chemical stabilization/solidification of the soil could be placed in the same manner as the other soil-like waste or intermixed with the building rubble. Waste placement in the disposal cell would be completed by placing contaminated soil and soil-like material across the final surface of the grout and rubble fill (Figure 5.7).

Organic material in the disposal cell would be limited to 5% by volume (MK-Ferguson Company and Jacobs Engineering Group 1992b). The requirements for waste disposal in the UMTRA Program specify that organic material should be distributed uniformly within a compacted layer and throughout the disposal cell to eliminate pockets or thick layers that might result in differential settling over the long term. About 26,000 m^3 (34,000 yd^3) of organic material would require disposal under Alternative 6a, which is less than 3% of the estimated total 956,000 m^3 (1,250,000 yd^3) of contaminated material.

About 751,000 m^3 (982,000 yd^3) of imported clay, fill, sand, gravel, riprap, and topsoil would be required for construction of the disposal cell under Alternative 6a. This material would be delivered directly to the disposal cell area or staged in an approximately 3-ha (8-acre) construction material staging area located in the northwestern portion of the site.

Good engineering practices would be used during construction and operation of the disposal cell to prevent and/or mitigate potential radon and dust emissions and contaminated surface water runoff. Any precipitation runoff within the disposal cell area would be directed

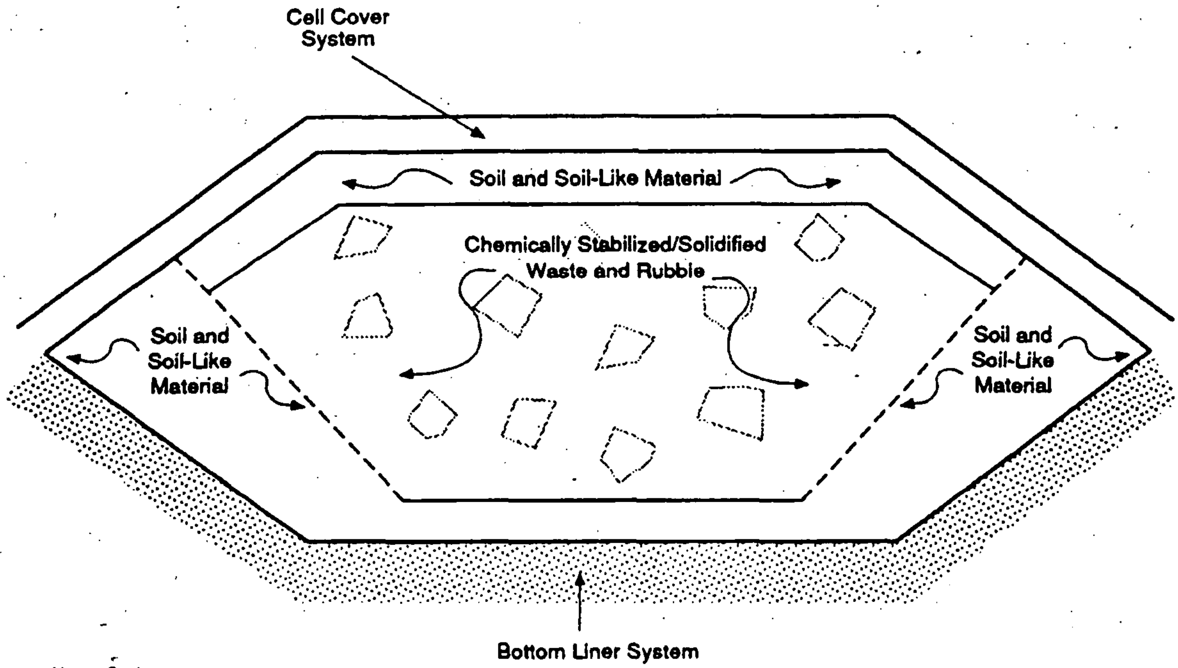

FIGURE 5.7 Schematic Cross Section of Conceptual Waste Placement in the Disposal Cell under Alternative 6a

to sumps or captured by the leachate collection and removal system and pumped to a lined retention basin. Surface water runon would be controlled by diversion ditches and berms. Windblown particulates from fine-grained materials used in cell construction and during waste placement would be controlled by periodic spraying with water and/or dust suppressants. Upon completion of a section of the radon attenuation and infiltration barrier, the surface would be sealed with a steel-wheeled roller to minimize erosion. In addition, clean cover material for the radon attenuation barrier would be staged alongside the disposal cell as the waste was being placed, and the cell phases would be encapsulated as they were completed. Radon emissions would be monitored during construction and operation of the disposal cell. Engineering controls to minimize radon emissions, such as wetting or covering surfaces, would be implemented as necessary. Workers within the controlled area would be required to wear the appropriate level of personal protective equipment when working with the contaminated material.

Following completion of remedial activities and closure of the treatment and storage facilities and the disposal cell, the site would be graded and vegetated. The toe of the disposal cell would be used as a grade-control feature. The land surface immediately adjacent to the toe would slope away from the cell; from this point, the surface would be graded to match undisturbed areas, prevent ponding, minimize erosion, and provide a transition into natural drainages in the area. All impoundment structures would be removed following grading and revegetation to provide for natural drainage throughout the site and to minimize any changes in watershed areas from current conditions. Except for the disposal cell, which would be planted with grasses, the land surface would be seeded with hardy, native vegetation. If the potential for erosion existed, selected channels would be lined with riprap. Approximately 409,000 m^3 (535,000 yd^3) of imported fill material would be required for grading and closure of the site and vicinity properties.

5.3 ALTERNATIVE 7a: REMOVAL, VITRIFICATION, AND DISPOSAL ON-SITE

Alternative 7a involves the removal of contaminated material from each of the on-site source areas, treatment by vitrification as appropriate, and disposal in an engineered disposal cell on-site. The volumes of wastes to be removed, treated, and disposed of are summarized in Table 5.2. Also summarized are the volumes of borrow material required, the total effort (in person-years) for implementation, and the potential land areas impacted (which would depend on the borrow area selected as part of detailed design).

5.3.1 Removal

Under Alternative 7a, contaminated material would be removed from the source areas in the same manner as identified for Alternative 6a (Section 5.2.1).

5.3.2 Treatment

Of the two new facilities that would be constructed on-site, the volume reduction facility would be the same as described for Alternative 6a (Section 5.2.2). However, the sludge processing facility would differ. Although it would be constructed at the same location, this facility would contain unit operations for dewatering and vitrification instead of process equipment for chemical treatment. Support facilities and chipping and mulching of vegetation would be the same as described for Alternative 6a.

Under Alternative 7a, sludge from the raffinate pits and the more highly contaminated soil from various source areas (e.g., from the raffinate pits and TSA) would be treated by ceramic melting in the sludge processing facility. Process waste from operation of the water treatment plants would also be treated in this facility. The sludge processing facility would probably occupy an area of about 0.40 ha (1.0 acre). This land would require clearing and grading prior to installation of the foundations and necessary utilities, i.e., natural gas, electricity, and water. A single building would house the vitrification treatment units, each consisting of a raffinate pit sludge dewatering circuit, a feed preparation circuit, and a vitrification treatment circuit.

For purposes of preliminary conceptual design, the vitrification treatment circuit was assumed to be heated with fossil fuel and to operate 24 hours per day, 7 days per week, 12 months per year. Because this operating schedule is different from that assumed for removal and cell operations (8 hours per day, 5 days per week, 9 months per year), the material to be treated during the 3 months of winter operation would have to be stockpiled before and after processing. It was also assumed that, to the extent possible, the material removed during the

TABLE 5.2 Summary of Waste Volumes, Borrow Material, Effort, and Impacted Land Areas for Alternative 7a: Removal, Vitrification, and Disposal On-Site

Parameter	Value
Volume removed (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	425,400
Quarry soil (stored in TSA)	52,000
Structural material[a]	203,000
Water treatment plant residuals	3,600
Total	904,000
Volume treated (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	50,000
Quarry soil (stored in TSA)	50,000
Structural material	123,000
Water treatment plant process waste	3,600
Total	447,000
Volume after treatment (yd^3)	
Raffinate pit sludge	33,700
Sediment/soil (includes roads and embankments)	34,200
Quarry soil (stored in TSA)	34,200
Structural material[b]	Variable
Water treatment plant process waste	500
Total disposal volume[c] (yd^3)	
Raffinate pit sludge	33,700
Sediment/soil (includes roads and embankments)	409,600
Quarry soil (stored in TSA)	36,200
Structural material	203,000
Water treatment plant process waste	500
Total	683,000
Volume of borrow material[d] (yd^3)	
Waste removal and reclamation (on-site and vicinity properties)	535,000
Disposal cell	794,000
Total	1,330,000

TABLE 5.2 (Cont.)

Parameter	Value
Effort (person-years)	
Excavation and on-site handling[e]	210
Treatment	297
Disposal	210
Transportation of supplies and fill	61
Total	780
Total on-site area impacted (acres)	137
Total off-site area impacted (acres)	85 (borrow material)

[a] The volume estimate for structural material includes the material contaminated by site cleanup activities, such as piping and equipment from the two water treatment plants.

[b] The volume reduction of structural material would be variable (see text) and could be offset by volume increases from size reduction (e.g., of concrete blocks).

[c] Does not include any contingency factors. Compaction within the disposal cell could reduce the overall volume of structural material.

[d] For the representative analysis in this FS, off-site borrow of 895,000 m^3 (1,171,000 yd^3) of clay-rich soil was assumed to be available from a 61-ha (150-acre) parcel of nearby land owned by the Missouri Department of Conservation (Section 5.2.1.10). Additional borrow material such as gravel, sand, fill, and topsoil would be supplied by local vendors.

[e] Includes worker requirements associated with removing soil from vicinity properties and sediment from the Busch Wildlife Area lakes, as well as restoring all excavated areas. Also includes the requirements associated with transporting chemicals off-site for incineration at a permitted facility.

9-month excavation period would be treated as soon as it was excavated in order to minimize stockpiling and that the soil material stockpiled at the TSA would be available for feed during the 3-month winter shutdown. Additional, enclosed storage for dewatered sludge generated during the 9-month dredging period would be provided. The preliminary conceptual design of the vitrification facility is based on a 1:1 blending ratio (by weight) of dry raffinate pit sludge to dry soil, or the vitrification of soil alone, as identified in Koegler et al. (1989).

Feed preparation would be required for operation of the vitrification process. Because the various waste media to be treated have different characteristics, they would be treated separately within the feed preparation circuits of the sludge processing facility. The fine-grained, high-water-content raffinate pit sludge would be dredged and pumped as a slurry directly to a dewatering circuit within the facility. This sludge would require dewatering to minimize the impacts of excess steam on the effectiveness and sizing of the off-gas treatment system for the vitrification process (MK-Ferguson Company and Jacobs Engineering Group 1992b). The raffinate pit sludge could be dewatered with a cyclone dewatering system that uses centrifugal force, plate thickeners, and filtering methods, or a belt press system that uses a belt press, screens, and flocculation. If these systems did not adequately remove excess water, thermal drying might be required as a pretreatment step.

Figure 5.8 illustrates the process flowchart for the preliminary conceptual design of the feed preparation and vitrification treatment circuits. Within the feed preparation circuit, metallic components would be removed from the dewatered raffinate pit sludge and the sludge would be sized with crushing and milling equipment. This material would then be transferred to an enclosed storage bin. From the storage bin, a screw conveyor would transport the sludge from the hopper to a pug mill blender where it would be blended with soil or clay at the correct ratio. The mixture would then be split into separate feed streams and transferred by screw conveyor to parallel vitrification systems.

Soil and clay would be treated separately from sludge within the feed preparation circuit. The soil would be fed through a vibrating screen to remove material larger than about 2.5 cm (1 in.). Oversized material would be collected and placed in one of the staging areas for short-term storage prior to treatment or transported directly to the disposal facility. The soil would then be discharged to a physical treatment circuit similar to that described for the raffinate pit sludge, where it would be sized, stored in hoppers, and transferred by screw conveyor to the pug mill blender for mixing with the sludge prior to vitrification.

The preliminary conceptual design for the vitrification system assumes the use of a fossil fuel-heated ceramic melting system designed to accommodate 180 t/d (200 tons/d), 365 days per year. Two 90-t/d (100-ton/d) units were assumed in the preliminary conceptual design instead of one 180-t/d (200-ton/d) unit. The use of two units would require less engineering scale-up of existing systems and would increase process flexibility and reliability.

The vitrification process under Alternative 7a consists of three steps. In the first step, the waste material would be preheated and dried in a precombustor unit. In the second step, the dried material and the combustor gases would flow to a counter-rotating vortex heater. Fuel (natural gas) would be added at this stage, and the waste material in suspension would be heated to glass-forming temperatures, which would be about 1,250°C (2,280°F) for a sludge/soil mixture and 1,440°C (2,620°F) for soil alone. The intense mixing of the counter-rotating vortex heater would allow stable combustion in the presence of large quantities of inert particulates (MK-Ferguson Company and Jacobs Engineering Group 1992b). The organic compounds in the waste would be oxidized in this second step. In the third step, the combustion gases and heated material would be discharged to a cyclone separation/melting chamber. The melted product formed in this chamber and the combustion products would exit into a separator reservoir where a pool of melted material would be collected. The reservoir would provide sufficient residence time for completion of the glass-forming reactions. The hot exhaust gases would exit the melt reservoir and flow to the off-gas treatment system (described below). The molten product would be quenched in water to produce a fritted product with particle sizes ranging from 0.32 to

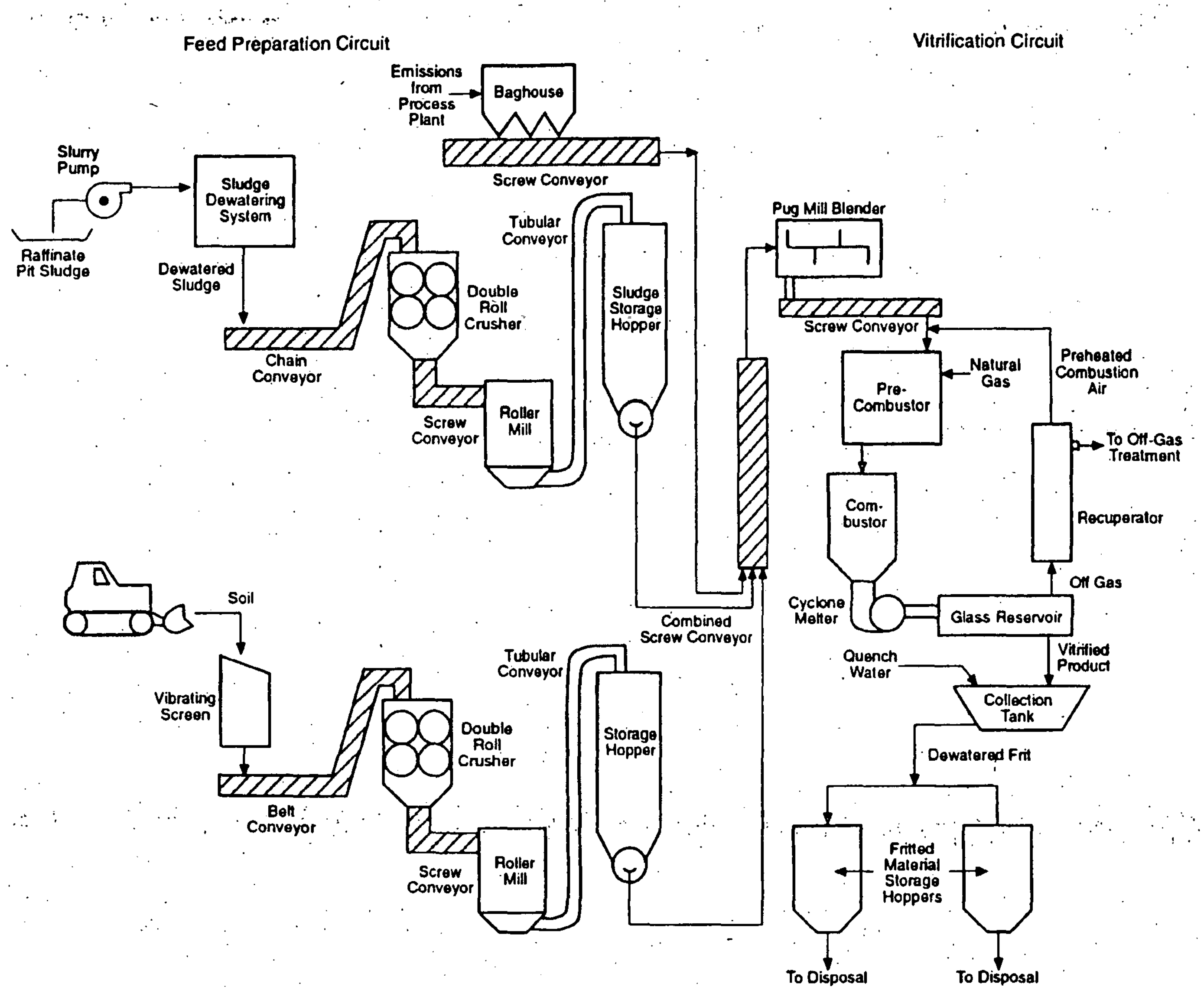

FIGURE 5.8 Process Flowchart for Vitrification under Alternative 7a (Source: Modified from MK-Ferguson Company and Jacobs Engineering Group 1992b)

0.64 cm (1/8 to 1/4 in.). The treated product would then be collected in hoppers, dewatered, and transferred to bins for transport to the disposal cell. The fritted product would be produced at a rate of about 113 t/d (125 tons/d), 7 days per week. The treated material produced during the 3 months of winter, about 4,900 m^3 (6,400 yd^3), would require storage in the TSA or an adjacent area prior to disposal.

The vitrified product would be tested by TCLP and other leach tests to ensure that it met leach-resistance requirements. If the material did not meet the established performance criteria, process modifications would be made on subsequent treatment batches. The operating parameters for the treatment process would be optimized during pilot testing. The treated product resulting from start-up testing would be required to consistently pass disposal criteria before full-scale operations would begin. The frequency of testing required to ensure product quality would be established during start-up testing.

On the basis of scheduling and operation rates for the preliminary conceptual design, the fossil fuel-heated ceramic melter would require a maximum of about 20,400 m^3 (720,000 ft^3) of natural gas per day. Laclede Gas Company in St. Charles, Missouri, has indicated that it could deliver up to 28,300 m^3 (1,000,000 ft^3) of natural gas per day and extend a gas pipeline to the Weldon Spring site (Figure 5.1) with enough capacity to ensure continuous delivery at the required rates (MK-Ferguson Company and Jacobs Engineering Group 1992b).

Operation of the vitrification facility would require a process engineer to oversee material and maintenance scheduling, optimize processing, and monitor both the off gas and vitrified product to ensure compliance with performance specifications. Other personnel required include supervisors, operators, maintenance persons, and laborers. Special training would be required. The scheduled mechanical availability of the facility was assumed to be 90%, and the preliminary conceptual design includes a production rate of 15% above the required throughput. Engineering and bench-scale and pilot-scale studies would be required prior to full-scale plant design and construction. These studies would determine process variables such as energy consumption, range of acceptable ratios of raffinate pit sludge to soil, minimum required operating temperatures, partitioning of contaminants between the melt and off gas, and the amount and type of required physical pretreatment.

Previous bench-scale treatability studies have been conducted and others are currently under way (Koegler et al. 1988, 1989; MK-Ferguson Company and Jacobs Engineering Group 1992b). Although the initial testing of vitrified Weldon Spring waste did not include the TCLP method, a modified EP-toxicity test was performed on vitrified raffinate pit sludge and soil, and the concentrations of contaminants in the leachate of the vitrified product were considerably below applicable limits (Section 4.4.4). Results from Materials Characterization Center 7-day and 28-day tests also indicated a highly leach-resistant product (Koegler et al. 1989).

At the operating temperatures reached during vitrification (1,250 to 1,440°C [2,280 to 2,620°F]), organic contaminants such as nitroaromatic compounds and some inorganic compounds such as nitrates would be completely destroyed (MK-Ferguson Company and Jacobs Engineering Group 1992b). Nitrates (NO_3) would be converted to gaseous molecules (nitrogen [N_2], nitrogen dioxide [NO_2], and nitrogen oxides [NO_x]). (Most of the nitrates are associated with the interstitial water in the raffinate pit sludge and would have been removed during dewatering, and the wastewater containing these and other soluble compounds would have been pumped from the dewatering circuit to the water treatment plant.) Similar to nitrate, some sulfate would be converted to gaseous molecules (sulfur dioxide [SO_2], oxygen [O_2], and sulfur oxides [SO_x]) during vitrification. The estimated amounts of contaminants in the waste feed to the vitrification facility and their projected fate after vitrification are presented in Table 5.3. Although the results of bench-scale testing have shown that the Weldon Spring waste can be successfully vitrified, they also indicate the need for further testing to evaluate treatment of waste materials representing the extremes in chemical variability and to test treatment equipment that would be similar in type and function to that required in full-scale operations. The total time required for further bench-scale and pilot-scale testing of the vitrification process is estimated to be about 2.5 to 3 years. Design, construction, and start-up of the full-scale vitrification facility is estimated to require about 5 to 7 years; however, the time required for these activities could be longer because of the innovative nature of this technology.

Airborne emissions would be minimized as follows: the raffinate pit sludge would be delivered and maintained in a slurry form until treatment began, and the dewatered sludge would be stored within an enclosure designed to prevent fugitive dust and radon emissions and would be conveyed to the feed preparation circuit through an enclosed conduit. Emissions from stockpiles and haul routes would be controlled as described for Alternative 6a. The building housing the vitrification equipment would have an air filtration system. Emissions from the vitrification process would be treated before being released to the atmosphere. The off-gas treatment system would be designed to remove entrained dust, submicron aerosols, and non-combustible gases created during vitrification of the waste and combustion of the fuel. As a final filtration step, the off gas would be passed through a high-efficiency-particulate air (HEPA) filter.

The flowchart for the preliminary conceptual design of the off-gas treatment system is shown in Figure 5.9. The system would consist of (1) a heat removal system; (2) a primary quench scrubber to quench the hot off gas, remove large entrained particles, and begin acid gas scrubbing; (3) a high-efficiency submicron aerosol scrubber to remove the volatilization/condensation aerosols and to scrub remaining acid gases; (4) a system to remove nitrogen oxides, if needed; and (5) a final filtration system consisting of gas preheaters and primary and secondary HEPA filters. The expected efficiencies of these treatment components are identified in Table 5.4.

Separate, dedicated off-gas treatment systems would be used for each vitrification treatment unit, but a common stack would be used for releasing the off gases (MK-Ferguson Company and Jacobs Engineering Group 1992b). The estimated off-gas emissions are presented in Table 5.5. On the basis of preliminary estimates, specific radon control measures would not be required (MK-Ferguson Company and Jacobs Engineering Group 1992b). If further system testing indicated that radon control measures were required, this could be accomplished by vacuum pretreatment of the feed to the vitrification system and carbon adsorption of the off gas. The off-gas treatment system would generate residuals consisting of quench/scrubber liquids (blowdown) and final filtration equipment such as used HEPA filters. Solids separated from the

TABLE 5.3 Fate of Contaminants during Vitrification

Contaminant	Unit	Annual Feed Rate[a]	Fate of Contaminants as Percent of Feed: Encased in Glass (%)	Scrubber Residuals (%)	Released to Atmosphere[b] (%)
Metals	tons				
Arsenic		28.3	77.57	22.43	5.9×10^{-6}
Cadmium		1.4	75.05	24.95	6.6×10^{-6}
Chromium		2.4	99.77	0.23	1.2×10^{-8}
Copper		18.7	99.77	0.23	1.2×10^{-8}
Lead		17.3	93.12	6.88	1.8×10^{-6}
Mercury		0.3	0	40.0	60.0
Nickel		21.4	99.77	0.23	1.2×10^{-8}
Selenium		2.3	0.06	99.94	2.6×10^{-5}
Vanadium		196	99.77	0.23	1.2×10^{-8}
Zinc		16.9	98.18	1.82	9.2×10^{-8}
Inorganic anions	tons				
Chloride[c]		0.3	0.10	94.90	4.99
Fluoride[d]		2.3	99.77	0.23	0.0023
Nitrates[e]		141	0	50.0	50.0
Nitrites[e]		1.4	0	50.0	50.0
Sulfate[f]		262	74.07	23.33	2.59
Nitroaromatic compounds[g]	tons				
2,4-DNT		0.2	<0.10	<0.10	0.0001
2,6-DNT		0.2	<0.10	<0.10	0.0001
2,4,6-TNT		5.9	<0.10	<0.10	0.0001
Other	tons				
Organic nitro groups		1.3	0	50.0	50.0
Thermal NO_x[h]		274	0	95.30	4.7
Total nonvolatile solids		45,600	99.77	0.23	1.2×10^{-8}
Radionuclides[i]	Ci				
Actinium-227		16.2	99.77	0.23	1.2×10^{-8}
Lead-210		58.5	93.12	6.88	1.8×10^{-6}
Polonium-210		55.1	99.77	0.23	1.2×10^{-8}
Protactinium-231		20.4	99.77	0.23	1.2×10^{-8}
Radium-226		23.6	99.77	0.23	1.2×10^{-8}
Radium-228		5.7	99.77	0.23	1.2×10^{-8}
Thorium-230		458	99.77	0.23	1.2×10^{-8}
Thorium-232		5.3	99.77	0.23	1.2×10^{-8}
Uranium-235		1.28	99.77	0.23	1.2×10^{-8}
Uranium-238		27.9	99.77	0.23	1.2×10^{-8}

See next page for footnotes.

TABLE 5.3 (Cont.)

[a] Based on an annualized daily average feed of 125 tons per day.

[b] Estimated from the expected operating conditions for the vitrification and off-gas treatment systems.

[c] Chloride is released as hydrogen chloride (HCl).

[d] Fluorides are not expected to volatilize and were therefore assumed to be released in the mineral form, e.g., apatite.

[e] Released as nitrogen dioxide (NO_2).

[f] Sulfate is released as sulfur dioxide (SO_2).

[g] Fate of nitroaromatic compounds is based on the minimum destruction and removal efficiency of 99.9999%. Partitioning between glass and scrubber sludge is based on an assumed treatment system efficiency of 99.9% and a destruction efficiency of 99.9%.

[h] Thermal nitrogen oxides (NO_x) are not present in the feed but are created from nitrogen and oxygen in the air; except for annual feed rates, quantities are reported as percentages of the NO_x-forming components of the feed (nitrates, nitrites, and organic nitro groups).

[i] The activities of actinium-227, protactinium-231, and uranium-235 were derived from the radiological source term analysis for the raffinate pit sludge (Table 2.3 of the BA [DOE 1992a]). Radon-222 is not included in this table because it was assumed that 100% of the radon is released to the atmosphere. It is estimated that about 100 Ci of radon-222 would be released from the off-gas treatment system over a 4-year period.

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

primary quench scrubber blowdown slurry would be returned to the melter for vitrification; the remaining liquid would be recycled to the scrubber after treatment. Slurry from the secondary aerosol/acid gas scrubber blowdown could not be fed to the melter because of the elevated concentrations of volatile metals (MK-Ferguson Company and Jacobs Engineering Group 1992b). It is possible that these residuals would require further treatment (e.g., by chemical stabilization/solidification) prior to disposal. Quantities of scrubber residuals and concentrations of contaminants in those residuals, as estimated from the preliminary conceptual design, are presented in Table 5.6. In both scrubbers, lime ($CaCO_3$) would be added to the liquid during off-gas treatment, thus increasing the quantity of scrubber blowdown solids requiring disposal. The final filtration system would be designed to control emissions of particulates; the used filters could be recycled to the melter for vitrification.

5.3.3 Disposal

The vitrified portion of the site waste would retain its radiological characteristics but would be chemically inert because organic contaminants and some inorganic contaminants would have been destroyed and the glass-like fritted product would be very resistant to leaching (Section 5.3.2); therefore, it could be reasonable to dispose of this material in a cell with a single

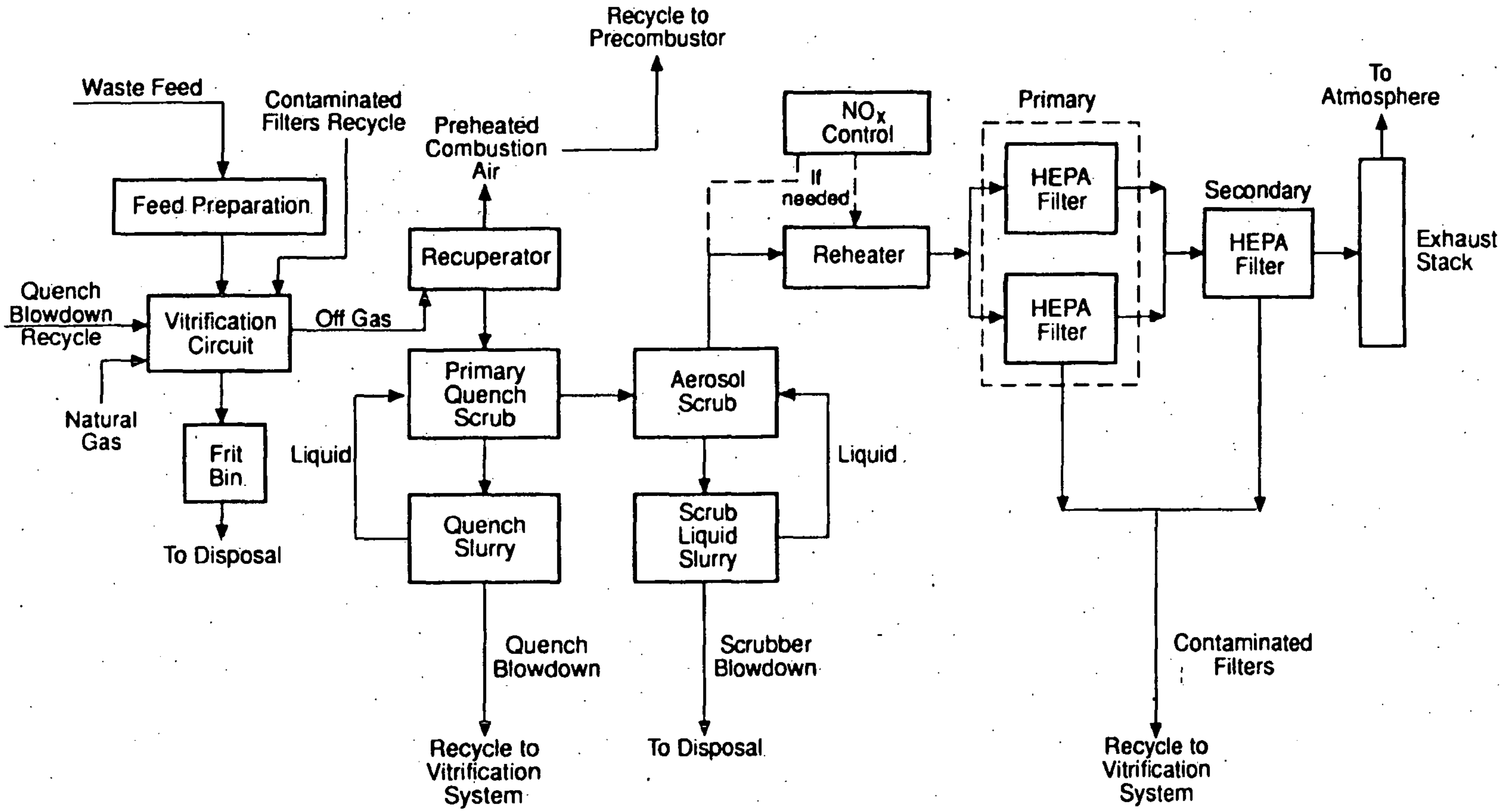

FIGURE 5.9 Conceptual Flowchart for the Off-Gas Treatment System under Alternative 7a (Source: Modified from MK-Ferguson Company and Jacobs Engineering Group 1992b)

TABLE 5.4 Expected Efficiencies of Off-Gas Treatment

Component	Expected Control Efficiency
Primary quench scrubber	90% nonvolatile metals and gross entrainment aerosol 20% mercury and other volatile metals (arsenic, cadmium, lead, selenium) 50% acid gases 7% nitrogen oxides
Submicron aerosol scrubber	98% gross particulates and nonvolatile metals 40% volatile and semivolatile metals 90% acid gases 25% nitrogen oxides
Nitrogen oxides control system (catalytic reduction of NO_x)	99% nitrogen oxides
Final filtration system (HEPA filters)	99.95% submicron aerosol particles (per HEPA stage)

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

foundation layer. A second cell would be used to contain the untreated waste, i.e., the less contaminated soil, sediment, and structural material; this cell was conceptually designed to be similar to that identified for Alternative 6a. The two cells are referred to as the vitrification cell and the combination cell, respectively. Final disposal cell design components would be determined during detailed remedial design.

A contingency factor of 10% was applied to the sizing of the disposal cells for preliminary conceptual design. The resulting waste containment capacity under Alternative 7a is 86,400 m^3 (113,000 yd^3) for the vitrification cell and 591,000 m^3 (773,000 yd^3) for the separate combination cell for untreated material. A conceptual layout of the two disposal cells is shown in Figure 5.10, and a typical section for the vitrification cell is shown in Figure 5.11. The design of the combination cell would be similar to that shown in Figure 5.6. The total area covered by both cells would be about 17 ha (42 acres): 4.9 ha (12 acres) for the vitrification cell and 12 ha (30 acres) for the combination cell. As for Alternative 6a, construction of the combination cell would not begin until the area within the cell footprint was verified as suitable for on-site disposal in accordance with state of Missouri requirements (Section 5.2.3). Because of the different type of material in the vitrification cell, disposal requirements could differ (see Section 6.3.2).

The disposal cell design considerations identified for Alternative 6a would be included in the design of both the vitrification and combination disposal cells under Alternative 7a. The preliminary conceptual design for the vitrification waste cell indicates that the foundation soil would be excavated to design grade. No bottom liners or leachate collection system would be

TABLE 5.5 Estimated Maximum Short-Term and Average Long-Term Emission Rates from Vitrification under Alternative 7a[a]

		Off-Gas Emission Rate from Melter		Controlled Emission Rate	
Contaminant	Unit	Maximum Short-Term	Average Long-Term	Maximum Short-Term	Average Long-Term
Solids (PM-10)	lb/h	500	312	5.0×10^{-4}	3.1×10^{-4}
Volatile metals	lb/h				
Arsenic		10.1	1.96	0.0024	4.7×10^{-4}
Cadmium		3.58	0.10	9.0×10^{-4}	3.0×10^{-5}
Lead		2.33	0.40	6.0×10^{-4}	1.0×10^{-4}
Mercury		0.52	0.06	0.248	0.030
Selenium		2.67	0.52	6.0×10^{-4}	1.3×10^{-4}
Anions/Acid gases[b]	lb/h				
Chlorides[c]		0.69	0.07	0.03	0.0035
Fluorides		5.37	0.55	0.27	0.0277
Nitrates[d]		273	23.9	191	16.7
Nitrites[d]		3.75	0.33	2.62	0.233
Sulfates		161	39.9	8.06	1.99
Nitroaromatic compounds[e]	lb/h				
2,4-DNT		6.0×10^{-5}	4.0×10^{-6}	6.0×10^{-5}	4.0×10^{-6}
2,6-DNT		1.1×10^{-4}	5.0×10^{-6}	1.1×10^{-4}	5.0×10^{-6}
2,4,6-TNT		0.00267	1.35×10^{-4}	0.00267	1.35×10^{-4}
Radionuclides[f]	pCi/d				
Actinium-227		4.42×10^{7}	4.43×10^{6}	44.2	4.43
Lead-210		9.80×10^{10}	1.64×10^{10}	2.4×10^{7}	3.82×10^{6}
Polonium-210		9.80×10^{8}	1.53×10^{8}	980	153
Protactinium-227		5.56×10^{7}	5.57×10^{6}	55.6	5.57
Radium-226		5.81×10^{8}	6.43×10^{7}	581	64.3
Radium-228		3.99×10^{8}	1.53×10^{7}	399	15.3
Radon-222		5.84×10^{11}	6.58×10^{10}	5.84×10^{11}	6.58×10^{10}
Thorium-230		2.51×10^{9}	1.31×10^{8}	2,510	131
Thorium-232		2.84×10^{7}	1.42×10^{6}	28.4	1.42
Uranium-235		3.51×10^{6}	3.51×10^{5}	3.51	0.351
Uranium-238		7.62×10^{7}	7.63×10^{6}	76.2	7.63

[a] Maximum short-term rate denotes the maximum hourly rate at 200 tons per day for processing the highest short-term concentrations of contaminants in the waste. Average long-term rate denotes the annual average rate at 125 tons per day for processing the long-term average concentrations of contaminants in the waste.

[b] Off-gas emission rates from the melter and controlled emission rates (lb/h) for the listed contaminants are as follows: hydrochloric acid gas (HCl) for chlorides, hydrofluoric acid gas (HF) for fluorides, nitrogen dioxide (NO_2) for nitrates and nitrites, and sulfur dioxide (SO_2) for sulfates.

[c] Organic chlorine would add 0.11 lb/h maximum and 0.018 lb/h average in the off gas before controls to result in total controlled emission rates of 0.036 lb/h maximum and 0.0044 lb/h average.

TABLE 5.5 (Cont.)

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[d] Amounts are from nitrate and nitrite in the source material. Nitroaromatic compounds would contribute an additional 2.8 lb/h maximum and 0.24 lb/h average NO_x to the off gas. Combustion gas would add 180 lb/h maximum and 110 lb/h average NO_x to the off gas. Including both sources increases the controlled emission rates to 320 lb/h maximum and 96 lb/h average.

[e] Estimates for off gas and controlled emission rates for nitroaromatic compounds were obtained by assuming a destruction removal efficiency of 99.99%.

[f] The activities of actinium-227, protactinium-231, and uranium-235 were estimated from the radiological source term analysis for the raffinate pit sludge (Table 2.3 of the BA). No control of radon release was assumed. It is estimated that about 100 Ci of radon-222 would be released from the off-gas treatment system over a 4-year period.

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

necessary for this cell because it would contain a glass-like waste form that would be very resistant to leaching. The cover would consist of the following, in ascending order from the waste contact: a filter layer, an infiltration and radon attenuation barrier, a frost protection/bedding layer, and an erosion protection layer consisting of either rock alone or choke rock and topsoil to support grass growth. (Although an infiltration/radon attenuation barrier might not be needed for the vitrified product, it was included to further protect against any potential releases to the environment.) The bottom liner and leachate collection and removal system for the combination cell under Alternative 7a would be identical to that described for the combination cell under Alternative 6a; the cover on the top and side slopes of the cell embankment would also be the same (Section 5.2.3).

On the basis of preliminary engineering information, the vitrification cell could involve both above-grade and below-grade construction (Figure 5.11). For planning purposes, it was assumed that the cell would be excavated to a maximum depth of about 7.6 m (25 ft) below the original grade, and the cell design height would be about 11 m (35 ft) above original grade at the point of maximum embankment height. The separate combination disposal cell would be constructed in two phases (Figure 5.10) and would follow a sequence similar to that described for construction of the disposal cell under Alternative 6a. The maximum design height for the cell would be about 23 m (74 ft) above original grade. Final adjustment to accommodate the actual volume of waste placed in the combination cell would be made in the second phase. Construction and operation of both the vitrification cell and the combination cell would take about 6.5 years, and both cells would be filled simultaneously.

The logistics of waste placement within the disposal cells under Alternative 7a would be governed by the properties of the waste. The 78,800 m^3 (103,000 yd^3) of vitrified material would consist of a uniformly graded, glass-like frit, 0.32 to 0.64 cm (1/8 to 1/4 in.) in diameter. This material would be cohesionless and would be mixed with or placed in alternate layers with a binder such as clay to promote waste compaction and increase the stability of the vitrification

TABLE 5.6 Scrubber Residuals from the Off-Gas Treatment System

Residual	Unit	Contaminant Concentration[a] Worst Case	Best Case	Expected Case
Quantity	t/yr	3,300	130	540
Metals	mg/kg			
Arsenic		2,000	19,000	11,000
Cadmium		110	1,100	570
Chromium		2	26	9
Copper		16	210	71
Lead		380	3,300	2,000
Mercury		37	1,900	180
Nickel		18	240	82
Selenium		620	16,000	3,800
Vanadium		160	2,100	750
Zinc		110	1,500	510
Calcium/sodium salts	mg/kg			
Carbonate as $CaCO_3$		730,000	25,000	28,000
Chloride as $CaCl_2$		130	3,400	760
Fluoride as CaF_2		20	190	80
Nitrate as $Ca(NO_3)_2$		143,000	0	456,000
Sulfites/sulfates as $CaSO_4 \cdot 2H_2O$		36,500	417,000	157,000
Radionuclides[b]	pCi/g			
Actinium-227		15	200	70
Lead-210		1,400	12,000	7,400
Polonium-210		51	660	230
Protactinium-231		19	250	88
Radium-226		22	290	99
Radium-228		5.3	69	24
Thorium-230		420	5,500	1,900
Thorium-232		4.9	64	22
Uranium-235		1.2	16	5.5
Uranium-238		26	340	120

[a] Contaminant concentrations are presented for scrubber residuals as worst-case (high residual quantities), best-case (low residual quantities), and expected-case conditions for scrubber efficiencies and absorbing compounds.

[b] The activities of actinium-227, protactinium-231, and uranium-235 were estimated from the radiological source term analysis for the raffinate pit sludge (Table 2.3 of the BA). Radon-222 is not included in this table because no control of radon was assumed.

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

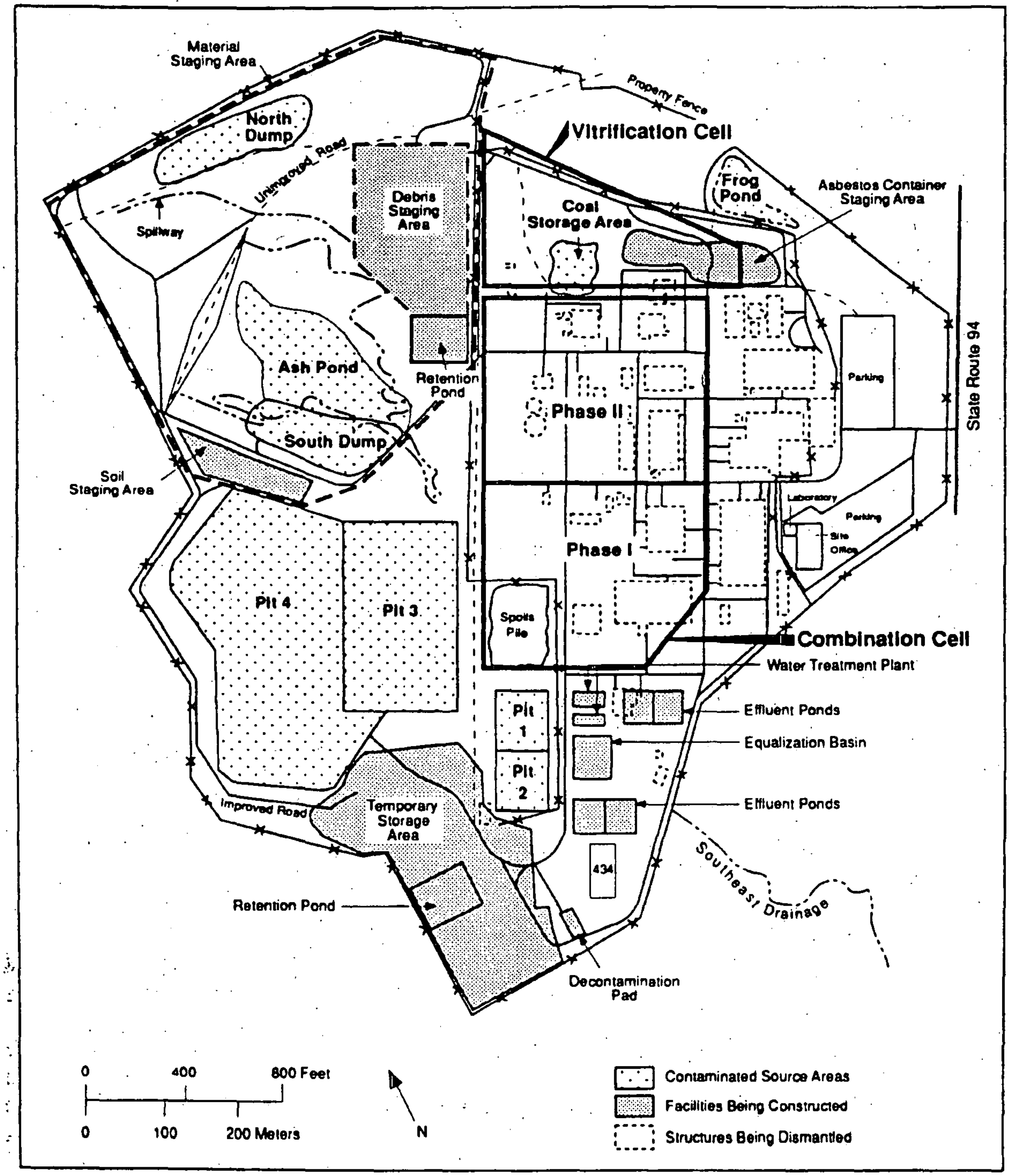

FIGURE 5.10 Conceptual Layout of the Vitrification Cell and Combination Cell for Alternative 7a

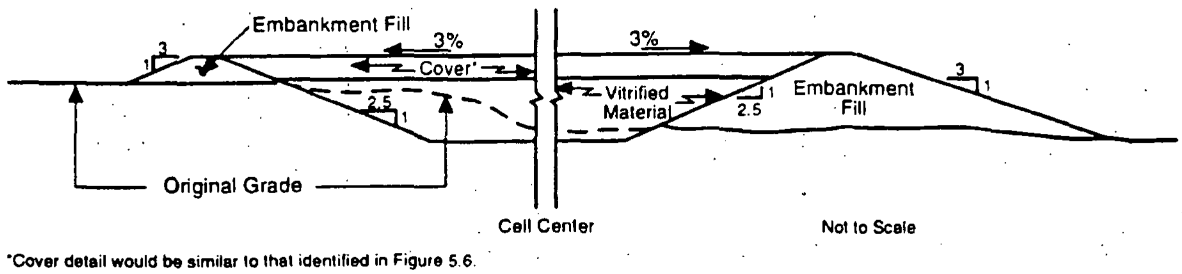

FIGURE 5.11 Typical Section of the Vitrification Cell (Source: Modified from MK-Ferguson and Jacobs Engineering Group 1992b)

cell. Two types of waste would be placed in the combination cell, about 288,000 m^3 (377,000 yd^3) of soil and soil-like waste and about 155,000 m^3 (203,000 yd^3) of rubble. The soil-like material would be placed around and on top of the individual rubble components in compacted layers. The use of grout might be necessary to prevent settling and eliminate the need for hand-compacting and placement of soil around the structural material. The grout could be prepared specifically for this purpose with uncontaminated or slightly contaminated soil; alternatively, the off-gas slurry blowdown from the secondary scrubber could be treated by chemical stabilization/solidification and the resulting grout could be used for this purpose.

A total of 607,000 m^3 (794,000 yd^3) of imported clay, fill, sand, gravel, riprap, and topsoil would be required for construction of two disposal cells under Alternative 7a. This material would be placed directly at the disposal facility or staged, as needed, in a construction material staging area that could cover about 3 ha (8 acres) in the northwestern portion of the site.

Good engineering practices and mitigative measures would be used during construction and operation of the disposal cells to prevent and/or mitigate potential radon and dust emissions and surface water runoff, as described in Section 5.2.3 for Alternative 6a. Following completion of remedial action activities and closure of the treatment and storage facilities and disposal cells, the site would be graded and vegetated as described for Alternative 6a.

5.4 ALTERNATIVE 7b: REMOVAL, VITRIFICATION, AND DISPOSAL AT THE ENVIROCARE SITE

Alternative 7b involves the removal of contaminated material from each of the on-site source areas, treatment by vitrification as appropriate, and disposal in an engineered cell at the Envirocare site near Clive, Utah. The volumes of wastes to be removed, treated, and disposed of are summarized in Table 5.7. Also summarized are the volumes of borrow material required, the total effort (in person-years) for implementation, and the potential land areas impacted (which would depend on the borrow area selected as part of detailed design).

TABLE 5.7 Summary of Waste Volumes, Borrow Material, Effort, and Impacted Land Areas for Alternative 7b: Removal, Vitrification and Disposal at the Envirocare Site

Parameter	Value
Volume removed (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	425,400
Quarry soil (stored in TSA)	52,000
Structural material[a]	203,000
Water treatment plant residuals	3,600
Total	904,000
Volume treated (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	50,000
Quarry soil (stored in TSA)	50,000
Structural material	123,000
Water treatment plant process waste	3,600
Total	447,000
Volume after treatment (yd^3)	
Raffinate pit sludge	33,700
Sediment/soil (includes roads and embankments)	34,200
Quarry soil (stored in TSA)	34,200
Structural material[b]	Variable
Water treatment plant process waste	500
Total disposal volume[c] (yd^3)	
Raffinate pit sludge	33,700
Sediment/soil (includes roads and embankments)	409,600
Quarry soil (stored in TSA)	36,200
Structural material	203,000
Water treatment plant process waste	500
Total	683,000
Volume of borrow material[d] (yd^3)	
Waste removal and reclamation (on-site and vicinity properties)	535,000
Disposal cell	794,000
Total	1,330,000

TABLE 5.7 (Cont.)

Parameter	Value
Effort (person-years)	
Excavation and on-site handling[e]	210
Treatment	297
Disposal[f]	210
Transportation of supplies and fill	27
Off-site transport of contaminated material	320
Total	1,100
Total on-site area impacted (acres)	105
Total off-site area impacted (acres)	138 (42 acres for disposal facility at Envirocare, 11 acres for rail siding at Wentzville, and 85 acres for borrow material)[g]

[a] The volume estimate for structural material includes the material contaminated by site cleanup activities, such as piping and equipment from the two water treatment plants.

[b] The volume reduction of structural material would be variable (see text) and could be offset by volume increases from size reduction (e.g., of concrete blocks).

[c] Does not include any contingency factors. Compaction within the disposal cell could reduce the overall volume of structural material.

[d] For the representative analysis in this FS, off-site borrow of 376,000 m^3 (492,000 yd^3) of soil was assumed to be available from a 61-ha (150-acre) parcel of nearby land owned by the Missouri Department of Conservation (Section 5.2.1.10). Additional borrow material for the Weldon Spring site — such as gravel, sand, fill, and topsoil — would be supplied by local vendors. Borrow material for constructing the disposal cell would be obtained by the Envirocare site operator.

[e] Includes worker requirements associated with removing soil from vicinity properties and sediment from the Busch Wildlife Area lakes, as well as restoring all excavated areas. Also includes the requirements associated with transporting chemicals off-site for incineration at a permitted facility.

[f] Effort for the off-site disposal component of Alternative 7b or 7c is expected to be similar to that required for on-site disposal.

[g] Does not include the area impacted to obtain borrow material for construction of a disposal cell at the Envirocare site.

5.4.1 Removal

Under Alternative 7b, contaminated material would be removed from the source areas in the same manner described for Alternative 6a (Section 5.2.1). Material not transported to the on-site treatment or disposal facilities would be delivered to a staging area for subsequent loading into containers for off-site transport. The containers used for preliminary conceptual design calculations are those designed to be handled by standard intermodal container equipment and to fit on railroad flatcars designed for the containers. These containers would be similar to those used for DOE's UMTRA Program. A staging and loading area of about 4 ha (10 acres) would be constructed in the northeastern portion of the site, within the location identified for an on-site disposal cell under Alternative 6a and 7a. This area would consist of roads, a prepared subbase, a gravel surface, and a concrete slab that would be constructed for container storage, decontamination, and transfer to haul trucks. The MSA could also be used as surge storage for contaminated soil to allow excavation to proceed at optimum rates and to allow a more uniform rate of removal from the site. Material stockpiles would be covered and water would be sprayed from trucks to minimize dust emissions during on-site hauling and loading operations. The 288,000 m^3 (377,000 yd^3) of untreated soil would be staged in stockpiles and would be loaded into containers that would be transported to the main staging and loading area for decontamination and transfer to haul trucks.

Following removal of contaminated source areas under Alternative 7b, final grading of the Weldon Spring site would incorporate broad, gently sloping drainage swales into the natural drainage paths. A crown would be established along the natural drainage divide, and all impoundment structures and depressions could be removed to provide positive drainage throughout the site. The absence of an on-site disposal cell would be expected to result in the continuity of existing watershed areas, with no appreciable change in area or gradient. A total of 409,000 m^3 (535,000 yd^3) of imported fill material would be required for this grading and closure of the site under Alternative 7b.

5.4.2 Treatment

The treatment component of Alternative 7b would be similar to that described for Alternative 7a. Following treatment, the vitrified material would be transported to the Envirocare site near Clive, Utah. Therefore, both the vitrification facility and the volume reduction facility would be equipped with car-loader systems for movement of containers during loading. The vitrification facility would also have a concrete slab for container storage and loading. Some vitrified product might have to be stockpiled because the storage hoppers could accommodate only about 1 week of production.

The volume reduction facility would be equipped with a modified railcar and car puller to receive the volume-reduced material after treatment. Off-site transport containers would be mounted on the modified railcar, and the car puller would move the railcar under the feed point. After the containers were filled to capacity, they would be covered, sealed, and the exterior surfaces decontaminated. The volume reduction facility would also have a concrete slab for container storage and loading.

On-site support facilities would be similar to those described for Alternative 7a, except no staging facility would be required for stockpiling material for disposal cell construction. Material in the mulch pile would be transferred to containers and transported to the main staging and loading area for off-site transport. Additional on-site facilities would be needed for loading containers and transferring the containers to haul trucks. Off-site support facilities would include a rail siding and facilities for container storage and transfer at the siding. These facilities are discussed in more detail in the description of the disposal component of this alternative (Section 5.4.3).

5.4.3 Disposal

The 4-ha (10-acre) main staging and loading area on-site would contain translifts for moving the filled containers and placing them on low-bed trucks equipped with brackets to hold the containers in place. Each truck would haul one container, and the weight of the container contents would be limited to 25 t (28 tons) because highway load restrictions limit gross vehicle weight to 36 t (40 tons). On the basis of a single shift, seven low-bed trucks making a maximum of five trips per day could transport 35 containers per day from the site to the rail siding in Wentzville, Missouri (at peak production). A total of about 38,600 trips would be required, for a combined one-way haul distance of 932,000 truck-km (579,000 truck-mi) to the Wentzville siding. The transport route from the site to Wentzville is shown in Figure 5.12. This transportation activity is expected to extend over 7 years.

The newly constructed rail siding would occupy about 4.5 ha (11 acres), including a concrete transfer and storage area with a gravel approach. The siding would have a translift for transferring the containers from the low-bed trucks to rail flatcars that could carry intermodal containers. The containers would be either staged at the siding or transferred directly to the flatcars.

A possible rail route for transport of the Weldon Spring waste to the Envirocare site is shown in Figure 4.3. This route would use the Union Pacific Railroad and travel through Jefferson City, Missouri; Kansas City, Missouri; Topeka, Kansas; North Platte, Nebraska; Cheyenne, Wyoming; Granger, Wyoming; Ogden, Utah; and Salt Lake City, Utah; to Clive, Utah. An existing rail spur would then be used to transport the waste from Clive, Utah, to the Envirocare site. Other routes and rail carriers could be utilized. The one-way haul distance to the Envirocare site from Wentzville, Missouri, by this route is about 2,400 rail-km (1,500 rail-mi). About 515 trips would be required, for a total one-way haul distance of 1,240,000 rail-km (773,000 rail-mi) over an estimated 7-year period.

Specific federal requirements for the off-site transport of chemically hazardous and radioactive material have been identified to address factors such as packaging and labeling (see Appendix G, Table G.3). Many states also have transportation requirements, including Missouri, and many require advance notification of shipments for radioactive material. Applicable requirements would be met for this activity.

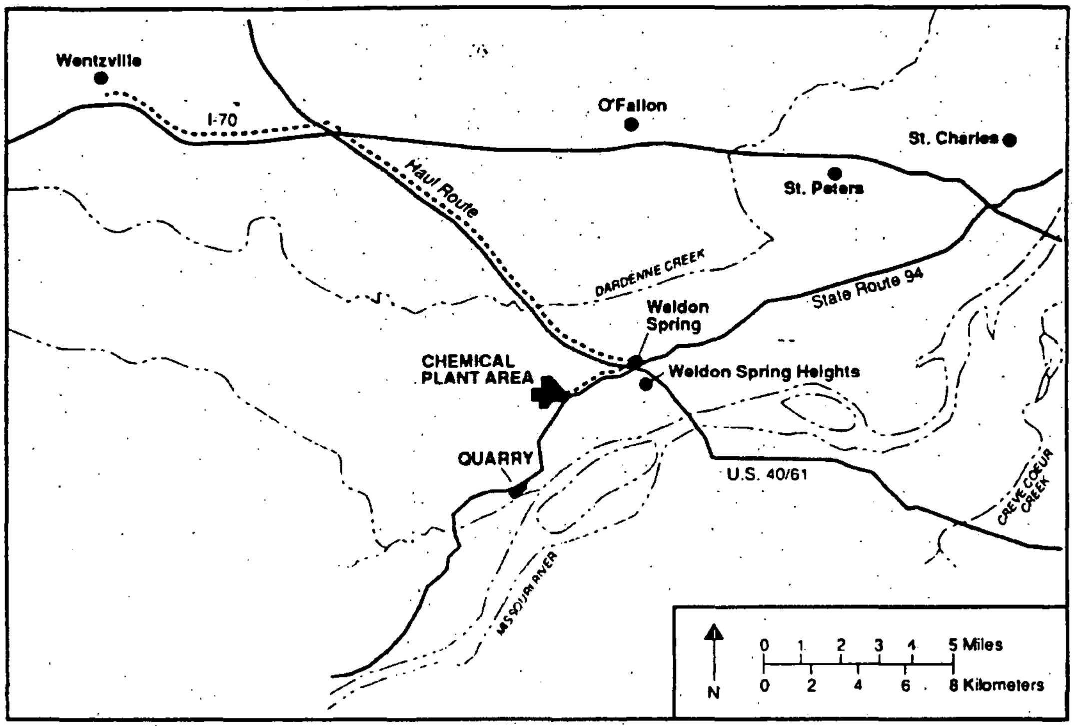

FIGURE 5.12 Haul Route from the Weldon Spring Site to the Wentzville Rail Siding

The Envirocare site is currently accessible by a rail siding. At that siding, the containers would be transferred to trucks with a translift and then transported to the disposal cell. At the disposal cell, the waste would be removed from the containers and placed in the cell. The containers would then be externally decontaminated, transferred to trucks for return to the rail siding, placed on rail flatcars, and transported back to the Wentzville siding for reuse.

The owner of the Envirocare site has a radioactive material license from the Utah Bureau of Radiation Control. Utah is an agreement state with the NRC for management of certain types of radioactive material. The current license permits the Envirocare facility to accept for disposal naturally occurring radioactive material (NORM) such as bulk waste contaminated with uranium, thorium, and radium. A permit for mixed NORM and chemically hazardous waste was granted in December 1990 by the Utah Bureau of Solid and Hazardous Waste and the U.S. Environmental Protection Agency, Region VIII. Although the facility is not currently licensed to receive material from the Weldon Spring site, Envirocare of Utah, Inc., has submitted an application for disposal of 11(e)2 by-product material to the NRC, and the NRC is currently preparing an EIS to support the license application. This environmental review process is currently projected to be completed in July 1993. The 260-ha (640-acre) site at Clive was originally selected, licensed, and used by DOE as a permanent disposal site for 2,100,000 m^3 (2,800,000 yd^3) of radioactive uranium mill tailings located in Salt Lake City, Utah, as part of the UMTRA Program; the UMTRA disposal cell occupies 40 ha (100 acres). Envirocare of Utah, Inc., purchased the remaining 220 ha (540 acres), and the Envirocare NORM waste disposal cell currently has a capacity of about 2,300,000 m^3 (3,000,000 yd^3) and occupies approximately 40 ha (100 acres). Support facilities occupy about 8 ha (20 acres), and the remaining 170 ha (420 acres) are identified for future disposal cell construction. The Envirocare facility has decontamination, storage, and staging areas as well as analytical laboratories.

Waste from the Weldon Spring site would be disposed of at the Envirocare site under Alternative 7b. The design of the specific disposal cell for this material would consider factors described for Alternative 7a (especially the nature of the waste), so the disposal facility could be similar to that described for on-site disposal. Any material that did not conform to the facility specifications would require special handling. Also, waste could not be placed in the cell during the winter months and would therefore require temporary storage either at the Envirocare site or the Weldon Spring site. The Envirocare site currently stores material on a synthetic liner, with a cover over the bulk waste. Wastes could be compacted within the disposal cell to a maximum of 11 m (37 ft) above grade (Envirocare of Utah 1991).

5.5 ALTERNATIVE 7c: REMOVAL, VITRIFICATION, AND DISPOSAL AT THE HANFORD SITE

Alternative 7c involves the removal of contaminated material from each of the on-site source areas, treatment by vitrification as appropriate, and disposal in an engineered cell at the Hanford site near Richland, Washington. The volumes of wastes to be removed, treated, and disposed of are summarized in Table 5.8. Also summarized are the volumes of borrow material required, the total effort (in person-years) for implementation, and the potential land areas impacted (which would depend on the borrow area selected as part of detailed design).

5.5.1 Removal

The removal component of Alternative 7c would be the same as described for Alternative 7b (Section 5.4.1).

5.5.2 Treatment

The treatment component of Alternative 7c would be the same as described for Alternative 7b (Section 5.4.2).

5.5.3 Disposal

Under Alternative 7c, the Weldon Spring waste would be disposed of at the Hanford site near Richland, Washington. Support activities at the Weldon Spring site would be the same as described for Alternative 7b (Section 5.4.3). A possible rail route for transport of the waste to the Hanford site is shown in Figure 4.3. This route would use the Union Pacific Railroad and travel through Jefferson City, Missouri; Kansas City, Missouri; Topeka, Kansas; North Platte,

TABLE 5.8 Summary of Waste Volumes, Borrow Material, Effort, and Impacted Land Areas for Alternative 7c: Removal, Vitrification, and Disposal at the Hanford Site

Parameter	Value
Volume removed (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	425,400
Quarry soil (stored in TSA)	52,000
Structural material[a]	203,000
Water treatment plant residuals	3,600
Total	904,000
Volume treated (yd^3)	
Raffinate pit sludge	220,000
Sediment/soil (includes roads and embankments)	50,000
Quarry soil (stored in TSA)	50,000
Structural material	123,000
Water treatment plant process waste	3,600
Total	447,000
Volume after treatment (yd^3)	
Raffinate pit sludge	33,700
Sediment/soil (includes roads and embankments)	34,200
Quarry soil (stored in TSA)	34,200
Structural material[b]	Variable
Water treatment plant process waste	500
Total disposal volume[c] (yd^3)	
Raffinate pit sludge	33,700
Sediment/soil (includes roads and embankments)	409,600
Quarry soil (stored in TSA)	36,200
Structural material	203,000
Water treatment plant process waste	500
Total	683,000
Volume of borrow material[d] (yd^3)	
Waste removal and reclamation (on-site and vicinity properties)	535,000
Disposal cell	794,000
Total	1,330,000

TABLE 5.8 (Cont.)

Parameter	Value
Effort (person-years)	
Excavation and on-site handling[e]	210
Treatment	297
Disposal[f]	210
Transportation of supplies and fill	27
Off-site transport of contaminated material	320
Total	1,100
Total on-site area impacted (acres)	105
Total off-site area impacted (acres)	138 (42 acres for disposal facility at Hanford, 11 acres for rail siding at Wentzville, and 85 acres for borrow material)[g]

[a] The volume estimate for structural material includes the material contaminated by site cleanup activities, such as piping and equipment from the two water treatment plants.

[b] The volume reduction of structural material would be variable (see text) and could be offset by volume increases from size reduction (e.g., of concrete blocks).

[c] Does not include any contingency factors. Compaction within the disposal cell could reduce the overall volume of structural material.

[d] For the representative analysis in this FS, off-site borrow of 376,000 m^3 (492,000 yd^3) of soil was assumed to be available from a 61-ha (150-acre) parcel of nearby land owned by the Missouri Department of Conservation (Section 5.2.1.10). Additional borrow material for the Weldon Spring site — such as gravel, sand, fill, and topsoil — would be supplied by local vendors. Borrow material for constructing the disposal cell would be obtained by the Hanford site operator.

[e] Includes worker requirements associated with removing soil from vicinity properties and sediment from the Busch Wildlife Area lakes, as well as restoring all excavated areas. Also includes the requirements associated with transporting chemicals off-site for incineration at a permitted facility.

[f] Effort for the off-site disposal component of Alternative 7b or 7c is expected to be similar to that required for on-site disposal.

[g] Does not include the area impacted to obtain borrow material for construction of a disposal cell at the Hanford site.

Nebraska; Cheyenne, Wyoming; Granger, Wyoming; McCammon, Idaho; and Nampa, Idaho; to Richland, Washington. Other routes and rail carriers could be utilized. At Richland, the railcars would transfer to a dedicated line operated by the Hanford site for the final 40 km (25 mi) to the disposal area. The one-way haul distance from Wentzville, Missouri, to the Hanford site by this route is about 3,400 rail-km (2,100 rail-mi). Approximately 515 trips would be required, for a total one-way haul distance of 1,740,000 rail-km (1,080,000 rail-mi) over an estimated 7-year period. Applicable requirements would be met for all transport activities.

The Hanford site is currently accessible by a rail siding. At that siding, the containers would be transferred to trucks with a translift and then transported to the disposal cell. At the disposal cell, the waste would be removed from the containers and placed in the cell. The containers would then be externally decontaminated, transferred to trucks for return to the rail siding, placed on rail flatcars, and transported back to the Wentzville siding for reuse.

The acceptance criteria for waste at the Hanford site prohibit several materials — including liquids, chemically incompatible materials in any waste container, explosives, and uncharacterized or poorly characterized waste (Willis 1990). The Hanford site is not currently prepared to receive the quantity and type of waste that would be generated by remedial action at the Weldon Spring site. Specific administrative procedures would have to be developed before the waste could be accepted.

Separate construction plans and a cell design have not been prepared for the Weldon Spring waste at the Hanford site. A disposal cell that would contain all of the Weldon Spring waste is estimated to require approximately 17 ha (42 acres), similar to the on-site disposal facility under Alternative 7a. Cell design considerations and support facilities would probably be similar to those identified for Alternative 7a.

6 DETAILED EVALUATION OF ALTERNATIVES

The EPA has established a framework for evaluating final remedial action alternatives to support the national goal of selecting appropriate remedies for contaminated sites. This goal focuses on protecting human health and the environment, maintaining that protection over time, and minimizing the amount of untreated waste associated with each site. Contaminated material that poses the principal threat at a site is prioritized (EPA 1990a).

Nine criteria are used as the framework for evaluating the final cleanup alternatives. The purpose of these criteria is to focus the evaluation on addressing statutory mandates identified in Section 121 of CERCLA, as amended, in order to determine the most appropriate solution for the specific problems at a contaminated site. These mandates include protection of human health and the environment, compliance with ARARs, a preference for permanent solutions with treatment as a principal element (to the maximum extent practicable), and cost-effectiveness. The evaluation criteria are used to determine the extent to which the national program goal is satisfied and the extent to which treatment and permanent solutions are practicable (EPA 1988a, 1990a).

The detailed evaluation of final alternatives for a remedial action is a two-stage process. During the first stage of evaluation, each of the alternatives is assessed against the individual criteria. This first-stage evaluation of the final remedial action alternatives for the Weldon Spring site is presented in this chapter; the evaluation is based on the conceptual descriptions of the final alternatives provided in Chapter 5. For the second stage of the evaluation process, the criteria are grouped into a tiered system to reflect their interrelationships and different levels of significance. During this second-stage evaluation, the alternatives are initially evaluated according to the threshold criteria, which must be met, and then compared with each other to identify relative advantages and disadvantages and trade-offs among the different balancing criteria. The purpose of the comparative analysis is to provide information for a balanced remedy selection. The second-stage evaluation of final remedial action alternatives for the Weldon Spring site is presented in Chapter 7.

The EPA has identified nine criteria in the NCP (EPA 1990b) that must be evaluated for each alternative retained through the screening stage [Section 300.430(e)(9)(iii)]. The factors that comprise each criteria and appropriate cross references to related discussions in this FS are listed as follows:

1. *Overall protection of human health and the environment* — which addresses protection from unacceptable risks in both the short term and the long term by minimizing exposures, in accordance with the purpose and objectives of this remedial action (Section 2.1). Due to its broad scope, this criterion also reflects the focus of the four following criteria (2 through 5).

2. *Compliance with ARARs* — which addresses the attainment of federal and state environmental requirements and state facility siting

requirements that are determined to be either applicable or relevant and appropriate to the alternative on the basis of site-specific considerations unless a waiver condition is appropriate. Various ARARs and the waiver conditions are identified in Appendix G, and the key requirements are discussed for each alternative in the individual subsections of this chapter.

3. *Long-term effectiveness and permanence* — which addresses residual risks (i.e., those risks remaining after completion of the remedial action), focusing on the magnitude and nature of those risks associated with untreated waste and/or treatment residuals; this criterion includes a consideration of the adequacy and reliability of any associated institutional or engineering controls, such as monitoring and maintenance requirements. Also addressed as part of this evaluation are the irreversible and irretrievable commitment of resources, impacts that could result from the potential loss of institutional controls, and short-term uses and long-term productivity, as appropriate to the alternative. A summary description of these three topics is provided in Sections 6.8 through 6.10. Potential risks associated with the no-action alternative are discussed in detail in the BA (DOE 1992a) and Appendix E and are summarized in Section 1.6. Soil cleanup criteria are developed for the action alternatives in Chapter 2, and summary information that will be used to help define the final remedy is presented in Section 2.5.

4. *Reduction of contaminant toxicity, mobility, or volume through treatment* — which addresses the degree to which treatment is used to address the principal threat(s) at the site; the amount of material treated; the magnitude, significance, and irreversibility of the given reduction; and the nature and quantity of treatment residuals.

5. *Short-term effectiveness* — which addresses the potential impacts of implementing the alternative on workers, the general public, and the environment during the action period; the effectiveness and reliability of mitigative measures; and the time required to achieve protectiveness. Also addressed as part of this evaluation are unavoidable adverse impacts and cumulative impacts associated with implementation, as appropriate to the alternative. Potential health impacts during the cleanup period are addressed in detail in Appendix F, applying information for airborne releases developed in Appendix C; key information is summarized in this chapter. A summary of mitigative measures is presented in Section 6.6, and a summary of unavoidable adverse impacts is presented in Section 6.7; cumulative impacts are discussed in Section 6.11.

6. *Implementability* — which addresses technical feasibility, including the availability and reliability of required resources (such as specific technologies, materials and equipment, facility capacities, and skilled workers), the ease of implementation, and the ability to monitor effectiveness; this criterion also addresses administrative feasibility, e.g., the need to coordinate with other agencies and the need for approvals or permits for off-site actions, as appropriate to the alternative.

7. *Cost* — which addresses both capital costs and annual operation and maintenance costs, as well as the combined net present worth. Costs for the individual components of the alternatives (e.g., treatment) are also considered.

8. *State acceptance* — which addresses the comments made by the affected state on the alternatives being considered for site remediation. Because state comments will not be received until after the RI/FS-EIS has been issued for public review, this criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

9. *Community acceptance* — which addresses the comments made by the community on the alternatives being considered. Because public comments will not be received until after the RI/FS-EIS has been issued for review, this criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

The five remedial action alternatives for the Weldon Spring site that have been retained through the screening process are evaluated in Sections 6.1 through 6.5 on the basis of criteria 1 through 7. In each section, the evaluation of the individual alternative against these seven criteria is organized to follow the order in which the criteria are listed in the NCP (EPA 1990b). For example, overall protectiveness is discussed in the first subsection for each alternative, possible long-term effects on human health and the environment are discussed in the third subsection, and short-term effects are discussed in the fifth subsection. Together, these three discussions present the comprehensive evaluation of each alternative relative to potential health and environmental impacts.

6.1 ALTERNATIVE 1: NO ACTION

6.1.1 Overall Protection of Human Health and the Environment

The no-action alternative would not be adequately protective of human health and the environment over the long term. Exposure of biota to on-site and off-site contaminants would continue, as would the potential for exposure of workers to on-site contaminants. Institutional controls would be used to minimize the potential for human exposure to significant levels of contamination. Under Alternative 1, sources of contamination would not be removed or treated; and, if institutional controls (including access restrictions and the environmental monitoring program) were not maintained, unrestricted access to contaminated material could result in risks that exceed the target levels established by the EPA (Section 1.6). Exposures could increase in the future if the containment in storage areas or the raffinate pit dikes failed. Adverse environmental impacts might also result, e.g., from biotic exposures, washout, or groundwater contamination at the raffinate pits (see the BA [DOE 1992a], Appendix E, and Section 6.11).

6.1.2 Compliance with ARARs

Potential regulatory requirements that might be applicable or relevant and appropriate to the final remedial action alternatives are identified and evaluated in Appendix G. With no further action, certain ARARs, including time limits for the storage of some site waste, would not be met. For example, under TSCA, material contaminated with PCBs is to be stored for no longer than 1 year prior to disposal; PCB-contaminated material (which also contains radioactive contaminants) is currently in storage on-site, so this requirement would apply. If no further action were taken, this requirement would not be met. Also, certain water quality criteria for the protection of aquatic life would be exceeded by contaminant concentrations in the raffinate pits because the pits might refill and reestablish current conditions following the interim action to remove and treat the water. In addition, if site access were unrestricted at some time in the future (e.g., under the scenario of a hypothetical loss of institutional controls), standards for general radiation exposure and levels of radium and thorium in soil given in DOE Orders and in the Uranium Mill Tailings Radiation Control Act would not be met (see Appendix G, Table G.2). Site conditions would be subject to review every 5 years, in accordance with federal requirements, because waste would remain on-site (EPA 1990a).

6.1.3 Long-Term Effectiveness and Permanence

In the case of no further action, monitoring and maintenance activities would be carried out at the site for an indefinite period. However, Alternative 1 would not be reliable in the long term because human contact with contaminated source areas might occur through unauthorized entry. Risks to individuals who might access the site in the future are discussed in detail in the BA and in Appendix E and are summarized in Section 1.6. Over time, contaminant levels in currently contaminated habitats could increase as a result of further transport and deposition of contaminated sediment and infiltration of contaminated water into soil. In addition, currently uncontaminated habitats could become contaminated, resulting in increased exposure of local biota. If institutional controls were lost (e.g., in the long-term future) such that monitoring and maintenance ceased and access became unrestricted, and if the containment in storage areas or the raffinate pit dikes failed, contaminants could migrate into nearby soil, surface water, or groundwater, or be released to the atmosphere — which could cause additional contamination of surrounding terrestrial and aquatic habitats, particularly along the drainage channels leading from the site to the Busch Wildlife Area and to the Missouri River.

6.1.3.1 Protection of Workers

Long-term monitoring and maintenance activities would be carried out for an indefinite period in the case of no further action. Workers would be present on-site periodically to maintain the fences and mow the grass, to patrol the site for security purposes, and to perform other monitoring and maintenance activities. The risk to a worker involved in these activities would be about 1×10^{-4} over a 10-year period. Over a 30-year period, these activities are estimated to result in nine cases of occupational injury and no occupational fatalities.

6.1.3.2 Protection of the Public

Potential impacts to members of the general public that might occur in the long term if no further cleanup action were taken at the site are discussed in Appendix E of this FS. Health effects from exposures under the transitional or interim site conditions that will result from completion of the interim actions, which include the dismantlement of site structures and the storage of quarry bulk waste at the TSA, are discussed in Appendix E (Section E.3). The incremental lifetime risk for a recreational visitor to the site would be similar to that estimated for baseline conditions, i.e., prior to the implementation of interim actions, because although certain exposures would no longer occur as a result of those actions (such as exposures inside the buildings), the related risk reductions would be offset by potential increased risks from exposures to new waste at the site (such as to the quarry bulk waste at the TSA).

In addition to estimating health effects from exposures associated with the features of the interim site conditions, potential health effects were estimated for several hypothetical individuals who were assumed to occupy the areas of soil across the site in the extended future after institutional controls are assumed to have been lost. The on-site receptors evaluated for this analysis, which is presented in Section E.4 of Appendix E, are a recreational visitor, a wildlife area ranger in an on-site ranger station, a resident, and a resident farmer. The incremental lifetime radiological risks estimated for a future recreational visitor and farmer from exposures to soil and air are 6×10^{-5} and 1×10^{-2}, respectively. Chemical carcinogenic risks are 2×10^{-6} and 5×10^{-5}, respectively, and noncarcinogenic effects are indicated for the farmer. The radiological risks estimated for the ranger range from 6×10^{-4} to 1×10^{-2}, and those for the resident range from 1×10^{-6} to 9×10^{-2}. Chemical carcinogenic risks are 2×10^{-5} for the ranger and range from 3×10^{-6} to 6×10^{-4} for the resident, with noncarcinogenic effects indicated for several locations (Appendix E, Table E.21). These risks would be due primarily to external gamma irradiation, inhalation of radon, and incidental ingestion of contaminated soil. Risks for a future recreational visitor off-site would be represented by those estimated for a current recreational visitor (Section 6.1.5).

6.1.3.3 Environmental Protection

Soil and Geology. In the case of no further action, soil and geology at the Weldon Spring site would remain essentially unchanged, and the concentrations of contaminants in the soil would remain at existing levels. However, natural processes such as tornadoes or earthquakes could result in the loss of containment and the dispersal of contaminants from the raffinate pits and storage areas. The likelihood of such extreme events at the site is discussed in Sections 1.3.2.2 and 1.3.2.5.

Water Quality and Hydrology. No additional contamination would be removed from source areas under this alternative. Surface water would be pumped from raffinate pits and other on-site impoundments and treated under an interim action, but, if it were assumed that institutional controls were lost in the extended future, they could refill with water over time and existing conditions could reestablish. The concentrations of contaminants in groundwater would probably increase over time because migration from source areas such as the raffinate pits would continue. In general, off-site surface water near the Weldon Spring site is influenced by groundwater, so potential long-term impacts to surface water quality cannot be effectively assessed independently of groundwater. Potential long-term effects of the site on local water quality will be evaluated as part of the analyses for the groundwater operable unit.

Air Quality. Under the no-action alternative, air quality would be essentially the same as under current conditions. The site does not impact ambient air quality (Section 3.2.2.1 of the BA [DOE 1992a]), and the air pathway does not contribute to off-site health impacts.

Biotic Resources. Currently contaminated terrestrial habitats at the chemical plant area total about 72 ha (179 acres) and include about 22 ha (55 acres) of relatively undisturbed grassland/shrub and secondary growth upland forest habitat in the northern portion of the site (see Figure 7.2 in the BA [DOE 1992a]). Off-site terrestrial habitats that have been identified as radioactively contaminated include the riparian corridor of Burgermeister Spring and some of the drainage channels that receive runoff from the site; forest areas along some shoreline areas of Lakes 34, 35, and 36; and forest and grassland/shrub habitats associated with the vicinity properties (DOE 1992a). Contaminated aquatic and wetland habitats at the site include the raffinate pits, Ash Pond, and Frog Pond (Figure 1.3) and total approximately 15 ha (38 acres) (DOE 1992a). Off-site aquatic habitats that currently have contaminated sediment or surface water are Burgermeister Spring and Lakes 34, 35, and 36. Under Alternative 1, the level of contamination in these terrestrial and aquatic habitats in the future would be similar to current levels and might increase as a result of additional contaminant migration, e.g., if the raffinate pit dikes failed.

Nearly 380 species of terrestrial wildlife, 105 species of fish, and an unknown number of plant and invertebrate species occur in the Weldon Spring area, some of which use currently contaminated habitats at the site and vicinity properties (DOE 1992a, Appendix C). The use of the habitats by area biota and exposure of some species to contaminated media would continue under Alternative 1. No adverse ecological impacts are anticipated to biota from exposure to contaminants in site soil, but some adverse impacts are indicated for the raffinate pits (DOE 1992a).

No federal or state listed species are known to be currently exposed to or threatened by site contamination (DOE 1992a). However, some of the listed species might use some of the contaminated habitats over time and thus be exposed to contaminated media. Under the no-action alternative, the potential exists for transport of contaminated sediment and surface water from the Southeast Drainage to the Missouri River. If such transport occurred, the sicklefin chub, *Macrohybopsis meeki* (federal Category 2*); the sturgeon chub, *Macrohybopsis gelida* (federal Category 2); and the pallid sturgeon, *Scaphirhynchus albus* (federal endangered) could be exposed to site contaminants.

Several endangered avian species have been reported from the Weldon Spring area and could be exposed to radioactive and chemical contaminants through food chain transfer or direct contact with contaminated media; these species are the federal endangered bald eagle, *Haliaeetus leucocephalus*; least tern, *Sterna antillarum*; and peregrine falcon, *Falco peregrinus*; and the state endangered Cooper's hawk, *Accipiter cooperii* (DOE 1992a). If biouptake and/or bioaccumulation of site contaminants were to occur in local biota using contaminated habitats (e.g., waterfowl using the partially dewatered raffinate pits), these species could be exposed to site contaminants by preying on the contaminated biota or foraging on contaminated carrion or hunter-killed game.

The state endangered Blanding's turtle, *Emydoidea blandingii*, has recently been collected from the Busch Wildlife Area. Frog Pond and Ash Pond represent potential habitats for this species, although it is not known whether the Blanding's turtle occurs in these ponds. Under Alternative 1, Frog Pond and Ash Pond would continue to represent potentially suitable but contaminated habitats for this species. The state rare pied-billed grebe has been observed at the raffinate pits (MK-Ferguson Company and Jacobs Engineering Group 1992d), and exposures to pit contaminants could continue in the future if no further action were taken at the site.

Socioeconomics and Land Use. The absence of any further action at the site could potentially have long-term effects on population, economy, and land-use patterns in proximity to the site, depending on general growth in the area. Failure to stabilize or remove contaminated waste might inhibit future growth of the local population, as well as the value of land and housing. Nearby land use would likely remain the same for the reasonably foreseeable future (i.e., recreational use); however, land-use conditions that might exist in the long term cannot be projected with certainty at this time. The absence of any further cleanup on-site might negatively impact the establishment of industrial and commercial operations closer to the site.

Cultural Resources. No adverse effects to significant archaeological sites or cultural resources would occur under Alternative 1.

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*Category 2 (C2) species are federal candidates for listing as threatened or endangered.

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Reduction of toxicity, mobility, or volume through treatment is not applicable to Alternative 1 because this alternative does not involve treatment.

6.1.5 Short-Term Effectiveness

Institutional controls would be maintained at the site to limit human exposures under Alternative 1, but biota would continue to be exposed. Assuming no further cleanup occurs after the interim actions have been implemented, potential health effects were estimated for workers and for a trespasser from exposures that might occur over the next 10 years. Risks were also estimated for a recreational visitor who was assumed to visit individual contaminated locations off-site over the next 30 years. This evaluation is presented in Section E.2 of Appendix E.

Under Alternative 1, on-site workers responsible for monitoring and maintenance activities would be responsible for both routine sitewide maintenance (such as mowing the grass and repairing fences) and additional monitoring associated with the new storage facilities. Exposures associated with these activities are estimated to result in an annual incremental lifetime risk to a routine maintenance worker from external gamma irradiation of approximately 3×10^{-6}; the annual incremental risk from these exposures to a worker monitoring storage areas, i.e., the TSA, is estimated to be 8×10^{-6}. Combined with the risks from exposures to sitewide soil and air, the risk for the worker involved in activities at the new storage areas (for a shorter time) would be about 20% of the risk estimated for the routine maintenance worker over a 10-year period (1×10^{-4}). For a trespasser, risks would be at the low end of or below EPA's target range, and no noncarcinogenic effects would be indicated. For an off-site recreational visitor, estimated radiological risks would be within or below the target range at all but one vicinity property being addressed by this remedial action. The risk estimated for that property from repeated exposures (600 four-hour visits) over the 30-year period is 3×10^{-4} (Section 5.3.5.1 of the BA [DOE 1992a]).

6.1.6 Implementability

Minimum site operations would continue using readily available resources for monitoring and maintaining institutional controls.

6.1.7 Cost

Costs for the no-action alternative are associated with operating existing facilities, continuing the environmental monitoring program, and maintaining institutional controls at the site. Estimated total and present-worth costs for Alternative 1 are given in Table 6.1; annual costs are estimated to be about $1.2 million. Long-term maintenance costs are based on a 30-year period and include site monitoring costs (MK-Ferguson Company and Jacobs Engineering Group 1992b).

TABLE 6.1 Cost Estimate for Alternative 1

Activity	Estimated Cost (million $)
TSA operations[a]	2.0
MSA operations[a]	5.2
Water treatment plant operations[a]	2.0
Decontamination activities[b]	0.65
Long-term maintenance[b,c]	16.9
Total[b]	26.8
Present worth[b]	11

[a] Estimated costs are based on a 10-year design life for the TSA, MSA, and water treatment plant. Following this 10-year period, maintenance and monitoring would continue. These costs are included under long-term maintenance.

[b] Estimated cost for a 30-year period.

[c] Includes monitoring costs.

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

6.2 ALTERNATIVE 6a: REMOVAL, CHEMICAL STABILIZATION/SOLIDIFICATION, AND DISPOSAL ON-SITE

6.2.1 Overall Protection of Human Health and the Environment

Alternative 6a would provide for protection of human health and the environment at the Weldon Spring site by (1) removing the sources of contamination, (2) treating the materials that pose the principal threats at the site (e.g., the raffinate pit sludge and the more highly contaminated soil) by stabilization/solidification in a cement and fly ash-based matrix, and (3) placing treated and untreated materials in an on-site engineered disposal cell designed to prevent migration of contaminants from the cell to the environment. Potential on-site exposures and risks would be reduced toward background levels (Section 6.2.3). Institutional controls would be maintained at the disposal facility to provide continued protection against potential future exposures. Alternative 6a is not expected to result in any unacceptable impacts to human health or the environment during implementation; potential impacts are discussed in Section 6.2.5.

6.2.2 Compliance with ARARs

Alternative 6a would comply with pertinent ARARs and TBCs (including DOE Orders), with waivers as appropriate. A comprehensive listing of potential ARARs is presented in Appendix G. Although worker protection laws are not subject to the formal ARAR evaluation process because they constitute requirements with which the remedial action at the site would comply, they are also included in Appendix G to indicate additional standards that would be met.

Location-specific ARARs address the protection of historic sites, archaeological and cultural resources, endangered species and habitats, floodplains, wetlands, and prime farmlands. No impacts to archaeological and cultural resources are expected at the site because of past disturbances, but, depending on the borrow area selected during the detailed design stage as the source of fill material for this action, such resources could potentially be impacted off-site. No critical habitats have been identified as being impacted by activities at the site, but final site surveys to identify the presence of threatened and endangered species and habitats have not yet been completed. If occurrences were indicated, proper procedures would be undertaken to mitigate potential impacts prior to disturbing any affected areas.

No adverse long-term impacts to floodplains are anticipated (see Appendix H). A very small portion (about 0.5 ha [1.3 acres]) of the site at its northern boundary and vicinity property A6 are within the 100-year floodplain of the Schote Creek-Dardenne Creek drainage basin within the headwaters of Schote Creek. Following any required excavation or grading, this area would be restored to original conditions. The raffinate pits, Ash Pond, and Frog Pond have been designated as wetlands by the National Wetlands Inventory (U.S. Fish and Wildlife Service 1989). No practicable alternative exists for these areas but to remove and treat the contaminated sludge and sediment. The DOE has consulted with the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers relative to these wetlands (Section 6.2.3.3), and mitigative measures such as wetland replacement are being coordinated with the state of Missouri. No wetlands are present at the designated vicinity properties (see Appendix H), but, depending on the borrow area selected for this action, off-site wetlands in uncontaminated areas might be impacted. In this case, mitigative actions would also be developed for that area.

Prime farmland is located on-site and also at the potential borrow area off-site (U.S. Soil Conservation Service 1982). On-site farmland has been disturbed and contaminated by past activities. Nevertheless, mitigative measures would be taken to minimize any adverse impacts to the extent possible within the constraints of cleanup requirements; similar measures would be taken, as appropriate, at the local borrow area. Additional location-specific requirements are facility siting criteria for treatment, storage, and disposal facilities for hazardous waste. Certain waste at the site meets the regulatory definition of characteristic hazardous waste under RCRA because leachate concentrations determined by the TCLP test exceed the given limits. Therefore, RCRA siting requirements for new hazardous waste facilities would apply for certain facilities that would be constructed to treat and store that waste under Alternative 6a. Many of these requirements are incorporated by reference in the Missouri Hazardous Waste Management Law and Regulations.

Contaminant-specific ARARs depend on both the contaminant and the affected medium. The standards for annual doses to workers from radiation exposures are expected to be met both during and following completion of remedial action at the site. Requirements that may apply to airborne emissions include limits given in the National Emissions Standards for Hazardous Air Pollutants (NESHAPs). These standards provide limits on the emission of contaminants such as radionuclides to the atmosphere from DOE facilities, including the Weldon Spring site. For example, the limit for radon-222 (given as a flux) is 20 pCi/m^2-s, as an average for the entire site. These requirements would be met during and following implementation. Additional standards that may be applicable include maximum permissible exposure limits for radionuclides given in the Missouri Radiation Regulations and requirements for control of particulate matter emissions given in the Missouri Air Pollution Control Regulations.

Requirements in the Missouri Radiation Regulations include a radon-222 limit of 1 pCi/L above background in uncontrolled areas. Although the other limits are expected to be met during and after site cleanup under Alternative 6a, it is possible that activities at the TSA might result in temporary exceedances of the radon-222 standard, e.g., during periods when the radium-contaminated quarry bulk waste was being uncovered and loaded for treatment. These exceedances could occur at the fence line that separates the site from the Army property, depending on meteorological conditions (prevailing winds would tend to disperse the radon within the site boundary in most cases). Access to that property is controlled by the Army and the levels would decrease considerably with distance because of dispersion and transport, so no measurable impacts are expected. In addition, this standard would apply to the final remediation levels at the site, and it would be met at that time. If needed, the waiver condition that addresses intermediate actions for cases where the total remedial action will attain the given standard would be appropriate (EPA 1990a).

National limitations on ambient air concentrations, such as the National Ambient Air Quality Standards, and state ambient air quality requirements are not specifically applicable because they do not directly apply to source-specific emissions. However, they would be addressed in controlling emissions that could result from implementing Alternative 6a. Contaminant-specific requirements and guidelines for soil that were evaluated to develop cleanup levels for site soil are identified in Section 2.2; these include standards for radium, thorium, PCBs, and lead. Contaminant-specific requirements for other media are not developed as part of this remedial action (Table 2.2). The Clean Water Act requirements are considered potentially applicable to surface releases from the site, e.g., from construction activities during the cleanup period, and a National Pollutant Discharge Elimination System (NPDES) permit is in place with the state of Missouri under previous actions (Sections 1.5.1.2 and 1.5.1.4). (The discharge limits for the water treatment actions established in the permit are near drinking water quality.)

Action-specific requirements focus on waste treatment, storage, and disposal. Several requirements that apply to Alternative 6a are included in various provisions of RCRA and are incorporated by reference in the state regulations for solid and hazardous waste. For the storage component of this alternative, the 1-year time limit specified in the TSCA for PCB-contaminated material would apply. However, a waiver from this limit would be pertinent for the cleanup period on the basis of technical impracticability. That is, the PCB-contaminated waste in storage at the site is also radioactively contaminated, and a disposal facility is not currently available for this type of waste. In addition, the storage of this material constitutes an intermediate measure in the context of the overall remedial action. The requirement would be attained upon completion of this action under Alternative 6a.

For the treatment component of Alternative 6a, the facility for treating the highly contaminated sludge from the raffinate pits and certain other site waste would be constructed and operated in accordance with several requirements in RCRA and the parallel state law, as described below. The characteristic hazardous waste would be chemically stabilized/solidified to meet the RCRA treatment standards (i.e., to pass the leachate test). Thus, following treatment, the waste would no longer meet the definition for hazardous waste so related requirements would not apply to the subsequent disposal action. However, certain of these requirements would be considered relevant and appropriate to the disposal of this waste.

For the disposal component of Alternative 6a, no environmental laws are available that specifically apply to the combined waste that would be placed in the disposal cell. However, a number of laws contain requirements that apply separately to hazardous waste, uranium and thorium mill tailings, and demolition waste. Certain requirements would be considered relevant and appropriate to specific design components of the disposal cell on the basis of sufficient similarity of the different waste types and the appropriateness of the purpose of the requirements to the overall purpose of this action, i.e., to dispose of site waste in a manner that will protect human health and the environment in both the short term and the long term. Therefore, the cell design would incorporate the protective components from each of the pertinent regulations, including requirements given in RCRA, TSCA, the Missouri Hazardous Waste Management Law and Regulations, and the Uranium Mill Tailings Radiation Control Act. These requirements include designing for an effective life of at least 200 to 1,000 years, incorporating a radon barrier cover to limit radon releases to 0.5 pCi/L above background at the facility boundary, and incorporating a double liner and leachate collection system to contain the waste and monitor cell performance. A 5-year review of the effectiveness of the remedy would be conducted at the Weldon Spring site in accordance with CERCLA, as amended, because waste would remain on-site under this alternative.

Additional requirements address the siting of a new hazardous waste facility. The RCRA requirements and similar requirements in the state law specify that a treatment, storage, or disposal facility should not be constructed within 61 m (200 ft) of a fault in which displacement has occurred in Holocene time and that any facility located in a 100-year floodplain should be constructed, operated, and maintained to prevent washout of any waste by a 100-year flood. These requirements apply to locating the chemical stabilization/solidification facility on-site under this alternative because the unit is expected to treat some characteristic hazardous waste. However, they would not apply to the disposal facility because the waste would have been rendered nonhazardous by the treatment process so the regulatory prerequisite (i.e., the waste definition) would no longer be met. Nevertheless, the requirements are considered relevant and appropriate to the construction of that facility on the basis of sufficient similarity of the waste type and the appropriateness of the purpose of the requirement for this action, i.e., to limit the potential for facility displacement by a nearby earthquake. In actuality, all facilities that would be constructed at the Weldon Spring site under Alternative 6a would meet these siting criteria.

More stringent siting requirements for hazardous waste landfills identified in the Missouri Hazardous Waste Management Law and Regulations also specify that a disposal landfill should not be located in an area of unstable soil deposits subject to landslides or catastrophic collapse. This requirement does not apply to the disposal action under Alternative 6a because the waste would have been treated such that it no longer met the regulatory definition for hazardous waste. However, the requirement is considered relevant and appropriate to the action on the basis of sufficient similarity of the waste type and the appropriateness of the purpose of the requirement for this action, i.e., to limit the potential for facility displacement from subsidence.

Additional state siting requirements specify that 9.1 m (30 ft) of soil or other material with a permeability of less than 1×10^{-7} cm/s should be present between the bottom of the cell and the uppermost regional aquifer, or an equivalent protection may be based on at least 6.1 m (20 ft) of naturally occurring material. Again, these requirements do not apply to the disposal action because the waste would have been treated such that it no longer met the regulatory definition for hazardous waste. These criteria are considered relevant on the basis of sufficiently similar waste type, but the specific circumstances at the site were reviewed to determine whether they were well suited and therefore appropriate for the action. From this review, the requirements for the thickness and permeability of naturally occurring material are not considered appropriate in the context of in-place material because of the circumstances at the chemical plant facility — i.e., much of the site overburden was significantly altered during the extensive excavation, backfilling, and regrading that occurred as part of plant construction more than 20 years ago, and a number of subsurface features such as building foundations and pipes are present. However, after those features are removed, naturally occurring material would be used in combination with compacted fill to engineer to an equivalent level of protection to achieve the purpose of these requirements, i.e., to limit the potential for contaminant leaching to groundwater. Thus, these specific requirements would be adopted as design criteria to ensure that the properties of the disposal cell foundation (a combination of in-place materials and engineered fill) would attain the indicated performance measures.

Similarly, the restriction on the placement of waste containing free liquids in a landfill that is specified in both RCRA and the similar state law does not apply to Alternative 6a. Although the requirement is considered relevant to disposal of the chemically stabilized/solidified waste on the basis of sufficient similarity of the waste type, it is not appropriate because of the specific nature of the waste relative to its radionuclide content and the potential for emissions under the required method of waste placement. That is, the chemically treated waste should be maintained at an adequate moisture content during waste placement to control radon and particulate releases. Airborne contaminants that could be released if the waste were placed in the cell in accordance with this requirement, instead of in a wet form, could exceed DOE standards for occupational exposures (especially for thorium), thereby posing a health threat to workers nearby. Disposing of the cement-like material in a somewhat wet condition and allowing it to harden in the cell would also provide other benefits. For example, the overall density of the final waste form would increase because the material could move into small open spaces in the surrounding waste; this would improve the overall structural integrity of the cell for the long term and would result in a smaller total waste volume compared with the method identified in this requirement. Therefore, the restriction on placement of waste containing free liquids is not well suited to the specific circumstances of the remedial action under Alternative 6a. Its purpose of providing overall protection for human health and the environment would be better achieved by the wet placement method described for this alternative.

The RCRA land disposal restrictions would not apply to disposal under Alternative 6a because no listed waste would be disposed of on-site and any characteristic waste would be treated so that it no longer met the definition for hazardous waste. If any listed waste were identified as the remedial action progressed, these requirements would apply and the waste would be disposed of at an appropriate RCRA facility (e.g., off-site).

The off-site transport of the process chemicals to a permitted incinerator would be conducted in accordance with pertinent requirements. The application of specific environmental regulations to the treatment of liquid waste at the off-site incinerator would be addressed in the environmental compliance documents and activities for that facility.

6.2.3 Long-Term Effectiveness and Permanence

Monitoring and maintenance activities for Alternative 6a would be carried out at the site for an indefinite period. These activities would be conducted to ensure the effectiveness of waste isolation and would allow for an assessment of potential impacts and the need for responses to prevent exposures in the event of disposal cell failure. Chemical stabilization/solidification of the most highly contaminated material would greatly reduce the mobility of contaminants in that waste. Therefore, for the hypothetical scenario under which it is assumed that institutional controls are lost at the site in the long-term future and the cell subsequently fails, contaminant releases to the environment from that portion of the waste would be slow (e.g., hundreds to thousands of years) (Section 6.2.4).

6.2.3.1 Protection of Workers

Long-term monitoring and maintenance activities would be carried out for an indefinite period following implementation of Alternative 6a. Workers would be present on-site periodically to collect air and water samples, to inspect and maintain the containment system, to maintain the fences and mow the grass, to patrol the site for security purposes, and to perform other routine monitoring and maintenance activities. Exposures of workers to radiological and chemical contaminants would be negligible because the disposal cell would be designed to prevent releases of particulates and radon gas. In the 30 years immediately following implementation of Alternative 6a, it is estimated that about nine cases of occupational injury and no occupational fatalities would occur during site maintenance activities.

6.2.3.2 Protection of the Public

Following implementation of Alternative 6a, routine monitoring and maintenance activities would ensure the integrity of the containment system, and corrective actions would be performed as necessary. Therefore, releases of site contaminants and exposures of members of the public over the long term are expected to be negligible. The presence of fences would minimize the potential for intrusion into the disposal cell by members of the public in the foreseeable future. If it were hypothetically assumed that institutional controls were lost at the site in the long-term future and the cell subsequently failed, the greatly reduced mobility of contaminants from the chemically stabilized/solidified waste would reduce related impacts, e.g., to groundwater. The magnitude of future impacts would depend on the size of the release and the local land-use conditions at the time it occurred.

Residual risks would be reduced toward background levels by applying the ranges developed for soil cleanup criteria (Section 2.5) as appropriate to the long-term use of the land outside the disposal area, in accordance with DOE's ALARA process. By this process, contaminant concentrations would be reduced to the most protective levels practicable, so residual levels for each alternative could be similar. (The soil within the entire cell area would be effectively remediated because it would be removed prior to cell construction.)

On the basis of the expected levels of residual contaminants in site soil following cleanup, the estimated incremental lifetime risks of cancer induction from exposures to residual radioactive contaminants could be 7×10^{-6} for a recreational visitor; for a resident, the risks could range from 0 (i.e., background) to 6×10^{-3}. The elevated risk estimates result almost entirely from exposures to the estimated levels of indoor radon, which would be generated by the residual radium in soil (entering through the basement or foundation slab). However, the EPA has separately identified an acceptable level for indoor radon of 4 pCi/L (EPA 1992), and the indoor radon concentrations associated with the cleanup target and goal for radium are expected to be at or below this level at all site locations. The incremental lifetime risks from exposures to chemical contaminants would be below EPA's target range of 1×10^{-6} to 1×10^{-4}, and no noncarcinogenic effects would be indicated for either receptor at any location. (For comparison, the representative background radiological and chemical risks for a recreational visitor off-site would be 6×10^{-5} and 1×10^{-6}, and those for a resident would be 3×10^{-3} and 5×10^{-5}.) Results for other hypothetical receptors are presented in Appendix E (Section E.4) and summarized in Section 1.6. Additional information on residual risks is presented in Chapter 2.

6.2.3.3 Environmental Protection

Alternative 6a would result in a substantial reduction in levels of contamination and biotic exposures. If it were hypothetically assumed that institutional controls were lost in the extended long term and the disposal cell cover or liner failed, contaminants could be dispersed by wind or water. The most highly contaminated material would have been treated by chemical stabilization/solidification, so this material would resist degradation which would reduce related impacts, e.g., to local water quality.

The borrow material requirements of Alternative 6a, which total about 1,160,000 m^3 (1,520,000 yr^3), might result in adverse effects to the environment in both the short term and the long term. On the basis of current conceptual engineering information, most of this material (approximately 895,000 m^3 [1,171,000 yd^3]) could be obtained from a nearby source, potentially a 61-ha (150-acre) site along State Route 94, across from Francis Howell High School (Section 5.2.1.10). The borrow material could be removed to an average depth of up to 5.5 m (18 ft) from an area of approximately 21 ha (52 acres) within the larger site. Excavation of this soil could affect wetlands, prime farmland soils, and archaeological sites. The DOE would prepare separate documentation to assess effects for these resources after the specific borrow area was identified; impacts cannot be assessed at present because a detailed excavation plan has not been developed. Generic mitigation strategies for impacts are described in the following discussions for different resources, as applicable.

Soil and Geology. Construction of an on-site disposal cell for Alternative 6a would result in the permanent disruption of land at the site and the removal of soil currently in the area of the disposal cell. Contaminated soil would be placed in the MSA soil staging area until it could be placed in the disposal cell; uncontaminated soil would be used as fill on-site, as needed. Borrow material needed for on-site construction would be obtained from off-site sources. The excavation of soil from the potential 61-ha (150-acre) borrow site nearby would permanently disrupt portions of that area. Removal of borrow material from this area could have a long-term impact on prime farmland. Approximately 30% of the topsoil is mapped as Mexico fine loam, which is classified as a prime farmland soil (U.S. Soil Conservation Service 1982; Phillips 1992). Impacts to this soil would be mitigated by avoidance and, where necessary, by stockpiling topsoil (uppermost 0.6 m [2 ft]) during excavation and replacing it after removal of the underlying borrow material.

The regional geology of the Weldon Spring site and surrounding area would not be affected by implementation of Alternative 6a. Geological conditions are important mainly in terms of site suitability for construction of an on-site disposal cell; issues related to potential seismic events would be considered during detailed cell design. The potential impacts of an earthquake on a disposal cell could include landslides, liquefaction, and seismically induced settling of foundation soil and impounded waste, with subsequent failure of the disposal cell side slopes. The disposal cell design would incorporate appropriate protection against seismic damage to the integrity of the cell. A review of local conditions suggests that soil beneath the location of the proposed disposal cell is not susceptible to liquefaction or earthquake-induced settling (MK-Environmental Services Group 1991); this consideration would be further reviewed during final design if Alternative 6a were selected.

Water Quality and Hydrology. A system to monitor water quality over the long term would be implemented by incorporating design features into the disposal cell, installing monitoring wells around the perimeter of the cell, and regrading and revegetating the site following remedial activities. Under Alterative 6a, the original sources of surface water and groundwater contamination (e.g., the raffinate pits, soil in dump areas, and underground pipes) would be removed and placed in an engineered disposal cell on-site, thus eliminating the potential for additional impacts to those waters. The existing contamination in groundwater would remain and could migrate beyond the vicinity of the site. Over the long term, however, groundwater contamination resulting from past releases would be expected to gradually decrease, and any impact to hydrologically connected surface waters would also decrease. Current trends in water quality will be quantified as part of the analyses for the groundwater operable unit, for which separate environmental documentation will be prepared within the next several years.

No significant long-term hydrological impacts to the surrounding area would result from changes at the site. Runon and runoff controls would be used at the disposal cell, and the remaining areas of the site would be regraded to approximately original contours and would discharge surface runoff to existing off-site drainageways. Increases in surface runoff that might otherwise result from regrading would be minimized by revegetating the regraded areas to reduce runoff velocities.

Removal of borrow material from the potential site across from Francis Howell High School could have significant effects on the local hydrology at that area. However, no long-term effects on the quality of existing surface waters are expected. Construction of the borrow pit(s) would reduce surface water runoff from the affected area and could potentially result in the formation of up to about 21 ha (52 acres) of ponded water. However, the drainage to any pit would be limited because the potential borrow area is located on a plateau. Recharge to groundwater would be increased in the area of the borrow pit(s). Four wetlands are present in the potential borrow area (U.S. Fish and Wildlife Service 1989), and these could be eliminated as a result of the borrow activities, on the basis of current conceptual information. In addition, borrow activities could affect runoff to Prairie Lake, which receives drainage from the borrow area. Although the potential borrow area also drains to the Missouri River, construction of the borrow pit(s) would have no significant effect on the river. After removal of the borrow material, the borrow area could be contoured to control runoff and prevent ponding, the topsoil replaced, and the area revegetated. All activities associated with use of material from this borrow area and subsequent restoration activities would be coordinated with the state of Missouri.

At the completion of remedial action activities, the Weldon Spring site would be regraded and revegetated to prevent erosion. Final grading would ensure that the site would be well drained (i.e., no ponded water would be present on-site) to prevent any potential impacts to the disposal cell, and that current volumes of surface runoff to off-site streams would not be significantly altered. The drainages from Frog Pond, Ash Pond, and the raffinate pits would be returned to original conditions, and the only berms remaining would be those required to control runon and runoff at the disposal cell. Surface drainage at the disposal cell would be through sheet flow directed by embankment slopes and aprons onto the adjacent, gently sloping terrain. No concentrated flows would occur, and no directional structural elements for redirecting the flow would be required. The disposal cell would be actively monitored and maintained to prevent erosion. Periodic monitoring of nearby surface water and groundwater would continue, and periodic site inspections would be carried out to identify any damage to the disposal cell or other areas of the site from the erosive forces of heavy rains and wind, settling within the disposal cell, biointrusion, or severe natural phenomena such as an earthquake or a tornado. Maintenance activities would be performed as necessary.

A monitoring well system would be installed to enable the prompt detection of any localized releases from the disposal cell and the subsequent implementation of appropriate contingency plans. Monitoring wells would be placed around the disposal cell, close to the perimeter, to detect groundwater contamination that could result if liners failed. The leachate collection and removal system of the disposal cell would provide for additional monitoring of the containment system and early detection of potential leachate migration. Actual monitoring well locations would depend on the final facility location and design. The wells would be installed primarily in the uppermost weathered Burlington-Keokuk Limestone because this zone would likely exhibit the first effects of any cell release and is also the zone most likely to transport contaminants. The wells completed in the upper zone of the aquifer would serve as an early warning system to determine if any leachate generated from the disposal cell had percolated to the groundwater. Additional wells might be required to trace the extent of contamination, if detected, and its movement in the aquifer. Existing wells located in the general vicinity of the conceptual cell perimeter could be included in the disposal cell monitoring well network to either minimize the number of new wells constructed or provide additional monitoring capability. Angled monitoring wells might also be considered in the final system design. Unlike vertical monitoring wells, angle holes could provide direct monitoring beneath the disposal cell.

The selection of monitoring parameters would be based on the nature and placement of the waste in the cell (determined as part of final design), the ability to detect a particular parameter, the variability of the proposed parameter in background groundwater quality, and the effects of the unsaturated zone beneath the disposal cell on the mobility, stability, and persistence of the waste constituents. The parameters that are expected to be monitored in groundwater include uranium, major anions, and nitroaromatic compounds; these parameters are currently being monitored sitewide and in the surrounding area. Baseline conditions would be established by monitoring groundwater quality prior to and during cell construction. The final monitoring plan has not been developed but would probably include quarterly sampling at a number of locations for at least several years. (Additional discussion of groundwater monitoring is provided in Section 6.2.5.4.) The groundwater monitoring program would be developed in consultation with the state of Missouri and EPA Region VII.

Major springs in the area, such as Burgermeister Spring, would also be monitored for any indication of disposal cell failure. Because there is currently some contamination of springs from on-site sources, new baseline conditions would be established after the primary contaminant sources at the site were removed (including the raffinate pits and contaminated soil areas).

Potential effects on groundwater that might occur if the cell were to fail in the long term and no corrective measures were taken, e.g., under a hypothetical loss of institutional controls, were evaluated with a conservative analytical model. Details of the analysis are presented in

Appendix D and Tomasko (1992). The approach considers vertical transport of contaminants through the vadose (unsaturated) zone, mixing with groundwater in the saturated zone, and horizontal transport in the saturated zone to hypothetical receptor locations. The approach conservatively underestimates the time required for contaminants to reach a maximum concentration at the location of the receptor on the basis of the nature of groundwater flow in the site area.

Because the nature of the leachate expected from a disposal cell cannot be well defined until various treatability and design tests have been completed, the analysis considered a range of retardation values from highly mobile to relatively immobile. (Retardation values provide a measure of the relative movement of a contaminant through a porous medium compared with the ambient water; the higher the value, the more slowly the contaminant moves.) A retardation value of 1 was selected to represent a conservative solute (i.e., no retardation), such as nitrate; a value of 5 was chosen to represent contaminants that are relatively mobile in porous media, such as arsenic; and a value of 100 was selected to represent relatively immobile species, such as radium and thorium. The travel times estimated by this conservative method for dissolved contaminants to move from the bottom of a disposal cell at the Weldon Spring site through the vadose zone to the top of the water table and achieve a maximum concentration are summarized in Table 6.2.

Transport through the composite overburden material beneath a cell is assumed to occur under saturated conditions, with an average linear groundwater velocity equal to the harmonic

TABLE 6.2 Summary of Disposal Cell Failure Calculations for the Weldon Spring Site: One-Dimensional Vadose Zone[a]

Retardation	Maximum Concentration at Bottom of Unsaturated Zone (percent of initial concentration)	Time of Maximum Concentration at Bottom of Unsaturated Zone (years)
1	52	300
5	12	1,160
100	0.6	22,000

[a] These calculations include only the vertical flow component through the vadose (unsaturated) zone. The overburden is assumed to be 9.1 m (30 ft) thick and have a maximum hydraulic conductivity of 1.0×10^{-7} cm/s (3×10^{-4} ft/d) (see text).

mean hydraulic conductivity (Appendix D). For this evaluation, the thickness of the overburden was assumed to be 9.1 m (30 ft), and the saturated hydraulic conductivity was assumed to be 1×10^{-7} cm/s (3×10^{-4} ft/d). These values were chosen to be consistent with requirements of the state of Missouri for siting hazardous waste disposal facilities because they would be met (possibly by engineering to equivalents, e.g., by compaction) at the cell location. Although the Missouri siting criteria are not specifically applicable because characteristic waste would be treated so it no longer exhibited the hazardous characteristic, these criteria identify performance measures that would be addressed as part of cell design.

An analytical model was also used to calculate potential contaminant concentrations at hypothetical receptor locations. This model assumed a square-wave shape for the source at the water table below the location of the disposal cell. Because site-specific hydrological parameters permit a 100% contaminant breakthrough concentration at the receptor, peak breakthrough concentrations at the receptor could conservatively occur prior to the peak concentration at the vadose/phreatic zone interface (Tomasko 1992). The maximum solute concentration for a conservative solute (retardation value of 1) is estimated to be 0.14% of the initial concentration in leachate at all receptor locations considered in this calculation (Table 6.3). For moderately retarded solutes (retardation value of 5) and relatively immobile solutes (retardation value of 100), the maximum concentrations are estimated to be 0.032% and 0.0016%, respectively, at the hypothetical receptor locations.

The concentrations presented in Tables 6.2 and 6.3 are dimensionless (unitless) and are based on conservative assumptions. More representative concentrations can be obtained by multiplying the dimensionless concentrations by their corresponding source values in the leachate of the disposal cell. The estimated decrease in the maximum concentration between a release from the cell and arrival at the site boundary indicates that cell failure would have no significant effect on off-site groundwater quality (Tomasko 1992).

If groundwater monitoring indicated cell failure, resulting in conditions that were not protective of human health and the environment, a groundwater contingency plan would be implemented. The type of contingency response selected would depend on several factors, such as the lateral and vertical extent of contamination and the geochemical and physical properties of the contaminants. To address the potential for cell failure, various technologies that could be used as a contingency response — such as pump-and-treat systems, interceptor trenches, cutoff walls, in-situ chemical treatment, and in-situ biological treatment — will be reviewed and evaluated as part of the planning activities for detailed design and implementation.

The site is located on a shallow groundwater divide that trends east-northeasterly. The divide is located in the southern portion of the site (DOE 1992a). Groundwater north of the divide flows north toward Dardenne Creek, which is a tributary of the Mississippi River, whereas groundwater south of the divide flows south toward the Missouri River. On the basis of preliminary planning, the southern boundary of the conceptual disposal cell could coincide with this divide. Based on the water-table surface, groundwater would continue to flow beneath the disposal cell along these natural gradients; the presence of the disposal cell would not significantly disrupt the natural flow system.

TABLE 6.3 Summary of Disposal Cell Failure Calculations for the Weldon Spring Site: Entire Flow System[a]

Retardation	Maximum Concentration at Location of Receptors[b] (percent of initial concentration)	Time of Maximum Concentration at Location of Receptors[c] (years)
1	0.14	>300
5	0.032	>1,160
100	0.0016	>22,000

[a] These calculations are the combined results of three separate calculations: vertical flow through the vadose (unsaturated) zone, mixing, and lateral flow through the phreatic (saturated) zone.

[b] Hypothetical receptor locations are (1) the site boundary, (2) the closest downgradient well used for drinking water, and (3) the next closest downgradient well used for drinking water. These locations correspond to downgradient distances of 300 m (1,000 ft), 2.4 km (1.5 mi), and 4.0 km (2.5 mi), respectively. Results are the same for all locations. Groundwater flow is predominantly horizontal and to the north (DOE 1992a).

[c] Because of the conservative approach used, the times of maximum concentration are quantified here only as greater than corresponding times at the bottom of the vadose zone (see Table 6.2).

Two different groundwater flow models were developed for the Weldon Spring site to further evaluate the potential impact of the disposal cell on the ability to remediate contaminated groundwater. In the initial modeling effort, an analytical model was used to evaluate the feasibility of removing nonattenuated soluble contaminants from beneath the disposal cell. The results suggested that sufficient drawdown could be achieved so that the remediation capability would not be significantly affected by the presence of a disposal cell (MK-Environmental Services 1990). Subsequently, a more detailed, three-dimensional finite-element model was designed to better incorporate the conceptual characterization of the site hydrogeology. This numerical model included heterogeneity, anisotropy, and the varying thicknesses of the weathered and competent zones of the Burlington-Keokuk Limestone. The simulations were performed with the Coupled Fluid, Energy, and Solute Transport (CFEST) model developed by Gupta et al. (1986). This model was developed to help verify the current hydrogeologic conceptualization of the Weldon Spring site and to address whether the presence of a disposal cell would impact the ability to remediate groundwater beneath the cell. The results of the numerical modeling, which were based on an evaluation of steady-state groundwater flow velocity plots, indicate that groundwater would flow beneath the disposal cell along natural gradients (Durham 1992).

Therefore, the presence of a disposal cell at the Weldon Spring site would not significantly affect remediation capability for groundwater contamination.

Air Quality. Following waste removal and placement in a disposal cell, air quality at the Weldon Spring site over the long term would be similar to background conditions for the area. The cell cover would be designed and constructed to minimize the likelihood of any releases to the atmosphere. (Potential impacts that might occur if the cover were to fail are discussed in Section 6.2.4.) No long-term impacts on air quality are expected from use of the off-site borrow area because the disturbed site would be restored (e.g., regraded and revegetated) following its use, minimizing the potential for release of fugitive dust.

Biotic Resources. Following completion of all construction and excavation activities, disturbed areas on-site would be backfilled and revegetated. Fill material would consist of clean backfill and topsoil, and no long-term impacts to terrestrial biota are expected to result from the use of this material. Newly filled areas would be revegetated with native grass species, and some areas would be maintained (i.e., mowed), as required, for consistency with future uses of the site. A vegetation management program would be developed for the disposal cell area to prevent the establishment of large- and deep-rooted vegetation that could impact the integrity of the disposal cell.

The removal of contaminated soil, surface water, sediment, and vegetation at the site would prevent further exposure of terrestrial, aquatic, and semiaquatic vegetation and wildlife to contaminated media. Depending on the specific vegetation management plans developed for the site, some permanent loss of suitable habitat and vegetation could result from the implementation of Alternative 6a. However, no unique biota or critical habitats are known or expected to occur at the site, and the biota and habitats that are present occur elsewhere throughout the surrounding wildlife areas (DOE 1992a). The entire 88-ha (217-acre) site, including developed areas, represents less than 1.3% of the total habitat available in the surrounding Busch Wildlife Complex (684 ha [16,890 acres]), and the actual amount of relatively good quality habitat that would be temporarily lost (approximately 22 ha [55 acres] in the northern portion of the site) represents only about 0.3% of the available wildlife habitat in the Busch complex. Permanent loss of habitat would be limited to the area containing the disposal cell. The remaining regraded areas would be allowed to return to their natural state. Thus, the long-term loss of vegetation and wildlife habitat under Alternative 6a is not expected to significantly affect the terrestrial biotic resources of the area.

Under Alternative 6a, the removal of contaminated surface water and sediment would permanently eliminate all on-site surface water impoundments, including the raffinate pits, Ash Pond, and Frog Pond. The raffinate pits and the ponds are man-made, contaminated, and support very few fish (Frog Pond); however, they have been designated as wetlands by the National Wetlands Inventory (U.S. Fish and Wildlife Service 1989). The loss of these wetlands is not expected to significantly affect the wetland resources of the area. The on-site wetlands comprise approximately 15 ha (38 acres), which is about 6% of the total lacustrine and palustrine wetlands present in the surrounding Busch Wildlife Complex.

Compliance with Executive Order 11990, Protection of Wetlands, requires federal agencies to evaluate potential impacts on wetlands and to consider protection of wetlands to the extent possible in the decision-making process for all proposed actions; DOE has also established its own regulations (10 CFR 1022) for compliance with this order. As part of the compliance process, a floodplain/wetland assessment has been prepared (see Appendix H), and DOE has initiated wetlands consultations with the U.S. Army Corps of Engineers to determine the status of the on-site wetlands and the need for any wetland permits that could be required under Section 404 of the Clean Water Act (Hlohowskyj 1990). The Corps of Engineers determined that no permits for wetland filling or draining activities would be needed for the on-site wetlands because they occur within the boundary of an NPL site and are thus exempt from the requirements of Section 404 of the Clean Water Act (Jewett 1990).

The DOE also initiated consultations with the U.S. Fish and Wildlife Service regarding the need for mitigating the on-site wetlands that would be permanently lost as a result of remedial action (McCracken 1991a). The Fish and Wildlife Service suggested that DOE consider wetlands creation as a means of mitigating the loss of the on-site wetlands (Brabander 1991a), which is consistent with the DOE policy of no net loss of wetlands. The DOE has begun surveys of the on-site wetlands to document their size, type, and biotic composition. Upon completion of these surveys and additional consultations with the Fish and Wildlife Service and the Missouri Department of Conservation, DOE will develop a wetlands mitigation plan as part of the remedial action (McCracken 1991b; Nelson 1991). This plan will be incorporated into the comprehensive mitigation action plan that DOE will prepare to track mitigation commitments made in the forthcoming ROD, in accordance with DOE's procedures for implementing NEPA (10 CFR 1021).

The potential occurrence of several federal threatened, endangered, and candidate species — including the bald eagle, peregrine falcon, and pallid sturgeon — has been indicated for the general area of the Weldon Spring site (Tieger 1988; Brabander 1990, 1992). A biological assessment has been prepared to evaluate the potential for Alternative 6a to adversely affect these species (see Appendix I). This assessment has been submitted to the U.S. Fish and Wildlife Service for concurrence and is currently under review. No critical habitat occurs at the site for the bald eagle, and this species is not expected to frequent the site. The peregrine falcon is a transitory migrant through the area that could occasionally forage at the site for brief periods. Because of the absence of suitable habitat or their infrequent and transitory occurrence in the site vicinity, few or no impacts are anticipated to the bald eagle or peregrine falcon. Several state listed species also occur in the area. No surveys for these species have been initiated at on-site or off-site locations. The pied-billed grebe, a state rare species, has been observed at raffinate pits 2 and 4. Because Frog Pond and Ash Pond might represent suitable habitats for Blanding's turtle (state endangered), the ponds would be surveyed for the presence of this species before remedial activities were initiated. This species has historically been restricted to the extreme northeastern and northwestern corners of the state of Missouri (Johnson 1987) and has only recently been found in the Weldon Spring area (DOE 1992a). If found on-site, the turtles would be collected live and transferred to Busch Wildlife Complex personnel for release elsewhere in the complex. Loss of the Frog Pond and Ash Pond habitats would not be expected to adversely affect this turtle because suitable habitat occurs elsewhere in the Busch Wildlife Complex, the contaminated surface water and sediment of these on-site ponds might adversely affect individuals utilizing them, and the carrying capacity of the wildlife complex is not likely to be exceeded.

Following removal of contaminated sediment from Lakes 34, 35, and 36 in the Busch Wildlife Area, these habitats and their biota would be restored by the Missouri Department of Conservation under its lake drainage and sediment removal program. Thus, no permanent loss of aquatic habitats or biota is expected at these lakes following completion of Alternative 6a. Revegetation activities would be conducted at the vicinity properties, and no adverse affects to vegetation, wildlife, or habitats in the area are expected.

If institutional controls were lost at the site at some time in the future such that no corrective measures were taken if the cell failed, some contaminants would be released and would result in subsequent exposure of vegetation and wildlife, including federal and state listed species. The extent of potential habitat contamination and exposure of biota would depend on the extent and magnitude of contaminant migration following cell failure. However, these impacts are expected to be minor because the highly contaminated material would have been treated to resist leaching and the disposal cell would be designed and constructed in a manner to be effective for at least 200 years and up to 1,000 years.

Borrow (fill) material would be obtained from an off-site source; the representative source evaluated for this analysis is a 61-ha (150-acre) tract of land located opposite Francis Howell High School (Section 5.2.1.10). This area supports a variety of vegetation types, including (1) early successional old fields dominated by herbaceous plants (e.g., goldenrod, aster, and grasses), (2) agricultural fields of milo (a sorghum), and (3) narrow strips of trees (e.g., cottonwood, willow, and elm) along shallow ravines. Red cedar trees are scattered across the area. Up to 21 ha (52 acres) of that site would be disturbed to provide borrow material, either as a single borrow area or as several smaller ones. The loggerhead shrike (*Lanius ludovicianus*), a federal Category 2 (C2) species, has been reported from this potential borrow area. This species is considered a probable nesting species in the area (Missouri Department of Conservation 1991), and may be nesting in that location. Additionally, the potential borrow area may provide suitable habitat for Bachman's sparrow (*Aimophila aestivalis*), also a C2 species. Thus, removal of borrow material could result in the loss of potential nesting habitat for one or both of these species (see Appendix I). Except for potential impacts to prime farmland (Section 6.2.3.3), removal of borrow material would not be expected to impact any other unique or sensitive biotic resources because the site is largely old fields or agricultural fields.

Socioeconomics and Land Use. The area of the disposal cell is estimated to be about 17 ha (42 acres), which represents about 19% of the site; this land would be permanently dedicated to waste disposal. The cell would have a maximum height of about 23 m (74 ft) when completed. On the basis of this height and overall size, the visual impact on the surrounding area could be considerable; however, the adjacent terrain is hilly and removal of existing structures would create a net improvement in the aesthetic character of the site. In addition, the land area that would be dedicated to waste disposal is a very small fraction of the total amount of available land in the site area, which includes thousands of acres of surrounding wildlife areas. No change would be expected in local population growth, nearby industrial and commercial operations, or land-use patterns. The net long-term impact of Alternative 6a on these factors is expected to be positive because the site waste would be isolated and controlled. The removal of soil from a nearby representative borrow area might impact prime farmland at that location, but mitigative measures would be taken to minimize impacts, and most of that area supports recreational use so no significant changes in land use are expected.

Cultural Resources. Alternative 6a would not adversely affect archaeological sites or cultural resources. In 1986, the Missouri State Historic Preservation Officer (SHPO) determined that an archaeological survey of the chemical plant area was not required because of prior disturbance to the area, a low potential for archaeological remains, and possible health risks (Weichman 1986).

Excavation at the representative 61-ha (150-acre) borrow area could impact archaeological sites, but adverse effects to sites that meet eligibility criteria for the *National Register of Historic Places* would be mitigated through avoidance or data recovery. The area south of State Route 94 that has been identified as a possible general location for the nearby borrow source was subject to file data review and an archaeological field survey. The field survey consisted of a walkover at 15- to 23-m (50- to 75-ft) transect intervals and shovel testing at 23-m (75-ft) intervals along the same transects (Walters 1992). Sixteen archaeological sites (1 historic and 15 prehistoric) were recorded in or adjacent to the potential borrow site area, and three sites (all prehistoric) were recorded along a corridor identified as a potential haul road for excavated borrow material. Eleven prehistoric sites located within the borrow area apparently contain undisturbed buried remains (i.e., artifacts deposited below the plow zone). Any of these sites that would be subject to unavoidable adverse effects (i.e., disturbance or destruction) would require testing to determine *National Register* eligibility. Sites determined eligible by the Missouri SHPO would be subject to mitigative data recovery (i.e., excavation) (Hansman 1992).

6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Several treatment technologies would be implemented for different media under Alternative 6a, as identified in Section 5.2.2. Several of these technologies are common to all of the final action alternatives, such as volume reduction of structural material, composting of wooden debris, and incineration of liquid process chemicals. Evaluation of the reduction of toxicity, mobility, and volume through treatment for these technologies is discussed in Chapters 3, 4, and 5. The treatment method that is unique to Alternative 6a is chemical stabilization/solidification. This method would be used to treat the sludge and soil from the raffinate pits, soil from the quarry (in storage at the TSA), and process waste from the water treatment plants. The chemical treatment of these materials would address the principal threats associated with contamination at the Weldon Spring site by significantly reducing contaminant mobility.

The entire volume of raffinate pit sludge (168,000 m^3 [220,000 yd^3]) and about 30% of the contaminated soil (76,500 m^3 [100,000 yd^3]) would be treated by chemical stabilization/solidification. The chemically stabilized/solidified material would increase 32% in volume and

64% in weight as a result of the addition of cement and fly ash. This corresponds to a total treated volume of 327,000 m^3 (428,000 yd^3) and a total weight of 557,700 t (614,700 tons) for that material. The overall waste volume would increase by 12% for this alternative. The inherent toxicity of the waste would not be reduced.

The mobility of contaminants in the chemically stabilized/solidified material would be reduced as a result of adsorption onto ferric hydroxide precipitates, precipitation as relatively insoluble hydroxide compounds, and/or encapsulation into the cement-like mineral structure (MK-Ferguson Company and Jacobs Engineering Group 1992a). The cement-like reactions that occur during chemical stabilization/solidification cause a significant decrease in permeability and loss of free water. Upon cessation of free water drainage, soluble contaminants can only be mobilized through leaching.

The degree of mobility of contaminants in a treated waste form is indicated by leach resistance. Recent testing of chemically stabilized/solidified waste from the Weldon Spring site indicated that the stabilized waste would pass the TCLP test (see Table 4.2) (Waste Technologies Group 1992). Previous Oak Ridge National Laboratory studies have also demonstrated the ability of cement-stabilized waste to immobilize metals (Gilliam and Loflen 1986; Gilliam et al. 1985). The chemical stabilization/solidification process has been used for wastes containing various contaminant types. For example, the immobilization of PCBs in soil has been demonstrated using a cement-like proprietary additive; and soil contaminated with PCBs, volatile organics, and metals has passed the TCLP test after chemical stabilization using proprietary additives and pozzolanic materials (MK-Ferguson Company and Jacobs Engineering Group 1992b).

Contaminant release from chemically stabilized/solidified material is a diffusion-controlled process. Contaminant flux is regulated by the initial contaminant concentration in the waste, the contaminant-specific diffusion coefficients in the treated waste, and the surface-to-volume ratio of the leaching solid. Leachability indexes (defined as the negative logarithm of the diffusion coefficient) indicate relative degrees of leach resistance, ranging from 7 to 15 (readily leachable to immobile). Leachability indexes for chemically stabilized waste range from more than 10 for metals to about 8 for organic compounds and nitrates (Gilliam 1990). Bishop (1988) developed a formula based on Fick's first law of diffusion to estimate diffusion-controlled contaminant release from a chemically stabilized/solidified waste. The calculated time to leach 100% of a contaminant for given leachability indexes and waste particle surface-to-volume ratios (as indicated by the diameter of a particle of chemically stabilized/solidified material) is given in Table 6.4. Highly immobile contaminants have relatively high leachability indexes and are contained in large fragments or monolithic forms. Under Alternative 6a, the chemically stabilized/solidified waste would be placed in the cell as a grout and would set up as a monolithic solid. Potential fracturing of the stabilized waste would increase the surface-to-volume ratio, thus increasing leach rates; however, the expected fracturing of the waste material in an intact disposal cell is not expected to increase the surface-to-volume ratio significantly.

Different chemically stabilized/solidified waste products have shown a wide range of contaminant leach rates. The mechanisms of contaminant attenuation within the treated product

TABLE 6.4 Estimated Time to Leach 100% of Contaminants[a]

Leachability Index	Leaching Time Relative to Particle Diameter	
	1-inch Diameter	10-inch Diameter
7	61 hours	253 days
8	25 days	7 years
9	253 days	69 years
10	7 years	692 years
11	69 years	6,920 years
12	692 years	6,920 years
13	6,920 years	>6,920 years
14	>6,920 years	>6,920 years
15	>6,920 years	>6,920 years

[a] Based on solving for t_n in the equation

$$P = 1.128(10^{-0.5Lx})(t_n^{0.5})(s/v)$$

where: P = percent leached, set equal to 100%; Lx = leachability index; t_n = time, in seconds; and s/v = surface-to-volume ratio, in cm^{-1} (Bishop 1988).

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

are not sufficiently understood to allow quantitative predictions of the degree of contaminant isolation. One factor that could impact the leachability of the chemically stabilized waste is the presence of set-inhibiting compounds in the waste. Leachability is a function of exposed surface area, so a treated waste containing set-inhibiting compounds could degrade more rapidly than a treated waste containing no set inhibitors because the waste containing set inhibitors would fracture more easily, thereby increasing the exposed surface area and making it more susceptible to leaching.

Contaminants that can impact the setting characteristics of chemically stabilized/ solidified waste include halides, sulfates, arsenates, phosphates, and various organic compounds such as nitroaromatics (MK-Ferguson Company and Jacobs Engineering Group 1992a). Halides and arsenates are present in the raffinate pit sludge and site soil, but at concentrations below set-inhibiting levels. Setting interferences caused by sulfates would be prevented by selecting specific reagent types, i.e., Type II Portland cement and Class F fly ash (MK-Ferguson Company and Jacobs Engineering Group 1992b). Sludge containing phosphates at much higher levels than is present in the Weldon Spring sludge and soil has been successfully stabilized at other sites (MK-Ferguson Company and Jacobs Engineering Group 1992b). Localized zones of soil from the quarry contain about 2% total nitroaromatics (DOE 1990b). Tests have shown that similar low levels of phenolic compounds (2%) decrease the final set strength of chemically stabilized/ solidified waste (MK-Ferguson Company and Jacobs Engineering Group 1992b). Even if the nitroaromatic compounds behaved similarly to phenolic compounds, these localized zones of nitroaromatics would be distributed during excavation and treatment and the resulting concentrations would not be expected to decrease the final set strength significantly. Bench-scale testing of chemical stabilization/solidification of the quarry soil is currently under way. If nitroaromatic compounds prove to interfere with stabilization, the soil could be pretreated by composting to reduce the concentration of nitroaromatics prior to chemical stabilization/solidification.

Another important parameter in determining the strength and porosity of chemically stabilized/solidified waste is the water-to-cement ratio. Further bench-scale and pilot-scale studies would be conducted to define the leachability of contaminants from chemically stabilized/solidified Weldon Spring waste and to optimize the treatment process to address these considerations.

Very limited information on the expected longevity of chemically stabilized/solidified waste is reported in the literature (MK-Ferguson Company and Jacobs Engineering Group 1992b). The long-term stability would also depend on the integrity of the engineered disposal cell. The disposal cell would be designed to protect the treated waste from infiltrating water and freeze/thaw temperature variations, and the waste would not deteriorate as long as this protection was maintained. If it were hypothetically assumed that the disposal cell cover failed and no corrective measures were taken so that water could infiltrate into the cell, this water could react with the cement-like material binding the contaminated media (e.g., by hydration), such that the treated product could begin to dissolve and weaken over time. During dissolution and weakening, contaminant leaching would increase because of increased contaminant diffusion through the solidified waste as a result of differential solutioning in fractures, degradation of the cement matrix, and an increased surface-to-volume ratio from fracturing and crushing (MK-Ferguson Company and Jacobs Engineering Group 1992b).

The mobility of metals is generally increased in acidic solutions. Cement-stabilized products typically have a high capacity to buffer acidic solutions because of their alkaline constituents, e.g., calcium hydroxide [$Ca(OH)_2$]. The pH buffering capacity of the chemically stabilized/solidified waste can act to neutralize infiltrating solutions and thus maintain an alkaline, less corrosive leachate (MK-Ferguson Company and Jacobs Engineering Group 1992b). Chemically stabilized/solidified material produced at another site was reported to have a buffering capacity of 3.89×10^{-3} meq/g at a pH equal to or greater than 7 (MK-Ferguson Company and Jacobs Engineering Group 1992a). The same buffering capacity for the chemically stabilized/solidified waste at the Weldon Spring site would maintain any generated leachate at or above a pH of 7 (neutral pH) for a period of about 100 years, even under continued exposure to acid rain conditions. Therefore, rapid dissolution of the stabilized mass by acidic conditions is unlikely.

Limited data are available to quantify the durability of chemically stabilized/solidified waste upon exposure to the environment, i.e., if the disposal cell failed and no corrective actions were taken. The durability of the product after failure would depend upon the degree of failure and the quantity and quality of infiltrating water. Contaminants would leach from the cement matrix slowly over time, and the leach rate would increase with an increase in dissolution or fracturing of the treated waste. Because it is possible that the chemically treated product could eventually be leached and degraded if it were assumed that the waste was continuously exposed to the environment over a long period of time, the chemical stabilization/solidification process could be considered not entirely irreversible. However, because the disposal cell would be designed to last for at least 200 to 1,000 years and monitoring and maintenance activities would be conducted for the long term, the likelihood of this waste exposure scenario is very low.

Treatment residuals from the chemical stabilization/solidification process would include ventilation filters from the fly ash and cement storage silos and ventilation filters from the building housing the mixing equipment. Washdown water and sediment would be returned to the treatment system, and equipment would be sealed to minimize generation of dust. Filters contaminated during the treatment process would be placed in the disposal cell.

6.2.5 Short-Term Effectiveness

6.2.5.1 Duration of Remedial Activities

Remedial action activities under Alternative 6a are expected to be completed in about 10 years, excluding long-term maintenance. The waste removal component of Alternative 6a would be completed in about 7 years and would be performed in parallel with treatment and disposal activities. Approximately 9 years would be required to complete all activities associated with chemically stabilizing/solidifying the raffinate pit sludge and more highly contaminated soil. Testing, design, construction, and start-up would require approximately 4 to 5 years; and the treatment plant would operate for 4.5 years — assuming 20 work days per month, 9 months per year, and allowing for a 3-month winter shutdown. Construction and operation of all three phases of the disposal cell would require about 8 years.

6.2.5.2 Protection of Workers

On-site workers during the remedial action period would include both remedial action workers and on-site office workers. The remedial action worker requirements for implementing Alternative 6a are estimated to be about 560 person-years. In addition, about 200 individuals would be working on-site in the project office building during this period. To minimize potential occupational exposures to contaminants, remedial action activities would be conducted in accordance with applicable regulatory limits and health and safety plans developed for the Weldon Spring site.

The potential occupational impacts associated with the specific handling and treatment processes were estimated on the basis of the assumptions presented in detail in Appendix F. The health risks (measured in terms of the incremental lifetime risk of cancer induction) to the maximally exposed remedial action worker are estimated to be approximately 1×10^{-3} and 8×10^{-5} for exposure to radioactive and chemical contaminants, respectively. The collective risk to the entire remedial action work force from radiation exposure is estimated to be 9×10^{-2}. Although some potential exists for noncarcinogenic effects (i.e., the hazard index to the maximally exposed remedial action worker was estimated to be greater than 1), use of protective clothing and respiratory protective equipment would minimize the likelihood of such effects. Thus, actual exposures to contaminants would be well below applicable regulatory limits. On the basis of statistics for construction activities of comparable size and scope, no occupational fatalities are expected to occur during implementation of Alternative 6a; approximately 82 cases of occupational injury are estimated to occur, with about 790 lost workdays. Alternative 6a could be implemented in a manner that would not jeopardize the safety of workers (Appendix F, Section F.6).

6.2.5.3 Protection of the Public

During implementation of Alternative 6a, the general public could be exposed to radioactive and chemical contaminants released from the site via airborne dust and gaseous emissions. The principal activities resulting in the generation of fugitive dust and gases would be waste excavation, treatment, loading/unloading, and grading. Estimates of related emissions are presented in detail in Appendix C. Airborne releases resulting from accidents occurring on-site would be small compared with releases from routine remedial action activities. Potential exposures to members of the general public during the remedial action period were estimated on the basis of the conservative scenario definitions and assumptions presented in detail in Appendix F.

Inhalation of airborne contaminants is the most probable route of exposure from site releases for the general public during the remedial action period. The risk assessment results indicate that no significant incremental health impacts are predicted at the off-site receptor locations for the general public. The health risks to the maximally exposed member of the public are estimated to be 6×10^{-7} and 3×10^{-8} for exposure to radioactive and chemical contaminants, respectively. The hazard index is much less than 1, indicating that no noncarcinogenic effects are anticipated. The collective radiological risk to the population within 5 and 80 km (3 and 50 mi) of the site are estimated to be 3×10^{-3} (for a population of 10,700) and 2×10^{-2} (for a population of about 3 million), respectively; the actual radius of impact would likely be less than 5 km (3 mi). No adverse impacts to off-site individuals are expected as a result of contaminant releases during implementation of this alternative (Appendix F, Section F.6).

6.2.5.4 Environmental Protection

Soil. Soil disturbance during implementation of Alternative 6a would result primarily from preparation of the disposal cell location, construction of access roads, and excavation of contaminated areas and borrow areas. Construction and excavation activities could potentially disturb a large fraction of soil on the 88-ha (217-acre) site, as well as soil at the vicinity properties and access roads.

Construction and excavation activities at the site could result in the erosion of exposed soil areas. Good engineering practices and mitigative measures, such as straw bales and siltation ponds, would be used to minimize potential erosion and sediment transport as needed. Following completion of all construction and excavation activities, disturbed areas would be filled with clean backfill and topsoil and revegetated with native grasses. These areas would be maintained, as required, in accordance with future uses of the site.

Construction and excavation activities associated with use of a nearby borrow area and development of an associated haul road could also result in the erosion of exposed soil areas. On the basis of current conceptual plans, in addition to the 21 ha (52 acres) of possible excavation impacts (Section 6.2.3.3), 13 ha (33 acres) would be subject to temporary surficial disturbance during soil removal due to creation of an access road, topsoil stockpile areas, and equipment parking locations. As for on-site activities, good engineering practices and mitigative measures would be used to minimize erosion and sediment transport.

Contamination of off-site soil could potentially result from spills of contaminated materials being hauled to the site from vicinity properties or from spills of containerized liquid waste during transport to an off-site incinerator. Contingency plans would be in place to address the removal of spilled material and contaminated soil (or other surface material) from the area of an off-site spill. The potential for off-site spills under Alternative 6a is very low because of the small total distances over which containerized chemicals and contaminated materials would be moved (see Appendix F, Section F.7.1). The estimated number of relevant transportation-related accidents is much less than 1.

Water Quality and Hydrology. Construction and excavation activities at the site could result in the release of sediment and fugitive dust and the subsequent transport of this material to nearby surface water. Waste-handling activities (e.g., transportation) could also generate dust, resulting in increased sediment loading of surface runoff. Contaminants adsorbed to sediment or dust and contaminants dissolved or suspended in surface runoff could also be transported to off-site surface water during the action period. These potential short-term impacts would be minimized, as discussed below.

Good engineering practices and mitigative measures would be used during construction and excavation to minimize water erosion and the transport of sediment and contaminants from exposed areas. These measures would include surface grading; using berms and silt fences; covering surfaces with straw, mulch, riprap, or geotextile membranes; and using revegetation mats in those areas with high water velocity. Surface runon and runoff controls would be implemented at the site to minimize transport of sediment and/or contaminants to off-site areas (e.g., the site would be graded to divert storm flows around exposed areas). Siltation ponds would be constructed near the perimeter of the site, as necessary, to further minimize the off-site transport of sediment or contaminated surface runoff by collecting runoff draining to the site perimeter. Potentially contaminated surface runoff, including any water that had come in contact with contaminated areas or had been used for dust control in contaminated areas, would be collected in the ponds and monitored for contaminants. Water that was determined to be contaminated would be transferred to the newly constructed on-site water treatment plant for treatment and then released off-site in batches. (To determine whether treatment was needed, contaminant concentrations in the collected water would be compared with the NPDES limits established for the water treatment action [Section 1.5.1.4]; these limits are near drinking water quality.) The NPDES standards for treatment of runoff from construction areas to control suspended solids would be met before water would be released to off-site areas from the siltation ponds. Sediment would be removed from the siltation ponds periodically and sampled for contaminants. Contaminated sediment would be retained for disposal on-site.

Activities associated with excavation of a borrow area and construction and use of a related haul road could release sediment and fugitive dust that might reach nearby surface water. As for on-site activities, good engineering practices and mitigative measures would be used to control releases of fugitive dust and to minimize water erosion and the transport of sediment from exposed areas. On the basis of preliminary engineering information, surface modifications at the borrow area and haul road could eliminate four wetlands present at that area and would affect surface runoff during the action period. Runoff from the haul road and borrow area could initially increase. However, a depression would be created by removal of the borrow material, which would subsequently result in decreased runoff from the borrow area and increased recharge to groundwater. Only small effects on surface water quality are expected outside the borrow area because most runoff would be contained in the excavated area and mitigative measures would be used to control movement of sediment outside that area.

The potential for short-term impacts to surface water from other sources would also be minimized. A contingency plan would be in place to address cleanup of any spills of contaminated materials or chemicals. All decontamination water would be monitored, and any water determined to be contaminated would be treated in the on-site water treatment plant before release. Mitigative measures for reducing fugitive dust generation — such as wetting surfaces, using dust suppressants, and controlling water erosion — would minimize the potential for contaminated airborne particulates to impact off-site surface water. Surface water in the vicinity of the site would be monitored in accordance with the existing permit to assess changes in contaminant concentrations and potential impacts to water quality during the action period. If any increased levels of contaminants were detected, appropriate action would be taken to further control migration of contaminants and to mitigate potential adverse impacts.

During the action period, the surface water hydrology of the site would be affected by paving or altering surfaces and by excavating several contaminated areas. Surface modifications at support areas, along roads, and during excavation and preparation of the disposal cell would tend to increase surface water runoff. The berms around the raffinate pits would be removed following excavation of the contaminated sludge from the pits. Runon and runoff controls implemented to mitigate off-site transport of sediment or contaminants would also change existing runoff patterns. Off-site hydrological impacts resulting from changes at the site are expected to be small because the area impacted is a small fraction of the drainage areas and runoff from the site would be controlled by siltation ponds. The National Flood Insurance Rate Maps for St. Charles County (Federal Insurance Administration 1978) indicate that a portion of the Weldon Spring site (the area west of Ash Pond along the site fence line) and vicinity property A6 lie within the headwaters of the Schote Creek 100-year floodplain (see Appendix H).

The removal of contaminated soil and sediment from these areas would temporarily affect up to about 0.6 ha (1.4 acres) of floodplain along the drainage leading from the Ash Pond area; this area represents a very small portion (<0.001%) of the entire Schote Creek 100-year floodplain. No significant impacts to flood storage volume are anticipated because the area of floodplain that would be disturbed is small and the area would be restored to its original contours upon completion of remedial activities.

Effluent from the site water treatment plant that would be released to the Missouri River (Section 1.5.1.4) would be of high quality, so related surface water impacts would be negligible (MacDonell et al. 1990). Additional water from surface runoff impounded in the perimeter siltation ponds would also be treated in the on-site water treatment plant if it contained contaminants at levels exceeding the concentration limits specified in the existing NPDES permit. The decreased volume of water discharged to drainages off-site as a result of retention in the on-site siltation ponds would alter the surface runoff from the site. Following remedial action, the current off-site discharges from the former process and sanitary sewer systems to the Southeast Drainage and the current releases of contaminated surface runoff to the Southeast Drainage and the other off-site drainages would cease. Thus, Alternative 6a would have a positive impact on surface water in the vicinity of the site because the quality of water leaving the site would be improved. (The Southeast Drainage will be addressed as part of a separate response action within the next several years.)

Groundwater concerns in the short term would be addressed by implementing source control actions, i.e., removing the sources of groundwater contamination, and by monitoring to ensure initiation of a timely response, if needed. (Groundwater is being addressed as a separate action for the project, for which documentation will be prepared within the next several years.) The existing groundwater monitoring program would be expanded to evaluate the protectiveness of Alternative 6a during and after removal of the contaminated sources. The primary source areas at Weldon Spring include the raffinate pit sludge and the soil in the areas of Ash Pond, Frog Pond, North Dump, South Dump, raffinate pits, site water treatment plant, and short-term storage areas (Figure 1.3). A monitoring well network surrounding the primary contaminant source areas would provide information on groundwater quality to establish baseline conditions, to monitor groundwater elevations and concentrations during source removal (e.g., soil and raffinate pit sludge), and to evaluate the effect that removal of contaminated soil and sludge has on groundwater. For each source area, the number of wells needed to provide adequate monitoring would depend primarily on the volume and concentration of contaminated material to be removed and the permeability and thickness of the overburden.

On the basis of an initial assessment of the current monitoring well network (Figure 6.1), it appears that approximately four additional monitoring wells might be appropriate in the vicinity of the raffinate pits, Ash Pond, and South Dump. Additional monitoring in these areas may be necessary because of the extent and depth of contaminated material and because the clay till in these areas, which comprises part of the overburden, is not as thick (less than 3 m [10 ft]) relative to other areas on the site. The four new wells would be completed in the upper weathered zone of the Burlington-Keokuk Limestone. Three of the proposed wells would be

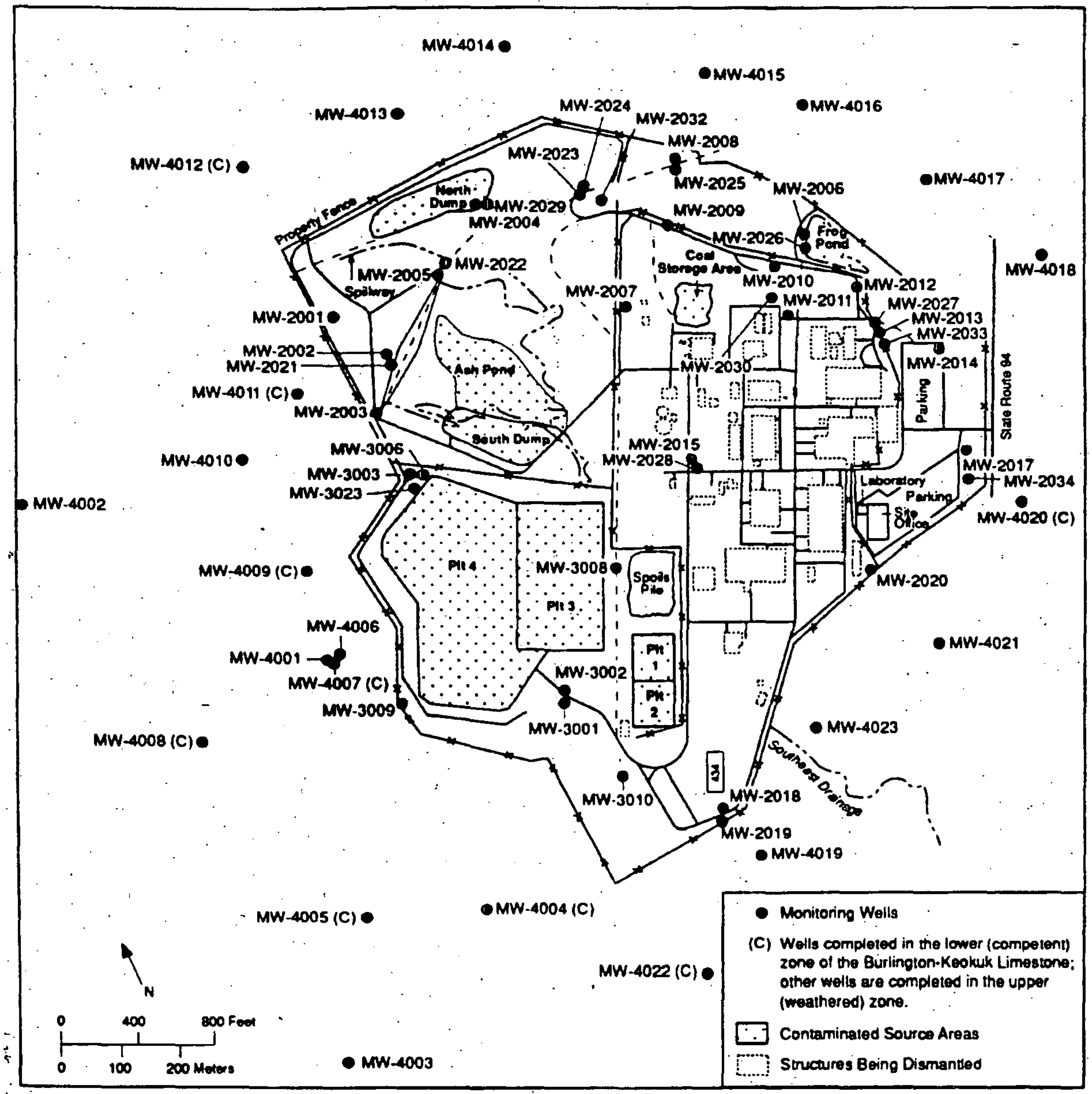

FIGURE 6.1 Current Monitoring Well Network for the Weldon Spring Site

downgradient wells installed north of Ash Pond within the site boundary — one between MW-2002 and MW-2005, one near MW-2022, and the third between MW-2004 and MW-2024. These locations correspond to a surficial drainage area and a bedrock valley low that are consistent with the location of a preferred groundwater pathway. The fourth well would also be constructed in the upper weathered Burlington-Keokuk Limestone west of raffinate pit 4, near MW-4009, to provide additional monitoring in the upper aquifer near the raffinate pits. The remaining source areas appear to be adequately monitored by the current monitoring well network.

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. For example, it is likely that the monitoring frequency would be higher in the vicinity of Ash Pond, the raffinate pits, and the South Dump where the overburden is not as thick and the extent, depth, and level of soil contamination is greater than at other areas of the site. The monitoring parameters would depend on the contaminant(s) in the material being removed from a particular area and on the mobility, stability, and persistence of the particular contaminant(s). As part of the final monitoring design, major springs in the area, such as Burgermeister Spring, would also be monitored for changes in water quality during source removal activities. Monitoring parameters for the springs would probably be the same as those for groundwater; however, the frequency of sampling would be seasonal (quarterly) and based on precipitation events.

Air Quality. Ambient air quality in areas accessible to the general public is regulated by both state and federal standards. Missouri standards are the same as the national ambient air quality standards (Appendix G, Table G.2); these standards address six pollutants: sulfur oxides (as sulfur dioxide), carbon monoxide, ozone, nitrogen dioxide, lead, and particulates as PM-10 (i.e., particles with an aerodynamic mean diameter ≤10 µm). Because Alternative 6a, (and the other final action alternatives) involves primarily construction and earth-moving activities, the most significant air quality impacts would result from fugitive dust that could increase PM-10 concentrations. The exhaust emissions from heavy equipment would not be expected to significantly impact air quality, and nonparticulate pollutants are not expected to occur at high levels (Appendix C). Potential health impacts from radioactive and chemical contaminants associated with airborne particulates are identified in Section 6.2.5.2 (for workers) and Section 6.2.5.3 (for members of the general public).

Both annual average and 24-hour particulate emissions were modeled and compared with ambient standards; details of the modeling analysis are presented in Appendix C. The emissions generated by remedial action activities were assumed to be limited by standard techniques for fugitive dust control. The actual techniques that would be used will be specified in more detail in subsequent engineering studies; the techniques discussed in Appendix C, Section C.3.5, are representative of those that are expected to be used.

The annual average air quality standard for PM-10 is 50 $\mu g/m^3$, as the annual arithmetic mean; this value is based on measured daily concentrations over 3 years or predicted daily concentrations for 1 year. The 24-hour standard for PM-10 is 150 $\mu g/m^3$, with not more than three expected exceedances permitted in any three consecutive years. The highest annual average particulate concentration predicted for an off-site location during the remedial action period at the Weldon Spring site is estimated to be 8.5 $\mu g/m^3$ above background (the background PM-10 concentration is 24 $\mu g/m^3$ for the rural St. Louis area). This concentration would occur at the site perimeter near the north gate and is primarily associated with operation of the construction material staging area (uncontaminated material) and related road traffic. The PM-10 concentration would be highest at this location because the predominant wind direction at the site is from the south. The highest concentration estimated for an off-site receptor location is 1.1 $\mu g/m^3$ above background (at the highway maintenance facility), which is considerably below the annual air quality standard for PM-10. The highest 24-hour PM-10 concentration for an off-site location is estimated to be 280 $\mu g/m^3$ above background at the site perimeter near Frog Pond; the major contributor to this value would be backfilling operations with uncontaminated soil. The highest 24-hour PM-10 concentrations estimated for all other locations, except near the site boundary, are considerably below the 24-hour air quality standard (including background) (Appendix C, Section C.1.3.1).

The air quality at nearby receptor locations could be impacted during the cleanup period by the removal of uncontaminated material from the proposed borrow area across from Francis Howell High School and transport to the site for use in backfilling and cell construction. On the basis of the expected rate for borrow operations, the worst-case annual and maximum 24-hour concentrations are estimated to be 2.7 and 28 $\mu g/m^3$ above background, respectively, at Francis Howell High School. Dust control measures would be implemented, as necessary, at the borrow area and haul road to minimize any air quality impacts from uncontaminated fugitive dust (Appendix C, Section C.1.3.3).

In general, particulate emissions that could result from cleanup activities at the Weldon Spring site are expected to be relatively low. These emissions are not expected to impact human health or the environment because (1) the emissions would occur over a wide area, (2) the major contaminated source areas are located away from the site boundary, (3) much of the contaminated material would be handled in a wet condition, and (4) the work would be carried out by one work shift during daytime hours, which is when atmospheric dispersion conditions are the most favorable. Appropriate dust control practices would be used for activities adjacent to the site boundary so the potential air quality impacts associated with the proposed action would be relatively minor.

Biotic Resources. The short-term disturbance of on-site vegetation and wildlife habitat under Alternative 6a would result primarily from activities associated with (1) construction of the disposal cell, runon and runoff controls, material staging areas, and access roads and (2) excavation of contaminated soil and sediment. Local biota would be impacted primarily by habitat loss. Construction and excavation activities could temporarily eliminate up to 72 ha (179 acres) of vegetation and wildlife habitat at the site, including approximately 22 ha (55 acres) of relatively undisturbed old-field and upland forest habitats that occur in the northern portion of the site. The amount, type, and relative quality of terrestrial habitats that could be disturbed as a result of construction and excavation activities are listed in Table 6.5.

TABLE 6.5 Terrestrial Wildlife Habitats Potentially Affected by Remedial Action

Location	Area (acres)	Habitat Type	Relative Habitat Quality[a]
Raffinate pits area soil	34	Mowed grassland	Poor
Construction material staging area	8	Shrub and forest	Good
North access road	0.3	Grassland	Good
Area of potential disposal cell footprint	42	Mixture of shrub, old field, mowed grassland, and forest	Poor to good
Siltation ponds	14	Forest and mowed grassland	Good (forest) Poor (grassland)
North Dump area	1.9	Forest	Good
South Dump area	4.2	Shrub and grassland	Good
Ash Pond area	8.6	Mixture of shrub, old field, grassland, and forest	Good
Frog Pond area	1.9	Forest	Good
Chemical plant area (around chemical plant buildings and the coal storage area)	35	Mowed grassland	Poor
Off-site borrow area	52	Old field and agricultural fields	Good

[a] Quality assessment is based on habitat structure, appearance, and expected ability to support populations of desirable wildlife species but does not include consideration of contamination. This assessment was conducted by Argonne National Laboratory staff during site visits (Hlohowskyj 1992).

Alternative 6a would result in the permanent loss of approximately 15 ha (38 acres) of aquatic habitat at the site, including the raffinate pits, Ash Pond, and Frog Pond. During and following the remedial action, resident and migratory waterfowl and shorebirds would no longer be able to use these areas for nesting, feeding, and resting. Some resident biota (e.g., green sunfish, turtles, and frogs from Frog Pond) would be lost. The aquatic biota and habitats at the site are not unique to the area and can be found elsewhere in the Busch Wildlife Complex and St. Charles County.

Implementation of Alternative 6a would require the construction of an access road to the site for delivery of construction materials. Construction of this road would disturb a small amount of additional habitat within the Busch Wildlife Complex. The habitat, vegetation, and wildlife in this area are not unique and represent only a very small fraction of the total biotic resources within the Busch Wildlife Complex (DOE 1992a). Upon completion of all construction and remedial activities, the construction access road would be restored and would again provide suitable habitat for vegetation and wildlife.

Construction and excavation activities on-site would disturb large amounts of soil and would potentially result in increased erosion and fugitive dust emissions at the site that could impact terrestrial and aquatic habitats in the area. Increased erosion could temporarily increase turbidity and sedimentation in some local streams and lakes that receive drainage or runoff from the site. In addition, surface runoff could introduce soluble or sediment-bound contaminants to off-site aquatic habitats. To minimize potential impacts, erosion and fugitive dust control measures (e.g., use of water sprays and chemical dust suppressants) would be implemented during all construction and excavation activities. At uncontaminated areas, standard mitigative measures would involve the use of berms, silt fences, straw bales, and revegetation mats to reduce and control erosion during and after construction activities. At contaminated areas, mitigative measures such as dikes, siltation ponds (Figure 5.2), and drainage channels to drain and collect runoff would be implemented to control runoff and runon, thereby limiting the transport of contaminated sediment and soil. Thus, impacts to off-site aquatic resources from erosion and surface runoff are expected to be minor. Accidental spills of petroleum products (e.g., diesel fuel and oil) or excavated materials could potentially result in the exposure of local biota to site contaminants and in water quality degradation. Contingency plans would be in place for responding to accidental spills to minimize any potential impacts.

Local biota could also be disturbed, displaced, or destroyed as a result of human activity and noise associated with excavation and construction activities under Alternative 6a. The displacement of wildlife is not expected to be significant and the disturbance would be temporary. Upon completion of remedial action, wildlife would repopulate the disturbed areas.

Impacts resulting from construction, excavation, and transportation activities at the vicinity properties would be temporary and similar to those identified for on-site areas. Because only small areas would be disturbed at each of the vicinity properties, impacts to local biota would be minor and would not significantly affect local biotic resources. Some biota would be temporarily disturbed by activities associated with the renovation of Lakes 34, 35, and 36 by the Missouri Department of Conservation, and most aquatic biota inhabiting these lakes would be lost during drainage of the lakes. Following the removal of sediment, the habitats and biota at these lakes would be restored by the Missouri Department of Conservation under its lake renovation program.

Several state listed species occur in the area of the Weldon Spring site. With the exception of the state rare pied-billed grebe which has been observed on raffinate pits 2 and 4, no state listed species are known to occur at the site or the vicinity properties. Thus, no impacts to these species are expected to result from remedial action activities. A biological assessment has been prepared to evaluate the potential for the remedial action alternatives to adversely affect federal listed and candidate species (see Appendix I). This assessment has been submitted to the U.S. Fish and Wildlife Service for concurrence and is currently under review. No impacts to these resources are expected to result during on-site or off-site remedial action activities associated with Alternative 6a.

Implementing Alternative 6a would require about 1,160,000 m^3 (1,520,000 yd^3) of borrow material. Much of this material (i.e., 895,000 m^3 [1,171,000 yd^3] of clay-rich soil) could be obtained from the 61-ha (150-acre) off-site borrow area described in Section 5.2.1.10. On the basis of current conceptual information, up to 21 ha (52 acres) of old-field terrestrial habitat and four wetland areas would be permanently lost if that area were used, which would impact the biota using those habitats. The loggerhead shrike, a federal Category 2 (C2) species, has been reported from the potential borrow area. This species is considered a probable nesting species in the area (Missouri Department of Conservation 1991), and may be nesting in the proposed borrow location. This location may also provide suitable habitat for Bachman's sparrow, which is also a C2 species. Thus, the removal of borrow material from that area could result in the loss of potential nesting habitat for one or both of these species (see Appendix I, Section I.5.1), which could cause a short-term disturbance for these species from surrounding areas.

Socioeconomics and Land Use. Short-term impacts to socioeconomics and land use are expected to be minor. The remedial action worker requirements for implementing Alternative 6a are estimated to be about 560 person-years. Traffic on State Route 94 would increase because of the remedial action workers commuting to work from nearby communities and the trucks transporting materials to the site for implementing this alternative. The traffic volume would vary from year to year during the action period, and peak employee and truck traffic may not occur in the same year. Compared with current conditions, the peak increase in private vehicle use would be more than 500 trips per day, and the peak increase in truck traffic would be about 100 trips per day (Horner & Shifrin 1991). Current traffic on State Route 94 related to the Weldon Spring site is about 500 trips per day for private vehicles and about 50 trips per day for truck traffic.

The average daily traffic volume on State Route 94 at the chemical plant area is not available. However, the daily traffic volume on State Route 94 north of State Route D exceeds 8,200 vehicles per day (based on traffic counts taken in 1988 between State Route D and U.S. Highway 40/61), and the volume on State Route 94 north of State Route DD is about 1,700 (based on counts taken in 1988); the latter value is more representative of conditions near the chemical plant area (Horner & Shifrin 1991). (The locations of State Route 94, State Route D, and State Route DD are shown in Figure 1.2.) Compared with existing use of State Route 94, the temporary increase in traffic volume is not expected to produce significant problems; traffic associated with the remedial action would be controlled, and access and egress zones would be constructed to minimize impacts on nearby facilities and road traffic.

Limited effects are also expected on local employment. Fewer than 100 remedial action workers would be involved in on-site actions at any given time. These workers would probably be individuals currently living in the greater St. Louis metropolitan area. No significant numbers of workers (and families) are expected to move into the area as a result of remedial action activities at the Weldon Spring site beyond those who have already relocated to this area. Hence, there would be no significant impacts on public services such as schools and hospitals.

This alternative would have a positive impact on certain nearby industrial and commercial operations, such as stores, motels, and restaurants. No significant community impacts would occur after the project was completed because the workers (and their families) who have relocated to the area to work on this project are spread throughout the nearby communities and represent a very small fraction of the total population in the surrounding area (e.g., the population of St. Charles County is above 210,000). In summary, no significant labor or socioeconomic impacts are expected under Alternative 6a.

Implementation of Alternative 6a would not significantly impact nearby land uses. Most activities would be conducted at the Weldon Spring site; the only off-site areas involved in this alternative would be vicinity properties that would be remediated, potential borrow areas, and local roads. The short-term effects of obtaining off-site borrow material would be the same as those described in Section 6.2.3.3. Some short-term impacts on recreational use of the surrounding wildlife areas might occur as a result of noise, exhaust fumes, and dust associated with remedial action activities. However, these temporary impacts would be limited to the immediate vicinity of the site, and mitigative measures would be applied to ensure minimal impacts to off-site areas.

Cultural Resources. The potential for short-term impacts to archaeological sites and cultural resources under Alternative 6a would be the same as described in Section 6.2.3.3.

6.2.6 Implementability

Construction and operation of most components of Alternative 6a would be straightforward. Resources are readily available for removing contaminated sludge, soil, and sediment; reducing the volume or size of structural material; and constructing an on-site disposal cell. Standard excavation/construction equipment would be used to remove contaminated material and to construct the disposal cell. The volume reduction facility would also use standard technologies. The procedures and equipment for designing and constructing a disposal cell for material such as the Weldon Spring waste are well established and would be straightforward to implement. Additional studies might be required to determine optimal waste placement and compaction methods as part of the detailed design and optimization of the disposal operation.

The chemical stabilization/solidification facility would be relatively straightforward to construct and operate. All of the necessary equipment is readily available because the process is widely used in the construction and mining industries; it has also been used frequently in hazardous waste treatment applications. The treatment system would consist of a relatively standard configuration of industrial equipment. The chemical stabilization/solidification facility would require a supervisor and general laborers with industrial work experience, as well as maintenance personnel and laboratory and administrative employees. The wide use of mixing equipment and material-handling systems in a variety of applications has resulted in a large resource pool of operators and maintenance personnel. The relatively uncomplicated nature of the system for the Weldon Spring waste would not require highly experienced or specialized operators to ensure adequate product quality. Once further bench-scale and pilot-scale testing had defined and optimized the reagent-to-waste blend, the plant supervisor would be able to respond to operational problems that could arise during processing. For example, grout setting times could be modified (if needed) through the use of set accelerators or inhibitors, and contaminant immobilization could be enhanced through the addition of chemical reagents such as ion-exchange resins (MK-Ferguson Company and Jacobs Engineering Group 1992b). Continual testing of treatment batches during operation would determine required modifications to the standard blend to optimize product quality and immobilization of contaminants.

The chemical stabilization/solidification process would require delivery of several truck-loads of cement and fly ash each day. Scheduling of reagent delivery would be an important operational component of the treatment facility. Several cement vendors located within 160 km (100 mi) of the Weldon Spring site have indicated that adequate cement supplies would be available, and a local power company within 40 km (25 mi) has indicated that fly ash would be available in the necessary quantities (MK-Ferguson Company and Jacobs Engineering Group 1992b). About 1,160,000 m^3 (1,520,000 yd^3) of borrow material would be required to remediate the site under Alternative 6a, and this material is also available from local supplies.

The area available for the on-site disposal of contaminated material is limited. Approximately 17 ha (42 acres) would be required for a disposal cell design capacity of 956,000 m^3 (1,250,000 yd^3); this volume includes a 10% contingency factor. If the actual waste volume was lower, the final phase of the disposal cell would be modified by reducing the design height or altering the disposal cell footprint. If the actual waste volume was higher than anticipated, the disposal cell footprint could be extended. The extension of this footprint would be constrained by the presence of other on-site activities, such as excavation of the raffinate pits. Approximately 55 ha (137 acres) of the 88-ha (217-acre) site would be impacted during remedial action activities under Alternative 6a (Table 5.1). The treatment capacity of the chemical stabilization/solidification facility would be adequate to accommodate the expected volume of waste material to be treated. A 15% over-design capacity was included in the preliminary conceptual design of the facility to ensure that throughput demands could be met.

Alternative 6a utilizes established technologies. The technology for chemical stabilization/solidification has been widely demonstrated and does not require further development before it can be implemented at the Weldon Spring site. The EPA regards the chemical stabilization/solidification technology to be a proven remedial treatment method and had approved its use at 62 NPL sites as of 1991 (Chemical Engineering Progress 1991). Chemical stabilization/solidification has been used at several sites where the quantity of waste was more than 76,500 m^3 (100,000 yd^3) (Table 6.6). The wastes treated at several of these sites (sludge/soil contaminated with metals and organic compounds) have physical and contaminant characteristics similar to those of the Weldon Spring waste requiring treatment. The chemical stabilization/solidification technology has also been used at several other sites for treating metal-contaminated sludge in volumes of less than 76,500 m^3 (100,000 yd^3). Several vendors would be available to submit competitive bids. Thirteen companies were identified in an initial survey for potential vendors (MK-Ferguson Company and Jacobs Engineering Group 1992b).

TABLE 6.6 Sites Using the Chemical Stabilization/Solidification Technology for Waste Treatment

Site Location or Contractor	Waste Type	Contaminants	Treatment Volume (yd^3)
Phoenix, Arizona	Dry sludge	Metals	150,000
ENRECO, Kentucky	Sludge	Organic compounds	180,000
ENRECO, N.E. Refinery	Sludge	Oil and metals	100,000
Vickery, Ohio	Waste acid and sludge	PCBs and dioxins	235,000
Gurley Pit, Arkansas	Soil	PCBs and organic compounds	430,000
Douglassville, Pennsylvania	Soil and sludge	Metals and organic compounds	250,000

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

The chemical stabilization/solidification technology could be implemented at the Weldon Spring site without engineering scale-up. However, pilot testing would be required for about 1 year to optimize the treatment process. After final design and construction of the chemical stabilization/solidification facility, approximately 2 to 3 months would be required to bring the system on line. The preliminary conceptual design of the sludge processing facility has a design throughput of 130 t/h (140 tons/h). Existing pug mills have capacities of up to 180 t/h (200 tons/h). The throughput capacity of the chemical stabilization/solidification plant could be designed to process at any reasonable rate.

In summary, the chemical stabilization/solidification technology is considered to be a reliable process; it is well established and understood. The different kinds of equipment used in the preliminary conceptual design have fully documented performance histories, so no significant problems or schedule delays are expected with regard to implementing this technology. In addition, the system is relatively uncomplicated and would be readily accessible for repairs.

If problems did arise with the treated product, it is expected that they could be readily addressed by modifying the blend of contaminated media and reagents or by adding additional reagents. For example, an inadequate product strength resulting from excess water could be adjusted by removing excess water from the raffinate pit sludge through dewatering or blending the sludge with dry soil. Several reagents are available that could attenuate specific contaminants during chemical stabilization/solidification, and they could be added if the waste media/reagent blend failed to adequately immobilize contaminants during processing (e.g., ferrous sulfate could be added to adsorb or precipitate arsenic). Prior to treatment, media containing set-inhibiting concentrations of nitroaromatics could be pretreated to reduce concentrations to levels that would not impact setting. The chemical stabilization/solidification process would require further testing and optimization with Weldon Spring waste to resolve these issues.

Disposal of the waste in an engineered disposal cell incorporating design features that have been used in other cells to dispose of wastes similar to those at the Weldon Spring site is considered a reliable process. A land-based disposal facility, with containment in the form of a leachate collection and removal system and with engineered barriers incorporated into the design of the liner and cover systems, would provide significant and reliable isolation of the waste from the environment. The engineered disposal cell would be designed to last at least 200 to 1,000 years.

The effectiveness of the main components of remedial activities under Alternative 6a would be monitored. The leachability of the chemically stabilized/solidified product would be continually tested to monitor the effectiveness of the treatment process. The effectiveness of the disposal cell would be monitored through several systems. Any leachate generated from the waste placed in the engineered disposal cell would be captured by the leachate collection and removal system, directed to sumps, and treated in the water treatment plant. Within a few years following disposal, leachate drainage would be expected to end because drainable free water would have been removed and infiltration into the disposal cell would be prevented by the cover system. Any leachate generated following closure of the water treatment plant would be collected and treated in a mobile water treatment system. The disposal cell cover would be visually inspected periodically to identify and repair any areas of erosion, animal burrowing activities, or deep root growth. Radon emanation would also be monitored after closure to ensure compliance with release standards. Survey markers would be placed on the disposal cell to aid in assessing settling. Groundwater monitoring wells would be located to detect changes in groundwater quality, as described in Section 6.2.3.3. If an increase in leachate were detected in the leachate collection and removal system, a thorough cell cover inspection and repair program would be initiated. The monitoring system associated with the on-site disposal cell would provide the information needed to determine if corrective action should be taken to prevent the migration of contaminants into the environment.

The implementation of Alternative 6a would not adversely impact the performance of additional remedial actions that might be required in the future at the Weldon Spring site. The ability to remediate groundwater at the site would not be impacted by the presence of an on-site disposal cell (Section 6.2.3.3).

The administrative feasibility of Alternative 6a would be straightforward. Remedial action activities at the Weldon Spring site are being coordinated with the state of Missouri and EPA Region VII. This coordination would continue. The implementation of Alternative 6a would not require any additional coordination with other agencies beyond those already occurring, and no permits would be required for on-site activities.

6.2.7 Cost

Feasibility-level cost estimates for all of the final action alternatives were prepared in accordance with cost guidelines established by the EPA (1987c). Costs were derived from standard cost-estimating sources and from cost estimates developed specifically for the site (MK-Ferguson Company and Jacobs Engineering Group 1992b). Production rates are generally based on 6.5 hours of productive labor per day, taking into account 1.5 hours lost for clothing changes and showers. Project durations were based on 9 work months per year and 20 work days per month. Other costs such as tools, indirect costs, and bond and insurance costs were estimated on the basis of various percentages of other costs (see MK-Ferguson Company and Jacobs Engineering Group 1992b). Present worth was calculated from procedures identified in EPA guidance at a 10% discount rate (EPA 1987c). Long-term maintenance costs are based on a 30-year period and include annual monitoring costs (MK-Ferguson Company and Jacobs Engineering Group 1992b).

The total and present-worth costs for Alternative 6a are given in Table 6.7 and are estimated to be $157 million and $79 million, respectively. Equipment capital costs for chemical stabilization/solidification are estimated to be $1.03 million, with an installed cost of $3.1 million (MK-Ferguson Company and Jacobs Engineering Group 1992b). Bench-scale and pilot-scale testing is estimated to cost $2.1 million. Treatment is estimated to have a total operating cost of $14.7 million for processing the 248,000 m^3 (324,000 yd^3) of contaminated raffinate pit sludge, soil, and other waste.

The costs for removal and on-site hauling of material could increase if material quantities were higher or production rates were lower than those used for the estimate. The disposal facility cost estimate was based on vendor quotes for material prices and conservative estimates of construction production rates. Disposal facility costs could increase if a larger facility was necessary on the basis of updated waste quantity estimates; however, costs have been included for the quantities of material estimated to result from future related actions (Section 1.5.3). A lower cost would result from higher production rates or lower material prices. The chemical stabilization/solidification operating costs are influenced mostly by the quantity of cement and fly ash required and the prices for those reagents. Costs of removal, treatment, and disposal of the containerized waste stored in Building 434 would be affected by the total quantity of containerized waste, the costs for transportation, and the fee charged by the receiving facility. The overall costs could increase if documentation expenses for waste transport exceed the percentage of direct labor cost assumed for operating expenses.

6.3 ALTERNATIVE 7a: REMOVAL, VITRIFICATION, AND DISPOSAL ON-SITE

6.3.1 Overall Protection of Human Health and the Environment

Alternative 7a would provide for protection of human health and the environment at the Weldon Spring site by (1) removing the sources of contamination, (2) treating the materials

TABLE 6.7 Cost Estimate for Alternative 6a

Activity	Estimated Cost (million $)
Removal	
Raffinate pits dredging/excavation	11.9
Chemical plant area preparation[a]	2.8
Building foundation and underground pipe removal[a]	5.9
Soil and sediment excavation	1.7
Building 434 waste removal[a]	0.6
Vicinity properties excavation[b]	
Army properties 1, 2, 3 and Busch properties 3, 4, 5[a]	0.4
Busch Lakes 34, 35, and 36[a]	0.4
Army properties 5 and 6[a]	0.3
Removal subtotal	24.0
Treatment	
Bench- and pilot-scale testing	2.1
Sludge processing facility construction	3.1
Sludge processing facility operations	14.7
Volume reduction facility construction[a]	2.9
Volume reduction facility operations[a]	2.5
Construction of second treatment train (distillation) of water treatment facility[a]	1.2
Water treatment plant operations	3.5
Treatment subtotal	30.0
Disposal	
Disposal facility construction material tests	0.9
Disposal facility construction	47.6
Disposal cell operations	7.2
Disposal subtotal	55.7
Other	
Material hauling	9.7
TSA operations[a]	2.0
MSA operations[a]	5.2
Decontamination station operations[a]	1.2
Facilities removal[a]	1.8
Site restoration	3.4
Long-term maintenance[c]	23.9
Other subtotal	47.2
Total	157
Present worth	79

[a] Items that are part of the final action alternatives and for which the cost estimate does not differ between alternatives.

[b] Includes both excavation and restoration costs.

[c] For a 30-year period; includes environmental monitoring.

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

that pose the principal threats at the site by vitrification, which incorporates the contaminants into a glass-like matrix, and (3) placing treated and untreated materials into an engineered disposal cell to minimize the potential for contaminant migration. On-site exposures and risks would be reduced toward background levels (see Section 6.3.3). Institutional controls would be maintained at the disposal facility to provide continued protection against potential future exposures. Alternative 7a would not be expected to result in any unacceptable impacts during implementation; potential impacts are discussed in Section 6.3.5.

6.3.2 Compliance with ARARs

Compliance with ARARs under Alternative 7a would be similar to that identified for Alternative 6a except additional requirements that regulate emissions could be relevant and appropriate to the off gas from the vitrification facility. These requirements include the Missouri Air Pollution Control Regulations for maximum allowable emissions of particulate matter from fuel-burning equipment used for indirect heating, restrictions for emissions of visible air contaminants, and restrictions for emissions of particulate matter from industrial processes. State ambient air quality standards could also be considered relevant and appropriate for Alternative 7a, insofar as the vitrification process would have a potential to emit pollutants above specified de minimis emission levels specified in these regulations. Emission requirements for hazardous waste incineration under RCRA could also be relevant and appropriate for this alternative for treatment of characteristic waste, and emission requirements for burning of hazardous waste in boilers or industrial furnaces could be relevant and appropriate under Alternative 7a because vitrification might be considered similar to an industrial furnace (melting furnace). In this case, the pertinent requirements would be addressed. Compliance with disposal requirements under Alternative 7a would be similar to that described for Alternative 6a, except the restriction from placement of free-standing liquids in the disposal cell would be met for the vitrified material.

6.3.3 Long-Term Effectiveness and Permanence

Monitoring and maintenance activities for Alternative 7a would continue at the site for an indefinite period. These activities would be conducted to ensure the effectiveness of waste isolation and would allow for an assessment of potential future risks and the need for preventing any potential exposures in the event of disposal cell failure. Vitrification of the most highly contaminated material would greatly reduce the mobility of contaminants (Section 6.3.4). Therefore, in the unlikely event of loss of institutional controls at the site and subsequent cell failure, the release of contaminants from that material from continued exposure to the environment would be very slow.

6.3.3.1 Protection of Workers

Exposures of workers during monitoring and maintenance activities following implementation of Alternative 7a would be about the same as for Alternative 6a because of the similarity of conditions involved. Exposures of workers to radioactive and chemical contaminants would be negligible because the disposal cell would be designed to prevent releases of particulates and radon gas. In the 30 years immediately following the implementation of Alternative 7a, it is estimated that about nine cases of occupational injury and no occupational fatalities would occur during site maintenance activities.

6.3.3.2 Protection of the Public

Following implementation of Alternative 7a, releases of site contaminants and exposures of members of the public over the long term are expected to be negligible. Routine monitoring and maintenance activities would ensure the integrity of the containment system, and corrective actions would be performed as necessary. The presence of fences would also minimize the potential for intrusion into the disposal cell by members of the public in the foreseeable future. If institutional controls were lost in the long term and the cell subsequently failed, the greatly reduced mobility of contaminants from the vitrified product would minimize related impacts. The magnitude of future impacts would depend on the magnitude of the release and local land-use conditions at the time it occurred. Soil remediation for Alternative 7a would be similar to that described for Alternative 6a (Section 6.2.3.2).

6.3.3.3 Environmental Protection

The long-term environmental effects associated with Alternative 7a would be about the same as for Alternative 6a because institutional controls that include monitoring and maintenance would be continued at the disposal area for the long term. If it were hypothetically assumed that the cell holding the vitrified waste failed and no corrective measures were taken, environmental impacts could result but would tend to be somewhat less than those associated with cell failure for Alternative 6a over the very long term because contaminant mobility from the vitrified product would be reduced and some contaminants would have been destroyed. In addition, the end product of vitrification is expected to resist degradation longer than the end product of chemical stabilization/solidification. The vitrified portion of the waste would represent 15% of the total waste volume, and leachate from the larger nonvitrified portion of the waste would be the same as that for Alternative 6a. The conceptual monitoring well design for the disposal cells for Alternative 7a would be approximately the same as for Alternative 6a; final design would be based on the specific configuration determined for the disposal cell(s) during detailed design.

6.3.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

The treatment method used for Alternative 7a would be vitrification. The highly contaminated waste (including raffinate pit sludge, the more highly contaminated soil, and process waste from the water treatment plants) would be vitrified to reduce contaminant toxicity, mobility, and volume — thereby addressing the principal threats at the Weldon Spring site. The vitrified material would undergo a 68% decrease in volume and a 52% decrease in weight as a result of treatment. This corresponds to a total treated volume of 78,800 m^3 (103,000 yd^3) and a total weight of 166,000 t (183,000 tons). The volatilization of water would result in a significant decrease in the weight of the glass product. The overall waste volume would decrease by 24% for this alternative. The toxicity of radiation in the site waste would not be reduced by this treatment method (or any other).

The entire volume of raffinate pit sludge and about 30% of the contaminated soil would be treated by vitrification. The operating temperatures considered for the preliminary conceptual design for vitrification of the Weldon Spring wastes (1250°C [2,280°F] to 1440°C [2,620°F]) would destroy organic compounds at an efficiency of about 99.9999% (MK-Ferguson Company and Jacobs Engineering Group 1992b). This irreversible destruction of contaminants would reduce the toxicity of the waste. The nitroaromatic compounds that are present as contaminants in about 9,600 t (10,000 tons) of quarry soil would be destroyed at the temperatures reached during vitrification (Table 5.3).

Approximately 90% of the nitrates in the raffinate pit sludge is present in the interstitial water that would be removed prior to vitrification. During sludge dewatering, the nitrates and other soluble compounds would be transferred in the wastewater pumped from the dewatering circuit to the water treatment plant. During vitrification, nitrates, nitrites, and organic nitro groups present in the feed material would be converted to gas (e.g., nitrogen, carbon dioxide, oxygen, and hydrogen) by thermal energy, and nitrogen converted to nitrogen oxides could be removed during off-gas treatment (MK-Ferguson Company and Jacobs Engineering Group 1992b). Sulfate would be converted to gaseous sulfur oxides, which could also be removed in the off-gas treatment system; the amount of sulfate remaining in the vitrified material would be determined during bench-scale and pilot-scale testing. The estimated fate of contaminants following vitrification and the estimated off-gas emissions are given in Tables 5.3 and 5.5 (Section 5.3), respectively. Most of the metals, including the radionuclides, would be retained in the final glass-like product. Bench-scale and pilot-scale studies would be conducted to 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 various stages of the off-gas treatment system. The results of these studies would be used to determine the configuration of the final off-gas treatment system to maximize contaminant removal.

Vitrification could also result in a significant reduction in contaminant mobility. Leachability testing of vitrified Weldon Spring sludge and soil indicated a highly leach-resistant product (Table 4.1). 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 TCLP test (MK-Ferguson Company and Jacobs Engineering Group 1992b). 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. Leachability test results and geologic evidence suggest that very high leachability indexes (greater than 14) are likely (MK-Ferguson Company and Jacobs Engineering Group 1992b). Natural volcanic glass (a natural analog to the vitrified product), age dated at several million years, typically has a diffusion-controlled leached rind (outer layer that has been leached over time) of only a few millimeters in thickness.

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 Weldon Spring waste; however, the short residence time in the melter would minimize the potential for immiscible phase development. Iron, sulfide, or sulfate immiscible phases could occur. Reducing conditions in the melter would favor the development of iron and/or sulfide immiscible phases. Depending on the temperature of the melt, an iron phase could concentrate cadmium, copper, lead, and silver; this enriched phase could result in greater leachability of those contaminants. Maintaining control of the iron and organic carbon content in the feed stream to low levels would help prevent the formation of an immiscible iron phase (MK-Ferguson Company and Jacobs Engineering Group 1992b). Reducing conditions would also tend to partition arsenic, cadmium, copper, lead, mercury, selenium, silver, and zinc into a sulfide phase. Exposure of this product to oxygenated water could result in the oxidation of the sulfide mass, thus generating an acidic, contaminant-rich solution. Under oxidizing conditions, a sulfate phase would be formed that could be enriched in barium, cadmium, calcium, lead, magnesium, radium, strontium, and uranium (UO_2^{2+}); in contact with water, contaminants in this phase could be dissolved and released (MK-Ferguson Company and Jacobs Engineering Group 1992b).

If the contaminants in the raffinate pit sludge were quantitatively concentrated into a soluble immiscible phase, the vitrified material could fail the TCLP test (MK-Ferguson Company and Jacobs Engineering Group 1992b). However, many of the metals of concern (arsenic, cadmium, lead, mercury, and selenium) would be at least partially removed from the waste during the vitrification process because of volatilization and capture in the off-gas treatment system. In addition, if a sulfate phase formed, it would be a volumetrically small component of the glass; for example, it might represent from about 0.8 to 1.8% sulfate as calcium sulfate ($CaSO_4$) (MK-Ferguson Company and Jacobs Engineering Group 1992b). Also, if formed, the sulfate phase would be distributed throughout the silica phase of the melt unless sufficient time were allowed for this phase to become separated from the silica phase and coalesce; this separation would probably not occur because of the short residence times required in existing melting systems. Rapid cooling of the melt, such as occurs in generating a fritted product, would cause the sulfate phase to be encapsulated within the silica glass, minimizing its ability to leach. Bench-scale and pilot-scale testing would be required to optimize the vitrification process to address these considerations.

The weathering behavior of volcanic glass 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. Dissolution rates of quartz, which has a solubility rate similar to that of glass, indicate that nearly 30 million years would be required to dissolve a 0.25-cm (0.1-in.) sphere. 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 waste are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates (Hansen and Fitzpatrick

1989). On the basis of the longevity of volcanic glass and diffusion calculations, the vitrified product should withstand environmental exposure for thousands of years (MK-Ferguson Company and Jacobs Engineering Group 1992b).

Treatment residuals of the vitrification process would be produced from off-gas collection and subsequent treatment. The estimated quantities and characteristics of these residuals are identified in Table 5.6 (Section 5.3.2). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Pilot testing of the off-gas treatment system would be necessary to accurately quantify the treatment residuals requiring disposal. Scrubber residuals from the primary scrubber and spent filters would be returned to the vitrification system (Section 5.3.2). The scrubber residuals that could not be processed in the vitrification system would require further treatment prior to disposal, e.g., by chemical stabilization/solidification.

6.3.5 Short-Term Effectiveness

6.3.5.1 Duration of Remedial Activities

Remedial activities under Alternative 7a would be completed in about 10 years, excluding long-term maintenance. The removal component of Alternative 7a would require about 7 years, the same amount of time as identified for Alternative 6a. Approximately 9 years is projected for completion of all activities associated with vitrifying the raffinate pit sludge and more highly contaminated soil. The time to implement the treatment component of Alternative 7a could be prolonged if pilot-scale and full-scale testing (start-up) of the vitrification facility resulted in scale-up and operational difficulties because of the innovative nature of this treatment technology. Testing, design, construction, and start-up could require at least 5 to 7 years, with the possibility of a longer period depending on the difficulties encountered. The treatment plant would operate for 4 years — assuming that operations would be conducted 24 hours per day, 365 days per year. Construction and operation of the disposal cells under Alternative 7a would require about 8 years, the same as that identified for Alternative 6a.

6.3.5.2 Protection of Workers

On-site workers during the operational period would include both remedial action workers and on-site office workers. The remedial action worker requirements for implementing Alternative 7a are estimated to be about 780 person-years. In addition, about 200 individuals would be working on-site in the project office building during this period. To minimize potential occupational exposures to contaminants, remedial action activities would be conducted in accordance with applicable regulatory limits and health and safety plans developed for the Weldon Spring site.

The potential occupational impacts associated with the specific handling and treatment processes were estimated on the basis of the assumptions presented in detail in Appendix F.

Occupational impacts for Alternative 7a would be similar to those incurred under Alternative 6a because the same waste would be treated and similar activities would be required. The incremental health risks to the maximally exposed remedial action worker are estimated to be 1×10^{-3} and 8×10^{-5} for exposure to radioactive and chemical contaminants, respectively. The collective risk to the entire remedial action work force from radiation exposure is estimated to be 2×10^{-1}. Although some potential exists for noncarcinogenic effects (i.e., the hazard index to the maximally exposed worker was estimated to be greater than 1), use of protective clothing and respiratory protective equipment would minimize the likelihood of such effects. Actual exposures to contaminants would be well below applicable regulatory limits. On the basis of statistics for construction activities of comparable size and scope, no occupational fatalities are expected to occur during implementation of Alternative 7a; approximately 110 cases of occupational injury are estimated to occur, with about 1,100 lost workdays (Appendix F, Section F.6). Safety hazards associated with the high temperatures and the complexity of the vitrification process compared with the chemical treatment process could result in more worker accidents. To address this concern, additional measures would be taken to implement Alternative 7a in a manner that would not jeopardize the safety of workers.

6.3.5.3 Protection of the Public

During implementation of Alternative 7a, the general public could be exposed to radioactive and chemical contaminants migrating from the site via airborne dust and gaseous emissions. The principal activities resulting in the generation of fugitive dust and gases would be waste excavation, treatment, loading/unloading, and grading, as described for Alternative 6a (Section 6.2.5.3). Some small differences would result from stack emissions from the vitrification facility and sequencing of certain handling and treatment operations. Airborne releases resulting from accidents occurring on-site would be small compared with releases from routine remedial action activities. Potential exposures of members of the public during the remedial action period were estimated on the basis of the conservative scenario definitions and assumptions presented in detail in Appendix F.

Estimated exposures of the public for Alternative 7a would be similar to those incurred under Alternative 6a. Although the respective treatment facilities — i.e., the chemical stabilization/solidification facility for Alternative 6a and the vitrification facility for Alternative 7a — differ fundamentally in design, atmospheric particulate releases would not differ significantly. In general, the same waste would be treated under the respective treatment processes for each alternative, the facilities would be enclosed, and particulate releases would be controlled by collection systems such as air particulate filters. Radon emissions would be approximately 40% higher for the vitrification alternatives because of gaseous releases during the vitrification process.

The effluent from the vitrification facility would be monitored to ensure that the off-gas treatment system was functioning properly. Failure of specific components of this system could result in short-term increases in atmospheric emissions. If this occurred, the vitrification system would be shut down and the off-gas treatment system repaired. The risks to workers or members of the general public from such accidental releases would be small compared with those associated with routine releases (e.g., from waste excavation) during implementation of this alternative.

The results of the risk assessment indicate that no significant incremental health impacts are predicted for members of the general public. The health risks to the maximally exposed member of the public are estimated to be 7×10^{-7} and 3×10^{-8} for radioactive and chemical contaminants, respectively. The hazard index is much less than 1, indicating that no noncarcinogenic effects are anticipated. The collective radiological risks to the population within 5 and 80 km (3 and 50 mi) of the site are estimated to be 3×10^{-3} (for the population of 10,700) and 2×10^{-2} (for the population of about 3 million), respectively; the actual radius of impact would likely be less than 5 km (3 mi). No adverse impacts would be incurred by off-site individuals as a result of contaminant releases during implementation of this alternative (Appendix F, Section F.6).

6.3.5.4 Environmental Protection

Short-term environmental impacts associated with the implementation of Alternative 7a would be similar to those associated with Alternative 6a. In addition, Alternative 7a would involve potential effects related to emissions from the vitrification process and construction of the natural gas pipeline and tie-in facility (Figure 5.1 and Section 5.3).

Soil. Short-term impacts would be similar to those described for Alternative 6a (Section 6.2.5.4) except construction of the natural gas pipeline would result in temporary soil disturbance over an area of about 1.3 ha (3.2 acres) along the 5.3-km (3.3-mi) route of the pipeline. This disturbance would be of short duration, and the route would be revegetated and restored to its original contours after the cleanup period.

Water Quality and Hydrology. Short-term impacts would be similar to those described for Alternative 6a (Section 6.2.5.4) except construction of the natural gas pipeline could release additional sediment and fugitive dust that might affect nearby surface waters. However, the width of the disturbed area would be small, about 1 m (3.3 ft), and good engineering practices and mitigative measures would be used to minimize any adverse effects. Other issues, including those related to groundwater, are the same as described for Alternative 6a (Section 6.2.5.4).

Air Quality. Short-term impacts to air quality are predicted to be similar to those identified for Alternative 6a (Section 6.2.5.4). Although Alternative 7a would involve an additional release of emissions from the vitrification facility, these emissions are expected to be insignificant relative to other emissions such as fugitive dust.

The highest annual average PM-10 concentration predicted for an off-site location during the remedial action period is estimated to be 6.5 $\mu g/m^3$ above background. This value is slightly lower than that predicted for Alternative 6a. This concentration would occur at the site perimeter near the north gate and is primarily associated with operation of the construction material staging area (uncontaminated material) and related road traffic. This location would have the highest PM-10 concentration because the predominant wind direction at the site is from the south. The highest concentration estimated for an off-site receptor is 0.8 $\mu g/m^3$ above background (at the highway maintenance facility), which is considerably below the annual air quality standard for PM-10. The highest 24-hour PM-10 concentration for an off-site location is estimated to be 280 $\mu g/m^3$ above background at the site perimeter near Frog Pond; the major contributor to this value would be backfilling operations. The highest 24-hour PM-10 concentrations estimated for all other locations, except near the site boundary, are considerably below the 24-hour air quality standard (including background) (Appendix C, Section C.1.3.1).

The vitrification facility is assumed to be operating 24 hours per day, 365 days per year. This operation is unlikely to have significant impacts on air quality because the facility would include an effective off-gas treatment system. If this system were to fail, airborne emissions could increase in the short term until the failure was detected by the real-time monitoring system, and the vitrification facility was shut down for repair. The short-term impact on air quality from such an occurrence would be small relative to other releases from routine operations such as excavation, backfilling, and regrading. The air quality impacts associated with obtaining backfill would be less than those for Alternative 6a because of lower fill requirements. Appropriate dust control practices would be used for activities adjacent to the site boundary, so the potential air quality impacts associated with implementing this alternative would be relatively minor.

Biotic Resources. The impacts to biotic resources from implementation of Alternative 7a would be similar in nature, magnitude, and duration to those identified for Alternative 6a (Section 6.2.5.4). Some additional, minor impacts could result from construction of the natural gas pipeline that would supply the fuel necessary for the vitrification process.

Construction of the 5.3-km (3.3-mi) belowground pipeline would disturb approximately 1.3 ha (3.2 acres) of land within the Weldon Spring Wildlife Area adjacent to and south of State Route 94 (Figure 5.1). This area currently supports a mixture of habitat types, including some shrub plantings, row crops, old fields, and native grasslands (Missouri Department of Conservation 1989). The vegetation in this area is actively managed to control fescue and enhance wildlife habitat, especially small game populations. The loggerhead shrike, a federal C2 species, has been reported from the area, and suitable habitat for Bachman's sparrow, another C2 species, may also be present in this area. Some vegetation and wildlife habitats along the pipeline right-of-way would be destroyed during construction, but impacts to non-listed biotic resources from this habitat loss would not be significant because the affected area represents less than 0.02% of the total area of the Busch Wildlife Complex. Construction of the pipeline could temporarily disturb habitat used by the loggerhead shrike and possibly by the Bachman's sparrow as well. Impacts to these species, if present, would be primarily through construction noise and human activity. However, potential impacts to these species are expected to be minor (see Appendix I) and to not result in any adverse effects to either species. Following completion of pipeline construction, the right-of-way would be revegetated in accordance with the state management plan and practices currently in place for this area (Missouri Department of Conservation 1989); no right-of-way maintenance is planned following completion of the pipeline (Gonzales 1991). In summary, impacts from construction of the natural gas pipeline would be temporary. Also, no impacts to biotic resources are anticipated from the off-gas emissions generated during the vitrification process.

Socioeconomics and Land Use. Short-term impacts to socioeconomics and land use associated with the implementation of Alternative 7a are expected to be minor and similar to those for Alternative 6a (Section 6.2.5.4). The remedial action worker requirements for implementing Alternative 7a are estimated to be about 780 person-years, which is about 40% higher than the 560 person-years estimated for Alternative 6a. The effects on local employment and private vehicle use in the vicinity of the site would be somewhat higher for Alternative 7a than for Alternative 6a, but this increase would not be significant. The increase in truck traffic associated with Alternative 7a would be similar to that for Alternative 6a.

Cultural Resources. With one possible exception, impacts to archaeological sites and cultural resources are expected to be the same for Alternative 7a as described for Alternative 6a (Section 6.2.5.4). Incremental impacts could be associated with construction of the natural gas pipeline, and an additional field survey might be required for this alternative.

6.3.6 Implementability

The vitrification technology for Alternative 7a would require engineering scale-up to be implemented full scale at the Weldon Spring site. Pilot testing, detailed design, fabrication, installation, and 3 to 6 months of full-scale operation would be needed to optimize the treatment process (MK-Ferguson Company and Jacobs Engineering Group 1992b).

Construction and operation of the removal and disposal components of Alternative 7a would be straightforward. Readily available resources and standard procedures would be used for the removal component, and the designs of the proposed cells for the disposal component have been used at other sites. Cells with leachate collection and removal systems have been constructed at municipal landfills, and disposal cells for wastes similar to those at the Weldon Spring site have been constructed at several locations across the country. The use of a separate combination disposal cell for the untreated material might require the use of grout to prevent settling around the structural material being disposed of. Placement of the cohesionless vitrified material in the vitrification cell would probably require mixing of the glass-like particles with a clay binder or placing alternate layers of waste and clay in the cell. As part of the detailed design and optimization of the disposal operation, additional studies would be carried out to determine optimal waste placement and compaction methods.

About 17 ha (42 acres) would be required for the dual disposal cell design under Alternative 7a, for a total capacity (both cells) of approximately 680,000 m^3 (890,000 yd^3), including a 10% contingency factor. If disposal volumes were greater than anticipated, the disposal cell footprint would be extended or side slopes adjusted to accommodate additional capacity. This extension would be constrained by the presence of other on-site activities, e.g., excavation of contaminated areas. Approximately 55 ha (137 acres) of the available 88 ha (217 acres) at the site would be impacted during remedial action activities under Alternative 7a (Table 5.2). Implementation of this alternative would require about 1,017,000 m^3 (1,330,000 yd^3) of borrow material, which is available from local supplies.

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 Weldon Spring 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 at the Weldon Spring site would include construction of a natural gas pipeline to the site. A natural gas line is currently within 5.5 km (3.5 mi) of the site and could easily be extended to the site.

Fuel resources would be readily available for the treatment component of Alternative 7a. A 15% over-design capacity was included in the preliminary conceptual design of the vitrification facility to help ensure that throughput demands could be met. The vitrification process would require about 1.6×10^4 m^3/d (5.6×10^5 ft^3/d) of natural gas, which is available locally. This is a small amount compared with an estimated total use of natural gas in the St. Louis area, i.e., about 9×10^6 m^3/d (3×10^8 ft^3/d).*

Operation of the vitrification facility would be somewhat more 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 process improperly sized material prior to vitrification. The equipment needed for this circuit is readily available because this component of the process is widely used in the mining industry; this process would not require specially trained operators.

Fossil fuel-heated ceramic melters are widely used in the existing commercial glass-making industry, and the melter circuit would require modification of this technology; an estimated 95% of manufactured glass is processed with this technology (MK-Ferguson Company and Jacobs Engineering Group 1992b). Although fossil fuel-heated ceramic melters from the glass-making industry could be modified to process the Weldon Spring waste, adaptation to the treatment of radioactive and chemically hazardous waste is currently available only in pilot-scale plants with relatively small throughput capacities of about 23 t/d (25 tons/d). Implementing this technology for Alternative 7a would require increasing the capacity of these pilot-scale systems to the preliminary conceptual design capacity of 90 t/d (100 tons/d) for the Weldon Spring site. Further bench-scale and pilot-scale testing, engineering design, construction, and start-up of the vitrification facility would probably require at least 5 to 7 years. Joule-heated

*Estimated from the annual natural gas consumption for the state of Missouri, 6.9×10^9 m^3 (242×10^9 ft^3) in 1986 (DOE 1988), and the ratio of the population of the St. Louis metropolitan area (2,467,000) to the population of the state of Missouri (5,141,000) in 1988 (U.S. Bureau of the Census 1990).

ceramic melters have been used to vitrify liquid high-level radioactive waste, radioactively contaminated soil, and waste contaminated with heavy metals in quantities ranging from 4.5 to 410 t (5 to 450 tons) (MK-Ferguson Company and Jacobs Engineering Group 1992b). One vendor has been identified for the fossil fuel-heated ceramic melter technology, and 15 vendors have been identified for the electrically based (joule-heated ceramic melters or plasma arc torch) and in-situ vitrification technologies (MK-Ferguson Company and Jacobs Engineering Group 1992b). On the basis of the factors discussed in Section 3.2.4.2, the fossil fuel-heated ceramic melter technology was selected as the representative vitrification technology for this assessment.

A trained process engineer would be needed to operate both the physical pretreatment and melting circuits of the fossil fuel-heated 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 might be drawn from the commercial glass-making industry or the high-level radioactive waste vitrification industry. The fossil fuel-heated ceramic melter system could be designed to operate largely by computer, with a combination of human and computerized oversight (MK-Ferguson Company and Jacobs Engineering Group 1992b). Start-up of the vitrification facility would require at least 6 months to 1 year; however, because the fossil fuel-heated ceramic melter system has not been previously used at the scale required for the Weldon Spring 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 fossil fuel 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 fossil fuel-heated ceramic 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% continuous operation efficiency (MK-Ferguson Company and Jacobs Engineering Group 1992b). Pilot-scale operation of the fossil fuel-heated ceramic melter developed by Vortec has been reported at 90 to 95% availability (Carpenter 1991).

The off-gas treatment system would use standard air pollution treatment and control devices. However, although the capabilities 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 stream expected from fossil fuel-heated vitrification of radioactive and chemically hazardous waste at full scale. The off-gas 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, and 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 fossil fuel-heated ceramic melter at the Weldon Spring site.

The reliability of the off-gas treatment system is not well defined. Although information is available on the reliability of the off-gas treatment system for the joule-heated ceramic melter, differences between the fossil fuel-heated and joule-heated melter technologies make it inappropriate to extrapolate data from one technology to another. In addition, because no pilot-scale or full-scale fossil fuel-heated ceramic melter system has been operated to vitrify waste similar to that at the Weldon Spring site, no data exist on the reliability of the off-gas treatment circuit proposed in the preliminary conceptual vitrification system identified for Alternative 7a. 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 7a would be regularly monitored. The off-gas treatment system would include on-line monitoring equipment to determine the off-gas composition and ensure compliance with applicable requirements. Final design of the off-gas system would identify optimal types and locations of required monitoring devices. The effectiveness of the vitrification process would be monitored by regular testing of the treated product. If a sample failed leachability criteria, additional samples would be collected more frequently, and these samples would be tested and analyzed to determine the cause of the problem. The failed material could be revitrified if necessary, and process modifications would be instituted. Activities associated with monitoring and maintenance of the disposal cell would be the same as identified for Alternative 6a (Section 6.2.3.3).

The implementation of Alternative 7a would not adversely impact the performance of additional remedial actions at the Weldon Spring site. For example, the presence of two on-site disposal cells would not affect the ability to remediate groundwater beneath the cells.

The administrative feasibility of Alternative 7a could be affected by the stack releases. That is, airborne emissions associated with the vitrification process might necessitate a permit from the state of Missouri for the release of hazardous constituents to the atmosphere. Remedial action activities at the Weldon Spring site are being coordinated with the state of Missouri and EPA Region VII, and this coordination would include the development of appropriate measures to address the vitrification emissions under Alternative 7a.

6.3.7 Cost

The total and present-worth costs for Alternative 7a are given in Table 6.8 and are estimated to be $182 million and $97 million, respectively. Equipment capital costs for vitrification are estimated to be $6.8 million, with an installed cost of $25.6 million (MK-Ferguson Company and Jacobs Engineering Group 1992b). Treatment is estimated to have a total operating cost of $20.5 million for processing the 248,000 m^3 (324,000 yd^3) of contaminated raffinate pit sludge, soil, and other waste. Bench-scale and pilot-scale testing is estimated to cost $8.2 million, and raffinate pit sludge dewatering is estimated to cost $2.5 million.

The disposal cell cost estimate was based on separate disposal cells for vitrified material and all untreated material. If more stringent liner systems were incorporated into the design of the cell for the vitrified material, the costs for this component would increase. Costs for the off-gas treatment system in the preliminary conceptual design of the vitrification facility were estimated to be $5.9 million for construction and $4.4 million for operation. These costs are highly dependent upon the results of further bench-scale and pilot-scale studies that would optimize the system requirements. The equipment costs for vitrification could change by selecting different vendors or types of equipment. In addition, if the treatment design throughput were changed such that operation of more units or a larger unit were required, the cost estimates would increase accordingly. Other cost variations would be as identified for Alternative 6a (Section 6.2.7).

6.4 ALTERNATIVE 7b: REMOVAL, VITRIFICATION, AND DISPOSAL AT THE ENVIROCARE SITE

6.4.1 Overall Protection of Human Health and the Environment

Alternative 7b would provide for protection of human health and the environment at the Weldon Spring site by (1) removing the sources of contamination, (2) treating the materials

TABLE 6.8 Cost Estimate for Alternative 7a

Activity	Estimated Cost (million $)
Removal	
Common removal costs (see Table 6.7)	10.4
Raffinate pits dredging/excavation[a]	14.4
Soil and sediment excavation	1.7
Removal subtotal	26.5
Treatment	
Common treatment costs (see Table 6.7)	6.6
Bench- and pilot-scale testing[a]	8.2
Sludge processing facility construction[a]	25.6
Sludge processing facility operations[a]	20.5
Water treatment plant operations	3.5
Treatment subtotal	64.4
Disposal	
Disposal facility construction material tests	0.9
Disposal facility construction	37.1
Disposal cell operations	6.7
Disposal subtotal	44.7
Other	
Common other costs (see Table 6.7)	10.2
Material hauling	9.3
Site restoration	3.4
Long-term maintenance[b]	23.9
Other subtotal	46.8
Total	182
Present worth	97

[a] Items for which the cost estimate does not differ between Alternatives 7a, 7b, and 7c.

[b] For a 30-year period; includes environmental monitoring.

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

that pose the principal threats at the site by vitrification, and (3) transporting all contaminated material to the Envirocare site near Clive, Utah, for disposal. Protection of human health and the environment in the vicinity of the Envirocare site would be ensured by placing all contaminated material in an engineered disposal cell to minimize the potential for contaminant migration. Exposures and risks at both the Weldon Spring and Envirocare sites would be limited to very low levels. In addition, Envirocare of Utah, Inc., would maintain controls at its facility to provide further protection against potential exposures. (Because it is privately owned, DOE would have limited ability to ensure and maintain institutional controls at the Envirocare site.) Alternative 7b is not expected to result in any unacceptable impacts during implementation (Section 6.4.5).

6.4.2 Compliance with ARARs

Compliance with location-specific and contaminant-specific ARARs under Alternative 7b would be the same as identified for Alternative 7a (Section 6.3.2). Compliance with action-specific requirements for activities that take place on-site under this alternative would also be the same as identified for Alternative 7a. The application of specific environmental regulations to activities being considered for the off-site facilities, such as treatment of liquid waste at an off-site incinerator and disposal of the solid material at the Envirocare site would be addressed in appropriate environmental compliance documents and activities by the owners/operators of those facilities. Requirements for transportation of hazardous materials are not part of an environmental law and hence are not subject to evaluation for attainment or waiver as part of the ARAR process. However, they would be pertinent to the remedial action under Alternative 7b for transport of wastes to the Envirocare site and are therefore included in the general discussion. The DOE would conduct transportation activities in compliance with all appropriate shipping, packaging, and labeling requirements, including those specified for radioactive material in 49 CFR 173 (Appendix G, Table G.3).

Under the Atomic Energy Act, as amended, DOE can transfer 11e(2) by-product material only to organizations licensed by the NRC to receive such material. This requirement would be applicable to the disposal of the 11e(2) by-product material from the Weldon Spring site at the Envirocare site under Alternative 7b. The Envirocare site has been permitted by the state of Utah to accept mixed hazardous and NORM waste. The site owner/operator (Envirocare of Utah, Inc.) has also applied for (but not received) a license to dispose of 11e(2) by-product material. The RCRA requirements for a manifest system, recordkeeping, and reporting would be addressed if the waste to be shipped off-site met the prerequisites for definition as hazardous waste. In this case, the RCRA financial requirements would also be applicable to the owner/operator of the Envirocare site.

6.4.3 Long-Term Effectiveness and Permanence

Under Alternative 7b, the existing contaminated material would be removed from the Weldon Spring site, and the entire site could be released for future uses. Soil remediation is expected to be the same as for Alternative 7a, except soil within the area that would have been used for disposal would be selectively remediated (i.e., less soil would be removed for cleanup). Residual risks associated with future uses would be as described for Alternative 6a (Section 6.2.3.2) The contaminated material would be placed in a disposal cell at the Envirocare site, and Envirocare of Utah, Inc., would be responsible for the monitoring and maintenance activities at that facility. These activities would be expected to ensure the effectiveness of waste isolation and allow the assessment of potential future risks and the need for preventing any potential exposures if the disposal cell failed. Vitrification of the most highly contaminated material would greatly reduce the mobility of contaminants in that portion of the waste. Therefore, if institutional controls were lost at the Envirocare site over the long term and the cell subsequently failed, only very slow releases of contaminants to the environment would result from leaching of the vitrified material. The Envirocare site is located in an arid environment in which precipitation is much lower than the Weldon Spring site, so the potential for human exposure to surface water or groundwater contaminated by any contribution from the Weldon Spring waste would be small. Under current land-use conditions, people do not live near the Envirocare site. If current conditions continue, the potential for public health impacts would be low. However, local air quality might be impacted by wind dispersal (e.g., of the untreated soil) because wind speeds can be high and the area is sparsely vegetated (DOE 1992d).

6.4.3.1 Protection of Workers

Exposures of workers during long-term monitoring and maintenance activities at the Envirocare site would be similar to exposures under Alternative 7a for disposal at the Weldon Spring site because the wastes involved would be the same, and the conditions for workers at the two locations would be similar. Exposures of workers to released contaminants (e.g., particulates and radon gas) would be negligible because the disposal cell would be designed and maintained to control such releases. In the 30 years immediately following implementation of Alternative 7b, it is estimated that about nine cases of occupational injury and no occupational fatalities would occur during routine monitoring and maintenance activities.

6.4.3.2 Protection of the Public

The potential for long-term exposures of members of the public in the vicinity of the Envirocare site under Alternative 7b would be low if it is assumed that current land use in the area continues. It is expected that the disposal cell would be designed to last for at least 200 to 1,000 years. However, if institutional controls were lost in the future and the cell failed, any nearby members of the public might be impacted. The nature of these impacts would depend on the magnitude of the release and local land-use conditions at the time it occurred. The dry climate would reduce the potential for migration of contaminants from the cell to surface water or groundwater. However, groundwater might be impacted if the waste became saturated over time (e.g., by infiltration through cover cracks during heavy storms). The dry conditions, wind speeds, flat terrain, and sparse vegetation would result in higher air quality impacts from wind dispersal of the untreated material if it were exposed; this might impact human health if individuals were in the affected area when the material was dispersed.

6.4.3.3 Environmental Protection

Soil and Geology. The long-term impacts on soil associated with Alternative 7b would be similar to, but smaller than, the impacts associated with Alternative 6a (Section 6.2.3.3). About 409,000 m^3 (535,000 yd^3) of soil would be required from nearby borrow sources at the Weldon Spring site, which is about one-third the volume of borrow material required for Alternative 6a (the additional 607,000 m^3 [794,000 yd^3] for disposal cell construction would be taken from the area of the Envirocare site). Up to 21 ha (52 acres) of land would be permanently disrupted at the representative nearby borrow area under Alternative 7b. Impacts to prime farmland at that area (if used) could be similar to that for Alternative 6a because although the amount of borrow material would be lower, the same area would probably be excavated to a lesser depth. Construction of a rail siding at Wentzville could result in the permanent disruption of up to 4.5 ha (11 acres) of land at that location. Because the disposal cell would be constructed at the Envirocare site, about 17 ha (42 acres) would be permanently disrupted at that location, and soil currently in the area targeted for that disposal facility would be removed.

Earthquakes predicted for the Envirocare site would result in peak horizontal accelerations in bedrock of 0.31 g, with return periods of more than 10,000 years (DOE 1984). Potential seismic risks would be considered during cell design. Implementation of Alternative 7b would not affect the regional geology of the Weldon Spring site, the Envirocare site, or their surrounding areas.

Water Quality and Hydrology. After the sources of contamination were removed from the Weldon Spring site, contaminant levels in nearby surface water and groundwater would tend to decrease. Construction of a rail siding at Wentzville is not expected to result in any long-term effects on water quality. Also, assuming that the monitoring and maintenance activities continue for the long term, no significant long-term impacts on surface water or groundwater quality are expected at the Envirocare site.

No other long-term hydrological impacts are expected under Alternative 7b at the Weldon Spring site, the Wentzville siding, or the Envirocare site. No effects are expected at the Weldon Spring site because the site would be regraded to approximately original contours and surface runoff would be directed to existing off-site stream channels. If a new rail siding were constructed at Wentzville, it would be constructed on an approximately level area not located in a floodplain. At most, only a few hectares (acres) of land would have any surface modifications that might affect runoff, and runoff and runon controls would be used, as needed, to control storm-water flow in the area and to minimize any long-term impacts. The Envirocare site is not in a floodplain, and the disposal cell would have little influence on runoff in the area because the size of the cell would be relatively small compared with the size of the watershed in which it would be located and only a small amount of runoff would occur in that arid environment (DOE 1992d).

If the disposal cell were to fail and no corrective measures were taken, nearby surface water could potentially be affected. However, the Envirocare site is located in a closed basin in an arid region, and the nearest permanent surface water body is located in a different basin, about 45 km (28 mi) from the site (DOE 1992d). The arid conditions and distance to nearby surface water would limit the potential for adverse effects on surface water quality.

The current monitoring well program at the Envirocare site includes sampling of about 10 of 42 wells located around the existing disposal cell. Samples are routinely analyzed for contaminants that are representative of the waste types present in the cell. Envirocare of Utah, Inc., would be expected to conduct similar activities for monitoring the containment effectiveness for the Weldon Spring waste disposed of at the Envirocare site.

The potential effects on groundwater resulting from failure of a disposal cell at the Envirocare site were evaluated with a conservative model, in the same manner as the evaluation of disposal cell failure at the Weldon Spring site (Section 6.2.3.3). The details of the analysis are presented in Appendix D and Tomasko (1992). The overburden material at the Envirocare site is about 5.5 m (18 ft) thick, and the equivalent, harmonic mean saturated hydraulic conductivity calculated from laboratory measurements is 4.3×10^{-7} cm/s (0.0012 ft/d) (Bingham Environmental 1991). Infiltration of leachate from a disposal cell was assumed to occur under saturated conditions, with an average linear groundwater velocity equal to the harmonic mean of the saturated hydraulic conductivity of the composite overburden. For this analysis, artificial or engineered bottom liners, which could further reduce the permeability of the overburden material, were not included in calculating the harmonic mean saturated hydraulic conductivity.

The approximate travel times required for dissolved contaminants to move from the bottom of a disposal cell at the Envirocare site through the vadose zone to the top of water table and achieve a maximum concentration are summarized in Table 6.9. Conservative estimates of the time required for dissolved contaminants to move from the bottom of a disposal cell, through the overburden, to a potential receptor location and achieve a maximum concentration are given in Table 6.10. The hypothetical receptor was assumed to be 1,600 m (5,280 ft) downgradient of the disposal cell. This distance was selected assuming that the cell would be located in the southeast corner of the Envirocare site. The concentration values presented in Tables 6.9 and 6.10 are dimensionless and are based on conservative assumptions. More representative contaminant concentrations could be obtained by multiplying the dimensionless concentrations by their corresponding source values in the leachate from the disposal cell. The estimated decrease in the maximum concentration of a conservative constituent between a release from the cell and arrival at the site boundary, combined with the distance to the nearest population center (for current land-use conditions), indicates that cell failure would have no significant effects on off-site groundwater quality at the Envirocare site.

Air Quality. The long-term impacts on air quality at the Weldon Spring site under Alternative 7b would be negligible because the sources of contamination would be removed and the site regraded and revegetated, thereby minimizing the potential for release of fugitive dust. Similarly, no long-term impacts on air quality are expected from the off-site borrow area because the disturbed sites would be restored (e.g., regraded and revegetated) following use. After placement of the Weldon Spring waste in a disposal cell at the Envirocare site, air quality in the area would be similar to existing conditions. The potential for air quality impacts if the cell were to fail in the future and no corrective actions were taken is indicated in Section 6.4.3.2.

Biotic Resources. Under Alternative 7b, the long-term effects on biotic resources at the Weldon Spring site and the Busch Wildlife Complex would be slightly less than those identified for Alternative 6a (Section 6.2.3.3) and Alternative 7a (Section 6.3.3.3) because the 17-ha (42-acre) area not used as a disposal facility would be returned to native habitat. However, additional impacts on biotic resources in the Weldon Spring area could result from the construction and

TABLE 6.9 Summary of Disposal Cell Failure Calculations for the Envirocare Site: One-Dimensional Vadose Zone[a]

Retardation	Maximum Concentration at Bottom of Unsaturated Zone (percent of initial concentration)	Time of Maximum Concentration at Bottom of Unsaturated Zone (years)
1	75	55
5	19	170
100	1	3,050

[a] These calculations include only the vertical flow component through the vadose (unsaturated) zone. No artificial or engineered bottom liners were assumed to be used for the disposal cell.

TABLE 6.10 Summary of Disposal Cell Failure Calculations for the Envirocare Site: Entire Flow System[a]

Retardation	Maximum Concentration at Location of Receptor[b] (percent of initial concentration)	Time of Maximum Concentration at Location of Receptor[b] (years)
1	3.3	272
5	0.66	1,270
100	0.033	25,360

[a] These calculations are the combined results of three separate calculations: the vertical flow component through the vadose (unsaturated) zone, mixing, and the lateral flow component through the phreatic (saturated) zone.

[b] Hypothetical receptor is located about 1,600 m (5,280 ft) downgradient of the disposal cell.

operation of a rail siding at Wentzville, which could potentially result in the permanent loss of approximately 4.5 ha (11 acres) of wildlife habitat. No state listed species or sensitive communities are known to occur in the Wentzville area (Dickneite 1991). In the event that an existing siding were leased for Alternative 7b, no permanent effects on biotic resources would be expected in the Wentzville area.

Cell construction and maintenance at the Envirocare site would result in the permanent loss of approximately 17 ha (42 acres) of semidesert shrubland, assuming that the area requirements would be the same as at the Weldon Spring site for the same volume of waste. The plant community at the disposal cell location (primarily shadscale-gray molly) would be permanently lost, and wildlife using this area would be destroyed or permanently displaced. None of the vegetation, habitats, or wildlife that would be affected are unique, so implementation of Alternative 7b would not be expected to significantly affect the ecosystem of the area. In addition, no impacts to aquatic resources are expected because of the absence of aquatic habitats (DOE 1984) and state listed species (Fairchild 1991).

The U.S. Fish and Wildlife Service has identified the federal threatened bald eagle (*Haliaeetus leucocephalus*) and the federal endangered peregrine falcon (*Falco peregrinus*) as possibly occurring in the area (Johnson 1991). Rush Valley and Skull Valley — located about 48 and 24 km (30 and 15 mi), respectively, to the east of the Envirocare site — are used as wintering areas by the bald eagle, and two peregrine falcon hack sites are located about 42 km (26 mi) east and 88 km (55 mi) northeast of the site. The U.S. Fish and Wildlife Service has expressed concern about potential impacts to these populations and to potential habitats on the Envirocare site (Fairchild 1991). A biological assessment evaluating the potential for adverse impacts to these resources for Alternative 7b has been prepared and submitted to the U.S. Fish and Wildlife Service for concurrence and is currently under review (see Appendix I). Because of the distances from the site to these areas, no impacts to either of these listed species are anticipated from the human activity associated with operation and long-term maintenance of the disposal cell.

Failure of the disposal cell in the absence of corrective measures could result in the release of some contaminants and subsequent exposure of local vegetation and wildlife. The extent of habitat contamination and exposure of biota would depend on the nature and magnitude of the cell failure, the extent of contaminant dispersal following cell failure, and the implementation of response measures. Because of the absence of aquatic habitats and state listed species in the area, no impacts to these resources are expected. Also, because of the distances to the peregrine falcon hack sites and the bald eagle wintering areas (from 24 to 88 km [15 to 55 mi]), no impacts to these areas would be expected. Little or no impact to foraging habitat for the bald eagle and peregrine falcon is anticipated at the Envirocare site, and exposure of these species to contaminants via food chain transfer is not considered likely (see Appendix I).

Under Alternative 7b, approximately 409,000 m^3 (535,000 yd^3) of borrow material would be required, which is about one-third the volume needed for Alternative 6a. Up to 21 ha (52 acres) of upland habitat and four wetlands at the potential borrow area would be impacted. The loggerhead shrike, a federal C2 species, has been reported from that area. In addition, the potential borrow area may provide suitable habitat for Bachman's sparrow, another C2 species. Thus, if that location were used, removal of borrow could result in the permanent loss of suitable forging and nesting habitat for these species.

Socioeconomics and Land Use. Disposal of the Weldon Spring waste at the Envirocare site would have no significant effects on socioeconomics and land use in the vicinity of that site. The site is a commercial waste disposal facility, and land holdings within a 15-km (9-mi) radius are predominantly public domain administered by the Bureau of Land Management (DOE 1992d). Current use of the area appears confined to sheep grazing (on state leases) and recreational vehicle operation, but such uses are apparently minimal; poor soil conditions and isolation from urban areas render agricultural or residential development unlikely in the reasonably predicted future (DOE 1984).

Removal of contaminated waste from the Weldon Spring site would eliminate any potential effects on future population and economic growth in the immediate area. Construction of a new rail siding at Wentzville, if necessary, could affect local land-use patterns, depending on the location selected for the siding. Up to 4.5 ha (11 acres) of residential, agricultural, or commercial land would be committed to long-term industrial use. The removal of soil from a nearby representative borrow area might impact prime farmland at that location, with effects and mitigative measures similar to those for Alternatives 6a and 7a.

Cultural Resources. Construction of a rail siding at Wentzville, if undertaken in a previously undisturbed area, might require an archaeological field survey to identify, evaluate, and mitigate potential adverse effects to significant archaeological sites. A review of records at the Archaeological Survey of Missouri indicates that no sites are currently recorded in the Wentzville area (Missouri Archaeological Society 1991). Removal of borrow material from the potential off-site borrow area could adversely affect archaeological sites that meet eligibility criteria for the *National Register of Historic Places*. Impacts would probably be less than for Alternatives 6a and 7a because the smaller volume of borrow material required would reduce the depth (and possibly the area) of the area disturbed. Adverse effects to eligible sites would be mitigated through avoidance, or if necessary, data recovery (excavation).

Removal of waste to the Envirocare site would have no adverse effects on archaeological sites or cultural resources, including historic structures listed on or eligible for the *National Register of Historic Places*. An archaeological field survey of the Envirocare site was carried out during August 1981 (DOE 1984). Except for several isolated fragments of glass (undated remains of the historic period), no artifacts were encountered. No buildings or structures of historic significance occur in the affected areas.

6.4.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Reductions in contaminant toxicity, mobility, and volume would be the same for Alternative 7b as for Alternative 7a (Section 6.3.4).

6.4.5 Short-Term Effectiveness

6.4.5.1 Duration of Remedial Activities

Remedial activities under Alternative 7b are projected to be completed in about 10 years. The removal and treatment components of Alternative 7b would require the same amount of time as identified for Alternative 7a. The time required to complete the off-site transport and disposal component of Alternative 7b is estimated to be about 7 years, which includes time for procurement of equipment and facilities. These times could be longer if delays occurred in the acquisition of necessary licenses and permits and associated administrative procedures required for transport and disposal of the Weldon Spring waste at the Envirocare site (or if implementation of the vitrification process at the Weldon Spring site is delayed).

6.4.5.2 Protection of Workers

The remedial action worker requirements for implementing Alternative 7b, including requirements for off-site transportation, are estimated to be about 1,100 person-years. In addition, approximately 200 individuals would be working on-site in the project office building during this period. To minimize potential occupational exposures to contaminants, remedial action activities would be conducted in accordance with applicable regulatory limits and health and safety plans developed for the Weldon Spring site.

The potential occupational impacts during the implementation of Alternative 7b would be similar to those incurred under Alternative 7a (Section 6.4.4.2). An assessment of the risks associated with implementing this alternative is presented in detail in Appendix F. The health risks to the maximally exposed on-site remedial action worker are estimated to be approximately 1×10^{-3} and 8×10^{-5} for exposure to radioactive and chemical contaminants, respectively. The collective risk to the entire remedial action work force from radiation exposure is estimated to be 2×10^{-1}. Although some potential exists for noncarcinogenic effects (i.e., the hazard index to the maximally exposed worker was estimated to be greater than 1), use of protective clothing and respiratory protective equipment would minimize the likelihood of such effects. Actual exposures to contaminants would be well below applicable regulatory limits (Appendix F, Section F.6).

The radiological risks to the additional workers for transportation activities would be less than those projected for on-site remedial action workers. The risk to the maximally exposed transportation worker from external gamma irradiation during incident-free transportation is estimated to be 2×10^{-4}. The collective risk to transportation workers is estimated to be 9×10^{-4}, which is significantly less than the risk to on-site remedial action workers. Actual exposures to contaminants would be well below applicable regulatory limits. On the basis of statistics for construction and transportation activities of comparable size and scope, no occupational fatalities are expected to occur during implementation of Alternative 7b. Approximately six transportation accidents are likely to occur, with no associated fatalities, and approximately 160 cases of occupational injury are estimated to occur, with about 1,600 lost workdays (Appendix F, Sections F.6 and F.7). Safety hazards associated with the high temperatures and the complexity of the vitrification process compared with the chemical treatment process could result in more worker accidents. To address this concern, additional measures would be taken to implement Alternative 7b in a manner that would not jeopardize the safety of workers.

6.4.5.3 Protection of the Public

Estimated exposures of the public in the vicinity of the Weldon Spring site during implementation of Alternative 7b would be similar to those for Alternative 7a. The health risks to the maximally exposed member of the public from site releases are estimated to be 7×10^{-7} and 3×10^{-8} for radioactive and chemical contaminants, respectively. The hazard index is much less than 1, indicating that no noncarcinogenic effects are anticipated. The collective radiological risks to the population within 5 and 80 km (3 and 50 mi) of the site are estimated to be 3×10^{-3} (for a population of 10,700) and 2×10^{-2} (for a population of about 3 million), respectively; the actual radius of impact would likely be less than 5 km (3 mi). No adverse impacts would be incurred by off-site individuals in the vicinity of the Weldon Spring site as a result of contaminant releases during implementation of this alternative (Appendix F, Section F.6).

Alternative 7b would require the transportation of a large volume of contaminated material off-site for disposal, which would result in incremental risks to the general public. The radiological impacts to the general public associated with transportation activities would be significantly less than those that would occur in the vicinity of the Weldon Spring site from releases generated during on-site treatment and handling activities. The risk to the maximally exposed member of the public from transportation activities is estimated to be 7×10^{-8}; this individual is assumed to be a resident living 30 m (100 ft) from the transport route who is at home during every shipment pass. The collective risk to the general public from radiation exposure resulting from transportation activities is estimated to be 3×10^{-3}. Although several transportation accidents are projected to occur during shipment of the waste to the Envirocare site, no fatalities are anticipated (Appendix F, Section F.7). The radiological risk to members of the public from transportation accidents is significantly lower than the risk from external gamma irradiation during incident-free transportation.

6.4.5.4 Environmental Protection

Soil. Soil disturbance at the Weldon Spring site during implementation of Alternative 7b would be similar to Alternative 7a, and similar mitigative measures would be used to control erosion (Section 6.2.5.4). Soil disturbance at the borrow area would be similar to that associated with Alternative 6a, but impacts might be lower because of the reduced requirements for borrow material. Soil disturbances for the pipeline would be the same as for Alternative 7a (Section 6.3.5.4). Standard mitigative measures would be used to reduce the potential for erosion during construction and operation of the rail siding at Wentzville. Because of the arid conditions at the Envirocare site, the potential for water erosion during disposal cell construction is low. Good engineering practices would also be used to reduce the potential for water erosion, and mitigative measures would be used as needed. Wind erosion could be more significant, but mitigative measures such as wetting of soil would be used to reduce the potential for wind erosion and minimize adverse air quality effects.

Issues related to the transport of contaminated material to the Weldon Spring site from vicinity properties and the transport of containerized liquid waste to an off-site incinerator would be the same as discussed for Alternative 6a. In the absence of an accident, transportation of waste to the Envirocare site would have no effect on off-site soil because closed containers would be used. Contingency plans would be in place to address spills, so if an accident occurred that resulted in the release of contaminated material, the spill area would be cleaned up; thus, no long-term effects are expected.

Water Quality and Hydrology. Potential short-term impacts to surface water near the Weldon Spring site during the action period for Alternative 7b would be generally similar to those discussed for Alternative 7a, and similar mitigative measures would be used. The potential for impacts associated with the borrow area could be reduced because of the reduced volume of the borrow material required under Alternative 7b. The potential for water quality impacts resulting from construction and operation of a rail siding at Wentzville would be minimized by the use of erosion control measures to prevent movement of sediment from the siding area. The disposal cell at the Envirocare site would be located about 45 km (28 mi) from the nearest perennial water body (DOE 1992d). Because conditions at the site are arid, construction of a disposal cell at the Envirocare site using good engineering practices would not affect local surface water during the remedial action period.

The contaminated material would be transported in closed containers, so any adverse effects on surface water or groundwater related to transportation are unlikely except in the event of an accident. If a spill occurred, it would be cleaned up in accordance with the contingency plan, and efforts would be made to prevent the movement of contaminated material to any nearby water body. Short-term issues related to groundwater for the Weldon Spring site would be as discussed for Alternative 6a (Section 6.2.5.4).

Air Quality. Short-term impacts to air quality at the Weldon Spring site would be smaller for Alternative 7b than Alternative 7a (Section 6.3.5.4) because emissions associated with disposal cell construction, operation, and closure (primarily from uncontaminated construction material) would occur off-site at the Envirocare site instead of at the Weldon Spring site; any impacts associated with fugitive dust at the off-site borrow area would also be lower. Construction of a rail siding in Wentzville could result in short-term increases in erosion and fugitive dust emissions; erosion control and dust control measures (e.g., silt fences, water sprays, and chemical dust suppressants) would be implemented during construction to minimize potential impacts. No impacts are expected from transportation to and operations at the rail siding because the contaminated material would be transported in closed containers. Disposal cell construction and operation activities at the Envirocare site are assumed to be similar to those for on-site activities. Preliminary screening-level calculations indicate that the 24-hour PM-10 concentration might exceed the air quality standard at that site boundary when weather patterns were unfavorable or the volume of material being handled was high (Appendix C, Section C.1.3.1). The same control measures used at the Weldon Spring site under Alternative 7a could be implemented at the Envirocare site under Alternative 7b to minimize potential impacts from fugitive dust emissions related to disposal cell construction and operations.

Biotic Resources. Under Alternative 7b, short-term impacts to biotic resources at the Weldon Spring site and the Busch Wildlife Complex would be similar to the impacts identified for Alternative 7a (Section 6.3.5.4). Use of the representative off-site borrow area would impact up to 21 ha (52 acres) of old-field habitat and agricultural fields land and four wetlands. The potential for impacts associated with the borrow area under Alternative 7b would be lower than for Alternative 7a because of the smaller amount of material required.

Impacts to biotic resources at the Wentzville rail siding would result primarily from construction and transportation activities at the site. However, because of the urbanized and disturbed nature of the rail corridor through Wentzville, little undisturbed vegetation or wildlife habitat is expected to occur at the rail siding location. Thus, few impacts to the biotic resources of the area are anticipated to result from the loss of vegetation or wildlife habitat at this location. The effects of noise, fugitive dust, and human activity that would occur as a result of construction and transportation activities at the rail siding would be temporary, and the resulting displacement of wildlife would not significantly affect local biota because of the limited wildlife expected to occur in the area. No federal listed species, critical habitats, state listed species, or sensitive biotic communities are known to occur in the Wentzville area (see Appendix I) (Brabander 1991b; Dickneite 1991).

Some wildlife in the vicinity of the Envirocare site could be affected by noise, human activity, and fugitive dust associated with construction of the disposal cell, transport of the waste to the site, and placement of the waste into the cell. Potential impacts from fugitive dust emissions would be minimized through the implementation of dust control measures during construction and transportation activities. Because of the limited biota present in the area, few impacts to local biota are expected, and any impacts would be temporary.

No federal listed species, state listed species, or critical habitats are known to occur at the Envirocare site (see Appendix I) (Fairchild 1991; Johnson 1991). However, the U.S. Fish and Wildlife Service (Johnson 1991) has identified the federal endangered bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*) as possibly occurring in the area. A biological assessment has been prepared that evaluates the potential for adverse impacts to listed, proposed, and C2 species (see Appendix I), and this assessment has been submitted to the U.S. Fish and Wildlife Service for concurrence and is currently under review. This assessment addressed cell construction and disposal activities at the Envirocare site. Because of the distances from the Envirocare site to the bald eagle wintering areas and the peregrine falcon hack sites (Section 6.4.3.3), no impacts are expected from cell construction and waste placement activities (see Appendix I). Although the bald eagle may forage in the vicinity of the site during winter months, the current and continued human activity at the Envirocare site likely preclude the use of the immediate surroundings by this bird.

Socioeconomics and Land Use. The effects on socioeconomics and land use near the Weldon Spring site from obtaining borrow material at an off-site location would be similar to those described for Alternative 6a (Section 6.2.5.4), but could be smaller because less material would be required. The remedial action worker requirements for implementing Alternative 7b are estimated to be about 1,100 person-years, which is about 40% higher than the 780 person-years estimated for Alternative 7a. Temporary impacts on the labor force and traffic volume near the Weldon Spring site would be similar to those for Alternative 7a (Section 6.4.3.3), except that additional truck traffic would occur between the site and the Wentzville rail siding. The transport of contaminated material to Wentzville would result in up to 42 vehicles per day (round trip) on both State Route 94 and U.S. 40/61. Current traffic on U.S. 40/61 is about 24,000 vehicles per day (Brocksmith 1991). Overall increases in truck traffic on State Route 94 would be about the same for Alternative 7b as for Alternative 7a. Temporary impacts on the labor force and traffic volume near the Envirocare site as a result of cell construction would be addressed in the separate EIS being prepared by the NRC to support the licensing action for that site (NRC 1991). This environmental review process is expected to be completed in July 1993.

Implementation of this alternative could result in the release of the entire Weldon Spring site for future uses. The size of the site, 88 ha (217 acres), is small relative to available land in this area. Hence, no significant impacts on local population growth or land use would be expected if this alternative were implemented.

Cultural Resources. No adverse effects to archeological sites or cultural resources would occur near the Envirocare site during implementation of Alternative 7b. Potential impacts associated with activities in the Weldon Spring area would be similar to those described for Alternative 7a (Section 6.3.5.4), with additional impacts possible at the Wentzville location (Section 6.4.3.3).

6.4.6 Implementability

The implementability of the removal and treatment components of Alternative 7b would be the same as described for Alternative 7a (Section 6.3.6). The implementability of the disposal component of Alternative 7b would depend on the implementability of both transport of the Weldon Spring waste to the Envirocare site and disposal at that site.

Off-site transport of the contaminated material to the Envirocare site would consist of truck transport from the Weldon Spring site to a rail siding in Wentzville, transfer of the material to railcars, and rail transport from Wentzville to the Envirocare site near Clive. Equipment, facilities, and the required personnel for truck and rail transport are readily available. The waste would be shipped in closed containers designed to be handled by standard intermodal container equipment and would fit on railroad flatcars specifically designed for the containers (see Appendix F, Section F.7). Similar containers have been used for waste from the UMTRA Program (MK-Ferguson Company and Jacobs Engineering Group 1992b).

A rail siding occupying about 4.5 ha (11 acres) would be constructed or leased in Wentzville under Alternative 7b. The Wentzville area has several existing sidings, and the Union Pacific Railroad could potentially assist in locating a siding that could be used for staging and loading. Construction and operation of a rail siding would be straightforward. Material staging and loading would be accomplished with standard, industry-proven technologies. Security personnel would be required at the siding for 24 hours per day, 7 days per week.

A permit for the construction and operation of the rail siding would also be required. The Union Pacific Railroad employs hazardous waste emergency response teams throughout its system. Information pertinent to shipment of the Weldon Spring waste (e.g., waste characteristics and emergency handling information) would be entered into the railroad computer system for access by the emergency response teams, if needed. A spill contingency plan would be developed and, in the event of a spill, an emergency response team would reload the spilled material into containers supplied from the Wentzville siding or the disposal facility, test the area for residual contamination, and clean the area, as needed. Transport of the waste off-site would require significant coordination among agencies. Many states require advance notification and permitting for shipments of radioactive material entering their domain, and all shipments would be required to meet applicable federal and state regulations.

The Envirocare site is licensed to accept NORM waste and is permitted to accept mixed NORM and chemically hazardous waste, and Envirocare of Utah, Inc., has submitted an application for disposal of 11e(2) by-product material to the NRC (Section 5.4.3). The time required for the Envirocare site to receive the license and necessary permits for accepting the Weldon Spring waste could result in schedule delays. An EIS for the disposal of 11e(2) by-product material at the Envirocare site is currently being prepared, and that environmental review process is projected to be completed in July 1993. Delays in this schedule could impact the schedule for off-site transport of the Weldon Spring waste to the Envirocare site.

The Envirocare site has adequate facilities to accept the Weldon Spring waste. The site occupies 227 ha (560 acres), of which about 40 ha (100 acres) is occupied by Envirocare NORM and mixed waste cells, and about 170 ha (420 acres) is available for the addition of future disposal cells such as would be constructed for the Weldon Spring waste under Alternative 7b (DOE 1992d). The Envirocare site is dedicated solely to the disposal of radioactive and mixed wastes. Transfer areas, storage areas, decontamination facilities, and a laboratory are available at the site. The site is accessible by a rail siding, where the containers could be transferred to trucks for movement to the disposal cell where the containers would be unloaded.

The administrative feasibility of Alternative 7b would be impacted by the requirements for coordinating off-site transport and disposal. Numerous state and federal regulations would need to be addressed, and licenses, permits, and administrative procedures would need to be in place before transport and disposal could take place. These requirements might impact the time required to implement this alternative.

6.4.7 Cost

The total and present-worth costs for Alternative 7b are given in Table 6.11 and are estimated to be $351 million and $197 million, respectively, including the cost of constructing and operating a disposal cell at the Envirocare site. The cost of disposing of wastes at the Envirocare site was determined on the basis of disposal fee quotes obtained from Envirocare of Utah, Inc. The disposal fee is estimated to be $158/t ($144/ton) (MK-Ferguson Company and Jacobs Engineering Group 1992b), but a detailed cost analysis would have to be performed before a firm price could be developed. An estimated cost of $60/t ($54/ton) for rail transport to the facility, including the return of empty containers, was obtained from Union Pacific Railroad (MK-Ferguson Company and Jacobs Engineering Group 1992b). The costs of constructing the rail siding at Wentzville and hauling the waste from the site to the siding are estimated to be $23.8 million. The total cost for off-site transport and disposal at the Envirocare site, including ancillary facilities, is estimated to be $214 million.

Disposal and rail transport fees increase the cost of Alternative 7b. Material hauling costs associated with off-site disposal are dependent upon the costs for the containers, constructing the rail siding, and hauling the waste by truck to the siding. The overall cost could increase if documentation expenses for waste transport exceeded the percentage of direct labor cost assumed for operating expense. Other cost variations would be as identified for Alternative 7a (Section 6.3.7).

6.5 ALTERNATIVE 7c: REMOVAL, VITRIFICATION, AND DISPOSAL AT THE HANFORD SITE

6.5.1 Overall Protection of Human Health and the Environment

Alternative 7c would provide for protection of human health and the environment at the Weldon Spring site by (1) removing the sources of contamination, (2) treating the materials that pose the principal threats at the site by vitrification, and (3) transporting all contaminated material to the Hanford site near Richland, Washington, for disposal. Protection of human health and the environment in the vicinity of the Hanford site would be ensured by placing all contaminated materials in an engineered disposal cell to minimize the potential for contaminant migration. Exposures and risks at both the Weldon Spring and Hanford sites would be limited to very low levels. Institutional controls would be maintained at the Hanford site to provide further protection against potential future exposures. Alternative 7c is not expected to result in any unacceptable impacts during implementation (Section 6.5.5).

6.5.2 Compliance with ARARs

Compliance with location-specific and contaminant-specific ARARs under Alternative 7c would be the same as identified for Alternative 7a. Compliance with action-specific requirements for activities that take place on-site under this alternative would be the same as identified

TABLE 6.11 Cost Estimate for Alternative 7b

Activity	Estimated Cost (million $)
Removal	
Common removal costs (see Table 6.8)	24.8
Soil and sediment excavation[a]	1.5
Removal subtotal	26.3
Treatment	
Common treatment costs (see Table 6.8)	60.9
Water treatment plant operations[a]	3.1
Treatment subtotal	64.0
Disposal	
Disposal facility construction material tests	-[b]
Disposal facility construction	-[b]
Disposal cell operations	-[b]
Off-site transport and disposal	214
Disposal subtotal	214
Other	
Common other costs (see Table 6.8)	10.2
Material hauling[a]	33.1
Site restoration[a]	3.2
Long-term maintenance	-[c]
Other subtotal	46.5
Total	351
Present worth	197

[a] Items for which the cost estimate does not differ between Alternatives 7b and 7c.

[b] The costs for construction and operation of a disposal cell at the Envirocare site are not explicitly identified because such costs are factored into the disposal fee, which is included in the cost estimate for off-site transport and disposal.

[c] Long-term maintenance of the Weldon Spring site would no longer be required because the contaminated media would have been removed from the site area. Costs for long-term maintenance at the Envirocare site are included in the disposal fee.

Source: MK-Ferguson Company and Jacobs Engineering Group (1992b).

for Alternative 7b. The application of specific environmental regulations to activities being considered for the off-site facilities, such as treatment of liquid waste at an off-site incinerator and disposal of solid material at the Hanford site, would be addressed in the environmental compliance documents and activities for those facilities. A site-specific NEPA document would be prepared by the owners/operators of the Hanford site if a new disposal cell were located there for the Weldon Spring waste.

6.5.3 Long-Term Effectiveness and Permanence

Under Alternative 7c, the existing contaminated material would be removed from the Weldon Spring site such that the site could be released for future uses. Residual risks would be as described for Alternative 7b (Section 6.4.3). The contaminated material would be placed in a disposal cell at the Hanford site, and monitoring and maintenance activities would be carried out at that site for the long term. These activities would be expected to ensure the effectiveness of waste isolation and would allow the assessment of potential future risks and the need for preventing any potential exposures if the disposal cell failed. Vitrification of the most highly contaminated material would greatly reduce the mobility of contaminants in that portion of the waste. Therefore, if it were hypothetically assumed that institutional controls were lost at the Hanford site in the long-term future and the cell subsequently failed, contaminants would be leached to the environment very slowly from the vitrified material. In addition, the Hanford site is located in an arid environment in which precipitation is much lower than at the Weldon Spring site, so the potential for human exposure to contaminated water would be small. However, air quality might be impacted by wind dispersal (e.g., of the untreated soil) because wind speeds can be high and the area is sparsely vegetated (DOE 1992d).

6.5.3.1 Protection of Workers

Exposures of workers during long-term monitoring and maintenance activities at the Hanford site would be similar to exposures under Alternative 7a for disposal at the Weldon Spring site because the wastes involved would be the same, and the conditions for workers at the two locations would be similar. Exposures of workers to released contaminants (e.g., particulates and radon gas) would be negligible because the disposal cell would be designed and maintained to control such releases. In the 30 years immediately following implementation of Alternative 7c, it is estimated that about nine cases of occupational injury and no occupational fatalities would occur during routine monitoring and maintenance activities.

6.5.3.2 Protection of the Public

The potential for exposures of members of the public in the vicinity of the Hanford site in the long term would be low, on the basis of current land use in the area. It is expected that the disposal cell would be designed to last at least 200 to 1,000 years. However, if institutional controls were lost and the cell failed, any nearby members of the public might be impacted. The nature of these impacts would depend on the magnitude of the release and local land-use conditions at the time it occurred. The dry climate would reduce the potential for migration of contaminants from the cell to water. However, several surface water bodies (including two rivers) are nearby, and surface runoff after heavy storms could be higher than at the Weldon Spring site (but comparable to the Envirocare site) because attenuating surface features such as dense vegetation are absent. In addition, the higher permeability of the overburden material compared to the two alternate disposal sites could result in groundwater impacts if the waste were saturated (e.g., by infiltration through cover cracks during heavy storms) and the foundation material of the cell was breached over time. The potential for impacts from airborne contaminants (e.g., from wind dispersal of untreated material) would be as described for Alternative 7b (Section 6.4.3.2).

6.5.3.3 Environmental Protection

Soil and Geology. The potential impacts on soil at the Hanford site under Alternative 7c would be similar to those at the Envirocare site under Alternative 7b (Section 6.4.3.3). Earthquakes predicted for the 200-West Area (the potential location for the disposal of the Weldon Spring waste) would result in peak ground accelerations of about 0.3 g, with a return period of 10,000 years (DOE 1991). Potential seismic risks would be considered during cell design. Implementation of Alternative 7c would not affect the regional geology of the Weldon Spring site or the Hanford site or their surrounding areas.

Water Quality and Hydrology. The impacts on water quality and hydrology both on-site and at the off-site disposal location under Alternative 7c could be similar to those for Alternative 7b (Section 6.4.3.3). In the absence of cell failure, no significant long-term impacts are expected on surface water or groundwater quality at the Hanford site under Alternative 7c. The disposal cell would not be in a floodplain and would not have significant influence on runoff in the area because the size of the cell would be small relative to the area of the drainage basin in which it would be located and because very little rainfall and runoff occur in the area.

Failure of a disposal cell at the Hanford site could potentially affect nearby surface water. However, the site is located in an arid region and the nearest surface water body, an ephemeral stream, would be more than 3 km (2 mi) from the disposal cell (DOE 1992d). The Columbia River is about 8 km (5 mi) north of the 200-West Area, and some of the disposal area drains to this river. The Yakima River, the nearest downgradient perennial water body for most of the 200-West Area, is about 24 km (15 mi) to the southeast. The arid conditions and distance to surface water would limit the potential for adverse effects on surface water quality.

The potential effects on groundwater resulting from failure of a disposal cell at the Hanford site were evaluated with a conservative model, in the same manner as the evaluation of disposal cell failure at the Weldon Spring site (Section 6.2.3.3). The details of the analysis are presented in Appendix D. The overburden material in the 200-West Area at the Hanford site (the potential location for the disposal cell) is about 30 m (100 ft) thick (Pacific Northwest Laboratory 1989) and has an estimated average saturated hydraulic conductivity of 75 m/d

(250 ft/d). Infiltration of leachate from the disposal cell was assumed to occur under saturated conditions, with an average linear groundwater velocity equal to the value of the saturated hydraulic conductivity. For this analysis, artificial or engineered bottom liners, which could reduce the permeability of the overburden material, were not included in calculating the average saturated hydraulic conductivity.

The approximate travel times required for dissolved contaminants to move from the bottom of a disposal cell at the Hanford site through the vadose zone to the top of the water table and achieve a maximum concentration are summarized in Table 6.12. Conservative estimates of the time required for dissolved contaminants to move from the bottom of a disposal cell, through the overburden, to a potential receptor location and achieve a maximum concentration are given in Table 6.13. The hypothetical receptor was assumed to be located 13,700 m (44,800 ft) downgradient (northeast) of the disposal cell at the site boundary. The concentration values presented in Tables 6.12 and 6.13 are dimensionless and based on conservative assumptions. More representative contaminant concentrations could be obtained by multiplying the dimensionless concentrations by their corresponding source values in the leachate from the disposal cell. The estimated decrease in the maximum concentration of a conservative constituent by about four orders of magnitude between a release from the cell and arrival at the site boundary indicates that cell failure would have no significant effects on off-site groundwater quality, assuming that the site boundary remains as it is (i.e., the site boundary is a considerable distance from the conceptual cell location).

Air Quality. The long-term impacts on air quality at the Weldon Spring site under Alternative 7c would be negligible because the sources of contamination would be removed and the site regraded and revegetated, thereby minimizing the potential for release of fugitive dust. Similarly, no long-term impacts on air quality are expected from the off-site borrow area because the disturbed sites would be restored (e.g., regraded and revegetated) following use. After placement of the Weldon Spring waste in a disposal cell at the Hanford site, air quality in the area would be similar to existing conditions. The potential for future air quality impacts, if the cell were to fail in the future and no corrective actions were taken, is indicated in Section 6.5.3.2.

Biotic Resources. Under Alternative 7c, the long-term effects on biotic resources at the Weldon Spring site, the Busch Wildlife Complex, and the Wentzville rail siding would be similar to the long-term effects identified for Alternative 7b (Section 6.4.3.3). The construction and operation of a disposal cell would permanently disturb approximately 17 ha (42 acres) of land and result in the permanent loss of some vegetation and wildlife habitat at the 200-West Area of the Hanford site. However, little undisturbed vegetation or wildlife habitat exists at this location because the Hanford waste management facilities and the Plutonium Processing Facility are located at the 200-West Area (DOE 1991). In addition, the Hanford site covers an area of approximately 145,000 ha (358,300 acres), of which 136,300 ha (336,600 acres) are relatively undisturbed and support a variety of plant and wildlife habitats and communities. Thus, the vegetation and wildlife habitats that could be permanently disturbed under Alternative 7c would represent no more than 0.012% of the total wildlife habitat present at the Hanford site.

TABLE 6.12 Summary of Disposal Cell Failure Calculations for the Hanford Site: One-Dimensional Vadose Zone[a]

Retardation	Maximum Concentration at Bottom of Unsaturated Zone (percent of initial concentration)	Time of Maximum Concentration at Bottom of Unsaturated Zone (days)
1	17	0.3
5	3.5	1.5
100	0.17	30

[a] These calculations include only the vertical flow component through the vadose (unsaturated) zone. No artificial or engineered bottom liners were assumed to be used for the disposal cell.

TABLE 6.13 Summary of Disposal Cell Failure Calculations for the Hanford Site: Entire Flow System[a]

Retardation	Maximum Concentration at Location of Receptor[b] (percent of initial concentration)	Time of Maximum Concentration at Location of Receptor[b] (years)
1	7.7×10^{-3}	12
5	1.5×10^{-3}	61
100	7.6×10^{-5}	1,220

[a] These calculations are the combined results of three separate calculations: the vertical flow component through the vadose (unsaturated) zone, mixing, and the lateral flow component through the phreatic (saturated) zone.

[b] Hypothetical receptor is located about 13,700 m (44,800 ft) downgradient of the disposal cell.

The U.S. Fish and Wildlife Service (Gloman 1991) has identified the federal endangered bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*), as well as several federal candidate species, as possibly occurring in the 200-West Area. Several species of plants and animals under consideration for formal listing by the federal government and the state of Washington also occur at the Hanford site. A biological assessment has been prepared (Appendix I) that evaluates the potential for adverse impacts of the remedial action alternatives on listed and proposed species. This assessment, which addresses the representative cell construction and waste disposal at the Hanford site, has been submitted to the U.S. Fish and Wildlife Service for concurrence and is currently under review. Except for the loggerhead shrike (C2), none of the listed or candidate species, or their critical habitats, are known to occur at or use the 200-West Area (Pacific Northwest Laboratory 1991). Thus, the long-term loss of vegetation and wildlife habitat that would result under Alternative 7c is not expected to affect significantly any of these species or their critical habitats. Construction of a disposal cell at the Hanford site could result in the permanent loss of about 17 ha (42 acres) of potential foraging and nesting habitat for the loggerhead shrike. Loss of this habitat is not expected to adversely affect this species because the amount that could be lost represents less than 1% of the undisturbed habitat present at the Hanford site (Appendix I).

If the cell were to fail and no corrective measures were taken, some contaminants could be released and subsequent exposures of local vegetation and wildlife could occur. The extent of potential habitat contamination and exposure of biota would depend on the nature and magnitude of cell failure, the extent of contaminant dispersal following cell failure, and the implementation of response measures.

Socioeconomics and Land Use. Disposal of the Weldon Spring waste at the Hanford site would have no significant effects on socioeconomics and land use in the vicinity of that site. The Hanford site is owned and operated by the federal government for the production of nuclear material, research, and waste management, so the use of this area for waste disposal would be consistent with existing and planned future land-use patterns. Potential impacts in the Weldon Spring area would be the same as described for Alternative 7b (Section 6.4.3.3).

Cultural Resources. Construction of a disposal cell in the 200-West Area of the Hanford site would not adversely affect significant archaeological sites or cultural resources at that location. A literature/file review and several field surveys (pedestrian walkovers) were conducted in the 200-West Area during 1988; about 15% of the area (3.59 km^2) was sampled (Chatters and Cadoret 1990). Three isolated artifacts and two historic archaeological sites were recorded; in addition, historic White Bluffs Road traverses the center of the 200-West Area (Chatters and Cadoret 1990, Figure 5). Although the isolated artifacts and sites are not significant cultural resources, White Bluffs Road appears to meet eligibility criteria for the *National Register of Historic Places* (36 CFR 60.4) (Chatters and Cadoret 1990). A disposal cell would not be constructed on or near this historic road. However, it might be necessary to undertake a field survey of low to moderate intensity (e.g., transect intervals of 50 to 100 m) of any previously unsurveyed and undisturbed affected areas prior to disposal cell construction.

All archaeological remains encountered during such a survey would be evaluated for eligibility to the *National Register* in consultation with the Washington SHPO; sites determined to be eligible would require mitigation of unavoidable adverse effects.

The 200-West Area is located within 10 km (6 mi) of several landforms, including Gable Mountain and Gable Butte, that have religious significance to local Native American people (Relander 1956; Chatters 1989). If Alternative 7c were selected, the affected Native Americans would be consulted with regard to any potential impacts to these and other areas of religious significance (as required by the American Indian Religious Freedom Act).

6.5.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Reductions in contaminant toxicity, mobility, and volume would be the same for Alternative 7c as described for Alternative 7a (Section 6.3.4).

6.5.5 Short-Term Effectiveness

6.5.5.1 Duration of Remedial Activities

Remedial action activities for removal, treatment, and transport time under Alternative 7c would be as described for Alternative 7b. These times could be longer if delays occurred in the establishment of administrative procedures required for transport of the Weldon Spring waste to the Hanford site for disposal (or if implementation of the vitrification process at the Weldon Spring site were delayed).

6.5.5.2 Protection of Workers

The remedial action worker requirements for implementing Alternative 7c, including the requirements for off-site transportation, are estimated to be about 1,100 person-years. In addition, approximately 200 individuals would be working on-site in the project office building during this period. To minimize potential occupational exposures to contaminants, remedial action activities would be conducted in accordance with applicable regulatory limits and health and safety plans developed for the Weldon Spring site.

The potential occupational impacts during the implementation of Alternative 7c would be similar to those incurred under Alternative 7a (Section 6.4.4.2). An assessment of the risks associated with implementing this alternative is presented in detail in Appendix F. The health risks to the maximally exposed on-site remedial action worker are estimated to be approximately 1×10^{-3} and 8×10^{-5} for exposure to radioactive and chemical contaminants, respectively. The collective risk to the entire remedial action work force from radiation exposure is estimated to be 2×10^{-1}. Although some potential exists for noncarcinogenic effects (i.e., the hazard index to the maximally exposed worker was estimated to be greater than 1), use of protective clothing and respiratory protective equipment would minimize the likelihood of such effects. Actual exposures to contaminants would be well below applicable regulatory limits (Appendix F, Section F.6).

The radiological risks to the additional workers required for transportation activities would be less than those projected for on-site remedial action workers. The risk to the maximally exposed transportation worker from external gamma irradiation during incident-free transportation is estimated to be 2×10^{-4}. The collective risk to transportation workers is estimated to be 9×10^{-4}. Actual exposures to contaminants would be well below applicable regulatory limits. On the basis of statistics for construction and transportation activities of comparable size and scope, no occupational fatalities are likely to occur during implementation of Alternative 7c. Approximately eight transportation accidents are likely to occur, with no associated fatalities, and approximately 160 cases of occupational injury are expected to occur, with about 1,600 lost workdays (Appendix F, Sections F.6 and F.7). Safety hazards associated with the high temperatures and the complexity of the vitrification process compared with the chemical treatment process could result in more worker accidents. To address this concern, additional measures would be taken to implement Alternative 7b in a manner that would not jeopardize the safety of workers.

6.5.5.3 Protection of the Public

Estimated exposures of the public in the vicinity of the Weldon Spring site during implementation of Alternative 7c would be the same as those described in Alternative 7a. The health risks to the maximally exposed member of the public from site releases are estimated to be 7×10^{-7} and 3×10^{-8} for radioactive and chemical contaminants, respectively. The hazard index is much less than 1, indicating that no noncarcinogenic effects are anticipated. The collective radiological risk to the population within 5 and 80 km (3 and 50 mi) of the site are estimated to be 3×10^{-3} (for a population of 10,700) and 2×10^{-2} (for a population of about 3 million), respectively; the actual radius of impact would likely be less than 5 km (3 mi). No adverse impacts would be incurred by off-site individuals in the vicinity of the Weldon Spring site as a result of contaminant releases during implementation of this alternative (Appendix F, Section F.6).

In addition, Alternative 7c would require the transportation of a large volume of contaminated material off-site for disposal, which would result in an incremental risk to the general public. The radiological impacts to the general public associated with transportation activities would be significantly less than those that would occur in the vicinity of the Weldon Spring site from releases generated during on-site treatment and handling activities. The risk to the maximally exposed member of the public from transportation activities is estimated to be 7×10^{-8}; this individual is assumed to be a resident living 30 m (100 ft) from the transport route who at home during every shipment pass. The collective risk to the general public from radiation exposure resulting from transportation activities is estimated to be 3×10^{-3}. Although several transportation accidents are projected to occur during shipment of the waste to the Hanford site, no fatalities are anticipated (Appendix F, Section F.7). The radiological risk to members of the public from transportation accidents is significantly less than the risk from external gamma irradiation during incident-free transportation.

6.5.5.4 Environmental Protection

Soil. Short-term impacts from soil disturbance at the Weldon Spring site would be the same for Alternative 7c as for Alternative 7b (Section 6.4.5.4). The type of soil disturbance at the Hanford site under this alternative would be similar to that described for the Envirocare site under Alternative 7b.

Water Quality and Hydrology. Potential short-term impacts to water quality and hydrology at the Weldon Spring site would be the same as described for Alternative 7b (Section 6.4.5.4). Impacts at the Hanford site are unlikely because precipitation is low and engineering controls would be applied.

Air Quality. Short-term impacts to air quality in the vicinity of the Weldon Spring site under Alternative 7c would be the same as those identified for Alternative 7b (Section 6.4.5.4). Disposal cell construction and operation activities at the Hanford site are expected to have negligible impacts on off-site air quality because the disposal cell would be located several kilometers (miles) from the site boundary. Control measures similar to those used at the Weldon Spring site under Alternative 7a could be implemented at the Hanford site. Such measures would minimize potential impacts to workers and other on-site personnel from fugitive dust emissions related to disposal cell construction and operation.

Biotic Resources. Under Alternative 7c, short-term impacts to biotic resources at the Weldon Spring site, the Busch Wildlife Complex, and the Wentzville rail siding would be similar to the impacts identified for Alternative 7b (Section 6.4.5.4). Construction of the disposal cell could disturb approximately 17 ha (42 acres) of vegetation and wildlife habitat within the 200-West Area at the Hanford site, and some wildlife would be permanently displaced. In addition, wildlife in the surrounding areas would be temporarily affected by the noise and human activity that would occur during both construction and transportation activities.

Construction activities in the 200-West Area could potentially result in increased erosion and fugitive dust emissions. Increased erosion could adversely affect the biotic community of West Lake, about 6.4 km (4 mi) northeast of the 200-West Area, but impacts would be temporary. Potential impacts to aquatic resources in the area would be minimized by the use of erosion control measures such as siltation fences, berms, and retention basins during cell construction. Impacts to local biota from fugitive dust emissions would also be temporary, and dust control measures such as water sprays and chemical dust suppressants would be used to minimize impacts.

No federal or state listed species or critical habitats are known to occur at the 200-West Area (Appendix I) (Pacific Northwest Laboratory 1991; Gloman 1991), but the federal endangered bald eagle (*Haliaeetus leucocephalus*) winters nearby along the Columbia River (Gloman 1991). No impacts to the bald eagle are anticipated to result from construction of the disposal cell because this species is not expected to be in the area during the summer months when construction activities would be occurring. The federal endangered peregrine falcon (*Falco peregrinus*) is a spring and autumn migrant in the Hanford area. Because of its migratory and transient nature in the area, no impacts to this species are expected from disposal cell operations. Several federal candidate species have also been identified as potentially occurring in the vicinity of the 200-West Area (Gloman 1991), and the loggerhead shrike has been reported at the area (Pacific Northwest Laboratory 1991). Except for this species, construction activities, human activity, fugitive dust emissions, and noise associated with Alternative 7c are not anticipated to affect any listed or candidate species or their critical habitats, primary food stocks, or foraging areas. Nesting and foraging of the loggerhead shrike in the vicinity of the proposed disposal cell could be disrupted during cell construction and other human activities.

Socioeconomics and Land Use. Short-term impacts on socioeconomics and land use near the Weldon Spring site would be the same for Alternative 7c as for Alternative 7b. Construction of a disposal cell at the Hanford site would have some temporary effects on the local labor force and transportation but no short-term effects on land use. Assuming a work force comparable to that needed for disposal operations under Alternative 7a (i.e., 210 person-years), increments in the local labor force and traffic volume would occur; however, based on data for 1988, these increments would not represent significant changes within the context of a total work force of 11,300 persons (Pacific Northwest Laboratory 1991). The Hanford site is owned and operated by the federal government for the production of nuclear materials, research, and waste management and disposal, so the construction and use of a disposal cell would be consistent with existing and planned future land-use patterns.

Cultural Resources. If Alternative 7c were selected, an archaeological survey might be required, depending on the specific location determined for the disposal cell. Details regarding potential archaeological remains at the Hanford site are discussed in Section 6.5.3.3. Impacts associated with activities in the Weldon Spring area would be as described for Alternative 7b (Section 6.4.5.4).

6.5.6 Implementability

The implementability of the removal and treatment components of Alternative 7c would be the same as for Alternative 7a (Section 6.3.6). The implementability of the disposal component of Alternative 7c would depend on the implementability of both transport to and disposal of the Weldon Spring waste at the Hanford site. The implementability of off-site transport of the Weldon Spring waste would be similar to that identified for Alternative 7b. After transport by truck from the Weldon Spring site to the rail siding at Wentzville, the waste would be loaded onto railcars and transported by the Union Pacific Railroad to Richland, Washington (the route used in this evaluation is described in Section 5.5.3). At Richland, the waste would be transferred to a dedicated railroad for the additional 40 km (25 mi) to the disposal area at the Hanford site.

The Hanford site comprises several different areas that are dedicated to various nuclear-related activities, including fuel reprocessing and waste management, research and development, nuclear fuel fabrication, and waste disposal. The Hanford site also has several retired nuclear reactors. The area within the Hanford site at which waste from the Weldon Spring site would be disposed (the 200-West Area) covers approximately 6.5 km^2 (2.5 mi^2) (DOE 1992d). The Hanford site currently accepts only small-quantity shipments of containerized waste, and the administrative procedures required for disposal of the large quantity of waste to be transported in bulk from the Weldon Spring site (approximately 522,000 m^3 [683,000 yd^3]) are not currently in place. A thorough evaluation of the hazardous nature of the waste would be required in accordance with the Washington State Administrative Code (WAC-173-003). Any waste determined to be hazardous or radioactive mixed waste would be stored at the Hanford site until a treatment facility became available.

6.5.7 Cost

The total and present-worth costs for Alternative 7c are given in Table 6.14 and are estimated to be $304 million and $171 million, respectively, including the cost of constructing and operating a disposal cell at the Hanford site. The cost of constructing a disposal cell at the Hanford site and the equipment and treatment costs would be similar to those identified for Alternative 7a. The cost for waste disposal is estimated to be $68 million on the basis of a fee of $130/$m^3$ ($100/$yd^3$) to dispose of the large volume of waste from the Weldon Spring site. As for the cost of disposal at the Envirocare site, this preliminary estimate would be refined specifically for the Weldon Spring waste during detailed design if disposal at the off-site facility were a component of the selected remedy. The cost for long-term monitoring and maintenance at the Hanford site is assumed to be the same as at the Weldon Spring site for Alternative 7a. An estimated cost of $76/t ($69/ton) for rail transport to the facility, including the return of empty containers, was obtained from Union Pacific Railroad (MK-Ferguson Company and Jacobs Engineering Group 1992b). The costs of constructing the rail siding at Wentzville and hauling the waste from the site to the siding are estimated to be $23.8 million. The total cost for off-site rail transport and disposal at the Hanford site, including ancillary facilities, is estimated to be $143 million.

Disposal and rail transport fees impact the cost estimate of Alternative 7c in the same manner as identified for Alternative 7b. Other cost variations would be the same as identified for Alternative 7a.

6.6 MONITORING AND MITIGATIVE MEASURES

The primary monitoring and mitigative measures that would be used at the Weldon Spring site in implementing any of the final action alternatives are summarized in Table 6.15. These measures would provide a high degree of effectiveness in minimizing the potential for adverse effects associated with implementation of the alternatives. The DOE will prepare a mitigation action plan to track mitigation commitments made in the ROD for this remedial

TABLE 6.14 Cost Estimate for Alternative 7c

Activity	Estimated Cost (million $)
Removal	
Common removal costs (see Table 6.11)	26.3
Treatment	
Common treatment costs (see Table 6.11)	64.0
Disposal	
Disposal cell operations	-[a]
Disposal facility construction material tests	-[a]
Disposal facility construction	-[a]
Off-site transport and disposal	143
Disposal subtotal	143
Other	
Common other costs (see Table 6.11)	46.5
Long-term maintenance	23.9[b]
Other subtotal	70.4
Total	304
Present worth	171

[a] The costs for construction and operation of a disposal cell at the Hanford site are not explicitly identified because such costs are factored into the disposal fee, which is included in the off-site transport and disposal cost estimate.

[b] Long-term maintenance of the Weldon Spring site would no longer be required because the contaminated media would have been removed from the site area. Costs for long-term maintenance at the Hanford site are assumed to be the same as those for waste disposal at the Weldon Spring site under Alternative 7a.

Source: Based on data from MK-Ferguson Company and Jacobs Engineering Group (1992b).

action, in accordance with DOE's procedures for implementing NEPA (10 CFR 1021). For activities related to the disposal cell, it is expected that similar measures would be implemented at the off-site facilities.

Mitigative measures for protecting air quality, such as wetting surfaces and using chemical dust suppressants and covers, would be implemented to control fugitive dust. The off gas generated by the vitrification process for Alternatives 7a, 7b, and 7c would be collected and treated. Air quality would be intensively monitored for all of the action alternatives to assess compliance with all pertinent air quality standards and ensure that appropriate controls could be applied in a timely manner.

TABLE 6.15 Major Monitoring and Mitigative Measures for the Action Alternatives

Factor	Potential Impact or Area of Concern	Mitigative Measure
Construction and excavation activities	Transport of uncontaminated soil to nearby surface water and wetlands	Good construction practices would be implemented, including sediment barriers, dikes, siltation ponds, and drainage channels to direct runoff away from downstream or downgradient surface waters and wetlands, with surface grading and revegetation upon completion of excavation.
	Transport of contaminated surface soil to nearby surface water and wetlands, runoff of contaminated surface water, and possible impacts of transport to groundwater	Good construction practices would be implemented, as described above. In addition, groundwater, surface water, and sediment would continue to be monitored for chemical and radioactive contaminants so that contaminated media could be collected for appropriate management, such as treatment of contaminated water before release off-site.
	Loss of aquatic and terrestrial habitats	Habitats would be restored, as appropriate. The final form of mitigation would be determined in consultation with appropriate state and federal agencies.
	Disturbance of local biota, area residents, and recreational visitors by noise and remedial action activities	Vehicle and equipment mufflers would be checked periodically and maintained in good condition.
	Disturbance of local biota, area residents, and recreational visitors and impacts to local air quality as a result of fugitive dust emissions	Dust would be controlled using wet methods and/or covers at the site, along the haul roads, at storage and staging areas, and at off-site construction and excavation areas. Chemical dust suppressants would be used if needed. Work areas would be covered, as needed, e.g., at night and during high winds.
	Radon and particulate emissions	Engineering controls — such as limiting the area of the working surface and using covers, water, or chemical agents — would be applied, as needed, to reduce radon and particulate emissions. Air would be monitored continuously through all phases of the action period.
Transport of contaminated material from vicinity properties to the site	Accidental spill (release) of contaminated material as a result of equipment failure or vehicular accident	Waste would be transported in covered trucks traveling at low speeds. Contingency plans would be in place to address any spills that might occur during waste transport.

TABLE 6.15 (Cont.)

Factor	Potential Impact or Area of Concern	Mitigative Measure
Transport of contaminated material from vicinity properties to the site (cont.)	Inadvertent transport of contaminated material on haul vehicle surfaces or tires leaving controlled areas	Haul vehicles would be decontaminated and inspected before leaving the site or off-site excavation areas.
Excavation of off-site borrow material	Erosion of soil, with transport to nearby surface water and wetlands	Good construction practices would be implemented, including sediment barriers and siltation ponds, as needed.
	Disturbance of local biota, area residents, and recreational visitors by noise	Vehicle and equipment mufflers would be checked periodically and maintained in good condition.
	Disturbance of local biota, area residents, and recreational visitors and impacts to local air quality as the result of fugitive dust emissions	Dust would be controlled using wet methods at the borrow area and along the haul road. Chemical dust suppressants would be used if needed.
Transport of borrow materials and supplies to the site	Inadvertent transport of contaminated material from the site on the haul vehicle surfaces or tires	Trucks hauling borrow material would not enter contaminated areas on the site.
Transport of waste to an off-site disposal location	Accidental spill (release) of contaminated material as a result of equipment failure or vehicular accident	Waste would be transported in closed containers. Contingency plans would be in place to address any spills that might occur during waste transport.
	Inadvertent transport of contaminated material on haul vehicle surfaces or tires leaving controlled areas	Haul vehicles and containers would be decontaminated and inspected before leaving any contaminated area.
All phases of active remedial activities	Protection of workers	All activities would be conducted in accordance with project health and safety plans and would include continuous monitoring of the work environment and the use of protective equipment, as needed.

TABLE 6.15 (Cont.)

Factor	Potential Impact or Area of Concern	Mitigative Measure
All phases of active remedial activities (cont.)	Protection of the general public	Air and water would be monitored at the site and vicinity, and appropriate responses would be implemented if measured contaminant levels increased significantly above background. Access to construction and excavation areas would be limited; public vehicle access would also be limited along some of the off-site haul routes. Engineering controls would be applied to minimize dust, radon, noise, and erosion during remedial action activities. Decontamination methods would be employed to minimize vehicle tracking of contaminants to surrounding uncontaminated areas. All traffic associated with the remedial action would be coordinated to minimize impacts on nearby facilities.
	Environmental monitoring	Air quality would be monitored for contaminated particulates and radon gas at the site perimeter, and at the nearby Francis Howell High School. Surface water and groundwater downgradient of excavation and construction areas would be monitored for chemical and radioactive contaminants, such as uranium. Groundwater would also be monitored at additional on-site and off-site locations, including the perimeter of the disposal cell area. Appropriate responses would be implemented as indicated by monitoring results.
Completion of all construction and excavation activities	Environmental restoration	Disturbed areas would be restored by regrading and revegetating with native and/or forage species. Wetlands would be constructed, as indicated, on the basis of consultation with the appropriate state and federal agencies.
	Disposal site maintenance and cell integrity	An operations plan would be in place to ensure monitoring of long-term disposal cell integrity. This plan would include regular cell inspection and site vegetation control programs, handling of any leachate, and air monitoring programs for groundwater, surface water, and air. Contingency plans would be developed to address any loss of disposal cell integrity and/or release of disposed materials.

Mitigative measures and good engineering practices would be used in all excavation and construction areas, including the borrow area, to control surface water runoff and to minimize erosion and transport of sediment from exposed areas. These measures would include constructing berms to direct the flow of surface water; constructing silt fences to minimize the amount of sediment leaving the area; covering exposed surfaces with straw, mulch, riprap, or membranes; and using revegetation mats in those areas with high water velocity. Siltation ponds would be constructed near the perimeter of the site, as necessary, to provide additional protection against the off-site transport of sediment or contaminated surface runoff. Siltation ponds would also be used at the borrow area, as needed. All runoff from contaminated areas would be contained within those areas by collection in siltation ponds, sampled for contamination, and treated in the site water treatment plant before release, if necessary. The use of mitigative measures and good engineering practices near disturbed areas, in combination with the use of siltation ponds near the site boundary and the management of potentially contaminated runoff, would effectively limit the potential for off-site movement of contaminants in water or sediment.

Air, surface water, and groundwater would be monitored before, during, and after remedial action activities. If adverse effects were detected, work would be stopped until the effects were controlled and/or appropriate contingency plans would be implemented.

For off-site disposal under Alternatives 7b and 7c, waste would be transported in closed containers and carried in dedicated trains to the disposal site. Contingency plans would be in place to address spills that might occur during any phase of off-site transport. Both haul vehicles and the exteriors of the containers would be decontaminated and inspected before leaving any contaminated area. Potential impacts from on-site accidental spills would be minimized by implementing appropriate operating procedures and contingency plans.

Following completion of all construction and excavation activities, disturbed areas on-site would be backfilled and revegetated, and disturbed areas outside the site boundary would be restored to natural conditions. Habitat restoration would be carried out in consultation with appropriate state and federal agencies.

Site cleanup activities would be conducted in compliance with the site safety and health plans, DOE safety regulations, and other pertinent requirements. Radiation monitoring and protection in the workplace would be provided for all workers. Prior to implementing the selected remedy, detailed plans would be developed to address (1) safe work practices, engineering controls, and worker protection equipment designed to reduce worker exposure and/or releases to the environment; (2) emergency response procedures; (3) monitoring techniques and frequencies; and (4) various contingencies and the anticipated responses to such contingencies.

6.7 UNAVOIDABLE ADVERSE IMPACTS

A number of unavoidable adverse impacts would occur if any of the action alternatives were implemented. These impacts are summarized in Table 6.16. Many of the unavoidable

TABLE 6.16 Summary of Unavoidable Adverse Impacts[a]

Affected Resource	Impact Type
Topography and soil	Much of the Weldon Spring site and 21 ha (52 acres) of land off-site could be disrupted by construction and excavation activities. Many impacts would be temporary, pending completion of remedial action activities and restoration programs. For Alternatives 6a and 7a, some areas of soil would be permanently replaced by surface features, such as the disposal cell and runon/runoff control system. A small portion (<0.001%) of the 100-year floodplain of Schote Creek would be disturbed during remedial action activities. This area would be restored to its original contours upon completion of these activities. For Alternatives 7b and 7c, impacts associated with disposal would be at the Envirocare or Hanford site, respectively, and additional soil disturbance would be associated with construction of a rail siding at Wentzville.
Air quality	Some temporary impacts to air quality at the Weldon Spring site would result from fugitive dust emissions associated with construction, excavation, loading, placement, grading, compacting, and transport activities. Lesser impacts would also be incurred from vehicle and equipment exhausts. If vitrification were selected (Alternative 7a, 7b, or 7c), incremental impacts to local air quality would result; these impacts are expected to be small, and they would be temporary, ceasing after remedial action activities are completed. Air quality impacts associated with cell construction and waste disposal would occur at the Weldon Spring site for Alternatives 6a and 7a, at the Envirocare site for Alternative 7b, and at the Hanford site for Alternative 7c.
Water quality	Construction and excavation activities at the Weldon Spring site would impact local surface water as a result of increased sediment and soil erosion and subsequent runoff and the possible transport of contaminants via runoff. Implementation of appropriate mitigative measures would limit the significance of these impacts. Impacts to local waters from increased siltation and turbidity would be temporary and would cease following completion of remedial action activities. Water quality impacts are not expected to the Envirocare or Hanford site (Alternative 7b or 7c) because these sites are in areas of low precipitation and at a considerable distance from potentially impacted surface water bodies.
Ecological resources	Excavation of fill material from an off-site borrow area would permanently impact up to 21 ha (52 acres) of old-field habitat and agricultural fields near the Weldon Spring site. These communities could reestablish, and because these habitat types are well represented in the region, little adverse impact to regional biotic resources is expected. Construction and excavation activities at the site would result in the disturbance of up to 72 ha (179 acres) of terrestrial habitat, including up to 22 ha (55 acres) of relatively good-quality grassland/shrub and upland forest habitat and 15 ha (38 acres) of palustrine wetland habitat. These areas represent a small fraction (about 1.3 and 5.7%, respectively) of the terrestrial and open water habitats present in the Busch Wildlife Complex.

TABLE 6.16 (Cont.)

Affected Resource	Impact Type
Ecological resources (cont.)	Excavation activities at other off-site locations (e.g., vicinity properties) would result in the temporary loss of a small amount of habitat in the surrounding Busch Wildlife Complex. Some upland forest, grassland, and shrub habitats would be disturbed. Vegetation and some wildlife associated with these areas would be destroyed, and other wildlife would be displaced. The impacts resulting from this habitat loss are not expected to significantly affect biotic resources in the area and would be temporary. Local biota could also be affected by impacts to air quality, noise levels, and water quality, but these impacts would be minor and temporary. All vegetation and some wildlife would be destroyed at the on-site disposal cell location for Alternatives 6a and 7a whereas other wildlife would be displaced. The loss of habitats from this area would be permanent. Similar impacts would be associated with the off-site disposal locations under Alternatives 7b and 7c, although the magnitude of impacts would probably be smaller because the density of vegetation and the numbers of wildlife species (and individuals) are relatively low. Some impacts to area vegetation and wildlife would be incurred during construction, excavation, and transportation activities as a result of unavoidable impacts to air quality, noise levels, water quality, and increased vehicular activity. These impacts would be minor and temporary and would cease following completion of remedial action activities.
Visual resources	Construction and excavation activities would result in some minor incremental increases over the current visual and aesthetic impacts of the chemical plant. Following completion of remedial action activities, some visual and aesthetic impacts would remain (e.g., a 23-m [74-ft] high mound for Alternatives 6a and 7a), but these would be of lower magnitude than current impacts at the Weldon Spring site. Visual impacts would be reduced through the maintenance of a vegetative cover. The long-term impacts would be incremental for the off-site disposal locations for Alternatives 7b and 7c. Impacts would also 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 action activities.

TABLE 6.16 (Cont.)

Affected Resource	Impact Type
Transportation	Temporary increases in road traffic would result from incremental worker travel and delivery of construction equipment and supplies. Off-site disposal of wastes for Alternatives 7b and 7c would involve transport of the Weldon Spring waste to distant locations in the western United States. All impacts would be temporary and would cease following completion of remedial action activities.

[a] Except as otherwise noted, the impacts to these resources would occur at the Weldon Spring site under each of the action alternatives; possible impacts of no action (Alternative 1) are discussed in Chapters 7 and 8 of the BA (DOE 1992a) and in Section 6.11 of this FS.

adverse impacts would be temporary. Adverse impacts associated with the no-action alternative are discussed in the BA (DOE 1992a), Appendix E, and Section 6.11.

6.8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Implementing any of the action alternatives would result in the permanent commitment of land for waste disposal. This commitment would occur at the Weldon Spring site for Alternatives 6a and 7a, at the Envirocare site for Alternative 7b, and at the Hanford site for Alternative 7c. The commitment of land for a disposal facility would be consistent with current land uses at each of the three alternative locations. The Weldon Spring site is a contaminated, inactive industrial complex under the custody of DOE, and it contains waste pits from past disposal practices; it is adjacent to a similar contaminated site owned by the Army. A disposal facility for this waste at either the Hanford site or the Envirocare site would be at a location dedicated to long-term waste storage and disposal.

The disposal cell for the Weldon Spring waste is expected to cover about 17 ha (42 acres), but the total amount of committed land could be somewhat larger because a buffer zone would be established around the cell, at least for the on-site disposal options. No other area of the Weldon Spring site would sustain a long-term impact or injury as a result of this remedial action. Perpetual care would be taken of the committed land because the waste would retain its toxicity for thousands of years. For example, the cover would be visually inspected, groundwater would be monitored, and the effectiveness of the overall system at the Weldon Spring site would be reviewed every 5 years under Alternatives 6a and 7a.

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 the removal, construction, and disposal activities of all of the action alternatives. Adequate supplies of these materials are readily available in the Weldon Spring area and would also be available in the area of the Envirocare or Hanford site under Alternative 7b or 7c. Additional fuel use would result from off-site transport of the waste. However, adequate supplies are available without affecting local requirements for these products.

The treatment process for the action alternatives would also require the consumptive use of materials and energy. The chemical stabilization/solidification process for Alternative 6a would require additives such as cement and fly ash. The vitrification process for Alternative 7a, 7b, or 7c would be very energy intensive and would require the commitment of a considerable supply of natural gas. Cement and fly ash are readily available locally in the quantities required, and natural gas could be obtained from the local utility.

Implementing any of the final action alternatives would not be constrained by the availability of resources or supplies beyond those currently available in the St. Louis area or expected to be available near the off-site disposal locations.

6.9 IMPACTS OF POTENTIAL LOSS OF INSTITUTIONAL CONTROLS

The DOE would maintain institutional controls at the Weldon Spring site if either of the on-site disposal alternatives (Alternative 6a or 7a) were selected. The site vicinity and groundwater would continue to be inspected and monitored to detect any change in the containment system resulting from natural physical or biological forces such as erosion of the cover, differential waste settling, or biotic intrusion by animal burrows or plant roots. If any deterioration of the containment system were detected, DOE would take any further actions that might be necessary to ensure the safety of the nearby environment. In the unlikely event that institutional controls were lost at some time in the distant future, deterioration of the containment system without corrective measures could result in the release of contaminants and potential future impacts on human health and the environment under any of the alternatives.

Deterioration of the cover over the waste could result in the release of radon gas and contaminated particulates to the air, and water infiltrating into the cell could result in leaching of contaminated material to surface water and groundwater if the foundation material was breached. Nearby individuals could be exposed to radiation if releases occurred. 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 impacts that could occur in the future would depend on the extent of the release and on local land-use conditions at the time it occurred.

Overall environmental impacts at the off-site disposal locations could be comparable to those at the Weldon Spring site. For the Hanford site (Alternative 7c), air quality impacts from the dispersal of untreated waste, if the waste were exposed, would probably be higher than those at the Weldon Spring site (Alternative 6a or 7a); these impacts would be related to the dry conditions, relatively sparse vegetation, and high wind speeds that would cause greater dispersal. Surface water impacts would probably be lower but might be similar after heavy storms, and groundwater might be impacted sooner (e.g., if the foundation were breached) after the waste became saturated over time as a result of infiltration through cover cracks because the higher permeability of the overburden might offset the precipitation differences. Incremental ecological impacts could occur, e.g., to threatened and endangered species. For the Envirocare site (Alternative 7b), impacts could be similar to those described for the Hanford site, except the time to groundwater impacts after waste saturation might be lower (comparable to those at the Weldon Spring site) because the overburden permeability is lower, and impacts to biota could be lower than for the other alternatives because fewer species and individuals are present.

If it were assumed that current land-use conditions continued, overall impacts to the general public would probably be lower for Alternatives 7b and 7c than for Alternatives 6a and 7a because the nearest receptors are currently about 30 to 40 km (19 to 25 mi) away from the Hanford and Envirocare sites, respectively, compared with 2 to 3 km (1 to 2 mi) for the Weldon Spring site. However, if homes were built closer to those sites over the extended future, overall impacts might be comparable.

It is also possible that humans could inadvertently intrude into the disposal cell if institutional controls were lost at some time in the future. Such intrusion could result in temporary exposure to the waste or more extensive exposure from activities such as farming or living in a building constructed on or near the disposal cell. For on-site disposal, the likelihood for protracted exposure at the disposal cell is low because the local community would be expected to retain awareness of the site and markers would be in place; even if these indicators were absent, a preconstruction survey would probably be conducted prior to intrusion into a manmade mound of that size. The likelihood of such intrusion would be similarly low for off-site disposal, for the same reasons. In any case, impacts could be significant if an individual were to intrude directly into the disposal cell.

6.10 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Implementation of any of the final action alternatives would require the short-term use of the Weldon Spring 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 waste disposal at either the Weldon Spring, Envirocare, or Hanford site. This commitment of land at any one of the three sites would not be inconsistent with current land uses, as described in Section 6.8. 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 Weldon Spring 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.

6.11 POTENTIAL CUMULATIVE IMPACTS

Remedial action activities at the Weldon Spring site involve the potential for cumulative impacts from the effects of those actions in combination with the effects of (1) other activities beyond the site boundary, most of which are outside the control of DOE, and (2) other cleanup actions being implemented for the site. Potential cumulative impacts are also associated with future activities being considered for the site, e.g., for the quarry, the Southeast Drainage, and groundwater at the chemical plant area. These effects will be addressed in environmental documents prepared separately for those actions, and they have also been discussed in this FS, e.g., relative to the positive impacts to the Southeast Drainage from site cleanup activities and the incorporation of volume estimates for waste that might be generated from future actions into design considerations for the disposal cell to support comprehensive project planning activities.

Activities unrelated to the Weldon Spring project are currently planned or are occurring near the site, including activities at the Busch Wildlife Complex and at the U.S. Army facility located adjacent to the site (Figure 1.2). Construction of a headquarters building for the Busch complex is planned for the near future; this activity should be completed prior to any major remediation efforts at the Weldon Spring site. Construction activities in the Busch complex will not involve contaminated material, and the major activity will be some distance from the Weldon Spring site. Other planned activities are small and localized, such as trail construction and planting of vegetation (Missouri Department of Conservation 1989; DeBruyckere 1991). Therefore, no significant cumulative effects are expected from these actions.

Some remedial action activities will probably be conducted at the adjacent Army NPL site at the same time activities are being conducted at the chemical plant area. Activities at the extensive Army property, which is currently in use as a training area, are expected to involve the cleanup of isolated areas of contamination. Although specific activities and schedules are not yet established, soil excavation and transport might occur simultaneously at both sites. Such activities are expected to generate dust and could result in sediment transport in surface runoff. Because the chemical plant area is downwind of the Army facility (on the basis of prevailing winds), fugitive dust from Army operations could reach the site. In addition, because of the surface water divide and the gently sloping nature of the topography at the chemical plant area, most runoff flows toward the Army property; drainage from much of both sites flows to the same off-site areas, so some additive turbidity and sedimentation impacts could occur. Some potential for cumulative environmental effects also exists because activities at the Army facility will similarly result in increased traffic, increased noise levels, and some loss of wildlife areas.

In addition to cleanup of the Weldon Spring site, the DOE is involved in cleanup activities at other contaminated sites in the St. Louis area. Material from these or other sites would not be taken to the Weldon Spring site, and vehicles transporting materials related to these sites would not operate near the Weldon Spring site. Therefore, no significant incremental effects resulting from other DOE activities at other sites are expected at the Weldon Spring site.

With regard to cleanup activities being conducted at the Weldon Spring site, potential cumulative health effects associated with the interim response actions and the currently planned cleanup action were assessed for each of the final remedial action alternatives. This assessment was conducted to ensure that the sum of the impacts associated with each individual action would not result in an unacceptable overall threat to human health and the environment. Four major interim actions are currently being implemented for the project, three of which involve activities at the chemical plant area. These four activities are (1) constructing and operating a water treatment plant at the quarry; (2) excavating bulk waste from the quarry for controlled storage at the chemical plant area, which involves constructing and operating the TSA;

(3) constructing and operating a water treatment plant at the chemical plant area; and (4) decontaminating and dismantling site structures for controlled storage at the MSA.

Potential cumulative impacts associated with these activities have been assessed in documentation for the successive actions (e.g., in MacDonell et al. 1990; DOE 1990b; Peterson and MacDonell 1991). Except for impacts from the combined effluent releases from the water treatment actions, the short-term impacts associated with activities that would occur at the quarry for bulk waste excavation and water treatment do not contribute to cumulative adverse impacts at the chemical plant area because these two areas are about 6.4 km (4 mi) apart and environmental conditions differ — including hydrogeology, topography, habitats, and meteorological conditions (DOE 1990b).

As with location, the timing of the various cleanup activities affects whether cumulative impacts would be expected for certain environmental resources, such as air quality. In contrast, incremental exposures to carcinogens could be assumed to have an additive effect for human health. It was conservatively assumed for this analysis that the same worker could be involved in each of the cleanup activities at the chemical plant area such that risks could be summed over actions and time to evaluate a hypothetical maximally exposed worker. Although estimates of noncarcinogenic effects should not be directly added without factoring in the actual sequencing or overlap of exposure times and segregating according to the specific health end points, they are included in the following discussion as screening-level information.

Potential cumulative health and environmental impacts associated with the interim actions for the project in combination with the activities for each final remedial action alternative for the chemical plant area are presented in Sections 6.11.1 and 6.11.2. The potential long-term cumulative impacts for these alternatives are discussed with the long-term protectiveness evaluation criterion in Chapters 6 and 7.

6.11.1 Health Impacts

6.11.1.1 Alternative 1

Cumulative health effects for Alternative 1 would be represented by the potential impacts of no further cleanup in combination with both short-term and long-term impacts associated with implementation of the interim actions. Health effects for the site under the no-action alternative are evaluated in detail in the BA (DOE 1992a) and in Appendix E of this FS; cumulative effects associated with the interim actions are also discussed in Sections E.2 and E.3.

Hypothetically assuming that institutional controls would be lost in the extended future, which is assumed to extend to 100 years and beyond, no maintenance workers would be present on-site in the long term. Therefore, cumulative worker impacts are only determined for the short term. During the period in which institutional controls are assumed to be maintained under Alternative 1, worker exposures associated with the interim actions would result from external gamma irradiation. The waste materials generated by these actions would be in controlled storage at the MSA and TSA by the time full field activities for the planned remedial action began; therefore, this storage would minimize other potential exposures such as inhalation or incidental ingestion.

Health effects for the water treatment action are associated with elevated external gamma radiation from the drummed process wastes. These residues would be stored at the TSA, and related risks contribute about 25% to the combined radiological risk of 8×10^{-6}/yr estimated for monitoring and maintenance activities at that facility. The additional risk from monitoring and maintenance activities at the MSA would be relatively minor because the decontaminated building debris would be much less contaminated than the quarry waste.

The combined risk from exposures resulting from the additional maintenance requirements for the interim actions under Alternative 1 is about 20% of the baseline estimate of 5×10^{-5}/yr for sitewide exposures of a routine maintenance worker who mows the grass and repairs fences across the site. Because routine maintenance work would be a full-time job and the same individual would not also conduct the other baseline activities, the cumulative radiological risk to an individual worker from the combined exposures under Alternative 1 is represented by the maximum rather than the sum of the two estimates; thus, hypothetically assuming a 10-year period for these actions, the cumulative risk would be 5×10^{-4}. Thus, the small cumulative effect of the additional monitoring and maintenance requirements for the stored material would not significantly increase the overall average risk for maintenance workers at the site.

If it were assumed that the same worker responsible for baseline maintenance activities under Alternative 1 had previously participated in bulk waste excavation activities at the TSA (radiological risk of 1×10^{-4}) and building decontamination activities (radiological risk of 3×10^{-4}), the risks associated with those previous activities would contribute significantly to the cumulative risk for that individual. For this case of maximum multiple exposures, the cumulative radiological risk to the individual remedial action worker would be 9×10^{-4}.

The chemical carcinogenic risk to a worker from the quarry bulk waste action was estimated to be 3×10^{-5}, and the risk from building decontamination activities was estimated to be 2×10^{-4}, using conservative assumptions. No chemical exposures would be associated with the monitoring and maintenance activities at the MSA and TSA under Alternative 1 because the waste would be controlled, but baseline risks from sitewide exposures during routine maintenance activities would be 1×10^{-5}. Thus, the cumulative chemical carcinogenic risk to an individual remedial action worker who was involved in each of the interim actions combined with the baseline activities of Alternative 1 would be about 2×10^{-4}.

The sum of the radiological and chemical risks for the maximally exposed worker would be 1×10^{-3}. (These estimates have only been summed to provide screening-level information for maximum worker impacts; summing these values is not necessarily appropriate because different assumptions are inherent in the methodologies used to estimate risks and because antagonistic and synergistic effects have not been addressed. The uncertainty associated with adding chemical risks and summing with radiological risks is discussed in Section 5.6.4 of the BA. In addition, conservative assumptions were used throughout the analyses, e.g., with respect to exposure without respiratory protection. By this approach, the results can be used to identify activities that could result in potential adverse impacts, for which appropriate monitoring and worker health and safety plans would be developed. Therefore, the impacts to workers during the actual remedial action activities would be substantially lower.)

To estimate a cumulative, collective radiological risk for the combined work force, it is assumed that the baseline work force for Alternative 1 includes two outdoor maintenance individuals: one who conducts routine sitewide maintenance activities, and another who conducts monitoring and maintenance activities at the MSA and TSA. The combined radiological risk for these workers would be about 6×10^{-4} over a 10-year period. The collective risk to the work force from TSA activities under the quarry interim action was estimated to be about 1×10^{-2}, and that for the buildings actions was estimated to be 3×10^{-2}. Therefore, the cumulative, collective radiological risk for the entire work force from exposures associated with all of these cleanup activities would be about 4×10^{-2}.

For the general public, health impacts would be low in the short term as a result of the positive cumulative effect of the interim actions. For example, removing the contaminated material from the quarry to the TSA for storage would reduce risks at the quarry without an offsetting increase in short-term risks at the TSA because erodible material would be covered or otherwise controlled so that no off-site releases would occur. However, if it is hypothetically assumed that institutional controls are lost in the long term, exposures to this material at the chemical plant area would result in incremental health effects, although the beneficial effects to air, groundwater, and surface water at the quarry would remain. Thus, for the contaminated material addressed by this action, the location, receptors, and primary exposure pathways would have changed but the potential for related risks could be comparable.

Cumulative short-term risks associated with the water treatment plant actions in the absence of further site cleanup under Alternative 1 could result from exposures to the treated water from both the Missouri River and the Southeast Drainage, if the drainage was used during part of the action (Section 1.5.1.4). The effluent from the quarry plant would be piped to the river, and effluent from the site plant might be discharged to the Southeast Drainage for gravity flow to the river during part of the discharge period. The incremental lifetime radiological risk from exposures to these effluents, for a bounding case that assumes discharge to the drainage for the full operational period, was estimated for an individual who would regularly ingest fish and drinking water supplied from the Missouri River. This estimate is about 1×10^{-9}, and the corresponding collective population risk for the estimated 2 million people who could be served by the downstream drinking-water treatment plants is 9×10^{-4}.

The incremental radiological risk to an individual who drinks water from the Southeast Drainage (representing both treatment plant effluent and contaminated surface runoff from the site) during repeated recreational visits to that location is estimated to be 8×10^{-7}, and the baseline risk from ingesting surface runoff alone is 4×10^{-6} (primarily because uranium concentrations in the treated water would be very low compared with the uranium concentrations in the drainage water). Assuming combined exposures, the cumulative radiological risk would be 5×10^{-6}, i.e., the risk would be represented by the combined exposures at the Southeast Drainage. The estimated total chemical carcinogenic risk from ingesting combined runoff and treatment plant effluent from the drainage is 4×10^{-6} (see Section E.2.3 of Appendix E). Summing these two values would result in a cumulative combined risk of about 9×10^{-6}. (Even though this value is a total combined risk, e.g., the contribution of background levels of metals has not been subtracted, it is well within the target range identified by the EPA for incremental risks at NPL sites.)

No incremental cumulative impacts would be expected to result from the water treatment plant actions in the long term if institutional controls were to fail. The pits and ponds would be expected to refill with water, and the contaminants that had previously been removed and containerized would still be on-site. Because these contaminants would be somewhat immobilized compared to their initial state, a very minor benefit with respect to potential impacts from leaching might be realized if the containment failed over time.

As with the quarry bulk waste, the buildings interim action would involve displacing contaminated material from one general exposure area to another but would permanently eliminate certain risks. These permanent reductions include risks associated with PCB-contaminated material that has been sent to a licensed incinerator off-site and risks from indoor radon, for which the health hazard results from ingrowth and accumulation of radon decay products in an enclosed space. Therefore, although the material stored at the MSA from the buildings action could serve as a source of new exposures in the long term, overall risks would probably decrease by about 30% because of the elimination of the radon risk.

The net long-term effect of offsetting impacts associated with these four interim actions in the absence of further cleanup is that certain risks could be slightly lower but overall risks would generally be comparable to those estimated for original, baseline conditions (Appendix E, Sections E.2 and E.3). Thus, the overall cumulative effect of the interim actions would be beneficial, but the benefit would be relatively minor if no further action were taken and site controls were assumed to be lost in the future. This outcome is to be expected because although site waste has been increasingly controlled as part of the interim actions, no permanent disposal decisions have been made that would provide long-term protection (except for a small amount of chemically contaminated material) because to do so prior to completing the analyses of reasonable alternatives in this RI/FS-EIS could have potentially biased the overall decision for site cleanup.

6.11.1.2 Alternative 6a

No additional cumulative health effects would be associated with the combined exposures from the water treatment actions beyond those described under Alternative 1. In implementing Alternative 6a, surface controls would be constructed at a number of locations across the site as part of a comprehensive plan to limit runoff releases. These controls would reduce contaminant concentrations in surface runoff to the Southeast Drainage, thereby reducing the potential risk from ingesting drainage water compared to Alternative 1. Although the cumulative effect of Alternative 6a on these potential risks would be positive during the cleanup period, the difference would probably be minor because site runoff is not the only source of contamination in the drainage (the sediment is also a source). Thus, the potential cumulative impacts for the surface water pathway in the short term are expected to be generally similar to those estimated for Alternative 1.

Cumulative health effects from the bulk waste and buildings actions would be dominated by the air pathway, and this is also the pathway of concern for Alternative 6a (as for all the action alternatives). The risk to the remedial action worker from monitoring and maintenance for the interim actions (described under Alternative 1) would be relatively small compared with impacts associated with implementing Alternative 6a. The potential radiological risk to a maximally exposed worker under Alternative 6a would be 1×10^{-3}, and the chemical carcinogenic risk would be 8×10^{-5}. The estimated hazard index exceeds 1, indicating a potential for noncarcinogenic effects. These values are presented in Section 6.2.5.3 and summarized in Table 7.2. (This information will be used to develop site-specific worker protection plans that would be implemented during the action period.) The cumulative radiological risk for the entire (collective) work force from these interim actions combined with cleanup activities under Alternative 6a would be 1×10^{-1}. Because the radiological risks estimated for remedial action workers are much higher than the chemical risks, this value also represents the combined risk associated with exposures to site contaminants during the implementation of Alternative 6a.

Potential impacts to the general public associated with the bulk waste and buildings actions would be much smaller than those associated with Alternative 6a. This is because the estimated off-site impacts from implementing these smaller-scope interim actions would be insignificant, the contaminated material resulting from the interim actions would be in controlled storage at the TSA and MSA, and erodible waste would be controlled such that any future releases off-site from those facilities would be negligible. In contrast, a large number of activities that could generate air emissions would be conducted on-site as part of the planned remedial action, including excavation, transport, and unloading of contaminated material from various source areas across the site. Therefore, the cumulative health impacts to the general public are represented by those for Alternative 6a. (Insofar as the material stored at the TSA and MSA would be included in these activities, emissions indirectly related to the interim actions would contribute to the impacts for this alternative; in any case, they are considered part of the overall cleanup activities for Alternative 6a.) The risks for this alternative are presented in Section 6.2.5.3 and are summarized in Table 7.2.

The potential for occupational accidents, with resultant fatalities and injuries, from the interim actions combined with the activities planned for the chemical plant area under Alternative 6a would be the sum of the accidents for the bulk waste activities and the building decontamination and dismantlement activities, combined with those for Alternative 6a. The total number of occupational fatalities for these combined actions is estimated to be 0.23, and the total number of occupational injuries is estimated to be 141. All cleanup activities associated with Alternative 6a would be conducted in accordance with site health and safety plans and health-based regulatory standards to minimize the likelihood of occupational accidents and the magnitude of exposures. In summary, no significant health effects to the general public or to workers are expected to result from implementing Alternative 6a concurrently with the interim actions.

6.11.1.3 Alternative 7a

The cumulative health effects for Alternative 7a would be generally similar to those described for Alternative 6a. However, risks during the remedial action period could be slightly higher for Alternative 7a because of impacts associated with the vitrification process, i.e., increased radon emissions and worker hazards. Cumulative effects for the general public and workers associated with the interim actions combined with the cleanup activities of Alternative 7a would be represented by the impacts for this alternative, for the same reasons described under Alternative 6a.

For workers, the cumulative, collective radiological risk associated with conducting the interim actions combined with activities for Alternative 7a is estimated to be 2×10^{-1}, which is about twice as high as for Alternative 6a. The potential radiological risk, chemical carcinogenic risk, and hazard index to a maximally exposed worker would be the same as for Alternative 6a. These values are presented in Section 6.3.5.3 and summarized in Table 7.2. The total number of occupational fatalities is estimated to be 0.29, and the total number of occupational injuries is estimated to be 169. The site-specific health and safety plans for Alternative 7a would be expanded beyond those for Alternative 6a to address the additional hazards associated with the vitrification technology. In summary, no significant adverse health effects to the general public or to workers are expected to result from implementing Alternative 7a concurrently with the interim actions.

6.11.1.4 Alternative 7b

The cumulative health impacts for Alternative 7b at the Weldon Spring site would be similar to those described for Alternative 7a. However, because disposal would take place off-site for Alternative 7b, additional worker impacts would be associated with the increased waste handling and transport activities, and incremental risks could be incurred by the public along the transportation route. Thus, cumulative health effects for an individual member of the general public associated with the interim actions combined with the cleanup activities of Alternative 7b would be represented by the potential impacts for this alternative, for the same reasons described under Alternative 6a. Additional, collective impacts to the general public along the transportation routes would result from the implementation of Alternative 7b. These risks are presented in Section 6.4.5.3 and summarized in Table 7.2.

The estimated radiological risk for workers associated with the interim response actions combined with Alternative 7b would be the same as described for Alternative 7a for the on-site activities, summing to about 2×10^{-1}. The potential radiological risk, chemical carcinogenic risk, and hazard index to a maximally exposed worker would be the same as for Alternative 7a. These values are presented in Section 6.4.5.3 and summarized in Table 7.2. However, the total number of occupational fatalities and injuries would increase to about 0.37 and 219, respectively, because of the off-site disposal component. The site-specific health and safety plans for Alternative 7b would be expanded beyond those for Alternative 7a to address the additional hazards associated with off-site waste transport. In summary, no significant health effects to the general public or to workers are expected to result from implementing Alternative 7b concurrently with the interim actions.

6.11.1.5 Alternative 7c

The cumulative health impacts for Alternative 7c would be essentially the same as those identified for Alternative 7b. Cumulative effects for the general public associated with the interim actions combined with Alternative 7c would be represented by the impacts for this alternative, for the same reasons described under Alternative 6a. Potential impacts during the cleanup period of Alternative 7c include collective impacts to the general public along the transportation routes; these risks are presented in Section 6.5.5.3 and summarized in Table 7.2. The cumulative and collective health impacts for workers, the occupational fatalities and injuries, and the nature of the site-specific health and safety plans would be the same as identified for Alternative 7b. In summary, no significant health effects to the general public or to workers are expected to result from implementing Alternative 7c concurrently with the interim actions.

6.11.2 Environmental Impacts

6.11.2.1 Alternative 1

Adverse environmental impacts could be associated with the site under general baseline conditions (DOE 1992a). The overall cumulative impacts to environmental resources from the interim response actions in combination with no further action in the short term would be beneficial because potential sources of exposure would have been removed from various locations at which impacts were occurring and because the controlled storage of this material would be maintained under the baseline site activities. For example, the quarry bulk waste and water treatment actions would reduce potential impacts to surface water and groundwater quality at the quarry and at the site in the short term because water that is leaching through the contaminated material at those areas will have been removed (as will the solid material at the quarry).

Similarly, air quality at the quarry will have improved because radon levels will decrease after the bulk waste is removed, and no offsetting adverse impact would be associated with the material at the TSA because of the controlled nature of this storage facility. In addition, the interim buildings action will eliminate a potential source of exposure to certain contaminants in the short term because radioactive dust and chemicals such as PCBs and asbestos will be removed from the buildings and containerized, and these containers would be maintained in controlled storage under the baseline activities of Alternative 1.

The impacts associated with excavating the bulk waste and constructing the water treatment plants and short-term storage areas represent the primary adverse impacts associated with these interim actions. Because these activities will already have occurred by the time the planned remedial action is implemented, no additional cumulative effects would be expected beyond those previously documented (e.g., in MacDonell et al. 1990; DOE 1990b; Peterson and MacDonell 1991). That is, the impacts to soil, air quality, and wildlife resulting from those previous excavation, construction, and waste placement activities would not contribute to a cumulative effect for the planned action, except in the sense that restoration of air quality or reestablishment of habitats in the disturbed areas would be delayed because the temporary facilities would remain on-site under Alternative 1.

Incremental surface water impacts could be associated with the treatment plant action because additional water could flow in the Southeast Drainage if effluent was discharged to the channel (section 1.5.1.4); this flow could result in incremental entrainment of particulates or channeling effects. However, no significant cumulative impacts to surface water, groundwater, or soil in the drainage or to wildlife that might drink from the drainage would be expected from this discharge. The additional water would represent only a fraction of the volume of water that could be naturally present in the drainage (e.g., after rainstorms), and the flow rate is expected to be well within rates commonly observed. In addition, the water quality of the effluent would be very high (approaching drinking water standards for humans), and no significant incremental effects would be expected from wildlife exposures. Thus, the cumulative environmental impacts would be generally represented by existing impacts.

The water treatment actions could also impact aquatic vegetation and wildlife. By removing and treating this contaminated water, some species will be destroyed or displaced and some aquatic habitats will be lost. However, no net adverse effects of significance are expected because this source of biotic exposure to contaminants would be eliminated. In addition, a mitigation action plan would be developed to offset the potential impacts from habitat loss.

Species of primary concern include two endangered species: pallid sturgeon and bald eagle, and four candidate (C2) species: sturgeon chub, sicklefin chub, loggerhead shrike, and Bachman's sparrow. The three fish species inhabit the main channels of large rivers (Pflieger 1975; Smith 1979), and have been reported from the Missouri River in the general vicinity of the Weldon Spring site (Brabander 1992). Up to 25 bald eagles roost during winter at the Howell Island Wildlife Area (Brabander 1992), but the bald eagle is uncommon to rare in the area during the remainder of the year (Missouri Department of Conservation 1991). The loggerhead shrike has been sighted several times at the potential borrow area (Thomas 1992); Bachman's sparrow has been observed in the Busch Wildlife Area (Missouri Department of Conservation 1991) and may also occur at the borrow area. The Weldon Spring site does not contain habitat designated as critical for these species.

Mitigative measures to control surface runoff were implemented during construction of the water treatment plants and haul road for transporting wastes from the quarry to the chemical plant to minimize the introduction of solids to the Missouri River. Additionally, the fish species are tolerant to turbid conditions (Carlander 1969; Pflieger 1975; Smith 1979). Elimination or modification of in-stream habitats that could impact these species would not be associated with construction for interim activities. Therefore, the interim actions would not be expected to impact the fish species, although interim action construction might contribute to disturbance of the bird species.

Under Alternative 1, effluent would continue to be discharged from the water treatment plants at the quarry and chemical plant area in the near term in compliance with NPDES permits issued to DOE by the Missouri Department of Natural Resources, which establish protective levels that approach drinking water quality. Therefore, discharges of the treated water would not be expected to adversely affect the three fish species.

If no further cleanup actions were taken, the possibility that the bald eagle might consume prey that had been exposed to site contaminants either directly (e.g., at the raffinate pits) or indirectly (e.g., at the off-site lakes to which contaminants have migrated) would continue. Nevertheless, the cumulative effect of the water treatment actions and quarry bulk waste excavation on this species would be positive because those actions reduce the potential for such exposures. Similarly, other species that might occur in the area such as the loggerhead shrike and Bachman's sparrow could be impacted by human disturbance associated with implementing the interim actions, but a net positive cumulative effect would result from removing the potential sources of direct and indirect exposures.

Additional species such as the interior least tern and peregrine falcon might also occur in the area, but because of the transient nature of their possible proximity to the site during the periods of disturbance, no adverse impacts are expected. In any case, the cumulative effect of the combined actions would be positive because the sources of contamination that might be transferred to these species via the food chain would have been removed. Other species for which the overall effect of these combined actions would be positive include the pied-billed grebe, Blanding's turtle, and wood frog.

If institutional controls were lost in the long-term future, many of the beneficial impacts associated with the interim actions under the continued monitoring and maintenance activities of Alternative 1 could also be lost. Incremental environmental impacts could result from dispersal of the material stored on-site as part of those actions and/or from exposures to this material. In addition, the raffinate pits and ponds could refill over time so related adverse environmental impacts could again occur because equilibrium contaminant concentrations could reestablish in this water from contact with the sludge or sediment. However, even in this case, the net cumulative effects of these interim actions would still be slightly positive because certain problems (such as those unique to the buildings and the bulk waste at the quarry) would have been fully eliminated.

If the containment features at the TSA and MSA were to fail in the long term, the dispersal of material from those facilities could result in incremental impacts to local surface water quality with regard to both increased turbidity and contaminant levels; the magnitude of potential impacts would depend on the extent of dispersal and deposition. Incremental groundwater impacts could also result from either surface water loss to the subsurface, e.g., beyond the northern site boundary, or leaching through the overburden if underlying containment features at the TSA (and to a lesser extent the MSA) were to fail and no corrective actions were taken. Air quality at the site could also be impacted, although these impacts would probably be less than for the other resources because the topography, climate, and meteorology of the area would tend to limit wind dispersal. Impacts associated with failure of the current containment system at the raffinate pits could be much more significant — e.g., washout and channeling could occur off-site and contaminants could be distributed over an extended area; groundwater quality might also be impacted.

In summary, no adverse cumulative impacts to environmental resources would be expected from the interim actions beyond those already associated with the site under Alternative 1. In fact, the overall effect of those actions would be positive.

6.11.2.2 Alternative 6a

Cumulative environmental impacts associated with the interim actions in combination with Alternative 6a would be represented by the impacts associated with this alternative because of the larger scope and longer duration of incremental disturbances associated with the site cleanup activities. That is, the incremental impacts associated with the interim actions, which would be generally similar to those described under Alternative 1, would be small compared with the potential effects of remedial action under Alternative 6a. These effects could include incremental concentrations of airborne particulates (some of which would be contaminated), increased quantities of sediment in surface runoff, and increased traffic and noise. Limited wildlife habitat in the surrounding area would be temporarily lost as a result of cleanup activities at the vicinity properties.

As indicated in the introductory discussion, remedial action activities conducted at the chemical plant area might also overlap with similar activities conducted at the adjacent Army site. In this case, the cumulative effects associated with this alternative would be higher because activities at both sites could each have similar impacts. Mitigative measures and engineering controls would be applied to minimize any potential for significant cumulative effects.

Implementing Alternative 6a would result in the temporary disruption of much of the chemical plant area, which would result in the loss and displacement of certain vegetation and wildlife during the cleanup period. However, much of the area that would be disturbed represents marginal habitat, and its value is minimal compared with the approximately 6,000 ha (15,000 acres) of higher quality habitat that surrounds the Weldon Spring site. Furthermore, the cleanup activities would result in the elimination of major sources of exposure to site contaminants by wildlife (particularly at the raffinate pits) that might serve as indirect sources of exposure for predator species. Disturbance of the off-site borrow area might also result in a loss of habitat for the loggerhead shrike and Bachman's sparrow. However, the overall cumulative impact to these bird species would probably be positive because although habitat disturbance could result in some displacement during certain activities under Alternative 6a, the potential direct or indirect exposures to site contaminants would be reduced by the cleanup actions.

The construction and earth-moving activities associated with Alternative 6a would increase the potential for turbidity and sedimentation in runoff to the Missouri River. However, these releases would be minimized by implementing good engineering practices. In any case, sediment discharges that might occur would not be expected to adversely impact the pallid sturgeon, sturgeon chub, or sicklefin chub, as discussed for Alternative 1. The overall cumulative effect for these and other species from implementing the interim actions combined with Alternative 6a would be positive because the sources of contamination that could be transferred to these species via the food chain would have been eliminated and the residual levels of contaminants of ecological concern across the site would be comparable to background.

Restoration of the Weldon Spring site, including planting with grasses and native vegetation, would reestablish habitat that could support potential (uncontaminated) prey for the bald eagle. This restoration would also compensate for some of the potential habitat loss that might affect the loggerhead shrike and Bachman's sparrow at the borrow area. Loss of the raffinate pits (and quarry pond) would result in a small cumulative loss of waterfowl habitat in the area. However, loss of those habitats would provide a net benefit for the wildlife in the area because a major source of potential contamination would be eliminated.

In summary, under Alternative 6a, the cumulative effect of the interim actions to treat surface water at the chemical plant area and the quarry and to remove the source of quarry contamination (the bulk waste) — combined with eliminating the sources of contamination at the chemical plant area — would be very positive. Although the implementation of Alternative 6a would eliminate most of the sources of contamination associated with the site, some contaminants would still remain at certain locations, such as the Southeast Drainage and Femme Osage Slough, so the potential for ecological exposures would continue at much reduced levels. The potential cumulative effects associated with future response actions for those areas will be addressed in environmental documents prepared within the next few years for the final stages of remedial action for the site.

6.11.2.3 Alternative 7a

Cumulative environmental impacts associated with the interim actions in combination with Alternative 7a would be generally similar to those described for Alternative 6a, although some additional impacts to air quality would be associated with stack emissions from the vitrification facility. If the Army were to implement a similar treatment technology at the adjacent site (e.g., incineration), additional stack emissions could be generated. In this case, the potential for significant cumulative effects from the combined emissions would be examined and necessary mitigative measures would be implemented. Also, construction of the gas pipeline parallel to State Route 94 for this alternative might result in short-term disturbance to the loggerhead shrike and Bachman's sparrow. However, the overall cumulative effect of this action on environmental resources would be positive, as described for Alternative 6a.

6.11.2.4 Alternative 7b

Cumulative environmental impacts associated with the interim actions in combination with Alternative 7b would be similar to those described for Alternative 7a, except that the incremental impacts associated with the disposal cell would occur at the Envirocare site instead of at the Weldon Spring site. Some of the habitat disturbance (about 25%) associated with constructing the cell on-site during the remedial action period could still occur under this alternative, because this same location would be developed into a staging area for loading waste for off-site transport. The impacts associated with the actual transportation that would occur over several years are expected to have only a small incremental effect on air quality, e.g., from vehicle emissions.

Because the incremental disturbance of wildlife and habitat at the siding location in Wentzville would probably be offset by the reduced disturbance at the nearby borrow area (due to reduced borrow material requirements), net disturbance in the area of the Weldon Spring site could be smaller for Alternative 7b than for Alternative 7a.

Impacts to the pallid sturgeon, sturgeon chub, sicklefin chub, bald eagle, and other species in the area of the Weldon Spring site from implementing this alternative might be slightly lower than those described for Alternative 6a because of the combined effect of reduced excavation requirements at the borrow area and construction and operation of the disposal cell at a distant location. However, these impacts of cell construction and operation would still occur, they would simply be displaced to the Envirocare site. Although these impacts would be addressed by the Envirocare site and would not add to cumulative effects specific to the Weldon Spring site, they would contribute to the cumulative effects considered in the context of all locations significantly affected by this action. Acknowledging these overall combined effects supports the appropriate evaluation of trade-offs for each alternative in selecting an appropriate remedy for the site.

The Envirocare site that would receive the Weldon Spring waste under this alternative also receives wastes of different types from a variety of sources. In addition, other waste management facilities are located in or planned for the same general area. The activities associated with Alternative 7b would result in the dedication of additional land for waste disposal, an increase in dust generation, and an increase in rail traffic in the area. An EIS is currently being prepared for the Envirocare site to address the environmental impacts of waste disposal at that location (NRC 1991), and that EIS would be expected to address potential cumulative effects. Therefore, the cumulative impacts that could occur at the Envirocare site from disposing of contaminated materials such as the waste from the Weldon Spring site, in combination with other activities at that area, would be addressed in that EIS.

6.11.2.5 Alternative 7c

The cumulative environmental impacts for Alternative 7c at the Weldon Spring site would be similar to those identified for Alternative 7b. For the Hanford site, waste management facilities are located primarily in the 200 Area (DOE 1991), and it was assumed that waste from the Weldon Spring site would be taken to this location. Various other activities are planned or ongoing at or near the 200-West Area, including the proposed construction of a major radioactive waste management facility, the Hanford Central Waste Complex. This facility would be used to characterize, treat, package, and store transuranic waste for eventual off-site shipment. The Plutonium Processing Facility, the Waste Encapsulation and Storage Facility, and the Transuranic Waste Storage and Assay Facility are already located in the 200-West Area. Therefore, it is likely that construction and operation of other facilities would be occurring in the same general area considered for disposal of the Weldon Spring waste. If Alternative 7c were selected, the potential cumulative effects that could occur from disposing of the Weldon Spring waste at the Hanford site would be examined in more detail in the environmental compliance documents for the Hanford site.

7 COMPARATIVE ANALYSIS OF ALTERNATIVES

The comparative analysis of final remedial action alternatives for the Weldon Spring site presents a comparison of the alternatives with regard to the nine evaluation criteria described in Chapter 6. This analysis is the second stage of the detailed evaluation process and provides information from which a balanced decision for site cleanup can be made. For this analysis, the nine criteria are grouped into three general categories that comprise the tiered evaluation system identified in the NCP (EPA 1990a). These categories are the threshold criteria, primary balancing criteria, and modifying criteria.

The threshold category contains the two criteria that must be satisfied by the selected alternative:

- Overall protection of human health and the environment, and

- Compliance with ARARs, unless a waiver condition applies.

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 selected as the cleanup remedy.

The primary balancing category contains the five criteria that are used to assess the relative advantages and disadvantages of the alternatives to determine the most appropriate solution for a given site:

- Long-term effectiveness and permanence;

- Reduction of toxicity, mobility, or volume through treatment;

- Short-term effectiveness;

- Implementability; and

- 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 waste. Together with the third and fourth criteria, they form the basis for determining the general feasibility of the remedy and 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 the remedy is cost-effective.

The modifying category consists of two criteria:

- State acceptance and

- Community acceptance.

As discussed in Chapter 6, this category can be fully considered only after this the RI/FS-EIS has been issued to the state and the public for formal comment. Therefore, these modifying criteria are not addressed in this comparative analysis. They will be addressed in detail in the responsiveness summary and ROD for this remedial action.

The alternatives are compared in Sections 7.1 and 7.2 with regard to the threshold and primary balancing criteria. The results of this analysis are summarized in Table 7.1.

7.1 THRESHOLD CRITERIA

7.1.1 Overall Protection of Human Health and the Environment

All of the alternatives except Alternative 1 (no action) would provide long-term protection of human health and the environment. This protection could not be ensured for the no-action alternative because only general baseline maintenance activities would continue, and contaminants could migrate from source areas over time, e.g., from the raffinate pits to groundwater, and result in possible future adverse impacts. Alternative 6a (removal, chemical stabilization/solidification and disposal on-site) would limit exposures to contaminants by removing the sources of contamination, treating the most highly contaminated material by chemical stabilization/solidification, and placing the treated and untreated materials in an engineered disposal cell to isolate the waste from the environment. Alternative 7a (removal, vitrification, and disposal on-site) is similar to Alternative 6a, except the treatment method would be vitrification and the vitrified material and the untreated material could be placed in separate cells of different design. Alternatives 7b and 7c (removal, vitrification, and disposal at the Envirocare site or Hanford site) are similar to Alternative 7a except that disposal would be off-site.

The two basic differences between the final action alternatives are the treatment method and the disposal location, which includes a transportation component for the off-site disposal alternatives. Therefore, impacts to workers and the general public from removal activities during the remedial action period would be similar for each alternative because the same areas would be excavated or dredged. However, incremental impacts to workers and the public from treatment activities could result from differences between the chemical treatment and vitrification operations. Additional emissions are associated with Alternatives 7a, 7b, and 7c compared to Alternative 6a because contaminants would be released from the stack of the vitrification facility. However, these emissions are expected to be controlled by an extensive air pollution control system within the facility, so related impacts would be small.

Potential health impacts for members of the general public during the cleanup period would be below EPA's target limits for protecting human health for each of the action alternatives. Impacts would be relatively higher for Alternatives 7b and 7c than for Alternative 6a or 7a because of the increased likelihood of exposures and accidents during the waste handling and transportation activities for off-site disposal. Worker impacts would be higher under the

TABLE 7.1 Comparative Analysis of Alternatives

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Overall Protection of Human Health and the Environment				
Could not ensure protection of human health and the environment in the long term.	Engineering and mitigative measures would be applied during the remedial action period such that no significant adverse impacts would occur to the general public or the environment. Worker exposures would be similarly controlled to levels within health-protective limits. Long-term exposures would be minimized by removing contaminated material from source areas to reduce residual sitewide risks toward levels comparable to background. The highly contaminated material would be chemically treated, and all waste would be placed in an engineered disposal cell to provide permanent containment. If the cell were to fail and no corrective actions were taken, potential health and environmental impacts would be much lower than under Alternative 1 because contaminants in the treated waste would be much less mobile than under existing conditions.	Generally similar to Alternative 6a, except as follows. Short-term impacts could be slightly higher because contaminants would be released from the stack of the vitrification facility during the remedial action period and the potential for accidents and worker injuries would increase as a result of the larger work force required, the high operating temperatures, and the lack of experience with such a large-scale application of this process to waste treatment. Long-term impacts could be somewhat lower if the cell were to fail and no corrective actions were taken, because certain contaminants would be destroyed by vitrification and the vitrified portion of the waste is expected to be less susceptible to leaching.	Similar to Alternative 7a, except long-term impacts that could occur if the cell were to fail over time would occur at the Envirocare facility instead of at the Weldon Spring site. Temporary impacts to air quality from the dispersal of untreated material might be higher than Alternative 6a or 7a, impacts to groundwater could be comparable to Alternative 7a, and impacts to surface water would be lower than Alternative 6a or 7a. Incremental radiological exposures would be incurred by workers and, to a lesser extent, by the general public during off-site waste transport, including transfer activities at the Wentzville rail siding. In addition, the likelihood of accidents and worker injuries would increase; the public could also be injured and/or exposed to contaminants from an accident. Radiological exposures associated only with waste transportation would be significantly lower than those resulting from waste removal, treatment, and disposal activities — which are also associated with Alternatives 6a and 7a.	Similar to Alternative 7a, except long-term impacts that could occur if the cell were to fail over time would occur at the Hanford facility. In the event of such a failure, overall impacts would probably be higher than Alternative 6a, 7a, or 7b. Impacts to air quality from the dispersal of untreated material might be higher than for Alternative 6a or 7a and comparable to Alternative 7b; groundwater could be contaminated sooner than Alternative 7a or 7b; impacts to surface water might be comparable to Alternative 6a or 7a and higher than Alternative 7b; and ecological impacts could be higher than Alternative 6a, 7a, or 7b. Impacts of off-site transportation would be similar to Alternative 7b.

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Compliance with ARARs				
Would not meet all ARARs, including EPA time limits for storing certain waste prior to disposal. If institutional controls were lost in the future and access was unrestricted, EPA and DOE standards for radiological exposures and for residual levels of radium and thorium in soil would not be met; if the raffinate pits refilled, certain water quality criteria for the protection of aquatic life would not be met.	Would meet all pertinent ARARs, including those for radiological exposures and residual soil concentrations. Appropriate health-based ARARs would be met for both workers and the general public during and following cleanup. A waiver from the state limit of 1 pCi/L above background for radon-222 might be pertinent during a limited period of TSA activities. The disposal cell would incorporate design features that would ensure compliance with performance objectives, considering relevant and appropriate standards from regulations such as the Uranium Mill Tailings Radiation Control Act, Toxic Substances Control Act, Resource Conservation and Recovery Act (RCRA), and Missouri Hazardous Waste Management Law and Regulations. A 5-year review of the effectiveness and protectiveness of the response would be conducted because waste would remain on-site.	Same as Alternative 6a, with additional requirements for the vitrification facility that would be met, including emission standards given in the Missouri Air Pollution Control Regulations and possibly incineration standards given in RCRA.	Same as Alternative 7a, with additional requirements for off-site transportation that would be met. Disposal requirements would be addressed by the Envirocare facility.	Same as Alternative 7b, except disposal requirements would be addressed by the Hanford facility.

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Long-Term Effectiveness and Permanence				
Current exposures and impacts would continue and could increase over time because of continued contaminant migration and the possible failure of existing containment systems. Over a 30-year period, monitoring and maintenance activities associated with no further action would result in an estimated 9 cases of occupational injury and no occupational fatalities. If institutional controls were lost in the future and access was unrestricted, the lifetime risk of cancer induction to an individual from exposures to radioactive and chemical contaminants, respectively, are estimated to be 6×10^{-5} for a recreational visitor and would range from 4×10^{-6} to 9×10^{-2} for a resident; noncarcinogenic effects would be indicated for the resident at less than 5% of the soil areas. Adverse impacts to biota could occur at highly contaminated areas such as the raffinate pits, and contaminants could migrate from the surface to groundwater.	More protective than Alternative 1 because the current sources of potential hazards would be removed to provide a permanent solution for those areas. Residual sitewide risks could be reduced toward levels comparable to background, and environmental conditions would improve. The ranges developed for soil cleanup criteria would be applied as appropriate to the long-term use of the site, in accordance with DOE's "as low as reasonably achievable" (ALARA) process. By this process, contaminant concentrations would be reduced to the most protective levels practicable, so residual levels for each alternative could be similar. For the waste, the highly contaminated material would be treated to limit the potential for future releases, prior to isolation in an engineered cell. If the cell were to fail at some time in the future, releases from that material would be slow because the lifetime of the treated product is expected to be hundreds to thousands of years (beyond the time of cell failure, assuming no corrective actions are taken). The disposal cell (continued on next page)	Similar to Alternative 6a, but could be somewhat more protective if the disposal cell were to fail in the long term and no corrective actions were taken because certain contaminants in a portion of the waste would be destroyed during vitrification (e.g., organic compounds in soil from the quarry, but not radionuclides). An effectively vitrified waste form is expected to be able to withstand environmental degradation for thousands of years. If the cell were to fail in the future, that portion of waste that is successfully vitrified could be relatively less susceptible to leaching than if it were chemically stabilized/solidified. Thus, contaminant concentrations in the leachate of that material could be lower, and the incremental contribution to overall groundwater impacts could be lower. Overall health and environmental impacts associated with maintenance activities and with cell failure in the absence of maintenance activities would be generally similar to Alternative 6a.	Generally similar to Alternative 6a or 7a, except soil within the cell area for that alternative would be selectively remediated under Alternative 7b and potential impacts would occur at the off-site location instead of on-site if the disposal cell were to fail in the future. If the waste were exposed, air quality impacts from wind dispersal of untreated material would be higher than Alternative 7a because wind speeds are higher, the climate is dry, and the site is sparsely vegetated. Related health impacts would depend on whether land use changed over the extended future; the nearest residence is currently about 40 km (25 mi) away so public exposures would be lower than Alternative 6a or 7a under current land use conditions (the nearest residence and town are 2 to 3 km [1 to 2 mi] from the Weldon Spring site). Potential groundwater contamination could be similar to Alternative 7a because, although annual precipitation is lower, the depth to groundwater is comparable and the overburden permeability is higher than the Weldon Spring site. No surface water impacts would be (continued on next page)	Similar to Alternative 7b, except impacts would generally be higher at the Hanford facility than at the Envirocare facility or the Weldon Spring site if the disposal cell were to fail in the future. Air quality impacts associated with the untreated material would be similar to Alternative 7b and higher than Alternative 6a or 7a because the terrain and meteorological conditions are similar to the Envirocare facility and much more conducive to wind dispersal than at the Weldon Spring site. Impacts to the general public would depend on future land use; if the relative population densities at the alternate sites remain the same, impacts would be higher than Alternative 7b and lower than Alternative 6a or 7a (the distance from the disposal location to the nearest town is about 30 km [19 mi]). If homes were built closer to the cell in the future, impacts might be similar to Alternative 6a or 7a (high winds and sparse vegetation might offset the additional distance). Assuming that the waste becomes saturated, (continued on next page)

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Long-Term Effectiveness and Permanence (Cont.)				
	would be designed to last for at least 200 to 1,000 years, and monitoring and maintenance would continue into the long term. In the 30 years immediately following implementation, about 9 cases of occupational injuries and no occupational fatalities are estimated to occur during site maintenance activities. If the cell were to fail and no corrective actions were taken, potential impacts to human health and the environment would be much lower than under Alternative 1 because the highly contaminated material would have been treated and would be much less susceptible to leaching and dispersal. In addition, the compaction of natural clay in the subgrade would limit transport. No adverse ecological impacts would be expected because the highly contaminated material would have been treated to reduce contaminant mobility and availability.		expected because the Envirocare facility is 45 km (28 mi) from the nearest surface water body. No adverse ecological impacts would be expected (as for Alternative 6a or 7a) because the highly contaminated material would have been treated to reduce contaminant mobility and availability.	groundwater impacts might occur sooner than Alternative 7a or 7b because, although the overburden is 3 or more times thicker, its higher permeability would more than offset the increased depth to groundwater. Surface water impacts could be higher than Alternative 7b and comparable to Alternative 6a or 7a because an ephemeral stream is within 3 km (2 mi) of the disposal location and two rivers are within 8 and 24 km (5 and 15 mi), respectively. Ecological impacts would be higher than Alternative 7b and somewhat similar to Alternative 6a or 7a, except potential impacts to threatened and endangered species could be higher under Alternative 7c.

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Reduction of Toxicity, Mobility, or Volume through Treatment				
Toxicity, mobility, and volume of contaminated material would not change.	The disposal volume of 772,000 m^3 (1,010,000 yd^3) would be larger than the volumes for the other action alternatives because chemical stabilization/solidification would result in a 32% increase in waste volume, or about 327,000 m^3 (428,000 yd^3) of treated product; this corresponds to an increase of 12% for the combined waste volume. The incorporation of contaminants into the treated product would significantly reduce contaminant mobility. The volume of certain structural material (primarily metal debris) could be reduced by 10 to 50%, depending on its type and physical configuration. The volume of wooden debris and vegetation could be reduced by at least 50% and up to 80 to 90% by shredding and composting, depending on process enhancement. The volume of rock and concrete would not be reduced.	The disposal volume of 522,000 m^3 (683,000 yd^3) would be smaller than that for Alternative 6a because vitrification would result in a 68% decrease in volume, or about 78,800 m^3 (103,000 yd^3) of treated product; this corresponds to a decrease of 24% for the combined waste volume. The reduction in contaminant mobility would be greater than Alternative 6a because the vitrified product would be incorporated into a glass-like matrix instead of a cement-like matrix. In addition, the toxicity of certain waste types would be reduced because organic contaminants in the portion of waste that would be treated (e.g., nitroaromatic compounds in the quarry soil) would be destroyed and some inorganic contaminants (e.g., nitrate) would be altered. For the other waste material, expected volume reductions would be the same as Alternative 6a. The off-gas system would generate treatment residuals consisting of spent filters and about 2,200 t (2,400 tons) of scrubber residuals (for the expected case over 4 years of operation).	Same as Alternative 7a.	Same as Alternative 7a.

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Short-Term Effectiveness				
Current exposures and impacts would continue. About 80 person-years of effort would be required for baseline activities over a 10-year period, and about 12 occupational injuries and 110 lost workdays are associated with these activities. Radiological and chemical carcinogenic risks estimated for an on-site maintenance worker under current conditions are 5×10^{-4} and 1×10^{-5}. The corresponding risks for a trespasser (member of the general public) are 9×10^{-5} and 1×10^{-4}, and noncarcinogenic effects are indicated.	Exposures would be higher than Alternative 1 because of particulate and gaseous (radon) emissions and external gamma irradiation associated with removal, treatment, and disposal activities. Mitigative measures would be implemented to minimize potential health and environmental impacts. Total worker effort is estimated to be 560 person-years. The risk of worker accidents would increase compared with Alternative 1; about 82 cases of occupational injuries are estimated to occur, with about 790 lost workdays. Worker protection would be used to control exposures. The risks of cancer induction from exposures to radioactive and chemical contaminants, respectively, are estimated to be about 1×10^{-3} and 8×10^{-5} for the maximally exposed remedial action worker and about 6×10^{-7} and 3×10^{-8} for the maximally exposed member of the general public. No adverse impacts to off-site individuals are expected from contaminant releases during implementation of this alternative; the radiological risk to the population within 5 km (3 mi) of the site is estimated (continued on next page)	Similar to Alternative 6a, except that the risk of worker accidents would increase (110 occupational injuries are expected to occur, with about 1,100 lost workdays) and emissions from the vitrification facility could result in increased airborne contaminant levels. These emissions are not expected to significantly affect human health or the environment because the facility would be equipped with an off-gas system to ensure protectiveness and additional mitigative measures would be applied. Additional worker protection against inhalation and ingestion of airborne contaminants would be required, as would increased protection against safety hazards associated with the treatment operations because high temperatures are used in the vitrification process. Total worker effort is estimated to be 780 person-years. The risks of cancer induction would not increase appreciably compared with Alternative 6a. The risks from exposures to radioactive and chemical contaminants, respectively, are estimated to be about 1×10^{-3} and 8×10^{-5} for the maximally exposed remedial (continued on next page)	Similar to Alternative 7a, except that the requirements for transportation of waste for off-site disposal would increase potential impacts to human health and the environment in the short term. Incremental radiological exposures would be incurred by workers and, to a lesser extent, by the general public during waste transport, including transfer activities at the Wentzville rail siding. Radiological exposures associated with transportation activities (including accidents) would be significantly lower than those resulting from removal, treatment, and on-site disposal activities for Alternatives 6a and 7a. The additional risks of cancer induction from transportation activities are estimated to be 2×10^{-4} for the maximally exposed worker and 7×10^{-8} for the maximally exposed member of the general public. In addition, the potential for accidents and the likelihood of worker injuries would increase; the estimated number of occupational injuries would increase to 160, with about 1,600 lost workdays; and six vehicular accidents would be expected, with no associated (continued on next page)	Similar to Alternative 7b, except that habitat used by a candidate species would be disturbed at the Hanford facility.

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Short-Term Effectiveness (Cont.)				
	to be 3×10^{-3}. Most impacts to biota would be temporary, but about 17 ha (42 acres) of habitat would be permanently altered at the cell location. Activities are not expected to impact threatened or endangered species. About 15 ha (38 acres) of on-site wetlands would be lost, but the excavation of these areas would remove a source of exposure and improve environmental conditions; related mitigation plans would be developed with the state of Missouri. Up to 0.6 ha (1.4 acres) of land within the 100-year floodplain of a nearby creek might also be excavated, but the area would be recontoured and revegetated so impacts would be temporary. Alternative 6a would be the most timely of all the action alternatives because it would use an established process and treatment could begin after standard engineering design and start-up activities. About 4 to 5 years would be required to treat the raffinate pit sludge and more highly contaminated soil. Approximately 895,000 m^3 (1,171,000 yd^3) of clay-rich soil would be required for borrow material; this soil could be obtained from a nearby source.	action worker and about 7×10^{-7} and 3×10^{-8} for the maximally exposed member of the general public. The radiological risk to the population within 5 km (3 mi) of the site is estimated to be 3×10^{-3}. The initiation of site cleanup under this alternative would be delayed compared with Alternative 6a because additional lead time would be needed to address engineering issues such as scale-up and optimization of the vitrification and off-gas treatment processes. About 4 years would be required to treat the raffinate pit sludge and more highly contaminated soil. The same amount of borrow material would be required as for Alternative 6a; this soil could be obtained from a nearby source.	fatalities. The public could also be exposed if contaminants were released during an accident. Additional mitigative measures would be implemented to reduce related impacts. Total worker effort is estimated to be 1,100 person-years. About 376,000 m^3 (492,000 yd^3) of soil would be required for borrow material; this soil could be obtained from a nearby source.	

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Implementability				
Minimum site operations would continue with the use of readily available resources.	Most straightforward to implement of the action alternatives. Chemical stabilization/solidification has been successfully applied at a number of contaminated sites and is an established technology. Pilot-scale testing, design, construction, and start-up would require less time than the vitrification technology of Alternatives 7a, 7b, and 7c; approximately 4 years would be required for these initial engineering activities. Chemical stabilization/solidification of the contaminated material would involve some special handling, but the equipment and process reagents are readily available from local suppliers. The process could be readily monitored in the short term, as could the effectiveness of the disposal cell in the short term and the long term (with the leachate collection/leak detection system and groundwater monitoring wells).	Less straightforward to implement than Alternative 6a because more extensive testing and optimization of the vitrification treatment system would be needed. Engineering scale-up, more highly trained personnel, and off-gas controls and monitoring would also be required. Vitrification is considered an innovative technology and has only been implemented for small waste quantities at the pilot-scale stage. Bench-scale and pilot-scale testing, design, construction, and start-up of the vitrification system at the Weldon Spring site would probably require at least 5 to 7 years. (Considerable uncertainty is associated with this estimate because of the innovative nature of the technology.) The off-gas treatment system would require extensive testing and optimization, and it would necessitate coordination and approvals with the state of Missouri for emissions (for substantive permitted conditions).	Same as Alternative 7a, except for off-site transport and disposal, which would be less straightforward to implement than on-site disposal because of the need for increased coordination among federal, state, and local agencies for the transportation route and in Utah. Handling and support facilities are available at the Envirocare facility. However, administrative procedures are not currently in place at the Envirocare facility for accepting the Weldon Spring waste, which is classified as 11(e)2 by-product material. Additional administrative difficulties could be associated with waste transport through the various states. About 515 train trips would be required over a projected 7-year period, for a total one-way haul distance of 1,240,000 rail-km (773,000 rail-mi).	Similar to Alternative 7b, but off-site disposal would be even less straightforward to implement because the Hanford facility currently accepts only small-quantity shipments of containerized waste from off-site sources, and administrative and handling procedures are not in place for accepting the large volume of waste from the Weldon Spring site. About 515 train trips would be required over a projected 7-year period, for a total of 1,740,000 rail-km (1,080,000 rail-mi).

TABLE 7.1 (Cont.)

Alternative 1: No Action	Alternative 6a: Removal, Chemical Treatment, and Disposal On-Site	Alternative 7a: Removal, Vitrification, and Disposal On-Site	Alternative 7b: Removal, Vitrification, and Disposal at Envirocare	Alternative 7c: Removal, Vitrification, and Disposal at Hanford
Cost				
The total cost would be the lowest in the short term (about $12 million over a 10-year period), but the comparative level of effectiveness would be low. In addition, the cost would be potentially higher than for the action alternatives over the long term because the scope of the required remediation effort could increase if cleanup actions were not implemented in the near term. That is, conditions could worsen considerably over time, necessitating an expensive emergency and/or expanded response in the future.	The total cost would be about $157 million, which is the lowest of the action alternatives for the same overall level of effectiveness. The estimated long-term maintenance cost is about $24 million, and the present-worth cost is about $79 million. The total cost is significantly lower than that for Alternative 7b or 7c because of the lower cost for on-site disposal.	The total cost would be about $182 million. The estimated long-term maintenance cost is about $24 million and the present-worth cost is about $97 million. A vitrification facility would cost about $24 million more to construct and operate than a chemical stabilization/solidification facility. However, the cost for on-site disposal of the vitrified waste would be about $45 million, which is $11 million less than for on-site disposal of the chemically stabilized/solidified waste, because of the smaller volume and less extensive design requirements for the vitrified product. The net cost difference from Alternative 6a is $25 million.	The total cost would be about $351 million, which is much higher than Alternative 7a. The total cost for off-site transport and disposal at the Envirocare facility, including construction of a rail siding in Wentzville, is estimated to be $214 million, of which $110 million is attributable to waste transportation. (The long-term maintenance cost is included in the estimate for waste disposal.) The present-worth cost is $197 million.	The total cost could be about $304 million, which is generally comparable to Alternative 7b. This value was determined from a preliminary estimate for waste disposal; a detailed cost analysis would be performed to develop a firm price if disposal at the Hanford facility were a component of the selected alternative. The total cost for off-site transport and disposal is estimated to be about $143 million, and the long-term maintenance cost is assumed to be the same as for Alternative 7a. The estimated cost for transporting the waste is about $16 million higher than for Alternative 7b because of the increased distance to the Hanford facility. The present-worth cost is $171 million.

vitrification alternatives because this process would require more workers and additional accidents could result from the hazards of high operating temperatures and limited field experience. Potential health impacts to workers and the general public from implementing the final action alternatives are evaluated in detail in Appendix F and summarized in Table 7.2. For the hypothetical scenario under which the cell is assumed to fail in the extended future without any corrective actions being taken, impacts could be somewhat lower for Alternative 7a than Alternative 6a because the vitrified portion of the waste could be less susceptible to leaching and the organic contaminants in that waste would have been destroyed.

The nature and extent of impacts to biota from implementing Alternatives 6a and 7a would be similar. Both alternatives involve the following activities: excavation of contaminated soil and sediment from the same locations; construction of access roads, staging areas, and other on-site support areas needed for the excavation and transport of the contaminated media; and excavation of borrow material from an off-site location. Potential environmental impacts associated with implementing Alternatives 6a and 7a include the permanent loss of some on-site habitats and off-site habitats at the nearby borrow area. Short-term impacts include the temporary loss of habitats at the vicinity properties; possible increases in contaminant transport to and turbidity and sedimentation in nearby surface water bodies; loss of vegetation and loss and displacement of wildlife on-site; disturbance of wildlife in nearby areas as a result of noise, dust, and human activity; and possible impacts of accidental spills of construction and operational materials. Mitigative measures would be implemented to minimize these short-term impacts.

Environmental impacts associated with implementing Alternatives 7b and 7c include those identified for Alternatives 6a and 7a, plus potential impacts from construction and disposal activities at the off-site disposal location, construction and operation of the Wentzville rail siding, and transportation of the waste from the Weldon Spring site to Wentzville and then to either the Envirocare site or the Hanford site. Impacts at the Weldon Spring site associated with the nearby borrow area would be somewhat lower for Alternatives 7b and 7c because of the reduced requirements compared with Alternatives 6a and 7a (because the cell would be constructed at an off-site location under Alternatives 7b and 7c, related impacts would occur at those locations). The potential consequences of cell failure in the extended future if no corrective actions were taken are summarized in Table 7.1.

7.1.2 Compliance with ARARs

Except for the no-action alternative, the attainment of ARARs under each of the final alternatives would be comparable; applicable requirements would be met both during and following cleanup unless a waiver condition applied. A comprehensive list of potential ARARs for this remedial action is presented in Appendix G, and waiver conditions are identified in Section G.2. Key requirements are discussed in Chapter 6 within the evaluation of each alternative against this criterion.

TABLE 7.2 Summary Comparison of Potential Health Impacts Associated with the Final Alternatives during the Action Period[a]

Receptor	Estimated Health Risk: Alternative 6a	Alternative 7a	Alternative 7b	Alternative 7c
General public in the vicinity of the Weldon Spring site				
Maximally exposed individual				
Radiological risk	6×10^{-7}	7×10^{-7}	7×10^{-7}	7×10^{-7}
Chemical carcinogenic risk	3×10^{-8}	3×10^{-8}	3×10^{-8}	3×10^{-8}
Chemical hazard index	0.0008	0.0008	0.0008	0.0008
Collective carcinogenic risk[b]				
Within 5 km of the site	3×10^{-3}	3×10^{-3}	3×10^{-3}	3×10^{-3}
Within 80 km of the site	2×10^{-2}	2×10^{-2}	2×10^{-2}	2×10^{-2}
Remedial action workers				
Maximally exposed individual[c]				
Radiological risk	1×10^{-3}	1×10^{-3}	1×10^{-3}	1×10^{-3}
Chemical carcinogenic risk	8×10^{-5}	8×10^{-5}	8×10^{-5}	8×10^{-5}
Chemical hazard index	10	10	10	10
Collective carcinogenic risk[b]	9×10^{-2}	2×10^{-1}	2×10^{-1}	2×10^{-1}
Persons along transport routes and transportation workers[b]				
Member of the general public				
Maximally exposed individual	NA[d]	NA	7×10^{-8}	7×10^{-8}
Collective carcinogenic risk	NA	NA	3×10^{-3}	3×10^{-3}
Transportation worker				
Maximally exposed individual	NA	NA	2×10^{-4}	2×10^{-4}
Collective carcinogenic risk	NA	NA	9×10^{-4}	9×10^{-4}
Remedial action workers and transportation workers				
Occupational fatalities	0.14	0.20	0.28	0.28
Occupational injuries	82	110	160	160

[a] Potential health impacts associated with Alternative 1 (no action) are discussed in detail in the BA (DOE 1992a) and Appendix E, and the results are summarized in Section 1.6. Estimated health effects for a maximally exposed individual from uncontrolled exposures to site contaminants under baseline conditions would exceed the levels shown for maximally exposed individuals.

[b] The analysis was limited to radiological health impacts (see Appendix F), and it represents an estimate of the potential population risk for the people within the given radius (see text). For the 5-km radius, the population was 10,700; for the 80-km radius, the population was about 3 million.

[c] Represents the estimated health risk to a remedial action worker who participates in the project for the entire cleanup period.

[d] NA means not applicable.

To summarize those evaluations, Alternative 1 would not attain certain applicable requirements, including the 1-year time limit for storage prior to disposal of material contaminated with PCBs. In addition, radiation protection standards would not be met if site access became unrestricted in the future. In contrast, Alternatives 6a, 7a, and 7b would meet applicable standards, with certain waivers. The following discussion addresses these action alternatives.

For each alternative, a waiver from the applicable 1-year time limit for storing PCB-contaminated material for disposal would be pertinent on the basis of technical impracticability, i.e., a facility is not currently available in which to dispose of this material because it is also radioactively contaminated. In addition, the storage would constitute an intermediate measure in the context of the overall remedial action — which would include the development of a disposal facility — and this requirement would be met upon completion of the action.

Similarly, a waiver would be appropriate for each alternative (if needed) from the applicable limit of 1 pCi/L above background for radon-222 in uncontrolled areas, which is identified in the Missouri Radiation Regulations. This limit might be exceeded at the property fence for certain periods during quarry bulk waste handling activities at the TSA under any of the action alternatives. However, a waiver would be pertinent during the cleanup period on the basis of the intermediate nature of the activity in the context of the overall remedial action, which would attain the standard upon completion.

Other requirements that would apply to air emissions and would be met for each alternative include the National Emission Standards for Hazardous Air Pollutants (NESHAPs), which identify among other standards a flux limit for radon-222 of 20 pCi/m^2-s as an average for the entire site. Additional requirements would apply to Alternatives 7a, 7b, and 7c — or would be considered sufficiently similar to be relevant and appropriate with regard to the type and source of airborne material — because emissions would be released from the stack of the vitrification facility under these three alternatives. These additional requirements include standards identified in the Missouri Air Pollution Control Regulations for controlling emissions of particulate matter.

Siting requirements for hazardous waste facilities identified in RCRA and parallel requirements in the Missouri Hazardous Waste Management Law and Regulations would be met for treatment and storage actions because hazardous waste would be managed on-site in those facilities under each alternative. For example, all new (temporary) site facilities would be constructed outside a 100-year floodplain and beyond 61 m (200 ft) of a fault in which displacement has occurred in Holocene time.

For disposal, no environmental laws or facility siting laws are available that specifically apply to the combination of materials that would be placed in the engineered cell. However, a number of laws contain requirements that apply separately to uranium and thorium mill tailings, hazardous waste, PCB waste, and demolition waste, and they would be combined to address the site waste. Certain requirements would be considered relevant and appropriate to specific design components of the cell on the basis of sufficient similarity of waste type and the appropriateness of the purpose of the requirement with regard to the overall purpose of this remedial action — which is to dispose of site waste in a manner that will protect human health and the environment in both the short term and the long term.

Therefore, the cell design would include components of the Uranium Mill Tailings Radiation Control Act, RCRA, the Missouri Hazardous Waste Management Law and Regulations, the Toxic Substances Control Act, and the Missouri Solid Waste Rules. Other than the state standards, which would be evaluated only for Alternatives 6a and 7a, these requirements would be addressed for each of the action alternatives. The key requirements include designing for an effective life of at least 200 to 1,000 years, incorporating a radon barrier cover to limit releases to 0.5 pCi/L above background at the facility boundary, and incorporating a double liner and leachate collection system to contain the waste and monitor cell performance.

Standards for the disposal of hazardous waste, including the RCRA Land Disposal Restrictions, would not specifically apply because the waste would have been treated such that it no longer met the definition for hazardous waste. (No listed waste has been identified at the site, and the characteristic waste would be treated by vitrification or chemical stabilization/ solidification to attain the specified treatment standards.) Nevertheless, many of these requirements would be considered relevant and appropriate on the basis of sufficient similarity with regard to the waste type and the purpose of the requirement, for example, to limit the potential for washout or subsidence of the facility.

For Alternatives 6a and 7a, these relevant and appropriate requirements include the state siting criteria that a hazardous waste disposal facility not be located in a floodplain area or seismic zone as described for the treatment and storage facilities, and also that a waste landfill not be located in an area of unstable soil deposits subject to landslides or catastrophic collapse. Additional state requirements for thickness and permeability of naturally occurring material beneath the cell would be considered relevant on the basis of waste type but not appropriate on the basis of the specific circumstances at the site. That is, with regard to in-place material, much of the site overburden was significantly altered during the extensive excavation, backfilling, and regrading that occurred as part of plant construction more than 20 years ago, and a number of subsurface features such as building foundations are currently present. However, after those features are removed, naturally occurring material would be used in combination with compacted fill to engineer to an equivalent level of protection in order to attain the performance standards of these requirements.

Similarly, the restriction on placement of waste containing free liquids in a landfill would be relevant but not appropriate to Alternative 6a because of the nature of the waste type. That is, because of the relatively high content of radium and thorium in the material that would be treated (especially the raffinate pit sludge), maintaining an adequate moisture content would be essential to the control of radon and particulate releases that might otherwise impact workers. Therefore, the alternate method of waste placement described for Alternative 6a would be applied to ensure worker protection. This method could also result in improved cell stability because the treated material would be able to move into open spaces and then set in place, thereby decreasing the overall potential for voids in the combined waste volume.

The effectiveness of the remedy at the site would be reviewed every 5 years for Alternatives 6a and 7a because waste would remain on-site (within the disposal cell) under these alternatives. For all activities being considered for an off-site facility, the specific environmental regulations would be addressed by the owners/operators in the environmental compliance documents and activities for that facility. For Alternative 7b or 7c, compliance with the disposal requirements would be the responsibility of the owner/operator of the Envirocare or Hanford site, respectively. A requirement that would apply only to disposal at the Envirocare site addresses the ability to accept 11e(2) by-product material, as defined by the Atomic Energy Act, as amended. An environmental review process is currently underway for that site to address this issue.

7.2 PRIMARY BALANCING CRITERIA

7.2.1 Long-Term Effectiveness and Permanence

Alternative 1 would not ensure long-term protection of human health or the environment because contaminants could continue to migrate from the various source areas and adverse impacts could occur if institutional controls were lost in the future. Under this hypothetical scenario, if site access were unrestricted and an individual was regularly exposed to the radioactive and chemical contaminants, a risk of cancer induction could result. The respective lifetime risks are estimated to be 6×10^{-5} for a recreational visitor and would range from 4×10^{-6} to 9×10^{-2} for a resident; noncarcinogenic effects would be indicated for the resident at less than 5% of the soil areas. Adverse impacts to biota could occur at highly contaminated areas such as the raffinate pits, and contaminants could migrate from the surface to groundwater. In contrast, all of the action alternatives would provide a permanent solution and long-term protection because they all involve removing contaminants from the source areas, treating the highly contaminated waste to reduce hazards, and isolating all waste in an engineered disposal cell. Under each alternative, the cleanup activities would reduce risks toward levels comparable to background.

Relative to residual risks, the ranges developed for the soil cleanup criteria (Section 2.5) would be applied as appropriate to the long-term use of the site, in accordance with DOE's "as low as reasonably achievable" (ALARA) process. By this process, contaminant concentrations would be reduced to the most protective levels practicable, so residual levels for each alternative could be similar. For Alternatives 6a and 7a, soil within the respective cell areas would be effectively remediated because it would be removed prior to cell construction, and soil outside the cell area would be remediated to the selected ALARA levels to support the release of the property for other use. Soil remediation for Alternatives 7b and 7c is expected to be generally similar to Alternative 7a, except less soil within the area of the cell might be removed because of selective remediation.

On the basis of preliminary ALARA-based cleanup criteria, the estimated incremental lifetime risks of cancer induction from exposures to residual radioactive contaminants would be 7×10^{-6} for a recreational visitor; for a resident, the risks would range from 0 (i.e., background) to 6 × 10^{-3}. Where the risks exceed EPA's target range of 1 × 10^{-6} to 1 × 10^{-4} for NPL sites, radon is the dominant contributor. However, the presence of radionuclides such as radon at the site represents a special case that was not explicitly accounted for in the development of EPA's target range, and the agency has identified a separate health-based level for this contaminant. The concentration of radon in indoor air that is considered acceptable by EPA (1992), i.e., 4 pCi/L, could be met by the cleanup criteria at all locations. The incremental lifetime risks from exposures to chemical contaminants would be within or below EPA's target range, and no noncarcinogenic effects would be indicated for either receptor at any location. Estimates for other hypothetical future individuals who might access the site are given in Appendix E and summarized in Section 1.6. For comparison, the representative background radiological and chemical risks for a recreational visitor off-site could be 2 × 10^{-5} and 1 × 10^{-6}, and those for a resident could be 3 × 10^{-3} and 5 × 10^{-5}.)

For the disposal component, the on-site cell for Alternatives 6a and 7a would be designed to last at least 200 to 1,000 years, and regular monitoring and maintenance activities would be conducted to ensure long-term effectiveness into the foreseeable future. Five-year reviews of the effectiveness of the remedy would be conducted in accordance with CERCLA, as amended. The on-site disposal cells of Alternative 6a and 7a would incorporate design features to withstand seismic events and the erosive forces of wind and extremely heavy rainfall, the side slopes would incorporate conservative safety factors to ensure long-term stability, and the leachate collection and removal system would be designed to serve a monitoring function that could continue for at least 30 years after cell closure (MK-Ferguson Company and Jacobs Engineering Group 1992b). The cells would be inspected regularly, and nearby surface water and groundwater would be routinely monitored as part of the active monitoring and maintenance program. This program would be implemented to ensure a timely and appropriate response to any cell damage that might be sustained by erosion, subsidence, biointrusion, a catastrophic event such as an earthquake or tornado, or other factors that could potentially compromise the cell's ability to contain the waste. Maintenance activities would include mowing the vegetative cover, controlling runon and runoff, maintaining the groundwater monitoring system, and operating the leachate collection and removal system until such time as a joint decision was made by DOE and the appropriate regulatory agencies (the EPA and the state of Missouri) to discontinue that component of the monitoring and maintenance program.

For this analysis, it was assumed that the disposal cell at the Envirocare or Hanford site under Alternative 7b or 7c would include similarly appropriate design features and that a similar monitoring and maintenance program would be followed to achieve the performance objectives for waste isolation. Therefore, the disposal cell is considered the key component of overall protectiveness in the future, and the long-term effectiveness and permanence of the disposal cell are expected to be generally similar for each of the final action alternatives. Thus, the primary difference between the alternatives arises from differences in the treatment methods as they could affect contaminant releases and subsequent impacts if any of the cells were to fail in the future and no corrective measures were taken.

The most heavily contaminated fraction of site waste — i.e., the raffinate pit sludge and underlying soil, the soil from the quarry, and process waste from the two water treatment plants

— would be treated by chemical stabilization/solidification under Alternative 6a and by vitrification under Alternatives 7a, 7b, and 7c. Vitrification would destroy organic contaminants in a portion of this treated material (e.g., the quarry soil), and both treatment technologies would produce a stable waste form that would be expected to last at least hundreds of years beyond exposure of the waste to the elements (sun, wind, and rain), e.g., if the disposal cell were to fail after 200 to 1,000 years and no corrective measures were taken. A small difference between these alternative treatment products could potentially be observed in the very long term because the chemically treated product is expected to maintain its durability for hundreds to thousands of years after an assumed cell failure, whereas the vitrified product is projected to last for at least thousands of years.

Thus, contaminant concentrations in the leachate that could result from the vitrified fraction of the waste (about 15% of the total volume) if the cell were to fail in the very long term could be lower than in the leachate from the chemically stabilized fraction. In addition, the vitrified portion would not contribute any organic compounds to the combined leachate from all site waste within the cell. However, the long-term effectiveness of vitrification for waste treatment has not yet been established because this is a developing technology. In addition, the fate of the contaminants in the waste that had not been treated would be the same under each alternative. Therefore, whether any difference in overall protection of human health and the environment between the chemical treatment and vitrification alternatives could actually be distinguished after hundreds or thousands of years cannot be determined at this time. Potential differences between the alternatives that could result from cell failure in the absence of corrective measures are summarized in Table 7.1.

Certain long-term environmental impacts would be common to all four action alternatives. Habitats would be permanently lost at the Weldon Spring site under each alternative because the same source areas would be disturbed by excavation and dredging; however, mitigative measures would be applied during and after these removal activities, and restoration efforts would replace a portion of the lost habitats. In addition, existing habitats over an estimated 17 ha (42 acres) or more of land at any of the alternative disposal locations would be permanently lost for the construction and maintenance of the cell. (This area is very small relative to the combined acreage of the surrounding habitats at each site.) An additional 4.5 ha (11 acres) of wildlife habitat could be lost under Alternative 7b or 7c because of construction of the rail siding in Wentzville for waste transfer. On the basis of preliminary conceptual information for the borrow area, about 34 ha (85 acres) of habitat near the Weldon Spring site could be disrupted to obtain borrow material for each of the action alternatives.

Permanent changes in land contours would also be associated with each alternative. Noticeable visual impact would result from the construction of a disposal cell at the Weldon Spring site because the maximum height is expected to be 23 m (74 ft) under Alternative 6a or 7a. However, the mound would be vegetated and the area to the south and west of the site is hilly, so this feature would blend somewhat into the local topography. Visual impacts from the disposal cell at the Envirocare or Hanford site (Alternative 7b or 7c) would be much lower, at least in the short term, because under current land use conditions the nearest residence is at least 16 km (10 mi) away.

7.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

The toxicity, mobility, and volume of contaminated material at the Weldon Spring site would not change under Alternative 1, except the effective mobility of the contaminants could increase if source controls were not applied. In contrast, all of the action alternatives would treat the same quantity and type of waste (including volume reduction of structural material and vegetation), and the overall reduction in contaminant mobility would generally be similar for each alternative. The volume of certain structural material (primarily metal debris) could be reduced by 10 to 50% under each alternative, depending on the type and physical configuration of the material. The volume of wooden debris and vegetation could be reduced by at least 50% and up to 80 to 90% by shredding and composting, depending on process enhancement. The volume of rock and concrete would not be reduced.

The chemical treatment process used for the highly contaminated portion of the waste under Alternative 6a would physically and chemically bind the contaminants in a cement-like matrix, so the mobility and leachability of contaminants in this treated material would be significantly reduced. However, the inherent toxicity of the waste would not change because no contaminants would be destroyed, and the total volume of chemically treated material would increase by 32% as a result of adding the stabilizing and setting agents. The combined waste volume would increase by 12% for this alternative.

The vitrification process used to treat the highly contaminated material under Alternative 7a, 7b, or 7c would physically bind the contaminants in a glass-like matrix, and this technology is capable of significantly reducing contaminant mobility and waste volume. Vitrification would also reduce the toxicity of organic contaminants in the material that was treated, e.g., by irreversibly destroying nitroaromatic compounds in the quarry soil. Vitrification would result in a 68% decrease in the volume of treated waste, which would correspond to a decrease of 24% for the combined waste volume. Although most contaminants in the treated material would be incorporated into the vitrified product to reduce mobility over the long term, some contaminants could be released during the treatment period as stack emissions of gas (including radon) and contaminated particulates. To address the potential for incremental air quality impacts and exposures under Alternative 7a, 7b, or 7c, an extensive pollution control system would be incorporated into the facility design to remove these contaminants from the off gas prior to its release. The off-gas system would generate residual waste consisting of spent filters and about 2,200 t (2,400 tons) of scrubber residuals (for the expected case over 4 years of operation). The filters could be recycled through the vitrification process (except during the last stages of treatment), but the scrubber waste would require other treatment, such as chemical stabilization/solidification, to limit subsequent contaminant mobility.

Treatability testing has been conducted with both chemical stabilization/solidification and vitrification using waste from the Weldon Spring site. Both processes demonstrated a significant reduction in contaminant mobility, and concentrations in leachate from the treatment products were well below the criteria used to determine whether a waste is a characteristic hazardous waste. Thus, although Alternatives 7a, 7b, and 7c would present an additional concern for air emissions compared to Alternative 6a, none of the action alternatives would be expected to result in a leaching (water mobility) concern relative to action-specific environmental standards.

The site waste would be isolated from the environment by containment in an engineered disposal cell under each alternative, which would further limit contaminant release. If it were assumed that institutional controls were lost over time and the disposal cell deteriorated without any corrective maintenance actions, the waste could be exposed. In this case, the difference between the alternatives would be determined by the treated portion of the waste because the fate of the untreated portion would be the same. With deterioration of the disposal cell cap, radon gas emitted from the treated waste would be released to the environment. The chemical stabilization/solidification process would reduce radon emissions by about 65%, and the vitrification process would reduce these emissions by about 99%. Because chemical stabilization/solidification immobilizes but does not destroy any contaminants, the contaminants could be slowly released as the cement/fly ash matrix deteriorated under continued exposure to the environment. Therefore, this process could be considered somewhat reversible over the very long term; the estimated durability of a waste form following effective treatment by chemical stabilization/solidification is at least hundreds of years. By comparison, vitrification could be somewhat less reversible because certain contaminants would have been destroyed (not the radionuclides) and the projected durability of an effectively vitrified waste is thousands of years; thus, leaching would be expected to occur at a lower rate for the vitrified material than for the chemically treated material. However, the incremental impacts associated with leaching from either treatment product compared to leaching from the remaining waste material over the very long term are not expected to result in significant differences in overall impacts because the vitrified waste represents only a small fraction (15%) of the total waste volume and the cement-like product could also potentially withstand degradation for thousands of years.

7.2.3 Short-Term Effectiveness

For Alternative 1, conditions would essentially remain the same in the short term and no significant changes in potential exposures would be expected. Estimated risks are summarized in Table 7.1. For the action alternatives, the various removal, treatment, and disposal activities at the Weldon Spring site would result in increased short-term exposures compared with Alternative 1. The short-term impacts of excavation are expected to be similar among the alternatives because the same material would be removed from each source area. For Alternatives 7a, 7b, and 7c, the additional hazards and off-gas emissions associated with the vitrification process could potentially increase impacts to human health and the environment during the treatment period above those for Alternative 6a. However, the expected impact to the public from emissions would be very small because extensive off-gas controls would be used. Estimated short-term risks during the cleanup period are summarized in Table 7.1. The risk of worker accidents associated with treatment would be higher for Alternatives 7a, 7b, and 7c than Alternative 6a because of the safety hazards associated with the high temperatures used in the vitrification process and increased worker requirements. The risk of transportation accidents would be higher for Alternatives 7b and 7c because of the large number of truck trips to the rail siding in Wentzville, Missouri (about 38,600 trips extending over 7 years), and the long distance to the disposal sites (about 2,400 km [1,500 mi] to the Envirocare site and 3,400 km [2,100 mi] to the Hanford site).

Potential short-term environmental impacts resulting from implementation of any of the final action alternatives include temporary habitat loss, increased sediment in surface runoff, generation of fugitive dust, loss of vegetation and loss and displacement of wildlife on-site, and disturbance of wildlife in nearby areas as a result of noise, dust, and human activity. Mitigative measures would be used to minimize these potential impacts.

Alternative 6a could provide a timely response, with a projected completion of cleanup activities within 10 years of the remedy selection. However, Alternatives 7a, 7b, and 7c could take longer because more intensive testing, optimization, and other engineering efforts would be required to scale the process for the large throughput rate needed for site application. Dual units would be used and treatment would be conducted year-round (24 hours a day, 365 days a year) to maintain the same overall schedule for time to completion as for Alternative 6a (for which chemical treatment would be conducted 8 hours per day, 9 months per year). Any unforeseen problems that might result from operating the scaled-up system could further affect the timeliness of the vitrification response. Additional delays could be associated with Alternatives 7b and 7c because many administrative issues would be involved in transporting waste through a number of states over several years; further delays could occur if the necessary license to allow site waste to be disposed of off-site were not obtained in a timely manner (e.g., for the Envirocare site under Alternative 7b).

7.2.4 Implementability

Alternative 6a would be the easiest to implement of all the action alternatives. The removal, treatment, and disposal activities could be carried out with standard equipment and procedures and readily available resources. The chemical stabilization/solidification technology has been applied successfully to treat large quantities of waste at a number of contaminated sites. Also, the EPA considers this a demonstrated treatment technology and has approved its selection as the remedy for many sites on the NPL, and the technology has been applied at other sites that are radioactively contaminated.

Construction and operation of a chemical stabilization/solidification facility on-site would be relatively straightforward and is expected to be reliable. Pilot-scale testing of the facility would require about 1 year, and design, construction, and start-up of the full-scale facility would require about 3.5 to 4.5 years (some of these activities could overlap). Resources such as equipment and operators would be readily available, and the process effectiveness could be readily monitored. The chemical stabilization/solidification process would require large quantities of fly ash and cement, but adequate supplies are available locally. Excavation of soil, sediment, and sludge and removal of structural material and debris from the MSA and TSA could also be accomplished with standard equipment and techniques. Construction of the disposal cell would be similarly straightforward and could be carried out with standard construction equipment and methods. The effectiveness of the cell as a containment system could be readily monitored in both the short term (with the leachate collection and removal system) and the extended long term (with groundwater monitoring wells). The administrative feasibility of Alternative 6a would also be relatively straightforward compared with the other alternatives because it would not involve stack emissions or interstate waste transport.

Although the removal and disposal aspects would be equally straightforward, the treatment component of Alternative 7a would be more difficult to implement than that of Alternative 6a. The vitrification process does not require the large quantity of chemical reagents needed for Alternative 6a, but large amounts of energy (fossil fuel) would be required. In addition, the facility would be less straightforward to construct and operate than the chemical stabilization/solidification facility. Vitrification of hazardous waste is considered an innovative technology. The joule-heated ceramic melter technology, which is evaluated as the representative process in this analysis, is currently being used to treat relatively small volumes of high-level radioactive waste. Limited field experience is available for the types and quantities of waste at the Weldon Spring site on which to base an assessment of the likely performance of the vitrification technology for Alternative 7a, 7b, or 7c. Similarly, the fossil fuel-heated ceramic melter technology is not widely available and has not been used on the scale required for the Weldon Spring waste. The number of trained personnel available to operate the process is also limited.

Further bench-scale and pilot-scale testing of the vitrification facility would probably require at least 2.5 to 3 years, which is considerably longer than the testing time needed for the chemical stabilization/solidification facility. Design, construction, and start-up is estimated to require at least 1.5 to 2.5 more years for the vitrification facility than for the chemical stabilization/solidification facility; however, delays in these activities could result from the innovative nature of the technology. Off-gas treatment would result in additional complexity, and delays could occur if inadequate controls were achieved during testing and optimization. The chemical stabilization/solidification process for Alternative 6a is a more conventional, established process that has been applied to contaminated material similar to the Weldon Spring waste. Compliance with emissions requirements might be an administrative issue for the off gas from the vitrification facility.

The implementability of removal and treatment activities for Alternatives 7b and 7c would be the same as for Alternative 7a. Off-site waste transport would be technically straightforward, and the necessary resources are available. For disposal, the Envirocare site has the resources and capacity to accept the Weldon Spring material but does not currently have the required license and permits, which limits the administrative feasibility of this option. The Hanford site currently accepts only small-quantity containerized waste from off-site sources, and the administrative and handling procedures needed for disposal of the large quantity of waste from the Weldon Spring site are not currently in place. Because off-site transport and disposal at either the Envirocare or Hanford site would also be subject to various state and federal requirements to address transport over the entire route for a number of years, administrative feasibility is much less straightforward for off-site disposal than for on-site disposal. Therefore, the implementation of Alternatives 7b and 7c would be much more difficult than Alternative 6a or 7a.

7.2.5 Cost

Alternative 1 would include monitoring and maintenance costs and would be the least expensive of all the alternatives in the short term. However, total costs are expected to be highest in the long term because site problems would probably worsen over time in the absence of cleanup (especially at the raffinate pits), such that the potential hazards and the magnitude of the cleanup effort could increase in the future. Therefore, the cost-effectiveness of the no-action alternative is very low.

Preliminary costs were estimated for the action alternatives to allow a balanced comparison, considering overall effectiveness. Final costs will be developed during the detailed design stage after the remedy for site cleanup is selected. The total costs, long-term maintenance costs, and present-worth costs for the final alternatives are summarized in Table 7.1. The costs of the removal, treatment, and disposal components of these alternatives are summarized in Table 7.3.

Alternative 6a is the least costly of the action alternatives because chemical stabilization/solidification is a standard treatment technology that can be implemented with relatively inexpensive equipment and supplies and the waste would not be transported off-site for disposal. Alternative 7a costs more than Alternative 6a because much higher costs are associated with vitrification; this process is less well developed for waste treatment applications, it is inherently more complex, and a larger work force and energy expenditures are required compared with the chemical treatment process of Alternative 6a. Although the vitrification process would decrease the final waste volume and related costs for on-site disposal, this difference does not offset the substantial costs associated with implementing the vitrification technology. Alternatives 7b and 7c are the most expensive alternatives because they combine the high costs of vitrification with those of waste transport and disposal off-site.

TABLE 7.3 Comparative Costs for Removal, Treatment, and Disposal Activities

	Estimated Cost ($ million)			
Activity[a]	Alternative 6a	Alternative 7a	Alternative 7b	Alternative 7c
Removal	24.0	26.5	26.3	26.3
Treatment	30.0	64.4	64.0	64.0
Disposal	55.7	44.7	214	143
Other	47.2	46.8	46.5	70.4
Total	157	182	351	304

[a] Additional detail is provided for the individual components of these activities in Tables 6.7, 6.8, 6.11, and 6.14. Disposal costs are based on preliminary estimates and would be refined specifically for the Weldon Spring waste during detailed design if disposal at the off-site facility were a component of the selected remedy.

Alternative 6a is also considered the most cost-effective of the action alternatives because it provides an equivalent measure of overall protection for human health and the environment, compared to the other alternatives, for a more reasonable cost. If it could be effectively implemented, Alternative 7a would reduce the toxicity of several contaminants (not the radionuclides) in waste from the raffinate pits and the quarry, and it is expected to provide some additional leach resistance for that portion of the waste in the extended future. Therefore, this alternative could provide some incremental benefit in the very long term for its additional cost; however, the overall effect of this benefit is expected to be relatively small for several reasons. The mobility of contaminants in the larger volume of site waste that would not be treated would be the same under each alternative. If realized, the incremental benefit might be observed after thousands of years — assuming the cell fails in the long term, no corrective actions are taken, and enough of the waste is continuously exposed for significant mobilization to occur. Moreover, the actual relative degradation rates between the chemically and thermally immobilized waste cannot be known (e.g., the durability of the chemically treated material could also extend beyond several thousand years and that of the vitrified material might not). In addition, this potential long-term benefit is somewhat offset by the potential for short-term incremental impacts associated with emissions from the vitrification facility during the action period.

The costs of Alternatives 7b and 7c are much higher than those of Alternative 6a or 7a, with no obvious benefit for overall protectiveness, as described for Alternative 7a. Of additional concern is the continued, long-term monitoring and maintenance of the Envirocare site (e.g., to thousands of years) under Alternative 7b. Because it is a commercial facility, the maintenance of institutional controls at this site would be the responsibility of a private company instead of the federal government. Therefore, continued long-term maintenance for this alternative might be considered somewhat less reliable than the other alternatives over the very long term, which is the time period over which any potential benefit might be realized from any differences in the fate of the treated product in the context of the overall waste volume. This concern does not exist for the other off-site disposal alternative, Alternative 7c, because the federal government would be responsible for maintaining institutional controls at the Hanford site — as it would if the waste were disposed of at the Weldon Spring site. For these reasons, Alternative 6a is considered the most cost-effective alternative for cleanup of the Weldon Spring site.

7.3 SUMMARY

In summary, except for the no-action alternative (Alternative 1), all of the final remedial action alternatives for the Weldon Spring site satisfy the threshold criteria for protecting human health and the environment and complying with environmental requirements, with waivers as appropriate. Under each alternative, exposures and risks would be minimized by removing the sources of contamination, treating the material that is highly contaminated, and isolating the treated and untreated materials from the environment in an engineered disposal cell. Sitewide residual risks would be reduced toward background levels and overall protectiveness would be comparable for each action alternative.

With regard to the primary balancing criteria, all alternatives are expected to provide a permanent solution that would ensure protection for a very long time, e.g., for at least 200 to

1,000 years. It is possible that the vitrification alternatives (Alternatives 7a, 7b, and 7c) could provide an incremental long-term benefit if the disposal cell were to fail and no corrective action were taken. The related benefit that might be observed in the distant future would be associated with the destruction of organic contaminants in a portion of the waste that would be treated and the expectation that the vitrified product would be more resistant to leaching over time. For example, the treated component of the waste could be leached after thousands of years have elapsed following cell failure for the vitrified material, compared with at least hundreds of years for the chemically treated material. However, the projected effectiveness of vitrification cannot be confirmed for the volume and type of material that would be treated at the site, and the chemically treated material could also reasonably be expected to withstand environmental degradation for a longer period, which could extend thousands of years. In addition, the vitrified material would comprise only 15% of the total waste volume, the remainder of which would contribute the same contaminants to the leachate associated with any of the alternatives. The application of institutional controls to monitor and maintain the disposal cell is also an important element of long-term protection. Alternative 7b might be somewhat less reliable than the other alternatives for this factor because the disposal site would be managed by a private company instead of the federal government.

Each of the action alternatives would reduce contaminant mobility. Waste volume would increase under Alternative 6a because setting and stabilizing agents would be added to immobilize the contaminated material. Waste volume would decrease under Alternatives 7a, 7b, and 7c, and the toxicity of certain contaminants in the vitrified material would also be reduced. However, Alternatives 7a, 7b, and 7c would generate additional waste from the off-gas treatment system. Neither treatment method would reduce the radiation toxicity of the site waste.

The short-term effectiveness of Alternative 6a would be higher than the other action alternatives. It would be the most timely of the alternatives because chemical stabilization/ solidification is an established treatment process that has been applied for many years at a variety of sites, and considerable experience has been gained in the field relative to system optimization, start-up, and operation for waste treatment. The time projected to complete the cleanup is about 10 years. In contrast, the vitrification alternatives would require a longer lead time to determine the appropriate procedures for ensuring effective treatment and minimizing potential health and environmental impacts, e.g., from airborne releases. The time for testing, engineering scale-up, design, construction, and start-up could be several years longer for Alternatives 7a, 7b, and 7c than for Alternative 6a. That is, site cleanup would probably be delayed under the vitrification alternatives because of the relatively developmental nature of the treatment process. Additional constraints could be associated with Alternatives 7b and 7c because administrative procedures (e.g., permits and agreements) are not in place for transporting and disposing of waste from the Weldon Spring site at either the Envirocare or Hanford site. The unavailability of these sites to receive waste from the Weldon Spring site could also affect the timeliness of the off-site disposal alternatives.

Environmental impacts at the Weldon Spring site from excavation and construction activities would be common for each action alternative, and comparable impacts would be associated with disposal activities at each of the alternative sites. Mitigative measures would be used to minimize potential short-term impacts. Incremental impacts to human health and the environment could be associated with stack emissions from the vitrification facility under Alternatives 7a, 7b, and 7c, but the facility would be equipped with extensive off-gas controls to minimize releases. The energy needs for the vitrification process are very much higher than for chemical treatment, so additional environmental impacts resulting from resource commitments would also be associated with these three alternatives. Worker impacts would also be higher for the vitrification alternatives because additional hazards are associated with this process and a larger work force would be required. Additional short-term impacts would be associated with the off-site disposal alternatives (Alternatives 7b and 7c), including incremental exposures and risks to workers and the general public from increased waste handling and transport to the western United States for disposal. The off-site transport of wastes could require construction of a rail siding in Wentzville, Missouri, for staging the waste and transferring it to railcars after truck transport (38,600 trips extending over a 7-year period) from the Weldon Spring site.

The implementation of Alternative 6a would be the most straightforward of the final action alternatives because it involves an established treatment method for which resources (including equipment, reagents, and operators) are readily available. In contrast, vitrification would be more difficult to implement because the process is much more complex, additional safety hazards are involved so more specialized training would be needed, and more intensive engineering efforts would be required to meet the treatment needs for the large volume of waste at the Weldon Spring site. The administrative feasibility of Alternative 7b or 7c would involve further difficulties associated with licensing, permitting, and other coordination issues, in addition to the development of administrative procedures to dispose of the Weldon Spring waste at the Envirocare or Hanford site.

Alternative 6a is considered the most cost-effective alternative for site cleanup. The estimated total cost of this alternative is about $157 million, and it would provide a similar level of overall effectiveness as the other action alternatives. Alternative 7a would cost about $25 million more than Alternative 6a, with no significant incremental benefit for human health and the environment. Potential adverse impacts in the short term would offset the benefit that might occur after thousands of years if the cell were to fail in the extended long term. The off-site disposal alternatives (Alternatives 7b and 7c) would be much more expensive than Alternative 6a (by about $200 million and $150 million, respectively) because they combine the higher costs of vitrification with the substantial costs for waste transport and off-site disposal, without a significant overall benefit for human health or environmental protection. Short-term impacts for these alternatives at the Weldon Spring site would be similar to those for Alternative 6a, additional accidents and exposures would be associated with off-site transport of the waste, and impacts that could occur if the cell were to fail in the long term would be generally similar but they would occur at the off-site location rather than at the Weldon Spring site.

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