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Remedial Investigation/Feasibility Study for Surface Impoundments Operable Unit Waste Area Grouping 1 Oak Ridge National Laboratory Oak Ridge, Tennessee

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Remedial Investigation/Feasibility Study for Surface Impoundments Operable Unit Waste Area Grouping 1 Oak Ridge National Laboratory Oak Ridge, Tennessee

Date Issued—May 1995

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Prepared for
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Office of Environmental Restoration and Waste Management

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ACRONYMS AND ABBREVIATIONS

Ag	silver
ALARA	as low as reasonably achievable
Am	americium
Ar	arsenic
ARAR	applicable or relevant and appropriate requirement
atm	atmosphere
Ba	barium
Be	beryllium
BNA	base-neutral acid
Bq	becquerel
C	carbon
Cd	cadmium
CDM	CDM Federal Programs Corporation
Ce	cerium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	*Code of Federal Regulations*
Cl	chlorine
cm	centimeter
Cm	curium
Co	cobalt
COC	contaminant of concern
Cr	chromium
Cs	cesium
Cu	copper
D&D	decontamination and decommissioning
dL	decaliter
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
DUST	Disposal Unit Source Term
Energy Systems	Martin Marietta Energy Systems, Inc.
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
Eu	europium

ACRONYMS AND ABBREVIATIONS (continued)

Fe	iron
FFA	Federal Facility Agreement
FR	*Federal Register*
FS	feasibility study
ft	foot
FY	fiscal year
g	gram
gal	gallon
H	hydrogen
ha	hectare
HEAST	Health Effects Assessment Summary Tables
HELP	Hydrologic Evaluation of Landfill Performance
Hg	mercury
I	iodine
ICRP	International Commission on Radiological Protection
in.	inch
IRIS	Integrated Risk Information System
kg	kilogram
km	kilometer
L	liter
La	lanthanum
LBF	low base groundwater flow
LOAEL	lowest observed adverse effect level
m	meter
μg	microgram
μGy	microgray
μR	microroentgen
mCi	millicurie
mg	milligram
Mg	magnesium
min	minute
mL	milliliter
mol	mole
mrem	millirem
Na	sodium
nCi	nanocurie

ACRONYMS AND ABBREVIATIONS (continued)

NEPA	National Environmental Policy Act
Ni	nickel
NIPDWS	National Interim Primary Drinking Water Standards
NOAEL	no observed adverse effect level
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
O	oxygen
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
Pb	lead
PCB	polychlorinated biphenyl
pCi	picocurie
Pd	palladium
ppm	parts per million
Pu	plutonium
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act of 1976
RI	remedial investigation
RME	reasonable maximum exposure
Rn	radon
ROD	record of decision
Ru	ruthenium
SAFER	streamlined approach for environmental restoration
SIOU	Surface Impoundments Operable Unit
Sr	strontium
TAL	target analyte list
TBC	to be considered
TCL	target compound list
TCLP	Toxicity Characteristic Leaching Procedure
TDEC	Tennessee Department of Environment and Conservation
TDHE	Tennessee Department of Health and Environment
Th	thorium
Tl	thallium

ACRONYMS AND ABBREVIATIONS (continued)

TOC	total organic carbon
TOX	total organic halides
TVA	Tennessee Valley Authority
U	uranium
UCL	upper confidence limit
VOC	volatile organic compound
WBS	work breakdown structure
Zn	zinc

EXECUTIVE SUMMARY

This remedial investigation (RI)/feasibility study (FS) supports the decision-making process concerning remedial action for the Waste Area Grouping 1, Surface Impoundments Operable Unit (surface impoundments) located at the Oak Ridge National Laboratory (ORNL). The surface impoundments are located within the confines of the U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee. ORNL, as part of ORR, is listed on the U.S. Environmental Protection Agency (EPA) National Priorities List. The DOE Oak Ridge Operations Office is responsible for managing remedial activities on ORR.

The surface impoundments are located in an industrial setting typical of most national laboratories, with institutional controls such as zoning, posted areas, fencing, and other security features. Employees are medically monitored. Access to contaminated areas is restricted. Risk levels from current exposures are acceptable and well below the EPA criteria. In addition, for the foreseeable future, there will be no unrestricted land use at ORNL where this situation would change.

The impetus for this document and remedial action includes migration of radionuclide and chemical contamination to the groundwater and surface waters, prevention of a widespread contamination that must be addressed in future remediations, or prevention of a design failure on berms never intended to last 50 years.

Throughout the document for each alternative proposed, emphasis is placed that the decision be based on sound benefit/cost reasoning. This report explains that the surface impoundments are one of many contaminated operable units located in the main plant area of ORNL. As such, before any remedial action is initiated, these other waste area groupings must be considered. This document also supports the overall goal of DOE, as carried out by the ORNL Environmental Restoration Program, which is to achieve as much overall cleanup as possible with limited available funding. The selected alternative for the surface impoundments should realize this goal.

In addition, DOE is performing this RI/FS as a streamlined approach for an environmental restoration (SAFER) pilot project. The document is streamlined, and the format is adjusted to facilitate this decision process while meeting regulator requirements and guidance.

INTRODUCTION

The initial ORNL mission was to conduct pilot radiochemical separation operations, produce gram quantities of plutonium, and demonstrate production technologies relating to separation techniques. A network of underground storage tanks and pipelines was constructed in 1943 to handle and store the radioactive and chemical waste liquids generated by these ORNL operations.

Impoundment 3524 was constructed at this time as a backup for storage of wastewater from these tanks. Following this, Impoundment 3513 was constructed. Later these two natural clay impoundments were used as holding basins as part of the process waste treatment system. The other two smaller impoundments (3539 and 3540) that make up the surface impoundments were constructed in 1964 with a 15.2-cm (6-in.) clay liner to hold process wastewater from the Building 4500 complex. These impoundments contain approximately 3,500 m^3 (4,640 yd^3) of sediment. These sediments are primarily contaminated with radionuclides with some Resource Conservation and Recovery Act of 1976 constituents (e.g., mercury and lead) and Toxic Substances Control Act constituents (polychlorinated biphenyls).

Remediation of the Waste Area Grouping 1 surface impoundments is being addressed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as specified in the Federal Facility Agreement. Because the sediments in the two unlined impoundments interact with groundwater, contaminants in these sediments can be transported into White Oak Creek and the Clinch River; therefore, these impoundments were selected for remediation through the ORR prioritization process.

The first step in the RI/FS process is to collect data. Historical data and data from the Waste Area Grouping 1 Phase I RI are available, so limited sample collection to support the RI/FS was performed concurrently with preparation of the RI/FS.

The second concurrent process is preparation of the baseline risk assessment for the operable unit. Current risk was evaluated for the operable unit as an industrial site under institutional control. Martin Marietta Energy Systems, Inc., monitors and maintains the protective water covers on the impoundments and expeditiously handles any compromise in the berms surrounding the impoundments. ORNL workers are protected by administrative controls; therefore, under current conditions there is no unacceptable risk to on-site employees.

Current off-site risk from water ingestion downstream from ORNL was evaluated assuming that institutional controls prevent access to the impoundments and that the only current

off-site pathway is migration of contaminants from the sediments through groundwater into White Oak Creek and then to Clinch River. Clinch River is the first point where off-site receptors can be exposed to contaminants from the surface impoundments. Current off-site risk from this scenario (off-site receptor drinking Clinch River water) is well below EPA's target risk range of 1×10^{-4} to 1×10^{-6}.

Future risks were evaluated for several scenarios. This area will probably be an industrial site for at least the next 30–100 years. Hypothetical, unrestricted residential scenarios were also evaluated for comparison purposes only. For the unrestricted scenario, the estimated risks suggest that corrective action is necessary to protect on-site and off-site employees and residents. The majority of the risk occurs when the protective water cover is removed by drought or berm failure, exposing sediments in the impoundments. When radionuclides such as ^{137}Cs and ^{239}Pu in the soil and sediment are exposed, future on-site risk to employees and residents is always unacceptable. Direct radiation contributes the majority of the risk. In addition, when contamination is modeled to simulate off-site migration after a berm failure, the risk at White Oak Dam and the Clinch River is unacceptable.

In summary, current on-site and off-site risks associated with the surface impoundments are at acceptable levels. However, additional considerations for the remediation of these surface impoundments include:

- contaminated sediments remain in contact with groundwater, and this contamination migrates into White Oak Creek;

- future risks are unacceptable in all scenarios when DOE no longer retains institutional control;

- future risk, both on site and off site, is also unacceptable if the 50-year-old berms that retain the contents of the impoundments continue to lose their structural integrity, allowing contamination from the impoundments to increasingly migrate into White Oak Creek. As the berms age, increasing maintenance will be required to maintain their integrity. Currently, during wet weather conditions, contaminated seepage appears at the base of the embankment of Impoundment 3513. Continued maintenance is focused on mitigating this seepage.

Remediation decisions for the surface impoundments will focus on risk management and the benefits obtained from implementation of each alternative and the cost of achieving that

benefit. There are benefits to taking action at the surface impoundments at this time. Benefits can be defined to include:

- risk reduction (both on site and off site);
- controlling the migration of contamination so that future remediation is not made more difficult because contamination is more widespread;
- isolating/relocating the contamination to facilitate monitoring and maintenance; and
- preventing berm failure.

The decision process will evaluate cost versus benefit of each alternative. Decisions can then be made by considering what is the best alternative for the next 30–100 years that does not preclude further action in the future.

Remediation decisions for the surface impoundments must also consider the condition and likely remediation decisions for the surrounding areas: Waste Area Grouping 1, ORNL, and ORR. If final remediation decisions for the surrounding areas are likely to primarily use closure-in-place strategies, then early decisions for "greenfielding" of small areas may not, in hindsight, have been the most cost-effective decisions. Conversely, if "greenfielding" is the final remedy, final costs could be somewhat higher if early operable units were remediated in place. Waste management issues must also be addressed in the decision process. These issues include decisions on the final disposition of wastes, whether on site or off site.

REMEDIAL ACTION OBJECTIVES

The following remedial action objectives must be addressed by the alternatives evaluated:

- prevent direct exposure, direct contact, inhalation, and ingestion by humans and animals with the contaminated sediments;
- reduce leaching of contaminants to drinking water sources;
- prevent potential future failure of the impoundments berm/embankment; and
- prevent the bioaccumulation of contaminants in ecological receptors.

ALTERNATIVE EVALUATION

Alternatives developed to achieve these goals range from no action to complete removal of contaminated sediments and off-site disposal. As required by CERCLA, these alternatives were selected to represent the range of potential actions at the site and are not intended to limit the decision.

The alternatives evaluated include the following:

- multilayer cap and institutional control,
- consolidation cell with simple dewatering,
- consolidation cell with ex situ treatment,
- consolidation cell off-SIOU/on-ORNL, and
- removal, treatment, and off-site disposal.

Important considerations regarding alternative evaluation for the surface impoundments include:

- Actions to be implemented at this site should be cost-effective and protective of human health and the environment for the foreseeable future (30–100 years), so that the maximum amount of funds can be directed toward the most pressing environmental problems at ORR.

- The impoundments remediation must be viewed in the context of the environmental concerns in the main plant areas as a whole, so that actions taken at this individual site are consistent with actions likely for the entire area. If complete removal and off-site disposal is not accomplished, actions taken should not preclude further action in the future.

Following is a brief description of the alternatives and issues to be considered in their evaluation. Table ES.1 summarizes the comparative analysis of the alternatives in meeting the CERCLA evaluation criteria.

ALTERNATIVE 1—NO ACTION

This alternative provides a baseline for comparison with other alternatives as required by the National Contingency Plan. In the no action alternative, it is assumed that existing institutional and operation controls, including actively maintaining the water cover on the

impoundments and repairing future seeps, are maintained for 100 years. During the period of institutional controls, this alternative protects human health. Releases of contamination to groundwater and to White Oak Creek would continue, causing a degradation of the environment in White Oak Creek and White Oak Lake.

ALTERNATIVE 2—MULTILAYER CAP AND INSTITUTIONAL CONTROLS

Alternative 2 includes installing a cap over all the ponds and long-term monitoring and maintenance. This alternative would protect human health during institutional control. However, groundwater contamination due to leaching of contaminants from sediments would continue. The cap would prevent airborne contamination for its several-hundred-year life.

ALTERNATIVE 3—CONSOLIDATION CELL WITH SIMPLE DEWATERING

Alternative 3 includes relocation of sediment and solid contaminants from Impoundment 3524 into Impoundment 3513, followed by retrofitting Impoundment 3524 with a consolidation cell liner and leachate collection system. The contaminated sediment from the surface impoundments would then be placed in this consolidation cell and maintained with a temporary cover to promote dewatering of these sediments through the leachate collection system. Once dewatering is complete, the final cap would be placed over the consolidation cell. This alternative would protect human health and the environment during the period of institutional control. The cap and liner would prevent airborne and groundwater contamination for their life of greater than 100 years.

ALTERNATIVE 4—CONSOLIDATION CELL WITH EX SITU TREATMENT

Alternative 4 includes the same activities as Alternative 3 with the addition of constructing a new treatment facility to stabilize the waste (i.e., stabilization, solidification, and containerization of waste) before placing it in the consolidation cell. Thus, no dewatering within the disposal cell would be required. This alternative protects human health and the environment during the period of institutional control. The cap and liner would prevent airborne and groundwater contamination for their life of greater than 100 years.

ALTERNATIVE 5—OFF-SIOU CONSOLIDATION CELL

Alternative 5 includes the same activities as Alternative 3 except that the sediment would be transported to a consolidation cell constructed off-SIOU at a preferred location at ORNL. This alternative would protect human health and the environment at the surface impoundments site

Table ES.1. Summary of comparative analysis of alternatives for CERCLA criteria, Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

CERCLA criteria	Alternative 1 No Action		Alternative 2 Multilayer cap, institutional controls		Alternative 3 Consolidation cell with simple dewatering		Alternative 4 Consolidation cell with ex situ treatment		Alternative 5 Off-SIOU consolidation cell		Alternative 6 Removal, treatment, and off-site disposal		CERCLA criteria
	During institutional Control	Loss of institutional control											
Overall protection of human health and the environment													Overall protection of human health and the environment
Future RME Risk			Total risk	Residual soil risk[a] excluded	Total risk	Residual soil risk excluded	Total risk	Residual soil risk excluded	Total risk	Residual soil risk excluded	Total risk	Residual soil risk excluded	Future RME Risk
Future employee	6×10^{-5}	4×10^{-3}	1×10^{-6}		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		Future employee
Clinch River	1×10^{-4}	5×10^{-3}	$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		Clinch River
White Oak Dam	7×10^{-3}	1×10^{-2}	1×10^{-4}	1×10^{-5}	9×10^{-5}	1×10^{-6}	9×10^{-5}	$<1 \times 10^{-6}$	9×10^{-5}	$<1 \times 10^{-6}$	9×10^{-5}	$<1 \times 10^{-6}$	White Oak Dam
White Oak Creek	3×10^{-2}	6×10^{-2}	2×10^{-3}	2×10^{-3}	3×10^{-4}	1×10^{-6}	3×10^{-4}	1×10^{-6}	3×10^{-4}	$<1 \times 10^{-6}$	3×10^{-4}	$<1 \times 10^{-6}$	White Oak Creek
On-site resident	No pathway	6×10^{-2}	3×10^{-3}	3×10^{-3}	4×10^{-4}	1×10^{-4}	3×10^{-4}	1×10^{-6}	3×10^{-4}	$<1 \times 10^{-6}$	3×10^{-4}	$<1 \times 10^{-6}$	On-site resident
Human health risk discussion	Risk to human health from migration of contamination to groundwater and White Oak Creek. Moderately protective off site at Clinch River while DOE maintains institutional controls	If water cover over sediment is lost, airborne contamination resulting in widespread human health risk is possible	Protective to receptor at White Oak Dam. Possible risk to human health from migration of contamination to groundwater and White Oak Creek. Protective while DOE maintains institutional controls		Protective to receptors at White Oak Dam, and possibly at White Oak Creek and at the site while DOE maintains institutional controls		Protective to future employees, residential receptors at White Oak Dam, and possibly at White Oak Creek while DOE maintains institutional controls		Protective to all receptors while DOE maintains institutional controls		Protective to all receptors due to removal of source material		Human health risk discussion
Ecological risk discussion	Risk to environmental receptors from consumption of fish in impoundments. Small risk from consumption of fish in White Oak Creek		No risk to environmental receptors		No risk to environmental receptors		No risk to environmental receptors		No risk to environmental receptors		No risk to environmental receptors		Ecological risk discussion
Compliance with ARARs	No ARARs under CERCLA. Not protective as required by CERCLA		Several waivers required		A few waivers required		A few waivers required		A few waivers required		Meets all ARARs		Compliance with ARARs
Short-term effectiveness	No increase or reduction in short-term effects on human health and environment		Potential for small, adverse short-term effects		Potential for moderate, adverse short-term effects		Potential for moderately high, adverse short-term effects		Potential for moderately high, adverse short-term effects		Potential for very high, adverse short-term effects		Short-term effectiveness
Long-term effectiveness	Not effective		Effective for period of institutional control		Very effective for period of institutional control		Very effective for period of institutional control		Very effective for period of institutional control		Very effective at site		Long-term effectiveness
Reduction of toxicity, mobility, or volume through treatment	None		None		Small reduction in volume		Significant increase in volume. Some decrease in mobility of most contaminants		Small reduction in volume		Significant increase in volume. Some decrease in mobility of most contaminants		Reduction of toxicity, mobility, or volume through treatment
Implementability	Very easy to implement		Easy to implement		Somewhat difficult to implement		Difficult to implement		Fairly difficult to implement		Extremely difficult to implement, both technically and administratively		Implementability
Present worth cost	$5,569,000		$21,230,000		$45,650,000		$87,243,000		$48,252,000		$148,637,000		Present worth cost

[a]Risk associated with soils to be remediated as part of the 3000 Watershed Soil Operable Unit.

ARAR = applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

during institutional control. The cap and liner would prevent airborne and groundwater contamination for their life of greater than 100 years. Potential benefits of this alternative include (1) the opportunity to select a more hydrogeologically suitable site than the surface impoundments, (2) location of the consolidation cell away from the most active areas of ORNL, and (3) the ability to incorporate wastes from other impoundments within ORNL into the same consolidation cell.

ALTERNATIVE 6—REMOVAL, TREATMENT AND OFF-SITE DISPOSAL

Alternative 6 includes building a new treatment facility to stabilize the waste before shipment to the Nevada Test Site for disposal. Because surrounding soils and groundwater are contaminated from other sources, long-term monitoring and other actions at the site would be subject to the Waste Area Grouping 1 3000 Watershed Soils and Groundwater Operable Units requirements.

KEY ISSUES FOR CONSIDERATION IN THE DECISION PROCESS

To select acceptable remedial actions, regulators and decision makers must consider the following key issues:

- determination of future land use and location of receptor for risk assessment;
- compatibility with remedial action for the main plant area;
- availability of treatment, storage, and disposal capacity for mixed waste at ORNL, ORR, and nationally; and
- combining waste from other operable units into off-SIOU consolidation cell.

A discussion of each of these issues follows.

Determination of Future Land Use and Location of Receptor for Risk Assessment

Each remedial alternative will protect human health and the environment; however, some remedial strategies include restrictions on the use of the site to prevent unacceptable exposure to contaminants. Remedial actions that include restricting the surface impoundments area to industrial use would require additional action in the future if unrestricted land use is chosen for ORR.

If ORNL is to be federally controlled industrial land use, DOE believes that existing institutional controls (fencing, access and use restrictions, and continued monitoring and maintenance) extending to the Clinch river would be readily implementable. This determination of future land use will dictate to a large degree the likelihood of exposure at these levels. If land use on ORR remains industrial with institutional controls restricting use of surface water and groundwater, then the nearest off-site resident would be at the Clinch River, about 2.4 km (1.5 miles) from the impoundments. Risk at this location would likely be reduced to acceptable levels because of dilution, entrainment of contamination in the sediment of White Oak Lake, and continued radioactive decay due to the longer period of time before the contamination reaches the receptor.

Designation of the site for federally controlled industrial land use for the foreseeable future appears reasonable because (1) the federal government has long-term plans to continue to use the site as a national laboratory, (2) the administrative controls in place and projected for the future are adequate to minimize risk of exposure of employees to residual contamination remaining after remediation, (3) adjacent areas will likely require similar use restrictions, and (4) the federal government cannot legally release control of a contaminated site.

Compatibility with Remedial Action for the Main Plant Area

Remediation activities at the surface impoundments should be consistent with actions taken for the surrounding ORNL area. The main plant area of ORNL surrounding the surface impoundments is characterized by contaminated soils, contaminated groundwater; miles of contaminated piping; other impoundments; and inactive low-level transuranic, and mixed-waste storage tanks. Lack of safe and effective remedial technologies and the high cost associated with attempts to remediate this area for unrestricted use suggest that the remedial strategy of the remainder of the plant area will be limited, and clean closure of the overall site will not occur within the next several decades.

Availability of Treatment, Storage, and Disposal Capacity for Mixed Waste at ORNL, ORR, and Nationally

Removal of the contaminated sediment from the surface impoundments is limited by current disposal capacities for mixed, low-level, and hazardous wastes. Alternatives that allow the sediments and soils to be managed in situ do not require additional on-site storage, handling, or packaging facilities or off-site transportation and disposal capabilities. Alternatives that include actions to remove the sediments and soils depend upon the future availability of adequate mixed-waste treatment, storage, disposal facilities, and permits for shipping waste through several states.

Combining Waste from Other Operable Units into Off-SIOU Consolidation Cell

At the request of EPA and the Tennessee Department of Environment and Conservation, an additional remedial alternative was added in June 1994, that allowed for an off-SIOU consolidation cell to be evaluated (Alternative 5).

It was determined early in the evaluation process that this would be a more costly alternative than the on-site cell, but could be attractive from a long-term planning standpoint because it allowed for one controlled cell to be constructed in a preferred location with potential to be expanded for consolidation with other ORNL waste. Other strategies include consolidation of waste from other ORNL impoundments with like contaminants using an expedited RI/FS process with a presumptive remedy, using the surface impoundments as an example.

1. INTRODUCTION

This report documents the results of the remedial investigation (RI)/feasibility study (FS) of the Surface Impoundments Operable Unit (SIOU) at Oak Ridge National Laboratory (ORNL) (Fig. 1.1). The SIOU is part of the Waste Area Grouping 1 (Fig. 1.2) and consists of four impoundments: Impoundment 3513 (Waste Holding Basin), Impoundment 3524 (Equalization Basin), and Impoundments 3539 and 3540 (Process Waste Ponds). (Fig. 1.3 depicts the features of the operable unit.) The U.S. Department of Energy (DOE) is performing the SIOU RI/FS as a streamlined approach for environmental restoration (SAFER) pilot project.

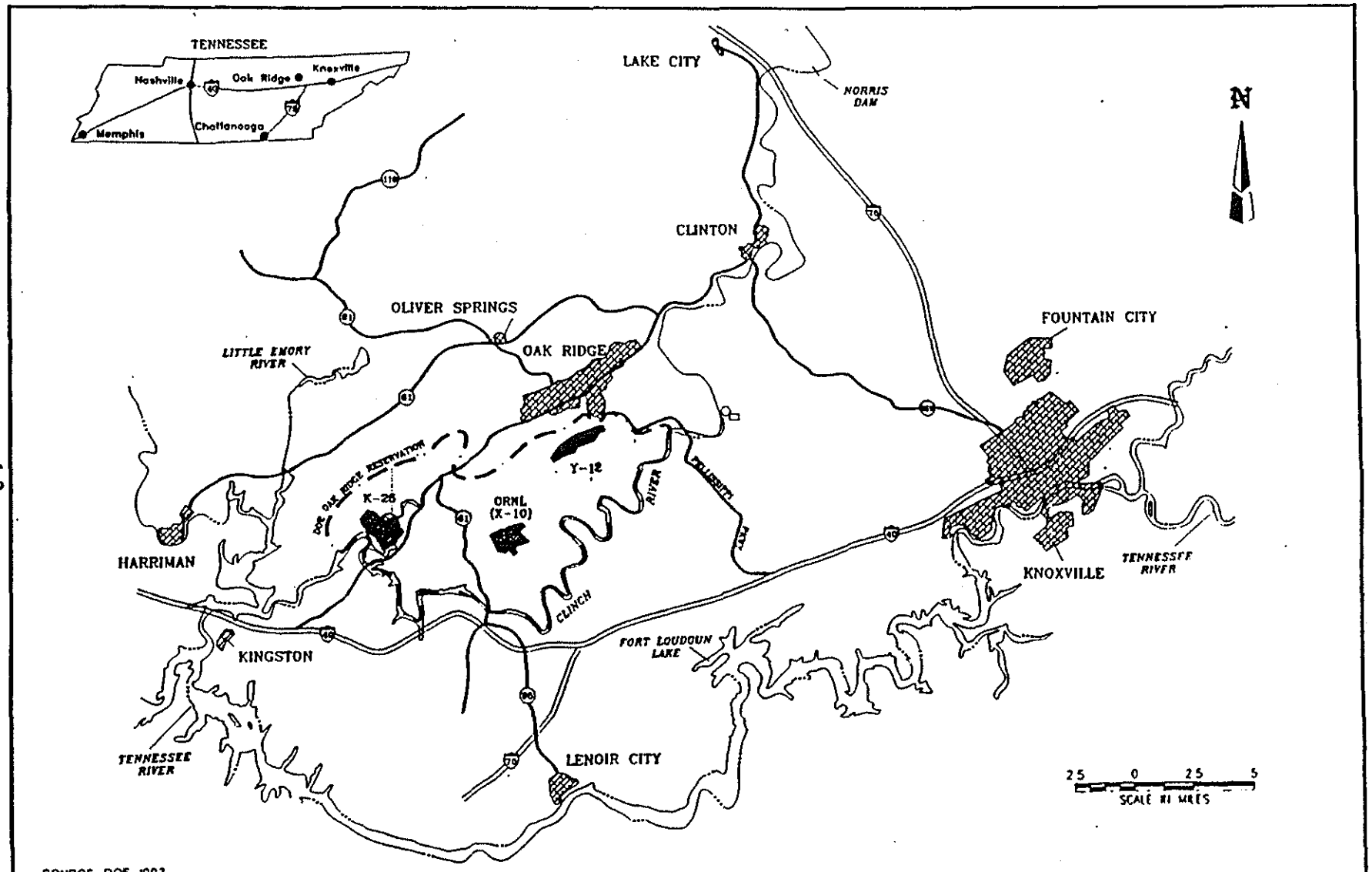
The impoundments are considered a single operable unit, principally because the four impoundments are in the same locale, share similar process histories, contain similar contaminants, and are candidates for the same remediation technology.

SIOU includes:

- surface water and sediments within the impoundments; and
- subimpoundment soil (i.e., soil below and on the sides of the impoundments) contaminated above acceptable levels.

Groundwater in this area will be addressed as part of the Waste Area Grouping 1 Groundwater Operable Unit. During remediation of SIOU, contaminated groundwater and soils may be encountered. Dealing with contaminated groundwater and soils, however, will be incidental to remediation of SIOU and not a remediation goal. Contaminated groundwater and soils not able to be handled as part of the chosen remedial alternative will be addressed as part of the Waste Area Grouping 1 Groundwater Operable Unit and Waste Area Grouping 1 3000 Watershed Soils Operable Unit, respectively.

ORNL, located within the DOE Oak Ridge Reservation (ORR) (Fig. 1.1), is owned by DOE and managed by Martin Marietta Energy Systems, Inc. (Energy Systems). The operable unit is located in the south-central part of the main ORNL plant area, just north of White Oak Creek (as shown in Fig. 1.2). This area was originally investigated in 1990–1991 to determine future remedial action of this site as reported in the Site Characterization Summary Report (DOE 1992a). However, it was determined that the over 100 solid waste management units that made up Waste Area Grouping 1 were too numerous to handle as one remedial action, and their diverse construction, usage, and current conditions did not lend them to like remedial action. Therefore,



SOURCE: DOE 1993

JE Fig. 1.1	**DOE Oak Ridge Reservation and vicinity** DOE - ORNL, WAG 1, Surface Impoundments - Oak Ridge, Tennessee	DOCUMENT ID 35H830 4002 15 / FS	DRAWING ID 95 11400 DWG	DRAWING DATE FEBRUARY 23 1995 Rev

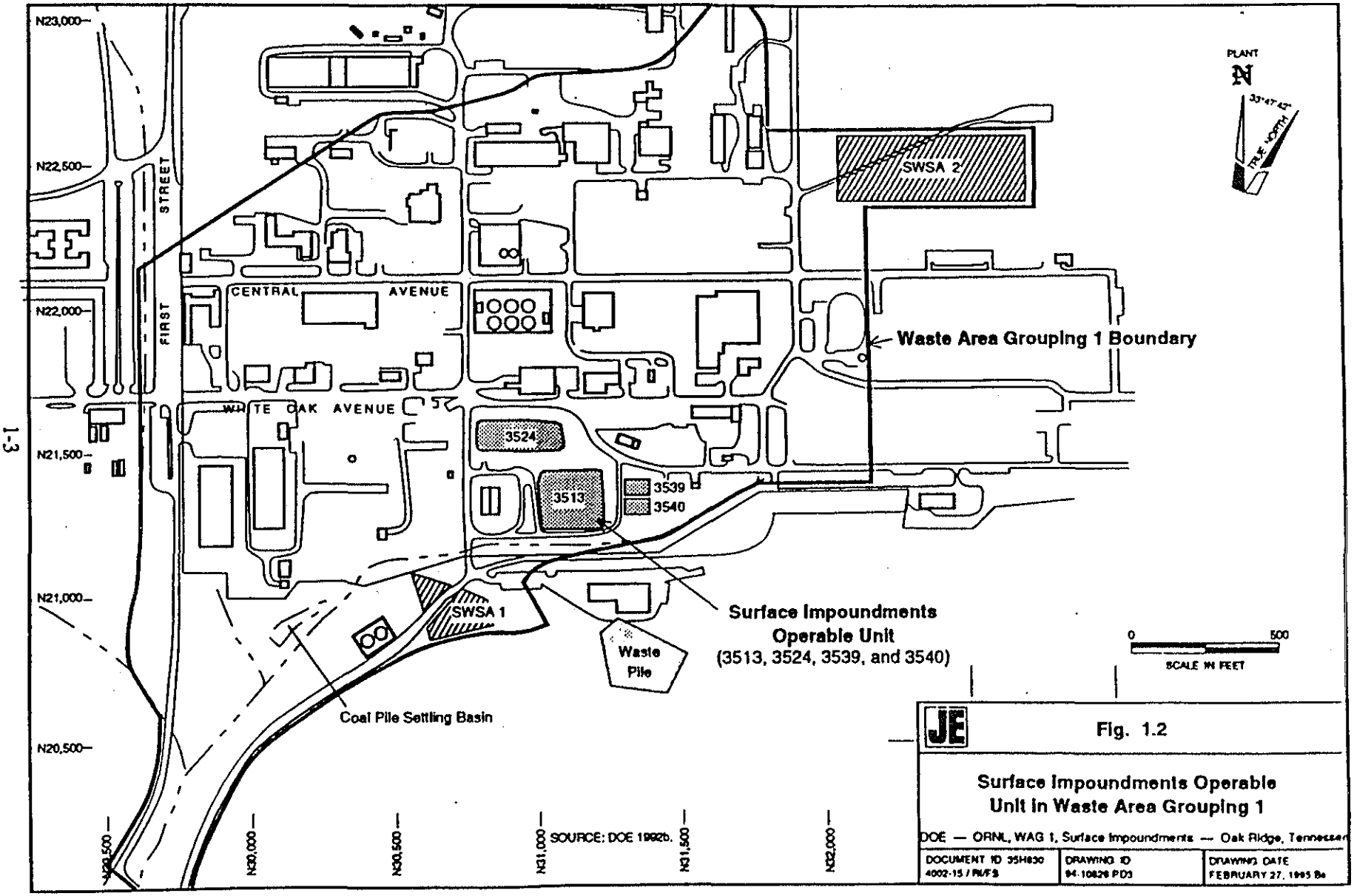
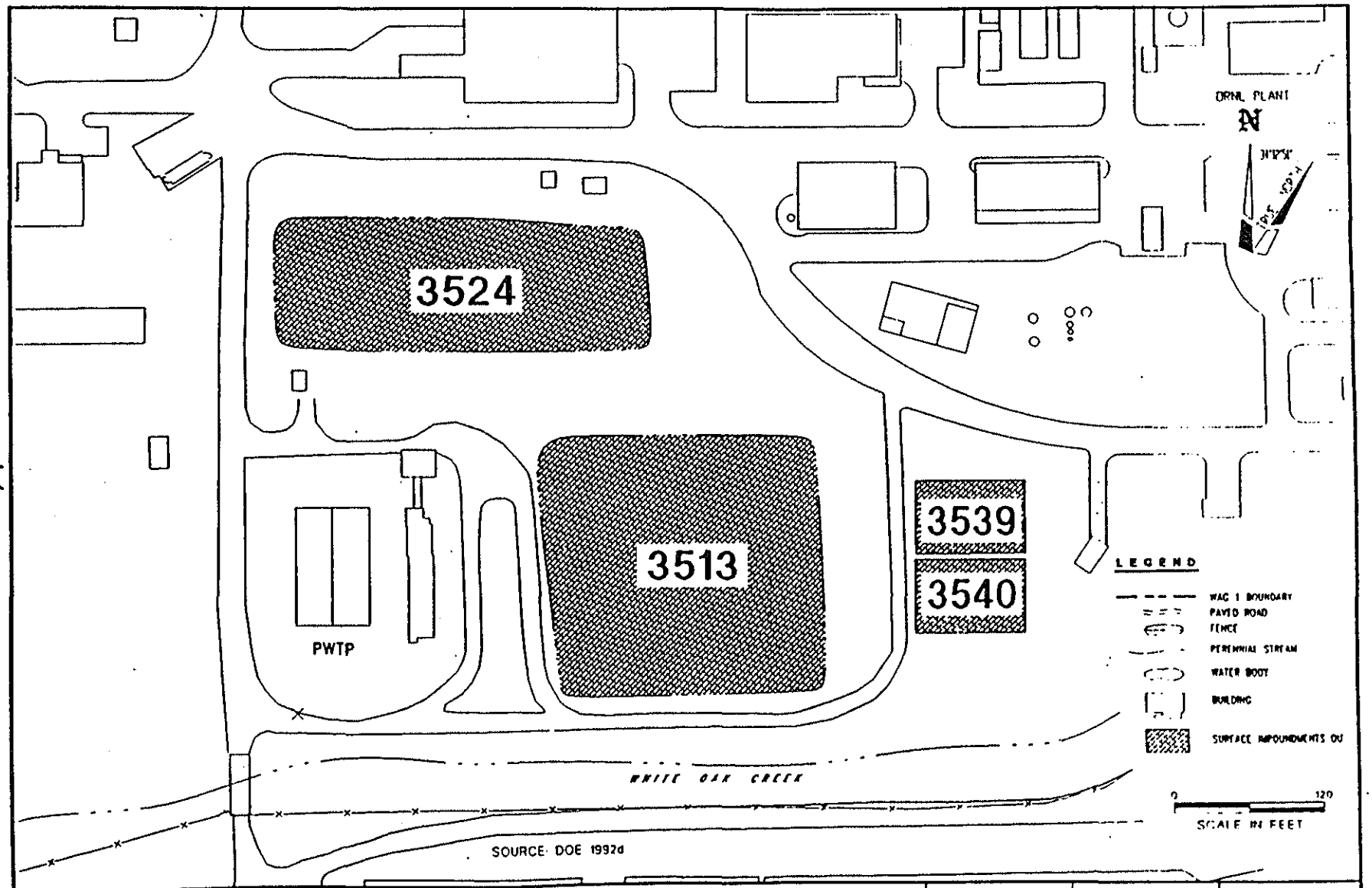


Fig. 1.2

Surface Impoundments Operable Unit in Waste Area Grouping 1

DOE — ORNL, WAG 1, Surface Impoundments — Oak Ridge, Tennessee

DOCUMENT ID 35H830 4002-15 / RI/FS	DRAWING ID 94-10826 PD3	DRAWING DATE FEBRUARY 27, 1995 Bs



JE Fig. 1.3	**Surface Impoundments Operable Unit** DOE - ORNL, WAG 1 Surface Impoundments - Oak Ridge Tennessee	DOCUMENT ID 35H830 4002-15 / FS	DRAWING ID 95 11402 DWG	DRAWING DATE FEBRUARY 22 1995 Rev

an operable unit strategy document (DOE 1992b) was prepared that divided the solid waste management units into operable units and prioritized them for remedial action. The SIOU was the third priority with Gunite tanks (North and South Tank Farms) and groundwater preceding it. These operable units are currently being addressed under separate documents.

Before 1954, Impoundment 3513 received the supernatant outflow through five pipes along the north side of the basin from the liquid low-level waste storage tanks of the South Tank Farm (Fig. 1.2). Water in the basin was treated with fly ash and soda lime to precipitate radionuclides before being discharged to White Oak Creek. Impoundment 3524 was used for emergency storage of liquid low-level waste (generated from various sources at ORNL) and as a flow equalization basin for the Process Waste Treatment Plant. Impoundments 3539 and 3540 were used as a dual-surge basin system designed to alternately receive and discharge process waste streams from the Building 4500 complex (DOE 1992a).

Although the impoundments are removed from routine service, Impoundments 3524, 3539, and 3540 are used occasionally to collect process wastewater when the holding capacity of the current storage tanks for the Process Waste Treatment Plant is exceeded. An additional surge tank has been designed to store process wastewater during wet weather and is scheduled to be in service by February 1996. With the additional surge tank in service, the impoundments will be removed from the waste management emergency service inventory and will be available for remediation under the Environmental Restoration (ER) Program.

1.1 REGULATORY INITIATIVE

ORNL contains both hazardous- and mixed-waste sites subject to regulation pursuant to the Resource Conservation and Recovery Act of 1976 (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended in 1986 by the Superfund Amendments and Reauthorization Act. Under guidelines and requirements of RCRA from the Tennessee Department of Environment and Conservation (TDEC), ORNL initiated investigation and groundwater monitoring of various sites within its boundaries in the mid-1980s. In November 1989, ORR was placed on the National Priorities List (NPL) of CERCLA sites.

DOE, the U.S. Environmental Protection Agency (EPA), and TDEC negotiated a Federal Facility Agreement (FFA) (DOE 1992c) in response to the NPL listing of ORR. The FFA was developed to integrate CERCLA, RCRA, and the National Environmental Policy Act (NEPA) and provide a legal framework for remediation activities on ORR. A common goal of those parties to the FFA was to ensure that past releases from process and waste management

operations at ORR were thoroughly investigated and that appropriate remedial action was taken to protect human health and the environment. The general purposes of the FFA are as follows:

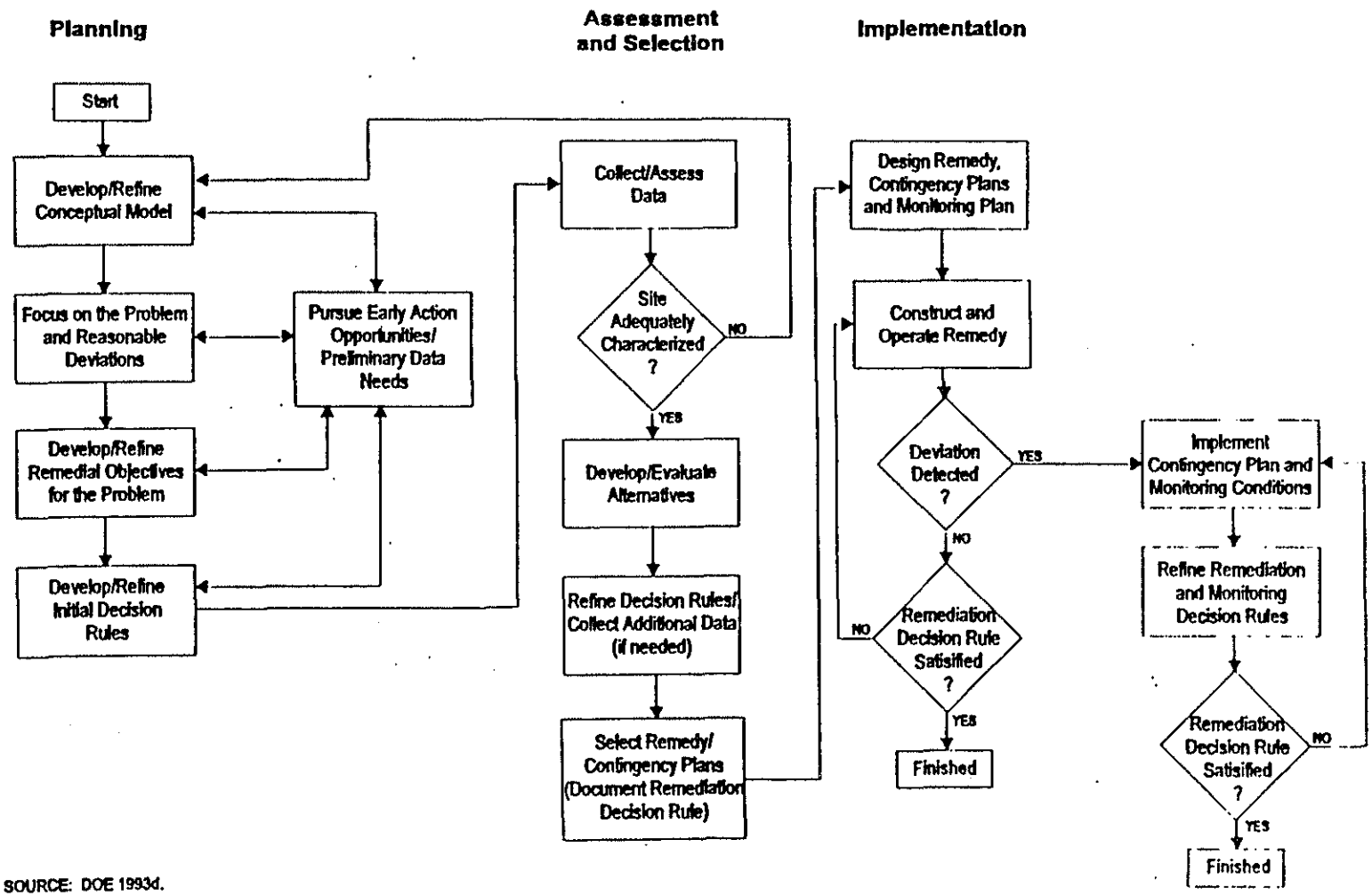
- to establish a framework and schedule for the development, implementation, and monitoring of response actions at ORR in accordance with applicable guidance and policy;
- to coordinate responses under CERCLA and RCRA to maximize flexibility and preclude redundant activity;
- to minimize duplication of analytical and investigative work;
- to ensure quality of data management; and
- to expedite response action with minimal delay.

This document meets the goals and intent of this agreement by implementing the SAFER process to streamline and focus the information presented on the problem and possible remedies. The following section summarizes the SAFER approach and is based upon experience, reasonable assumptions, and deviations from these assumptions. This is in contrast to the comprehensive investigations and analyses that are conducted for a traditional RI/FS that attempt to manage uncertainty through extensive data collection. Modifying the traditional approach is warranted because experience shows that uncertainties inefficiencies can be anticipated and managed. The result of this approach is an accelerated schedule and reduced cost. Figure 1.4 depicts the SAFER framework.

The following are the drivers for remediation of SIOU:

- possible future human health risk,
- the continuing release of contamination from unlined Impoundments 3513 and 3524 to the surrounding environment, and
- potential failure of the berm/embankments for Impoundments 3513 and 3524.

It is understood that DOE will comply with the requirements of NEPA as specified in 10 *Code of Federal Regulations* (CFR) 1021. DOE Order 5400.4, "Comprehensive Environmental Response, Compensation, and Liability Act Requirements," called for integration of NEPA and



SOURCE: DOE 1993d.

JE	Fig. 1.4	**SAFER framework** DOE - ORNL, WAG 1, Surface Impoundments - Oak Ridge, Tennessee	DOCUMENT ID: 35H830 4002-16 / FB	DRAWING ID: 95-11377 CDR	DRAWING DATE APRIL 21, 1995 Be

CERCLA requirements for DOE remedial actions at CERCLA sites. This issue was reaffirmed in FFA §I(A)(3) and §III(A)(2) and the Secretary of Energy Notice of February 5, 1990 (SEN-15-90). However, DOE's Secretarial Policy Statement on NEPA signed on June 13, 1994, states that rather than integrating NEPA and CERCLA requirements, DOE will hereafter rely on the CERCLA process for review of actions to be taken under CERCLA and will address and incorporate NEPA values directly into CERCLA documents.

Currently, with SIOU under institutional control with continued surveillance and maintenance, there is de minimus risk as discussed in Section 3.3. These surveillance and maintenance activities include visual inspection of the berm/embankment to identify potential seepage and, if necessary, to implement corrective actions (sealing seeps with bentonite) to prevent discharge into White Oak Creek. A stability analysis of the berm/embankment of Impoundments 3513 has deemed it safe with annual inspections required to identify any changes in conditions. Currently, the problem is that Impoundments 3513 and 3524 are unlined and continue to release contamination to the surrounding environment, even though these releases are within the EPA target range for off-site risk. DOE, as environmental managers, needs to determine how contaminated sediments in these unlined impoundments can be better managed in the foreseeable future. This document will guide the decision makers/stakeholders through the RI/FS process by focusing the data to this end.

1.2 SCHEDULE

The schedule for completing the RI/FS process can be found and tracked through the information provided in Appendix E of the FFA. There are provisions in the FFA to adjust the schedule, based on the scope of approved remedial actions, availability of funding, and other considerations.

Subsequent sections of this report provide details on the environmental setting, the site history and current conditions, nature and extend of contamination, the human health and ecological baseline risk assessments, the approach to selection of remedial alternatives, the evaluation of remedial alternatives, and conclusions of the report. Appendices provide the detailed presentation and analysis of data summarized in the main body of this RI/FS report.

2. DESCRIPTION OF PHYSICAL SETTING, OPERATIONAL HISTORY, AND CURRENT CONDITIONS

This chapter characterizes the environmental setting and provides a description of the SIOU components, including the operational history of the impoundments. The characterization of the environmental setting includes summary discussions on demography, land use, meteorology, and geology/hydrogeology. The operational history presents a description of the construction, piping, and similar components associated with the impoundments.

2.1 CHARACTERIZATION OF THE ENVIRONMENTAL SETTING

The focus of this document is to present adequate information required to understand the SIOU site conceptual models and risk assessments. The Site Characterization Summary Report for Waste Area Grouping 1 (DOE 1992a) contains a detailed discussion of the environmental setting.

2.1.1 Demography and Land Use

ORR is located on approximately 14,300 ha (35,800 acres) of federally owned land in East Tennessee. ORNL is located in the approximate center of ORR (Fig. 1.1). The Tennessee Valley Authority (TVA) Melton Hill Reservoir on the Clinch River and the Watts Bar Reservoir on the Tennessee River form the eastern, southern, and western boundaries of ORR. The northern boundary is within the corporate limits of the city of Oak Ridge, although the ORR is primarily to the west and south of the population center. Except for the city of Oak Ridge, the land within 8 km (5 miles) of ORR is predominantly rural and is used primarily for residences and small farms. Fewer than 13,000 people live within 8 km (5 miles) of the center of ORR (U.S. Department of Commerce 1991). As of February 1993, approximately 16,000 regular employees worked at ORR; 5,782 employees worked at ORNL. Most of the employees at ORNL work within the facilities located either within or adjacent to the main plant area of ORNL (Waste Area Grouping 1) where the SIOU is located.

2.1.2 Meteorology

The climate near ORR is strongly influenced by the presence of the Great Smoky Mountains to the southeast and the Cumberland Mountains to the northwest. The surrounding mountains frequently divert from this area the hot, southeasterly winds that develop in the summer along the southern Atlantic coast. In the winter, the Cumberland Mountains retard and weaken the force of cold air that commonly reaches south to these latitudes. The results of these moderating influences on the climate are warm, humid summers and cool winters. Noticeable

extremes in precipitation, temperature, and winds rarely occur. The Oak Ridge area receives an average 136.5 cm (53.75 in.) of precipitation annually (DOE 1992a). Maximum monthly precipitation generally occurs from December through March with the driest months being September and October.

Wind speeds are less than 11.9 km/hour (7.4 mph) 75 percent of the time. Tornadoes and high-velocity winds are rare, as are wind speeds exceeding 30 km/hour (18.5 mph). Evapotranspiration in the Oak Ridge area is estimated to be from 74–76 cm (29–30 in.) or from 55–56 percent of annual rainfall (TVA 1992; Moore 1988; Hatcher et al. 1992).

2.1.3 Site Geology/Hydrogeology

SIOU is located in Bethel Valley, which is underlain by the complex, interbedded limestones and siltstones of the Ordovician Chickamauga Group. The geologic strike of the Chickamauga Group in Waste Area Grouping 1 is about N50°E to N56°E, and the rocks dip to the southeast at an angle of 30–34°. Stockdale (1951) divided the Chickamauga into eight units designated, in ascending order, as Units A through H. The impoundments overlie Chickamauga Unit G, also known as the Witten Formation. The Witten consists of interbedded, nodular limestone; calcarenite; amorphous, thin-bedded limestone; and wavy-bedded limestone (Hatcher et al. 1992). The limestones of the Witten are generally dense and nonporous; however, the Witten is one of the more fractured units in the Chickamauga. Solution cavities have been observed in the Witten that could constitute pathways for groundwater movement and contaminant transport.

As part of the Waste Area Grouping 1 Site Characterization Summary Report investigation (DOE 1992a), 25 borings were drilled in the soil developed above Unit G (the Witten Formation), which underlies SIOU. Unit G soil is generally described in the field as a brown to yellow-brown silty clay. Examination of soil boring logs for the vicinity of SIOU indicate that the clay material is typically encountered within 0.3–0.6 m (1–2 ft) below ground surface. The soil boring logs describe the material as a low-plasticity clay. Material in the upper portion of the cores is brown to yellow-brown in color, but tends to change to grey to grey-brown with depth.

Based on data from monitoring well installations and soil borings, soils near the impoundments are 2.4–4 m (8–13 ft) thick and consist of clay and silty clay. The native soils are relatively impermeable and possess hydraulic conductivities in the range of 1×10^{-5} cm/second (Solomon et al. 1992). However, preferred groundwater flow pathways probably exist in backfill materials of higher permeability in the area's numerous pipeline corridors.

The bulk of the groundwater flow in the area of the impoundments is in the overburden and at the bedrock-soil interface. The horizontal hydraulic gradient in the overburden is primarily north-south into White Oak Creek; an east-west component exists in the area of Impoundments 3539 and 3540. Vertical hydraulic gradients (calculated from hydraulic head measurements in shallow/deep well pairs and in corehole CH009 just west of the site) are upward, indicating the impoundments are in a groundwater discharge area. Flow in the bedrock aquifer may not follow hydraulic gradients, but instead may follow preferred flow pathways in more permeable zones oriented along geologic strike or down-dip. Groundwater depth varies from 1.5–3.7 m (5–12 ft) below ground surface, and groundwater is in communication with surface water and sediments in Impoundments 3513 and 3524. Impoundments 3539 and 3540 have clay liners and are not in contact with the groundwater.

Based on the results of a microgravity survey conducted at SIOU in June 1994, which are consistent with the results of past geologic investigations at the site, extensive solution cavity (karst) development does not appear to exist in the area. This survey detects variations in the density of subsurface material (Wilson et al. 1994). In 1950, small solution cavities, several inches in width, were observed during drilling of a corehole at the southeast corner of Impoundment 3513. These cavities are all too small to pose a problem for implementing any of the evaluated remedial alternatives.

2.1.4 Ecology

The impoundments are man-made structures; no ditches, creeks or outfalls directly link the impoundments to nearby White Oak Creek. They contain hydrophytic vegetation growing along their edges [e.g., cattail (*Typha* sp.), softrush (*Juncus effusus*), and sedges (*Cyperus* sp.)]. However, these are pioneer species. There are no jurisdictional wetlands within SIOU (Rosensteel 1993), and no threatened or endangered species live at the site (Kroodsma et al. 1993; Barclay 1993).

2.1.4.1 Impoundments 3513 and 3524

Impoundments 3513 and 3524 are similar in ecology. At intervals, the Impoundment 3513 shoreline is densely vegetated by an approximately 1-m (3.3-ft)-wide strip of emergent aquatic macrophytes. The periphery of the impoundment is dominated by cattails (*Typha* sp.). Softstem bulrush (*Scirpus validus*), sedges (*Cyperus* sp.), dotted smartweed (*Polygonum punctatum*), water-pepper (*Polygonum hydropiperoides*), and black willow saplings (*Salix nigra*) are found dispersed along the circumference. Additionally, curly dock (*Eleocharis* sp.) and spike rush (*Eleocharis* sp.) are present in sparse amounts. Impoundment 3524 has a narrower zone of emergent aquatic macrophytes, dominated by cattails (*Typha* sp.), with sedges (*Cyperus* sp.) dispersed throughout. The impoundments are eutrophic and contain a mixed-species composition of phytoplankton.

Benthic filamentous algae and submerged macrophytes are seasonally abundant (Garten, Trabalka, and Bogle 1982). The gently sloped and grassy banks around the impoundments are approximately 3-6 m (10-20-ft) wide from the shoreline to the top of the impoundment banks at the fence. Japanese honeysuckle (*Lonicera japonica*) was found covering the fence surrounding the impoundment.

Species of fish in the impoundment include goldfish (*Carassius auratus*), channel catfish (*Ictalurus punctatus*), mosquito fish (*Gambusia affinis*), and bluegill sunfish (*Lepomis macrochirus*). These fish species, introduced into the impoundment in May 1977 for experimental purposes (Garten, Trabalka, and Bogle 1982), supplemented existing vertebrate fauna consisting of frogs (*Rana catesbeiana* and *R. palustris*) and possibly turtles. Cotton rats (*Sigmodon hispidus*) may frequent the vegetated banks (Garten, Trabalka, and Bogle 1982) of both impoundments. Other small mammals, including muskrats (*Ondatra zibethicus*), groundhogs (*Marmota monax*), and mink (*Mustela vison*) may forage in and around the impoundments. Although wires were strung over these impoundments to impede waterfowl use, Canada geese (*Branta canadensis*) are occasionally observed at the site. In June 1994, fish were collected from Impoundments 3524 and 3513. Subsequent analyses showed Aroclor-1254, Aroclor-1260, mercury, and selenium in fish tissue at levels that exceeded the no observed adverse effect levels (NOAELs) for some piscivorous wildlife that may prey upon them. Radiation analyses detected gross alpha and beta activity, ^{137}Cs, and strontium, although the radiation data were rejected during validation because of quality control (QC) problems.

Impoundments 3539 and 3540 are smaller than Impoundments 3513 and 3524. These impoundments are seasonally covered by duckweed. Unlike the other impoundments, Impoundments 3539 and 3540 have steep, riprap banks. Impoundment 3539 has smartweed (*Polygonum* sp.) and lady's thumb (*Polygonum persicaria*) along the fringe. Impoundment 3540 is surrounded by smartweed along the fringe, and emergent sedges are abundant on the eastern side of the impoundment, covering approximately one-fourth of the impoundment area. No fish inhabit these impoundments.

2.2 OPERATIONAL HISTORY

This section provides an overview of the operational history of the impoundments. A detailed discussion (including schematics) of the historical operations is given in Appendix A with an overview provided here in Table 2.1.

Impoundment 3513 was constructed in 1944 as a settling basin for various low-level waste streams that were diluted with process wastewater. The water within the impoundment

Table 2.1. Chronology of Waste Area Grouping 1 SIOU operations, ORNL, Oak Ridge, Tennessee

Date	Event
1943	Original east and west ponds that comprised Impoundment 3524 are constructed.
1944	Impoundment 3513 is constructed to hold wastewater for settling and decay of radionuclides. Diversion box north of Impoundment 3524 is installed to direct high activity wastewater to Impoundment 3524 for decay and lower activity wastewater to Impoundment 3513 for eventual discharge to White Oak Creek. A distribution box north of Impoundment 3513 directs wastewater into a system of weirs and baffles in Impoundment 3513.
1945	Overflow pipe from Impoundments 3524 and 3513 is installed.
1947	Piping is installed in south berm of Impoundment 3513 to allow collection, monitoring, and recycling of impoundment water through the impoundments, if needed.
1949	Evaporator installed to reduce the radioactivity of supernatant discharged to the impoundments from the South Tank Farm.
1953	East and west ponds (Impoundment 3524) are joined by removing central berm.
1954	High activity wastes are diverted. Impoundments begin receiving process wastewater of low activity.
1957	Process Waste Treatment Plant begins operations to provide chemical treatment and removal of suspended solids. Impoundment 3524 provided equalization of feedwater to the Process Waste Treatment Plant. Lower activity process wastewater was sent to Impoundment 3513. Weir and baffle system is removed from Impoundment 3513.
1961	Impoundment 3524 expansion to the west encounters shallow bedrock.
1964	Impoundments 3539 and 3540 are built to receive wastewater from Building 4500 and to provide emergency storage capacity.
1976	Impoundment 3513 is removed from service and retained for emergency storage capacity only.
1978	Accidental input of radionuclides to Impoundment 3513 results from a diversion box failure.
1986	Under National Pollutant Discharge Elimination System agreement, the weir box for Impoundment 3513 effluent is sealed, and accumulated water is pumped to Impoundment 3524 for treatment in Process Waste Treatment Plant. Piping in the south berm of Impoundment 3513 is sealed.
1989	Melton Valley Storage Tanks are completed and emergency storage capacity of Impoundment 3513 is no longer needed. Piping in the north berm of Impoundment 3513 is sealed. Impoundment 3524 stops receiving wastewater, except for emergency storage capacity.
1990	Impoundments 3539 and 3540 are removed from service.
1994	Corrective actions are taken to mitigate seal seeps in Impoundment 3513 embankment.

Note: See Appendix A for additional details and references.

ORNL = Oak Ridge National Laboratory
SIOU = Surface Impoundments Operable Unit
Waste Area Grouping 1 = consisting of the main plant area of ORNL

discharged into White Oak Creek through a series of overflow pipes located in the impoundment's southern berm until 1947, when direct discharge was discontinued. From 1957–1976, this impoundment received wastes that did not require treatment in the Process Waste Treatment Plant. Effluent from the Process Waste Treatment Plant was also discharged into the impoundment to allow settling of particulates. The impoundment was taken out of service in 1976 and is currently not in use.

Impoundment 3524 was constructed in 1943 for short-term storage of short-lived radionuclides to allow decay, thus reducing the radioactivity of the wastewater. However, after 1954, the impoundment received only process wastewater. From 1949–57, the effluent from Impoundment 3524 was pumped to Impoundment 3513. In 1957, the Process Waste Treatment Plant was placed on line, and Impoundment 3524 was used as an equalization basin for intermediate storage and collection of process wastewater for the Process Waste Treatment Plant until 1989. Currently it is used as an emergency storage basin to provide backup overflow capacity for the process wastewater storage tanks.

Water levels in Impoundments 3513 and 3524 are maintained to prevent possible overflows and to provide appropriate shielding for radiation from contaminated sediments. When the impoundment water levels are considered too high, the water is pumped to the Process Waste Treatment Plant. If personnel from Health Physics determine that radiation levels in the area surrounding Impoundment 3524 are too high, then process wastewater is added to the impoundments to raise the water level and provide additional shielding.

Impoundments 3539 and 3540 were constructed in 1964 and received process wastewater from the Building 4500 complex. Process wastes were ultimately discharged into White Oak Creek, following verification of radionuclide content and pH adjustments. If the waste exceeded acceptable limits, it was pumped to Impoundment 3524 to be treated at the Process Waste Treatment Plant. These impoundments were taken out of service in 1990. Currently, these two impoundments are used as emergency storage basins to provide backup overflow capacity during major storm events for the process wastewater storage tanks.

2.3 CONSTRUCTION AND CURRENT CONDITIONS

This section presents information on the original construction of the impoundments, subsequent alterations, current dimensions, and storage capacities. The history and current status of associated pipes, valves, and similar components are discussed. Appendix A presents historical and current piping within the operable unit boundaries.

2.3.1 Impoundment 3513

Impoundment 3513 is an unlined impoundment excavated into natural clay soil in 1944. Surface water runoff is contained by an earthen berm surrounding the impoundment and built up on the southern side. In February 1994 and again in January 1995, bentonite clay was applied along the south embankment/berm to prevent seeps, potentially changing the contours of the bottom of the impoundment along the southern berm. The berm is 5.5 m (18 ft) wide at the top and supports an approximately 3.7-m (12-ft)-wide gravel access road. A limited stability analysis of the impoundment's berm was conducted in 1994. Based on the general soil types, topography, and structural design of the berm, it was concluded that failure of the berm (i.e., the collapse of one portion or all of the berm) was unlikely.

Current storage capacity for Impoundment 3513 is approximately 7,116,575 L (1,880,000 gal) at normal pool elevation. The impoundment dimensions are 67 by 67 m (228 by 228 ft) at the top of the berm, sloping to 61 by 61 m (200 by 200 ft) at the bottom. The top of the embankment is about 3.7 m (12 ft) higher than the White Oak Creek streambed, indicating that the bottom of this impoundment is at approximately the same elevation as the streambed—235.5–235.8 m (772.6–773.6 ft) above mean sea level (Tschantz and Wylie 1992).

From 1944 until 1947, water exited the impoundment through five 20.3-cm (8-in.), vitrified-clay overflow pipes on the impoundment side of the south berm. It was discharged to White Oak Creek through three identified outfall pipes (numbered 306, 307, and 308) and two other unidentified outfalls. In 1947, greater control over discharges from the impoundment to the creek was desired. To accomplish this, pipes on the creek side were sealed with pipe plugs and compressions screws, and a 38.1-cm (15-in.), reinforced-concrete header pipe was installed in the berm. The header pipe leads to a weir box near the southwest corner of the impoundment. The weir box allowed monitoring of the effluent before discharge to White Oak Creek through a 62-cm (24-in.), reinforced-concrete outfall pipe (numbered 305). If effluent concentrations were above acceptable levels, a sump pump recycled the water to the impoundment.

In 1986, ORNL began operating under a National Pollutant Discharge Elimination System permit that included outfalls 306, 307, and 308. The National Pollutant Discharge Elimination System permit did not set limits on discharges from these outfalls, but outlined monitoring and reporting requirements for various parameters. As part of the agreement, outfall 305 was sealed at the weir box, and any accumulated water was pumped to the Impoundment 3513. In 1989, the inlets to the overflow pipes were sealed to prevent flow into the header pipe because of concerns about continued leakage to White Oak Creek. The overflow pipes, at an elevation of approximately 237.3 m (778 ft), were plugged using a mixture of bentonite and clay on the pond

side and using pipe plugs and compressions screws at the point of discharge to the creek. In 1992, seepage from the area of outfall 308 indicated recurrent leakage through the piping in the south berm (personal communication with Lou Holder, February 1994). To correct this, the pipes on the pond side were cut flush with the berm and plugged with bentonite and clay. In February 1994, seeps at the base of embankment were identified and corrective action (seep sealed with bentonite) was implemented to mitigate seepage to White Oak Creek.

2.3.2 Impoundment 3524

Initially, Impoundment 3524 consisted of two unlined impoundments separated by a berm constructed in 1943. Each impoundment had a capacity of 1,109,890 L (293,200 gal). In the early 1950s, the berm separating the two impoundments was removed, forming one impoundment. In 1961, an attempt was made to expand the impoundment further to the west; however, during excavation, shallow bedrock was encountered and construction activities ceased. (Bedrock pinnacles are visible above the water level in the impoundment during dry periods.) The berms on the east and south sides of the impoundment were increased by adding fill on top of the original berms. The south berm was raised 0.6 m (2 ft) using compacted clay, and the east berm was increased by 0.3 m (1 ft). The area and depth of the impoundment were increased both by excavation and by raising the height of the retaining berms. No other major modifications have been made to this impoundment.

The current capacity of Impoundment 3524 is 3,785,411 L (1,000,000 gal). Water is maintained in the impoundment by a 3-m- (10-ft)-high by 3-m- (10-ft)-wide earthen dike on the east, west, and south. Currently, the pond has dimensions of 29 by 84 m (95 by 275 ft) and an average depth of 2 m (6.7 ft). The depth varies between the eastern and western ends of the impoundment. The depth in the eastern portion of the impoundment is 2.7 m (9 ft) (according to Energy Systems Drawing D-36524) and becomes shallower in the western end because of the variations in the bedrock surface. The berms surrounding Impoundment 3524 were evaluated in 1985 (Tschantz and Wylie 1992). This evaluation was based on visual observations, analysis of soil types, topography, and hydrology of the area. No visible seeps have been noted in the berm.

The inflow pipe from the pumping station north of the impoundment is intact. The overflow pipe in the southeast corner of the impoundment was sealed in 1987. Riprap originally lined the banks of the impoundments above the mean water level. This riprap is not present today and probably was excavated when the impoundment was expanded.

2.3.3 Impoundments 3539 and 3540

Impoundments 3539 and 3540 (also known as the 190 ponds) were built in 1964 by excavation and construction of earthen dikes along the western sides. These impoundments are

lined with 0.15 m (0.5 ft) of compacted clay and a 0.6-m (2-ft) layer of riprap around the inside slope faces. The impoundments are 30.5 m (100 ft) by 18 m (58 ft), sloping down to 24 m (80 ft) by 10 m (33 ft) at the bottom. No major modifications have been made to these impoundments since their construction. The feed pipe from the process wastewater system (formerly the Building 4500 complex discharge) is intact, as are the discharge pipes.

Water levels in the impoundments are not regulated and fluctuate, depending on the amount of rainfall. The impoundments have never gone completely dry, but water levels have dropped to less than 0.3 m (1 ft). The current condition of the clay liners is unknown; however, there are no indications that either of these impoundments leaks. The groundwater monitoring wells surrounding Impoundments 3539 and 3540 do not indicate that contaminants are migrating into groundwater. In addition, the levels of rainwater present in the impoundments do not appear to significantly decrease over time, indicating that the water does not seep out, but rather evaporates.

The berms surrounding Impoundments 3539 and 3540 were evaluated in 1985. The evaluation was based on visual observations, analysis of soil types, topography, hydrology of the area, and structural design of the berms (Tschantz and Wylie 1992).

3. CONTAMINANT DISTRIBUTION AND ASSOCIATED RISKS

This section is a discussion of the contaminant fate and transport conceptual model for SIOU, and evaluations and summaries of the four primary contaminant sources/media present at SIOU. Of these four sources (sediment, subimpoundment soil, surface water, and surface soil) only sediments are summarized individually. The others are discussed in detail in Appendix B. A summary on groundwater is included to discuss its significance as a primary pathway for contaminant migration. The sources, the resultant exposure and risk characterizations associated with SIOU are presented. The information presented in this section provides the data necessary to identify risk associated with the OU and remedial alternatives to mitigate those risks.

In addition, this section provides:

- a summary of the field investigations conducted at SIOU and information on:
- the SIOU site conceptual model (Sect. 3.1),
- the nature and extent of contaminants by medium, with a summary of expected site conditions and reasonable deviations (Sect. 3.2),
- the exposure assessment, which discusses receptor scenarios and their exposure pathways (Sect. 3.3), and
- a summary of human health and ecological risk assessments (Sects. 3.7 and 3.8).

The summaries and interpretations made in this report are based on data collected from various historical investigations. Additional data were acquired during three sampling events conducted in summer 1994 to close data gaps identified in the early scoping for this project. Detailed information on these sampling events is included in Appendix B. References to the specific sources are provided; however, these data sources are not reproduced in this report.

3.1 FATE AND TRANSPORT CONCEPTUAL MODEL

The four impoundments constituting SIOU are physically connected by a series of underground and aboveground piping that controlled the distribution of waste liquid during the period of their operation. For this RI, each impoundment is a distinct unit having individual physical characteristics and sharing similar contaminants of concern (COCs).

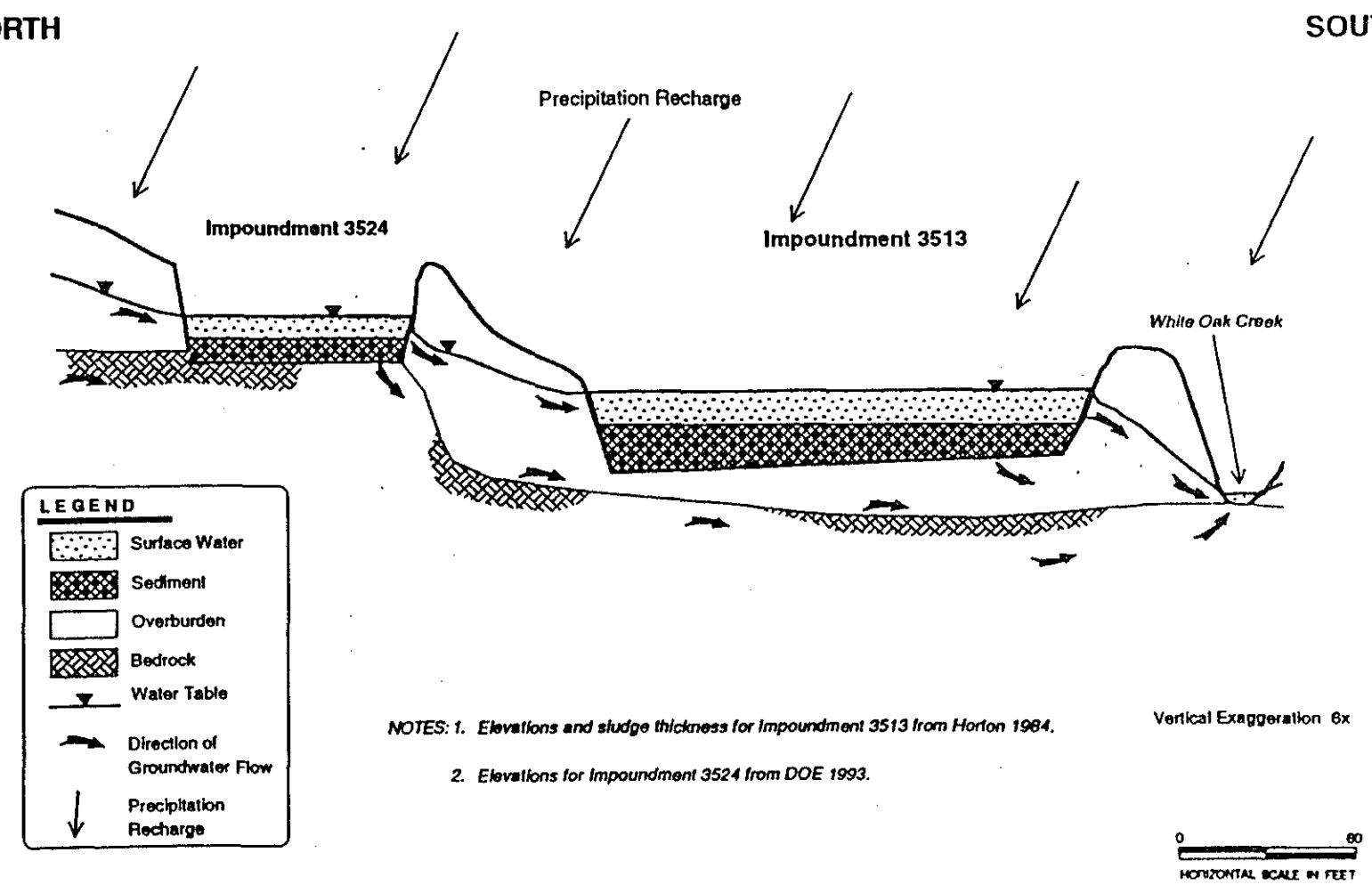
The available information addressing the nature and extent, as well as the fate and transport, of contamination at SIOU has been synthesized into a fate and transport conceptual model (Fig. 3.1). This conceptual model provides a framework for developing exposure assessments, and specifically displays the relationship between Impoundments 3513 and 3524, the ground surface, the top of bedrock, and the groundwater table.

As explained in Section 2.1.3, the impoundments are in a groundwater discharge area. Excavations to bedrock in the impoundments area revealed that bedrock surfaces do not show signs of significant weathering; therefore, solution features that could provide pathways between the impoundments and deeper bedrock are not likely. Groundwater in the bedrock is depicted as moving upward, and not downward. The bulk of the groundwater in the impoundments area flows from north to south and is within the soils at the interface between the soil and bedrock, ultimately discharging to White Oak Creek.

The groundwater table is perennially above the bottom of Impoundment 3513 and in contact with the sediments in the impoundment. The groundwater table is above the bottom of Impoundment 3524 during the wet season (from December to April) and is below the impoundment during the dry season. As a result, the sediments within this impoundment could dry out and become airborne dust particles during part of the dry season if measures are not taken to maintain the water level. Also, direct gamma exposure rates from contaminants within the sediments would increase due to the reduction in shielding provided by the surface water.

Table 3.1 shows the majority of contaminant inventories are within the sediments of the four impoundments, and in particular Impoundments 3513 and 3524. The other sources of contamination were found to be minor by comparison. In order of relative importance, they are: subimpoundment soils underlying the sediments, surface water within the boundaries of the impoundments, and surrounding soils that have become contaminated as a result of interaction with the contamination present in the sediments or with sources unrelated to the impoundments (i.e., pipeline leaks, spills, or contaminant sources upgradient of the impoundments). Table 3.1 lists the contaminated media present at SIOU and approximate total inventories of contaminants in SIOU. These percentages were derived from estimates of concentrations and volumes reported in Section 3.2 and detailed in Appendix B.

Calculations indicated that these other media would not, by comparison, contribute significantly to either human or ecological risks at SIOU relative to the sediments within the impoundments. Thus, they were not specifically addressed in Figure 3.1.



JE Fig. 3.1	**Fate and transport conceptual model** DOE — ORNL, WAG 1 Surface Impoundments — Oak Ridge, Tennessee	DOCUMENT ID 35H830 4003 15 / RI/FS	DRAWING ID 94-10364 PD3 A	DRAWING DATE FEBRUARY 27, 1995 Rev

Table 3.1. Sources of contamination in Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Percent of contamination[a]	Source	Description
> 90	Sediment	Deposited material within impoundments
< 5	Subimpoundment soils	Native soils in contact with and contaminated by sediment or impoundment water
< 3	Surface water	Ponded water within each of the four impoundments
< 2	Surface soils	Native soils around (and contaminated by) impoundments

[a]Based on contaminant concentration and volume, not risk.

ORNL = Oak Ridge National Laboratory
SIOU = Surface Impoundments Operable Unit

3.2 NATURE AND EXTENT OF CONTAMINATION

The following sections examine these four media in more detail and discuss the mechanisms that would allow migration of these contaminants. The data used to derive these interpretations were obtained from various historical investigations and the recent sampling events. Where necessary, some extrapolations were made from limited data sets.

3.2.1 Sediment

Containing over 90 percent of the contamination in the OU, sediments within the impoundments are composed of materials that have settled out or were precipitated from the various process waste streams. Organic matter from natural biological processes are also present, the product of a diverse, freshwater ecosystem that includes mixed phytoplankton, benthic algae, and varied aquatic invertebrates (Stansfield and Francis 1986a). The sediment characteristics vary slightly with each impoundment, depending mainly on the source of the process wastes received by each impoundment.

Appendix B presents geotechnical information for the impoundment sediments. Table 3.2 presents volumes of sediment along with other contaminated media.

Representative mean and reasonable maximum concentrations are reported for each impoundment in Table 3.3 for radionuclide concentrations and in Table 3.4 for chemical concentrations; data from Impoundments 3539 and 3540 were combined since the process history of these two ponds was identical. In accordance with *Risk Assessment Guidance for Superfund* (EPA 1989a), the reasonable maximum exposure (RME) concentration of a contaminant is the

Table 3.2. Summary of volumes of contaminated media in Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

	Impoundment 3513		Impoundment 3524		Impoundments 3539 and 3540		Totals	
	Probable	Maximum	Probable	Maximum	Probable	Maximum	Probable	Maximum
Dimension at crest (e−w × n−s)(ft)	228 × 228	NA	305 × 105	NA	90 × 60	NA	—	—
Dimensions at base (e−w × n−s)(ft)	200 × 200	NA	275 × 95	NA	74 × 44	NA	—	—
Slope of berm	0.5	NA	0.5	NA	1.0	NA	—	—
Sediment volume (in situ)[a] (yd^3)	3,160	3,460	1,400[b]	2,100	40	40	4,600	5,600
Sediment volume (dewatered)[c] (yd^3)	2,210	2,420	980	1,470	28	28	3,218	3,918
Depth of sediment layer[d] (ft)	2.0	2.2	1.8	2.3	0.3	0.3	—	—
Surface water volume[e] (ft^3)	138,000	139,000	83,400	85,700	11,100	11,100	—	—
Subimpoundment soils volume[f] (yd^3)	2,110	2,750	1,320	1,700	290	380	3,720	4,830
Surrounding soils volume[g] (yd^3)	740	960	670	870	370	480	1,780	2,310

[a]Based on probable conditions and reasonable deviation of sediment depth, respectively, and assuming regular dimensions for the pond.
[b]Probable volume from Braunstein et al. (1984), which accounts for bedrock directly underlying the impoundment. Deviation is based on deviation of sediment depth.
[c]Assume dewatering from 80 percent to approximately 50 percent moisture content by weight (based on centrifuging data from Tamura, Sealand, and Duguid 1977) results in 30 percent volume reduction.
[d]Sediment depths are mean and UCL_{95} from the following: Tamura, Sealand, and Duguid (1977) for Impoundment 3513 and Braunstein et al. (1984) for Impoundment 3524. Sediment depth of 4 in. in Impoundments 3539 and 3540 is from sampling logs for 1994 remedial investigation sampling.
[e]Water depth assumed to be 3 ft above top of sediment in all impoundments.
[f]Assumes probable condition is excavation 1 ft into subimpoundment soil on bottom and sides of impoundment. Deviation assumes 30 percent increase in volume from additional excavation.
[g]Assumes probable condition is excavation 1 ft deep over a 20-ft area surrounding crest of the berm. Deviation assumes 30 percent increase in volume from additional excavation.

e = east
ft = foot
n = north
NA = not applicable
ORNL = Oak Ridge National Laboratory
s = south
SIOU = Surface Impoundments Operable Unit
UCL = upper confidence limit
w = west
yd = yard

Table 3.3. Summary of concentrations for radioactive COCs, Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Radionuclide	Average (pCi/g dry)	RME (pCi/g dry)
Summary for sediments in Impoundment 3513		
Americium-241	4,200	4,600
Cesium-137	450,000	1,100,000
Cobalt-60	1,300	3,000
Plutonium-238	630	2,500
Plutonium-239, -240	19,000	24,000
Strontium-90	73,000	140,000
Summary for sediments in Impoundment 3524		
Americium-241	16,000	33,000
Cesium-137	210,000	360,000
Cobalt-60	3,000	7,800
Plutonium-238	1,100	3,500
Plutonium-239, -240	17,000	72,000
Strontium-90	91,000	140,000
Summary for sediments in Impoundments 3539 and 3540		
Americium-241	< 270	< 270
Cesium-137	54	92
Cobalt-60	5	6
Plutonium-238	0	20
Plutonium-239, -240	93	160
Strontium-90	96	140

COC = contaminant of concern
ORNL = Oak Ridge National Laboratory
pCi/g = picocurie per gram
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

Table 3.4. Summary of concentrations for chemical COCs, Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Contaminant	Frequency of detection	Range of detected concentration	Mean concentration (mg/kg)	RME concentration (mg/kg)
Summary for sediments in Impoundment 3513				
N-Nitroso-di-n-propylamine	6/9	3.6–34	12	26
Mercury	9/9	110–470	340	410
Zinc	9/9	260–620	580	620
Aroclor-1254	9/9	20–99	40	75
Aroclor-1260	3/9	21–38	23	29
Summary for sediments in Impoundment 3524				
N-Nitroso-di-n-propylamine	1/9	23	12	23
Mercury	9/9	43–920	396	560
Zinc	9/9	760–8,000	3,900	5,900
Aroclor-1254	9/9	11–140	75	130
Aroclor-1260	—	—	—	—
Summary for sediments in Impoundments 3539 and 3540				
N-Nitroso-di-n-propylamine	1/2	3.4	2.8	3.4
Mercury	2/2	730–800	760	800
Zinc	2/2	1,100–1,200	1,200	1,200
Aroclor-1254	2/2	150–180	170	180
Aroclor-1260	1/2	120	130	160

COC = contaminant of concern
mg/kg = milligram per kilogram
ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

lesser of the 95th percentile upper confidence limit of the mean (UCL_{95}) or maximum detected concentration. Since the sediments within the impoundments originated from a variety of operations over the course of their active periods, the distribution of contaminants within the sediments varies both aerially and vertically. However, though this fact had to be taken into account for the calculation of mean and reasonable maximum concentrations, it does not materially affect the outcome of the subsequent risk assessments.

Using the SAFER pilot program to enhance the document, only the contaminants requiring remedial action (see Tables 3.3 and 3.4) were reported. This had the net effect of concentrating only on the COCs for chemicals and radionuclides, as reported in the tables. Appendix B details concentrations for all chemicals and radionuclides that were analyzed for during the sampling events.

As indicated in Tables 3.2, 3.3, and 3.4, volumes and levels of radioactive contamination in Impoundments 3539 and 3540 are much lower than in either Impoundment 3513 or 3524. Substances regulated by RCRA and the Toxic Substances Control Act are also present. As detailed in Appendix C, additional calculations were performed to show that the transuranic radionuclides present in wastes generated from these ponds are not in sufficient quantiy to be classified as transuranic wastes by regulatory definition.

3.2.2 Subimpoundment Soils

Again, using SAFER, the discussion of subimpoundment soils is focused on, and limited to, soils in the immediate vicinity of the individual impoundments. The subimpoundment soils have been impacted by the materials placed in the impoundments and are most likely to be included in any remedial action addressing the sediments in the impoundments. They are discussed separately only to present a more complete picture of SIOU as it currently exists.

The contaminants within the subimpoundment soils are derived from leaching of the impoundment sediments and were found to be identical to those found in the overlying sediments. The concentrations in the subimpoundment soils have only been specifically measured separately from the sediments by Tamura, Sealand, and Duguid in 1977 at Impoundment 3513. This historical sampling event only measured samples for gross alpha, ^{90}Sr, and ^{137}Cs. It was possible to derive relative inventories of these contaminants in each media for these three measured contaminants and to extrapolate this partitioning to other contaminants, based on similar sorption characteristics. Appendix C explains these resultant concentrations in greater detail.

As expected, there is a significant reduction in concentrations from the sediments to the subimpoundment soils. In fact, only 3–4 percent of the total inventories of the three measured contaminants were in the subimpoundment soils of Impoundment 3513. Therefore, no attempt has been made to delineate the concentrations in the sediments from those in the subimpoundment soils. Also, since Impoundments 3539 and 3540 have clay liners, it is likely that contaminants have not penetrated as deeply below these impoundments.

3.2.3 Surface Soils

The surface soils surrounding the impoundments are defined as those soils that lie outside the impoundments but within the radiation control boundary, as identified by a yellow and magenta rope that was set based on results from a radiation walkover survey performed by Uziel, Williams, and Tiner 1989. Contamination within these operable unit soils is likely to be the results of pipe leaks, overflow from sumps or valve pits, or spills. However, contamination of surface soils also may have resulted from excavation of contaminated subsurface soils during construction of a diversion box or during expansion of Impoundment 3524. Appendix B presents a detailed assessment of the data available on surface soil contamination.

The waste streams feeding into the impoundments have historically consisted of both radioactive and chemical waste. During early operations, the waste was primarily radioactive waste and contained little or no chemical waste. As more buildings were constructed and the associated waste-treatment systems were brought on line, the waste streams contained lower concentrations of radionuclides and higher concentrations of various chemicals. In general, the concentrations of contaminants in the surface soils are trivial when compared to SIOU sediments, and they do not significantly impact the risk assessment.

Given that the potential sources of contamination are likely to be radioactive wastes containing varying concentrations of chemicals, any soils contaminated with chemicals would likely also have elevated concentrations of radionuclides. A review of the sampling data collected within SIOU indicates that all known chemical-contaminated areas also contain radionuclides (Huang et al. 1984, Uziel, Williams, and Tiner 1989, DOE 1992b), which tends to confirm this assumption. However, these data are limited to 12 samples, collected at 8 biased sampling locations, based on radiation walkover surveys (DOE 1992b). This relationship is important to establish and understand, because no data exist to definitively characterize the chemical contaminants in the soil. By establishing this correlation, it is possible to use radiological characterization data to estimate the total area of the SIOU surface soils that is impacted by contamination. Table B4.9 in Appendix B details these estimates.

3.2.4 Surface Water

The contaminants present in the surface waters of the impoundments are influenced by contaminants present in the sediment, the groundwater, and the process wastewater discharged into some of the impoundments. Contaminants present in the sediment may leach into overlying surface waters. The rate of leaching would depend upon the physicochemical properties of the contaminant, including its concentrations in the sediment, water solubility, and affinity for sediments. It would also depend on water environment, pH, and interaction or competition with other dissolved species. Impoundments 3539 and 3540 do not receive groundwater discharge. Groundwater will discharge into Impoundment 3524 when the groundwater table is high. The bottom of Impoundment 3513 is perennially within the groundwater table.

The contaminant concentrations in Impoundment 3524 are likely to vary seasonally. The discharge of groundwater and the periodic discharge of process wastewater are likely to add additional contaminants and dilute the concentrations of contaminants that have leached from the sediments. Heavy algae growths have been noted in this impoundment and will bioaccumulate certain contaminants from the water column.

Surface water from Impoundment 3513 has only been measured directly for the chemical COCs during one historical investigation (Stansfield and Francis 1985), and only one sample was collected for analysis during this investigation. Mercury measured in this sample was 0.0003 mg/L, and total polychlorinated biphenyls (PCBs) measured were 0.0006 mg/L. Appendix B details additional sampling parameters obtained during this and other studies at Impoundment 3513.

3.2.5 Groundwater

Although groundwater entering the OU is not considered a primary source of contamination at SIOU, it is an important contaminant transport mechanism. As groundwater migrates through the impoundments, contaminants in the sediments are dissolved in the groundwater and transported to groundwater discharge points.

Appendix B discusses in detail statistical analyses on historical groundwater data. These evaluations are useful for determining whether COCs are currently having a measurable impact on groundwater concentrations and for validating groundwater models used to predict future groundwater concentrations for risk assessment purposes. Groundwater has not been sampled for all the contaminants within the impoundment sediments, and thus the statistical analysis does not represent a complete list of potential groundwater impacts. However, the groundwater modelling effectively closed these data gaps.

The statistical analyses performed indicate that ^{90}Sr is the only COC for Impoundment 3513 that currently has an impact on groundwater concentrations. Impoundment 3524 currently has a measurable impact on gross beta concentrations, which is thought to be due to ^{90}Sr. No other COCs in these two impoundments have a measurable impact on current groundwater contaminant concentrations. The sediments within Impoundments 3539 and 3540 do not significantly contribute to groundwater contamination due to the low volumes of sediments and the clay liners in these impoundments.

3.2.6 Fish Within Impoundment 3513

Samples of mosquito fish (*Gambusia affinis*) within Impoundment 3513 were collected during the recent RI sampling events to support the ecological risk assessment. Appendix B presents detailed information on sampling.

A breakdown in chain-of-custody protocol lead to flagging the fish concentration data. Though rejected data are not typically used for risk assessment purposes, the maximum detected values were retained for consideration. For the contaminants of ecological concern, these maximum concentrations were 25.9 mg/kg for Aroclor-1254, 5.9 mg/kg for Aroclor-1260, 0.9 mg/kg for Hg, 1,100 pCi/g for ^{137}Cs, and 1,300 pCi/g for ^{90}Sr.

3.2.7 Probable Site Conditions and Reasonable Deviations

A key element of the SAFER process is identifying and managing uncertainties. This is accomplished by reviewing the information presented and evaluating uncertainties associated with site-, regulatory-, and technology-specific conditions. Table 3.5 presents a summary of the probable site conditions and reasonable deviations associated with site- and regulatory-specific conditions that could potentially impact the implementation of the remedial alternatives. These deviations and deviations associated with technology-specific conditions are addressed as part of the detailed discussion of alternatives in Chapter 4.

3.3 SIOU EXPOSURE ASSESSMENT

In this section, the baseline risk assessment addresses the environmental fate and transport of the COCs identified in the RI and the potential pathways by which human populations (e.g., residents and workers) could be exposed to radioactive and chemical contaminants at or originating from the SIOU site. Exposure estimates are provided for SIOU outdoors on the impoundments, the surrounding property within the radiological control boundary at the site, and the SIOU surface water and groundwater drainage system to White Oak Creek and the connecting waterways.

Table 3.5. Probable site conditions and reasonable deviations for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Probable site conditions	Reasonable deviations
Significant karst features do not exist that influence groundwater movement or direction. Groundwater velocity and flow direction are consistent across the impoundments	Karst features provide mechanisms for conduit flow, significantly altering groundwater velocity and direction on a local, variable scale
Contaminant levels in subimpoundment soils are much lower than sediment	Contaminant levels in subimpoundment soils approach concentrations in sediment
The only contaminant of concern leaching from sediment to groundwater is ^{90}Sr	Other contaminants of concern, such as mercury, are leaching from sediment

ORNL = Oak Ridge National Laboratory
SIOU = Surface Impoundments Operable Unit
Sr = strontium

Contaminant concentrations were determined by sampling and analysis, radiation survey measurements, and/or modeling. The data are summarized in this section of the baseline risk assessment and presented as the RME and mean (average) concentrations. The RME is defined as the UCL_{95} for exposure parameters and describes a reasonable maximum estimate of risk. The importance of the RME value is stressed because it adequately addresses the most susceptible portions of the receptor population and is critical in making remedial action decisions. In identifying primary pathways of exposure at each location, current and plausible future land uses of the properties and surrounding areas were considered.

This section also describes exposure scenarios, develops information on exposure pathways, estimates the concentrations of the radiological and chemical COCs at points of human exposure, and determines receptor intakes (doses). Appendix C provides assumptions. RME and mean estimates are presented for radiation dose and chemical intakes within each scenario. Section 3.6 discusses the uncertainties of the exposure assessment.

3.3.1 Characterization of Exposure Setting

The exposure setting for the SIOU site is described briefly in terms of both the natural environment and local land use and demography. Section 2.1 describes the setting in more detail. The following discussion provides information pertinent to the identification of exposure pathways and estimation of rates of exposure to contamination for hypothetical receptors.

3.3.2 Exposure Scenario Descriptions

In this baseline risk assessment, two time-dependent, hypothetical, exposure scenarios are considered:

- current use—land use remaining as it is now, and

- future use—land use that may change from an industrial setting in some areas to provide a different exposure condition.

3.3.2.1 Current use scenarios

Receptors considered at SIOU are employees who spend time both indoors and outdoors. While indoors, employees work in uncontaminated areas of a building; while outdoors, employees work outside around the SIOU parking lot, property, and impoundments. ORNL employees are currently using the municipal water supply. The current use scenario assumes that the employees do not consume drinking water from on-site wells located at the SIOU site. All wells located on SIOU are monitoring wells, and the yield associated with the wells [less than 378 L (100 gal) per day] would not support a residential household or commercial operation.

Other potential receptors at SIOU include transients who may be visitors, customers, commuters, trespassers, and temporary or contractor personnel. Additionally, a worker excavating the site for construction or cleanup purposes is a potential receptor. Because the exposure frequency and duration for a transient at SIOU are assumed to be a small fraction of the frequency and duration for an on-site employee, the transient receptor scenario is not considered further. An excavation-worker scenario was evaluated for SIOU during screening and was found to have lower risk than was calculated for employees because of the shorter exposure duration; therefore, the excavation-worker scenario is also not considered further. A full evaluation of an excavation-worker scenario is presented in the FS. The employee receptor provides a more conservative estimate of dose and intake at SIOU. Table 3.6 summarizes the current scenario.

3.3.2.2 Future use scenarios

For future use, four different hypothetical scenarios are considered. The first scenario assumes that the ORNL facility will remain a commercially operated industrial site. As in the current use scenario, on-site receptors are assumed to be employees who spend part of their time indoors in uncontaminated buildings and outdoors near SIOU. As in the current scenario, these employees use the existing municipal water supply and do not consume water drawn from on-site wells that could be impacted by potential seepage from SIOU, nor do they attempt to exhume the contents contained in SIOU.

Although residential receptors within or near the present ORNL boundary do not exist, residential occupancy there in the future cannot be discounted. Therefore, the second scenario assumes three possible future nearby resident locations: 10 m (33 ft) away at White Oak Creek

Table 3.6. Scenario/receptor descriptions for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Employee at SIOU
Current
The RME and average current employee are estimated to spend 8 hours/day on the site. One hour/day (RME) or 0.5 hour/day (mean) is spent outside maintaining or monitoring the property; the remainder of the day (7 hours/day) is spent in an uncontaminated building. The employee works 250 days/year and consumes no drinking water from the site.
Future
The RME and average future employee spends 1 hour/day (RME) or 0.5 hour/day (mean) outdoors and 7 hours/day within the building for 250 days/year as described above. The future employee does not consume contaminated drinking water from the site.
Child wading in White Oak Creek
Future
Both the RME and average individuals are represented as a child wading in the creek receiving runoff from the SIOU site. The child is assumed to play in the creek for 1 hour 7 times a year (average) and 45 times a year (RME) over the course of 6 years.
Resident at White Oak Creek, White Oak Dam, and Clinch River
Future
The RME and average future resident is assumed to reside at the specified nearby location and consume, contact, and inhale contaminants from surface water or groundwater at the location or from airborne particulates that might migrate from SIOU.
On-site resident
Future
The RME and average, future on-site resident is assumed to reside at SIOU. The on-site resident consumes contaminated groundwater or water from White Oak Creek and receives a direct radiation exposure (4 hours/day RME and 2 hours/day average) from the impoundments. In addition, in the future, it is assumed that the water cover will evaporate or be removed, exposing the sediment contents to the open air. No direct contact is assumed.

ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

where groundwater traversing the SIOU area surfaces and mixes with the White Oak Creek surface flow, 2,590 m (8,633 ft) away at White Oak Dam, and 3,505 m (11,683 ft) away at Clinch River. These locations were selected to evaluate the maximum health effects from potential releases of contaminants and subsequent off-SIOU transport by groundwater. Surface water and groundwater quality at these locations are assumed to be equivalent, and either source is used as a sole drinking water supply for the future resident scenarios.

The third future scenario assumes that a child wades in White Oak Creek adjacent to SIOU. This scenario is evaluated to represent the sensitive populations (pregnant women, older populations, handicapped, and small children) as specified in *Risk Assessment Guidance for Superfund* (EPA 1989a).

The fourth hypothetical scenario assumes that SIOU becomes available for residential use and that the residence is located adjacent to SIOU. The resident obtains a drinking water supply from White Oak Creek and resides adjacent to the impoundments.

3.3.3 Identification of Exposure Pathways

A complete exposure pathway consists of the following four elements: (1) a source and mechanism of contaminant release to the environment; (2) an environmental transport mechanism for the released contaminants; (3) a point of human contact with the contaminated medium; and (4) a route of entry for the contaminant into the human receptor at the exposure point. In some cases, the source itself (i.e., contaminated soil) is the exposure point, without a release to any other medium. An integration of sources, releases, fate and transport mechanisms, exposure points, and exposure routes is evaluated for complete exposure pathways. If any of these elements is missing, the pathway is incomplete and will not be considered further in the risk evaluation.

3.3.4 Summary of Exposure Pathways Included in Quantitative Assessment

Figure 3.2 shows potential exposure pathways at the SIOU site. Complete exposure pathways exist when a receptor could be exposed to a contaminated source. Table 3.7 summarizes potential exposure routes and potential receptors for each of the pathways, whether or not the pathway is included in the quantitative assessment and the rationale for inclusion or exclusion.

There is no complete groundwater pathway considered in current scenarios at SIOU because groundwater is currently not used at the site for drinking or other purposes. Monitoring results verify that, under current conditions, no significant migration of contaminants from SIOU has taken place. Therefore, groundwater usage by a resident located off site is not considered

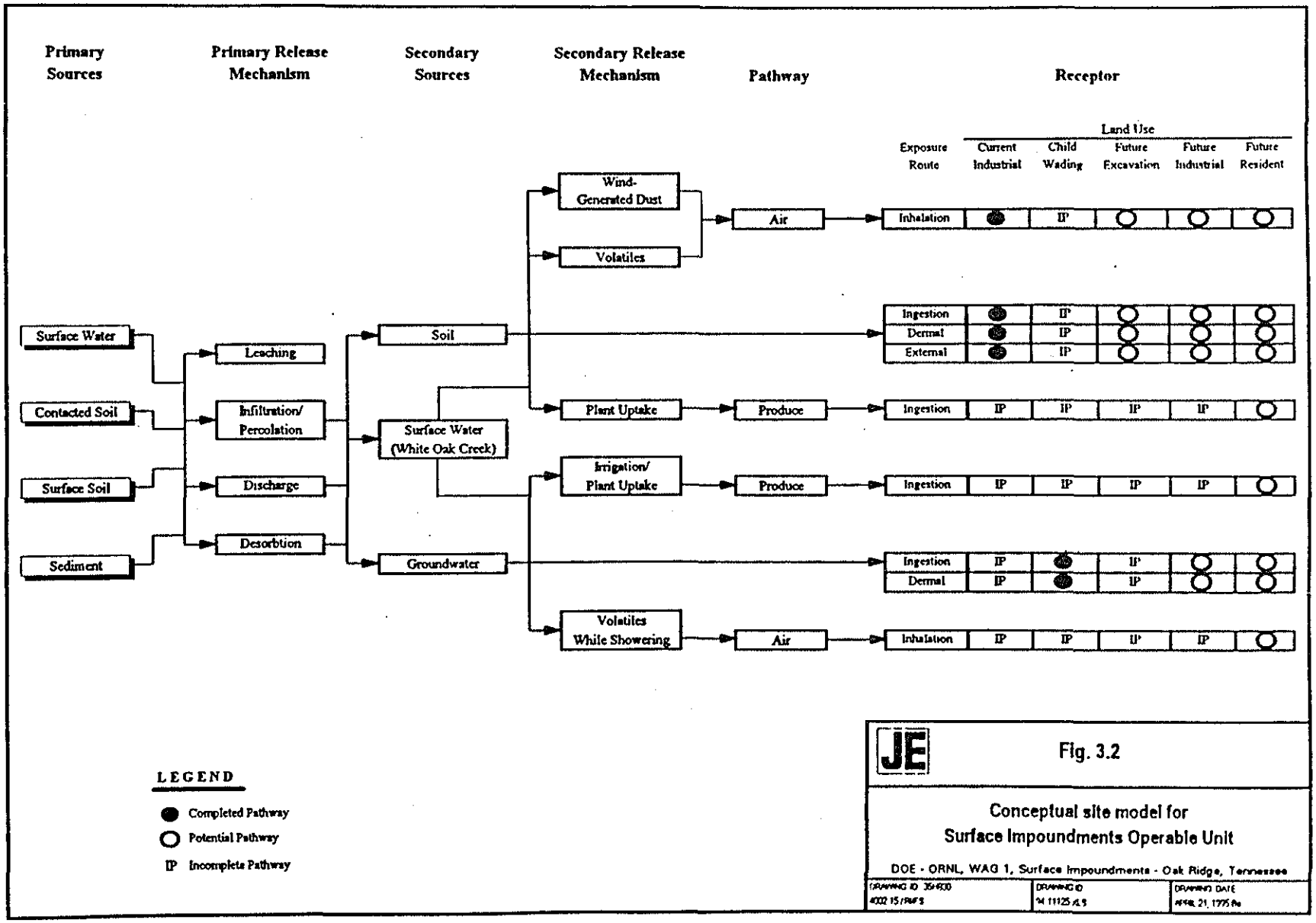


Fig. 3.2

Conceptual site model for Surface Impoundments Operable Unit

DOE - ORNL, WAG 1, Surface Impoundments - Oak Ridge, Tennessee

Table 3.7. Screening of potential exposure pathways for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Media/potential exposure route	Potential receptors	Pathway included in assessment? (yes/no)	Screening rationale
Soil[a] and sediment			
Direct radiation (radiological contaminants only)	Current employee	Yes	Radiological COCs assessed
	Future employee	Yes	Radiological COCs assessed
Dermal contact	Current employee	Yes	Direct access to soil considered
	Future employee	Yes	Direct access to soil considered
Air (from soil[a] and sediment)			
Particulate inhalation	Future nearby resident	Yes	All COCs assessed
	Future on-site resident	Yes	All COCs assessed
	Current employee	Yes	Air resuspension pathway
	Future employee	Yes	Air resuspension pathway
Vapor inhalation	Current employee	No	No applicable COCs
	Future employee	No	No applicable COCs
Surface water and sediment in White Oak Creek			
Dermal	Future child	No	No applicable COCs
Ingestion	Future child	Yes	All COCs assessed
Vapor inhalation	Future child	No	No applicable COCs
Groundwater or surface water			
Dermal	Current employee	No	No current groundwater usage
	Future employee	No	No future groundwater usage
	Future nearby resident	Yes	Applicable COCs assessed
	Future on-site resident	Yes	Applicable COCs assessed
Ingestion	Current employee	No	No current groundwater usage
	Future employee	No	No future groundwater usage
	Future nearby resident	Yes	All COCs assessed
	Future off-site resident	Yes	All COCs assessed
Vapor inhalation	Current employee	No	No current groundwater usage
	Future employee	No	Showering not evaluated for commercial land use
	Future nearby resident	Yes	Applicable COCs assessed
	Future on-site resident	Yes	Applicable COCs assessed
Food			
Ingestion	Future nearby resident	Yes	Mechanism for food contamination
	Future on-site resident	Yes	Mechanism for food contamination

[a]Soil is considered in residual risk.

COC = contaminant of concern
ORNL = Oak Ridge National Laboratory
SIOU = Surface Impoundments Operable Unit

in the current land use scenario. However, because metals do not undergo degradation and some of the radioactive contaminants have long half-lives, the potential migration of contaminants is analyzed for groundwater pathways in the future for the nearby resident and on-site resident scenarios.

3.3.4.1 Fate and transport mechanisms

Following release from sources, contaminants may migrate in environmental media by any of several transport mechanisms. Qualitative evaluation of fate and transport helps to identify media currently receiving contaminants released from the SIOU site. Additionally, media that might receive site-related contaminants in the future can be identified.

After a chemical is released to the environment it may be:

- transported (e.g., through the atmosphere),
- physically transformed,
- chemically transformed,
- biologically transformed,
- accumulated in one or more media, or
- radiologically decayed.

Because of site-specific factors, certain potential release mechanisms and receiving media do not play significant roles in contaminant fate and transport and resulting human exposure at the SIOU site. For example, because of the industrial nature of the site, plant uptake, bioaccumulation in animals ingesting plants, and subsequent human ingestion of contaminated vegetation and animals is not currently considered to be an important release mechanism to humans. However, it is considered important in the future because the residential scenarios are considered for the future scenario. Similarly, because of the current site conditions, surface water runoff is considered a significant transport mechanism.

Contaminants in the impoundment sediments are currently being accumulated in groundwater or transported off site. In addition, because some of the radioactive contaminants at SIOU have very long half-lives and the metals identified in soil do not undergo degradation, transport between soil and groundwater is evaluated for future scenarios.

3.3.5 Quantification of Exposure

Once potentially exposed populations and potential exposure pathways have been identified, exposure point concentrations can be estimated for specific pathways, and intakes can be calculated for each COC. Intake estimates for use in risk assessment are quantitative estimates

of the amount of chemical or radionuclide available to the receptor. Each intake model equation corresponds to ingestion, inhalation, or absorption and generates a calculated annual dose of radionuclides (mrem per year) and a daily chemical intake per unit body weight (mg/kg per day).

Ideally, exposure should be derived from estimates of site-specific activities and behavior patterns of receptor groups at potential risk of exposure. Where site-specific data are not available, EPA guidance has been used (whenever available) in selecting or deriving values for exposure parameters. Appendix C presents the parameter values and the equations used for intake/dose calculations for each exposure pathway. Consistent use of parameters is attempted for all models and scenarios. Site-specific data are used whenever possible.

3.3.5.1 Groundwater concentrations predicted in White Oak Creek

Ingestion of contaminated groundwater or surface water for future receptors was modeled starting with sediment data for radionuclide and chemical concentrations. Historical data from previous stream-sampling events were used to help calibrate the models for current use scenarios. Appendix C presents a description of the modeling effort, FT WORK, and how it is applied to the site. Limitations and boundaries for the interpretation of the results are also discussed. The model performs relatively simple transport computations applied to a complex mathematical description of subsurface geology and contaminant-specific migration characteristics. It defines the range of potential release scenarios. Table 3.8 shows the results of the FT WORK model, the average contamination concentrations at White Oak Creek, which correlate very well with the existing groundwater data, surface water data, and the White Oak Creek sampling data from summer 1994.

3.3.5.2 Exposure point concentrations

Exposure point concentrations are the concentrations in an exposure medium that may be contacted by a receptor. Exposure point concentrations of contaminants are used in the quantitative health risk assessments to estimate chemical intakes and radionuclide doses. Analyses were performed on samples collected from locations where human receptors may come in contact with the contaminants. When laboratory analyses are not available, exposure point concentrations were estimated using a variety of modeling techniques.

Because of the uncertainty associated with any estimate of exposure point concentration, the UCL_{95} is used as the RME point concentration. Although this concentration does not reflect the maximum concentration that a receptor could come into contact with at any one time, it is regarded as a reasonable estimate of the maximum concentration the receptor is likely to contact over time. In cases where the UCL_{95} exceeds the maximum measured concentration, the maximum measured concentration is used as a proxy concentration for the RME estimate in

Table 3.8. Average concentrations of radionuclides of concern for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Radionuclide	Predicted average concentration at White Oak Creek (pCi/L)
	Mean
Strontium-90	$2.50 \times 10^{+01}$
Plutonium-238	9.16×10^{-01}
Plutonium-239	7.63×10^{-01}
Europium-154	6.28×10^{-01}
Europium-152	6.87×10^{-01}
Americium-241	7.64×10^{-01}
Curium-244	7.50×10^{-01}
Cobalt-60	$7.06 \times 10^{+00}$

ORNL = Oak Ridge National Laboratory
pCi/L = picocurie/liter
SIOU = Surface Impoundments Operable Unit

accordance with EPA guidance (EPA 1989a). Radiological and chemical data sets were analyzed as described in Section 3.2 to estimate exposure point concentrations.

3.3.6 Summary of Exposure Estimates

3.3.6.1 Summary of radiological exposure estimates

Maximally Exposed Individuals. Table 3.9 shows the total, annual, radiological, effective dose equivalent estimates for the SIOU site. Contributions from soil ingestion and inhalation of particulates were calculated for workers in current and future scenarios. Contributions from on-site measurements of direct radiation were added to the dose tables for current scenarios; contributions from these components were modeled for the future employee and added to the dose. Again, because the SIOU aquifer will not support a drinking water well of sufficient quantity and with the presence of the existing municipal water system, the drinking water pathway was incomplete in both the current and future scenarios. Dose from ingestion of contaminated water was calculated only for a future resident at White Oak Creek, White Oak Dam, and off site at Clinch River. Ingestion of surface water and sediment was calculated for children playing at the SIOU surface drainage system in the current and future scenarios. Appendix C shows incremental dose components of all pathways.

Total dose for the current worker exposed while working both indoors and outdoors on site was 6.1 mrem/year in the RME and 1.8 mrem/year in the mean scenarios. All of the RME dose is from worker exposure inside the operable unit and occurs during the 1 hour/day a worker

Table 3.9. Total exposure dose summary for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Location	Receptor	Dose (mrem/year)	
		Mean	RME
Current use scenario			
SIOU	Employee	1.8	6.1
White Oak Creek	Child wading	No pathway	No pathway
Future use scenario			
SIOU (without water cover)	Employee	548.00	2,243.00
SIOU (without water cover)	On-site resident	2,079.00	4,488.00
White Oak Creek (without water cover)	Child wading	11.24	133.50
White Oak Creek (without water cover)	Resident	1,885.00	4,004.00
White Oak Dam (with water cover)	Resident	(813.00)	(2,074.00)
White Oak Dam (without water cover)	Resident	(250.00)	(250.00)
Total dose	—	1,063.00	2,324.00
Clinch River (with water cover)	Resident	9.50	22.30
Clinch River (without water cover)	White Oak Dam	250.00	250.00

mrem = millirem
ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

is assumed to work outside. The largest component of the current dose, direct radiation, is based on direct measurements from the site.

Total dose for the future worker exposed while working outdoors was 2,243 mrem/year for the RME and 548 mrem/year for the mean employee. More than half of the total future dose (72 percent) is from direct radiation exposure during the hour per day that the worker is assumed to spend outdoors. The direct radiation exposure is based on subsurface contaminants that become exposed over time. The two largest components of the total dose are direct radiation (72 percent) and inhalation (28 percent).

Exposure to future residents by consumption of water from White Oak Creek is 3,987 mrem/year in the RME and 1,767 mrem/year in the mean scenarios. Additional exposure to the on-site resident comes from direct radiation, plant ingestion, and inhalation. For the RME, there is a total dose of 4,488 mrem/year and for the mean a dose of 2,079 mrem/year. Exposure in the future scenario of a child wading in the White Oak Creek drainage system is 133.5 mrem/year for the RME and 11.24 mrem/year for the mean.

At White Oak Creek, the RME dose for the resident is 4,004 mrem/year and 1,885 mrem/year for the mean. At White Oak Dam, the RME dose is 2,074 mrem/year and 813 mrem/year for the mean. When the resident is moved off ORR to Clinch River, the dose drops dramatically to 22.23 mrem/year for the RME and 9.45 mrem for the mean. The drinking-water scenario contributes over 90 percent of the total dose.

In the RME scenario, the 0.6 m (2-ft) water cover is assumed to be removed. The direct radiation dose and dose from inhalation of airborne particulates from the dried sediments for the on-site resident is 9,220 mrem/year and 3,156 mrem/year for the mean. For the RME off-site resident at White Oak Dam or Clinch River, the inhalation and ingestion pathways account for a dose of 250 mrem/year from airborne particulates as a result of the cover being removed.

Average Population Dose. The population dose from the airborne dispersion of radioactive particulates to a radial distance of 80 km (50 miles) was estimated using CAP88-PC (Parks 1991). When the protective water cover is retained for the mean scenario, the exposure for an off-site resident living 3,505 m (11,683 ft) from the site is estimated at 0.01 mrem/year for the RME and 0.001 mrem/year for the mean. For the mean, this provides less than 1 percent of the total background dose from all sources and exposure routes and is considered insignificant in comparison with the natural background level.

3.3.6.2 Summary of chemical intake estimates

Chemical intakes through the exposure routes previously described were estimated for the contaminants of potential concern in soil and for modeled concentrations associated with the impoundment sediments. These estimates are generally expressed in terms of the mass of the chemical in contact with a receptor per unit body weight per unit time, with the units of mg/kg per day. Exposure point concentrations identified in Appendix C are used in the pathway-specific exposure calculations that estimate the total intake to the receptor. For this assessment, both average exposures and RMEs are estimated. Below is a brief discussion of the calculations of chemical intakes.

Incidental Ingestion of Soil, Sediment, and Surface Water. Incidental ingestion of soil is considered a potential route of exposure for the on-site employee. Work activities around the impoundments, particularly in the surface soils during maintenance activities, etc., present numerous opportunities for incidental ingestion of soil.

Incidental ingestion of sediment and surface water is a potential route of exposure in the future for a child wading in White Oak Creek. Concentrations of chemicals in these media were estimated from maximum predicted mass-loading to White Oak Creek.

Ingestion of Water. Ingestion of water is assumed to occur only in the future. Under future conditions, only a resident is assumed to ingest water from White Oak Creek that is contaminated by groundwater from SIOU.

Dermal Absorption of Chemicals in Soil and White Oak Creek Sediment. Dermal absorption of chemicals in soil is assumed for a current employee as a result of contact with contaminated soil during maintenance activities, etc.

Dermal absorption of chemicals in sediment in White Oak Creek is assumed for a child playing in White Oak Creek downstream from the impoundments. Concentrations of chemicals in sediment were estimated from water concentrations calculated from maximum predicted mass-loading to White Oak Creek. Using the applicable, chemical-specific Kd values and the water concentrations, sediment concentrations were extrapolated, assuming 100 percent partitioning from water to sediment.

Inhalation of Contaminated Particulates. Inhalation of SIOU sediment particulates contaminated with chemicals is a route of exposure for a future employee and a future resident at SIOU, assuming the current water cover is removed. For both receptors, chemical concentrations measured in the sediment and associated RME concentrations were used in the exposure calculations. While a hypothetical future resident is assumed to reside at SIOU, that assumption was also used as a screening evaluation for the off-site resident scenario because of the very low concentrations of chemicals in the sediment. This approach is conservative in that air dispersion and dilution are not assumed. If risks associated with the exposure concentrations under this scenario are below levels of concern, additional air dispersion modeling would not be necessary.

3.4 TOXICITY ASSESSMENT

This section briefly summarizes the effects of ionizing radiation and chemicals on exposed populations. Appendix C discusses in detail methods used to evaluate toxicity.

3.4.1 Radiation Toxicity

The potential health effects associated with exposure to radionuclides at the SIOU site are caused by low-level ionizing alpha, beta, and gamma radiation emitted by the members of the ^{137}Cs, ^{241}Pu, ^{90}Sr, ^{60}Co, and ^{241}Am decay series. The primary effects include an increase in the occurrence of cancer in irradiated individuals and possible genetic effects that may occur in future generations. The risk of serious genetic effects is much lower than the risk of cancer induction. Therefore, genetic effects are not the focus of this toxicity assessment, and radiological risks are

evaluated only with respect to incremental cancer probabilities per EPA guidance (EPA 1989a). Nonradiological health effects of uranium are considered, as appropriate, in the chemical toxicity section.

Radiation-induced health effects for humans have been confirmed only at relatively high doses or high dose rates with large populations. Exposure to a high dose of radiation (e.g., a thousand times the average, annual, background dose rate) during a short period of time (a few hours) produces detrimental effects in all the organs and systems of the body. For low doses, health effects are presumed to occur but can only be estimated statistically. Risk estimates are strictly applicable to large populations, because the appearance of health effects after an exposure is a chance event. For purposes of radiological impact assessment, the health effects are measured by cancer incidence in the exposed population. However, risk estimates in the low-dose range are uncertain because of extrapolation from high doses and because of assumptions made on dose-effect relationships and the underlying mechanisms of carcinogenesis. Radiation effects in the exposed population cannot be readily identified since radiogenic cancers are indistinguishable from those resulting from other factors. Studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural background, have not shown consistent evidence of an associated increase in the risk of cancer.

The only exposures at the SIOU site are chronic (long-term), low-level exposures. Although lethal effects in human populations from chronic, low-level exposure have never been documented, the effects have been projected from animal experiments (at high doses and dose rates). Studies assessing the difference between acute (short-term) and chronic (long-term) exposures show that, for a given dose, the radiation effects decrease dramatically as the exposure period is extended. Thus for sites like SIOU, where all exposures are longer term and low level, no immediate harmful effects are expected. Rather the statistical impacts of possible increases in cancer or genetic changes are the only credible, potential radiation effects (National Research Council 1990).

3.4.2 Methods of Evaluating Radiation Toxicity

For this baseline risk assessment, a risk factor of 6×10^{-7}/mrem (EPA 1989c; National Research Council 1990) was used to estimate the likelihood of cancer induction from radiation exposure. EPA used this risk factor to develop revisions to the National Emission Standards for Hazardous Air Pollutants for radionuclides under Section 112 of the Clean Air Act (EPA 1989c). It is a lifetime average value and believed to be representative of conditions defined for the exposure scenarios at the SIOU site.

The BEIR V study (National Research Council 1990) also presents a detailed description of current data on the health risks associated with radiation exposure. A mortality risk factor of about 8×10^{-7}/mrem is estimated in the BEIR V report. To compare this mortality risk factor with the risk factor used in this baseline risk assessment for induction of all cancers, whether fatal or not, the mortality risk factor must be adjusted. On average, the cancer mortality rate is about 60 percent of the cancer induction rate (EPA 1989c). The mortality risk factor (8×10^{-7}/mrem) can be modified to a total cancer induction rate of 1.3×10^{-6}/mrem (8×10^{-7} = 60 percent of 1.3×10^{-6}). BEIR V estimates were derived primarily from data on acute exposures (a single instantaneous exposure), and the BEIR V report suggests that it is appropriate to reduce this risk by applying a dose rate effectiveness factor of two or more in cases of continuous, low-level exposure. Thus, the radiation risk factor of 6×10^{-7}/mrem used in this report is consistent with the value recommended in BEIR V.

In addition to using dose-to-risk conversion factors to estimate risk, EPA also has developed guidance for radiological risk assessment consistent with existing guidance for assessing chemical carcinogenic risks (EPA 1989a). Carcinogenic risks are calculated for the radionuclides of concern in a manner similar to existing methods for chemical carcinogens by using an age-averaged, lifetime, excess cancer incidence per unit intake (and per unit external exposure). EPA has developed cancer slope factors per unit intake that are analogous to the slope factors developed for chemical carcinogens. Appendix B presents radiological carcinogenic risk estimated using EPA slope factors and conventional dose conversion factors for the future employee.

3.4.3 Chemical Toxicity

The toxicity information considered in the assessment of potential carcinogenic risks from chemical exposure includes (1) a weight-of-evidence classification and (2) a slope factor. The weight-of-evidence classification qualitatively describes the likelihood that an agent is a human carcinogen and is based on the available data from animal and human studies. A chemical may be placed in one of three groups to indicate its potential for carcinogenic effects: Group A, a human carcinogen; Group B1 or B2, a probable human carcinogen; and Group C, a possible human carcinogen. Chemicals that cannot be classified as human carcinogens because of a lack of data are categorized in Group D; those for which there is evidence of noncarcinogenicity in humans are categorized in Group E.

One chemical COC (arsenic) is classified as a Class A known human carcinogen. Fifteen chemical COCs are classified as probable human carcinogens. These include aldrin, Aroclor-1254, Aroclor-1260, beryllium, lead, the polycyclic aromatic hydrocarbons, [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthrene, benzo(k)fluoranthrene, bis(2-ethylhexyl)phthalate,

chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene], methylene chloride, and trichloroethylene. Appendix C, Section 4.1, summarizes toxicological properties of the chemical COCs, including both carcinogenic and noncarcinogenic factors. The table briefly describes chemical routes of exposure, critical effects, and carcinogenicity of the chemicals.

3.4.3.1 Methods of evaluating chemical toxicity

Appendix C, Section 4.1, presents toxicity values used in the risk characterization of chemical COCs. This table includes supporting toxicological information along with source identifiers. Toxicity values used in risk calculations include the chronic reference dose for noncarcinogenic risk and the slope factors for the carcinogenic risk.

The chronic reference dose is defined as "an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime." If the sum of the ratios of intake to reference dose value (i.e., hazard indices) for all contaminants is less than one, noncarcinogenic toxicity is unlikely. The slope factor is defined as a "plausible, upper-bound estimate of the probability of a response (i.e., cancer) per unit intake of a chemical over a lifetime" (EPA 1989a). The slope factors multiplied by the estimated lifetime intake levels yield lifetime cancer risk estimates. Both reference dose and slope factor values are specific to the route of exposure (e.g., either ingestion or inhalation exposure).

3.4.3.2 Chemicals for which EPA toxicity values are available

The EPA Integrated Risk Information System (IRIS) database was used to provide up-to-date toxicity values to use in SIOU risk calculations (EPA 1994). When values were not available in IRIS, the 1993 EPA Health Effects Assessment Summary Tables (HEAST) were used (EPA 1993a). A chemical may be under review or reexamination by EPA according to IRIS, and a value still may be obtained from HEAST. When values were not available in IRIS or HEAST, the Superfund Health Risk Technical Support Center–Environmental Criteria and Assessment Office was contacted. Provisional or interim values were obtained for these COCs, if they were available.

Oral slope factors are available for 15 of the chemicals of concern. Polycyclic aromatic hydrocarbons assume the oral and inhalation slope factors for benzo(a)pyrene. Inhalation slope factors are available for only four carcinogenic chemicals of concern. Oral reference doses are available for 42 of the 47 total COCs. Inhalation reference concentrations are available for eight of the noncarcinogenic COCs. Because of the potential for inaccuracy, derivation/conversion of reference concentrations to reference doses was not employed in the risk assessment.

3.5 RISK CHARACTERIZATION

This section presents risk estimates for reasonable current use and hypothetical future use scenarios for human receptors at the SIOU site. Human receptors include employees, on-site residents, off-site residents, and children wading in White Oak Creek. Radiological risks and chemical risks are estimated separately. The overall human health risk and associated uncertainties from exposure to both radiological and chemical contaminants are discussed.

For the radiological assessment, risk is defined as the lifetime probability of cancer morbidity and does not include genetic or noncarcinogenic effects. For the chemical assessment, risk is defined as the lifetime probability of cancer incidence for carcinogens and the estimate of exceeding toxic effect thresholds for noncarcinogens.

Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of pathway-specific exposure to carcinogenic contaminants. Results of the cancer risk estimates can be compared to the target risk range of 10^{-6} to 10^{-4}, or 1 in 1 million to 1 in 10,000, that is the goal EPA outlined in the National Contingency Plan.

EPA does not use a probabilistic approach to estimate the potential for noncarcinogenic health effects. Instead, the potential for noncarcinogenic effects is evaluated by comparing the average daily exposure (intake) over a specified time period (exposure duration) with a reference dose derived for similar exposure periods for each chemical. This ratio of exposure is called a hazard quotient. Hazard quotients for each potential COC are then summed to obtain a hazard index for the specific pathway. A hazard index greater than one has been defined as the level of concern for potential, adverse, noncarcinogenic health effects (EPA 1989a).

3.5.1 Risk Characterization Methodology

The first step in the risk characterization is to evaluate whether all information necessary to characterize risk is available for each exposure pathway and land use. Appendix C presents chemical intake and radiological dose calculations. The existence of toxicity information for the contaminants of potential concern included in the quantitative exposure assessment was also evaluated. Toxicity values consistent with the assumed exposure duration for the SIOU site were identified for use in the quantitative risk analysis.

3.5.2 Quantifying Radiological Risk

Exposures to low levels of ionizing radiation could result in cancer induction, genetic effects, or other detrimental health effects. The predominant health concern potentially associated with the radiological contaminants at the SIOU site is the development of cancer. Therefore, the

radiological health risks presented in this baseline risk assessment are limited to this concern. This approach is consistent with EPA guidance, which notes that, generally, the risk of cancer is limiting and may be used as the sole basis for assessing the radiation-related human health risks for a site contaminated with radionuclides (EPA 1989a).

Risk from exposure to radioactive contaminants was estimated in accordance with the recommendations of EPA (EPA 1989c), BEIR IV (National Research Council 1988), and BEIR V (National Research Council 1990). As discussed in Appendix C, a population-weighted average excess risk factor of 6×10^{-7}/mrem was assumed. Appendix C presents the radiation doses associated with the scenarios considered in this assessment. These doses are expressed as committed effective dose equivalents resulting from a 1-year exposure, in mrem per year, for all exposure routes.

The risk is estimated as follows:

$$\text{Risk} = (\text{Dose})\ (\text{ED})\ (\text{RF})$$

where:

Risk = risk of cancer incidence, expressed as unitless probability
Dose = committed effective dose equivalent in mrem/year
ED = exposure duration in years
RF = radiological excess cancer risk factor, $6 \times 10^{-7}/\text{mrem}^{-1}$

EPA cancer slope factors, as presented in the 1993 HEAST tables (EPA 1993a), were also used to assess radiological risk. A comparison between the EPA slope factor methodology and the conventional approach used here indicates a small variance in risk estimates. Use of slope factors tends to estimate risks that are lower than risks estimated using dose conversion factors. The conventional method was selected for presentation in this baseline risk assessment because it allows the maximum use of site-specific exposure information, reduces uncertainty associated with the assessment, and is consistent with the approach mandated in DOE Order 5400.5 (DOE 1990).

The radiological risks associated with exposures to contaminants at the SIOU site are in addition to risks from exposure to natural sources of radiation. Radiation exposure from natural sources of radioactivity results in an annual dose of about 300 mrem/year: 200 mrem/year from exposure to ^{222}Rn and its short-lived decay products and 100 mrem/year from exposure to other natural sources of radiation (NCRP 1987). Using the radiological cancer risk factor of 6×10^{-7} per mrem, the background dose of 300 mrem/year results in a lifetime risk of cancer induction of approximately 1.3 percent (1.3×10^{-2}) (EPA 1989a). EPA has estimated that the individual lifetime risk of fatal cancer associated with background radiation, including radon, is 1×10^{-2},

so these estimates correlate well. This corresponds to an estimated, fatal lifetime cancer rate of approximately 1 individual out of 100 for background radiation.

The radiological health risks given in this document are reported as incremental risks above that resulting from exposure to background radiation. To achieve this, measured background soil concentrations for each of the radionuclides analyzed were subtracted from the concentrations measured in the soil and sediment samples taken from the contaminated areas. Background was subtracted to allow comparison with EPA's target risk range, which does not include the contribution from background sources of radiation.

3.5.3 Quantifying Chemical Risk and Hazard Index

3.5.3.1 Cancer risk

The risk to an individual resulting from exposure to chemical carcinogens is expressed as the increased probability of a cancer occurring over the course of a lifetime. To calculate the increase in cancer risk, the estimated daily intake of a chemical carcinogen averaged over a lifetime is multiplied by a chemical-specific slope factor. Oral and inhalation pathway-specific slope factors have been derived by EPA for certain carcinogens; some carcinogens do not have a slope factor available or are presently under review by EPA. All slope factors utilized in the risk estimate calculations presented in Appendix C were obtained from EPA's IRIS (EPA 1994), when available. If the slope factors were not available on IRIS, they were obtained from EPA's HEAST (EPA 1993a). If slope factors were not available from IRIS or HEAST, EPA's Superfund Health Risk Technical Support Center–Environmental Criteria and Assessment Office was contacted, and interim or provisional slope factors were obtained for use in the risk characterization, where available (EPA 1992c).

The slope factor converts estimated daily intakes averaged over a lifetime of exposure directly to the incremental risk of an individual developing cancer. The carcinogenic risk estimate is generally an upper-bound estimate because the slope factor is typically derived as the UCL_{95} of the probability of response, based on experimental animal data. Thus, EPA is reasonably confident that the "true risk" will not exceed the risk estimate derived through use of the slope factor and is likely to be less than that predicted using slope factors (EPA 1989a). The estimation of daily intakes (averaged over a lifetime) resulting from exposure to the chemical carcinogens of concern was described and available slope factors were identified.

3.5.3.2 Hazard indexes

The potential for adverse health effects other than cancer is evaluated as the ratio of the daily intake for the exposure period over the reference dose. This ratio is the hazard quotient.

The reference dose is a provisional estimate of the daily exposure to the human population, including sensitive subgroups (with uncertainty spanning perhaps an order of magnitude). The reference dose is a reference dose below which appreciable risk of negative health effects during a lifetime for chronic exposure (or during a portion of a lifetime for subchronic exposure) would not be expected to occur. EPA has derived reference doses for both chronic and subchronic exposure periods. In accordance with Superfund guidance, chronic exposures for human beings range in duration from 7 years to a lifetime; subchronic human exposures range in duration from 2 weeks to 7 years (EPA 1989a). Because the potential exposures considered in this baseline risk assessment are for periods of more than 7 years, only chronic reference doses are considered. Appendix C presents the estimated average daily intakes resulting from exposure to the chemical contaminants of potential concern at the site, and Section 4.2 identifies the reference doses for these contaminants.

The noncancer hazard quotient assumes that there is a level of exposure (the reference dose) below which it is unlikely for even sensitive populations to experience adverse, noncarcinogenic health effects. The hazard quotients for each chemical addressed in the intake and exposure pathway are summed to obtain the hazard index, which allows assessment of the overall potential for noncarcinogenic health effects (EPA 1989a). When the hazard index exceeds 1, there may be concern for potential adverse health effects. For exposure to multiple chemicals, as at SIOU, a summed hazard index which exceeds 1 indicates a potential health risk, even if no single chemical exposure exceeds its reference dose (hazard quotient < 1).

The assumption of dose additivity is most properly applied to chemicals that induce the same effect by the same mechanism of action (EPA 1989a). When the hazard index exceeds 1 as a result of summing several hazard quotients, it is appropriate to segregate the chemicals by effect and by mechanism of action.

3.5.4 Risk Estimates for the SIOU Site

For clarity of presentation, the risk estimates resulting from potential radiological and chemical exposures are presented separately in the following sections. Exposure estimates are presented for each exposure scenario for the RME conditions (RME receptor) and for the average exposure conditions (mean receptor).

3.5.5 Radiological Risk Estimates

Table 3.10 presents the radiological risks for the SIOU site. Potential risks as a result of exposure to contaminants found at the SIOU site were estimated for reasonable current uses and hypothetical future uses of the site properties.

Table 3.10. Summary of radiological risk for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Location	Receptor	Risk[a]	
		Mean	RME
Current use scenario			
SIOU	Employee	6×10^{-6}	6×10^{-5}
Future use scenario, all pathways			
SIOU	Employee	3×10^{-4}	4×10^{-3}
SIOU	On-site resident	4×10^{-3}	3×10^{-2}
White Oak Creek	Child wading	1×10^{-5}	2×10^{-4}
White Oak Creek	Resident	3×10^{-3}	3×10^{-2}
White Oak Dam (with water cover)	Resident	2×10^{-3}	7×10^{-3}
White Oak Dam (without water cover)	Resident	NE	5×10^{-3}
Clinch River (with water cover)	Resident	2×10^{-5}	2×10^{-4}
Clinch River (without water cover)	Resident	NE	5×10^{-3}

[a]Numbers are rounded to one significant figure.

Note: Shading indicates values that exceed EPA's target risk range.
NE = not evaluated
ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

3.5.5.1 Current use

Estimated RME and mean carcinogenic risks for occupational workers spending time both indoors and outdoors on the SIOU site were 5.7×10^{-5} and 5.9×10^{-6}, respectively. Gamma irradiation contributes 100 percent of the total radiological risk to the worker. As mentioned earlier, there is no significant migration of contamination from ORR from SIOU and, therefore, no off-site current exposure and negligible risk to residents or sensitive populations surrounding ORR.

3.5.5.2 Hypothetical, future use scenarios

A hypothetical future employee has RME and mean risks estimated at 3.6×10^{-3} and 3.4×10^{-4}, respectively. Both of these risks exceed the EPA's suggested target risk range. Gamma irradiation and particulate ingestion and inhalation while outdoors contribute approximately 52 percent, 23 percent, and 25 percent, respectively, to the total risk estimate.

These risk estimates are based on modeled radiological soil and sediment concentrations and assume that the protective water cover remains on the impoundments.

The estimated radiological risks for RME and mean exposures for a child wading in White Oak Creek are 2.1×10^{-4} for the RME scenario and 1.0×10^{-5} for the mean. Exposure pathway risk distribution in the future use scenarios is water ingestion and dermal contact, which contribute the majority of the risk.

For the hypothetical on-site resident, the RME risk is 3.4×10^{-2}, and the mean is 3.7×10^{-3}. Direct radiation, plant ingestion, water ingestion, and inhalation of particulates compose the majority of the risk. When the hypothetical resident scenario is moved to White Oak Creek, the risks decrease only slightly to 3.0×10^{-2} for the RME and 3.0×10^{-3} for the mean. Both the on-site resident as well as the resident at White Oak Creek exceed the EPA's target risk range.

The estimated RME and mean risks for the hypothetical resident consuming water at White Oak Dam are 6.7×10^{-3} and 1.9×10^{-3}, respectively. These values also exceed the EPA target risk range. When the hypothetical resident scenario is extended to reach Clinch River, the risk for the RME is 1.5×10^{-4} and 1.7×10^{-5} for the mean and could be considered to be within the EPA's target risk range.

3.5.5.3 Future risk to the off-site population

Risk to the future off-site population was calculated by using the EPA Clean Air Act Assessment Package—1988 (CAP88-PC) and is in compliance with DOE Facilities [40 CFR 61.93(A)] procedures to calculate effective dose equivalents to members of the public.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six sources. The sources may be either elevated stacks, such as a smokestack, or uniform area sources, such as a pile of uranium mill tailings or dried lagoon or impoundment. Plume rise can be calculated assuming either a momentum or buoyancy-driven plume. Assessments are done for a circular grid of distances and directions for a radius of 80 km (50 miles) around the facility.

The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food and intake rates for people from ingestion of food produced in the assessment area. Estimates of the radionuclide concentrations in produce, leafy vegetables, milk, and meat consumed by humans are made by coupling the output of the atmospheric

transport models with the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109, terrestrial food chain models.

CAP88-PC uses population arrays in the same format as the mainframe CAP-88 program. Sample population distributions for several DOE facilities are provided with CAP88-PC which were generated from a database of 1980 census data. Since census enumeration districts vary widely in size, the database is not precise at estimating population groups that are very close to a facility. Accordingly, the arrays can be modified with user-supplied supplemental data obtained from on-site population surveys. Distributions of beef cattle, milk cattle, and crop productivity are generated by the program for the assessment area using average agricultural productivity data for each of the 50 states. A library of meteorological data for dispersion estimates is supplied with CAP88-PC for most major cities and DOE facilities.

Dose and risk are estimated by combining the inhalation and ingestion intake rates, air and ground surface concentrations with the dose and risk conversion factors used in CAP-88. The effective dose equivalent is calculated using the weighting factors in International Commission on Radiological Protection (ICRP) Publication 26. Risks are based on lifetime risk from lifetime exposure, with a nominal value of 4×10^{-4} cancers/rem. Doses and risks can be tabulated as a function of radionuclide, pathway, location and organ. CAP-88-PC also tabulates the frequency distribution of risk, showing the number of people at various levels of risk. The risk levels are divided into orders of magnitude, from one in ten to one in a million.

The CAP88-PC programs represent the best available verified programs for the purpose of making comprehensive dose and risk assessments. The Gaussian plume model used in CAP-88-PC to estimate dispersion of radionuclides in air is one of the most commonly used models in government guidebooks. It produces results that agree with experimental data as well as any model, is fairly easy to work with, and is consistent with the random nature of turbulence.

The Office of Radiation Programs has made comparisons between the predictions of annual average ground-level concentration to actual environmental measurements and found very good agreement. In the recent paper "Comparison of AIRDOS-EPA Prediction of Ground-Level Airborne Radionuclide Concentrations to Measured Values" (Beal et al. 1986), environmental monitoring data at five DOE sites were compared to AIRDOS-EPA predictions. EPA concluded that as often as not, AIRDOS-EPA predictions are within a factor of 2 of actual concentrations. Appendix C gives the input parameters used in the modeling.

Risk from exposure to inhalation of particulates (primarily ^{239}Pu, ^{241}Am, and ^{137}Cs) migrating off site when the existing water cover is removed and the exposed sediments in the

impoundments dry up is 4.5×10^{-3} to a maximally exposed individual (RME) residing 3,505 m (11,683 ft) (Clinch River) from the site, as well as at 2,500 m (8,333 ft) from the site.

This value is significant when compared to the background incidental cancer rate. The risk to the maximally exposed individual is expected to be higher than that to the rest of the population within an 80-km (50-mile) radius of the SIOU site. This population risk evaluation is intended for use in as low as reasonably achievable (ALARA) evaluations consistent with the requirements of DOE Order 5400.5 (DOE 1990) and the implementing guidance for remediation activities (Gilbert et al. 1989). This process requires that, after the applicable radiation protection limits (e.g., dose) are met, the dose/risk shall be further reduced while taking into account technical, economic, and social factors.

3.5.6 Chemical Risk and Hazard Index Estimates

Risk characterization is the summation of information developed out of the site characterization, exposure assessment, and toxicity assessment. Risk or hazard is a function of both exposure and toxicity. Therefore chemical intake (exposure) estimates are converted to cancer risk and hazard indices by multiplying or dividing by a toxicity factor (slope factor or reference dose), respectively. Appendix C presents chemical cancer risk estimates, expressed as incremental lifetime cancer risks and hazard indices. These measures of site risk were estimated for reasonable, current land uses and hypothetical future uses of the site and surrounding property. Receptor scenarios evaluated for both land use conditions are the same as those evaluated for the radiological risks.

3.5.6.1 Current use scenarios

Appendix C presents calculations for incremental lifetime cancer risks and hazard indices for potential exposure to chemicals present in soil. The estimated incremental lifetime cancer risks for an employee are 1×10^{-6} (RME) and 2×10^{-8} (mean), which are both below the EPA target risk range. This suggests that potential risk associated with contact with chemicals present in SIOU under the exposures evaluated are acceptable. The hazard indices for the current employee spending time both indoors and outdoors at SIOU were less than 1 for both the RME and the mean. These values being less than unity suggests that adverse health effects are not likely to occur due to contact with chemicals from SIOU under the exposure scenarios evaluated.

3.5.6.2 Future use scenarios

Total RME and mean carcinogenic risks to a future employee are estimated to be 4×10^{-6} and 5×10^{-7}, respectively. Appendix C presents calculations. Risk to the employee is driven by combined inhalation of sediments from all four impoundments with Process Waste

Ponds 3539 and 3940 contributing most to the risk estimate through this pathway. However, the total cumulative risk is within the EPA target range, suggesting that risks are acceptable for the exposures evaluated. The hazard indices for the future employee were less than 1 for both the RME and the mean exposure, again suggesting that adverse health effects are not likely to occur, based on the exposures evaluated.

Total RME and mean carcinogenic risk estimates for the child wading scenario were 4×10^{-5} and 6×10^{-6}, respectively. Appendix C presents calculations. For this scenario, the primary pathways contributing to these risk estimates are ingestion of sediments and dermal absorption. The principal chemical within these pathways is N-nitrosodi-n-propylamine. As previously discussed, the exposure concentration in sediment in White Oak Creek was extrapolated from maximum predicted mass-loading to the creek from groundwater flow modeling. This modeling requires a Kd value, which may be conservative, given the nature of the subsurface soil, etc. However, both risk estimates are within the EPA target risk range. In addition, hazard indices estimated for this scenario are less than 1, suggesting that adverse health effects are not likely to occur, based on the exposures evaluated.

Total RME and mean carcinogenic risk estimates for a resident living at White Oak Creek near SIOU are 2×10^{-3} and 4×10^{-4}, respectively. Appendix C presents calculations. For this receptor scenario, the primary exposure pathways contributing to these risk estimates are ingestion of groundwater (i.e., surface water from White Oak Creek). The chemical contributing nearly 100 percent of the risk is N-nitrosodi-n-propylamine. As previously discussed, the exposure concentration in White Oak Creek was calculated from maximum predicted mass-loading to the creek from groundwater flow modeling, assuming dilution. This modeling requires a Kd value, which may be conservative, given the nature of the subsurface soil, etc. These risk estimates exceed the EPA target risk range, indicating that exposure to chemicals (primarily N-nitrosodi-n-propylamine) is unacceptable. However, the probability that White Oak Creek would actually be used as a domestic water source is very remote. The hazard indices estimated for this scenario are less than 1, suggesting that adverse health effects are not likely to occur, based on the exposure evaluated.

Total RME and mean chemical carcinogenic risk estimates for an off-site resident living near White Oak Dam are 9×10^{-4} and 2×10^{-4}, respectively. Again, ingestion of water (i.e., surface water in White Oak Creek at the dam) is the primary pathway contributing to the risk estimates. As previously discussed, the concentrations calculated in White Oak Creek at SIOU were used in estimating concentrations at the dam, assuming a dilution factor of 2. This is rather conservative, in that actual dilution is likely higher, resulting in lower exposure concentrations and thus risk. As discussed above, the primary chemical contributing to the risk estimates is

N-nitrosodi-n-propylamine. While both of these risk estimates exceed the EPA target risk range, risks are likely overestimated. Also, using White Oak Creek at the dam as a domestic source of water is highly unlikely. The hazard indices estimated for this exposure scenario are less than 1, suggesting that adverse health effects are not likely to occur, based on the exposure evaluated (Tables 3.11 and 3.12).

3.6 UNCERTAINTY IN THE ASSESSMENT PROCESS

The risks presented in the SIOU baseline risk assessment are single-point estimates of risk rather than probabilistic estimates. Therefore, it is important to attempt to specify the uncertainties inherent in the risk assessment to place the risk estimates in proper perspective.

A quantitative statistical analysis of uncertainty has not been performed. Instead, key assumptions and site-related variables that contribute most to the uncertainty have been identified. The uncertainty associated with each variable discussed is described as low (i.e., probably will not impact the risk outcome), moderate (i.e., may impact the risk outcome slightly), or high (i.e., is likely to significantly impact the risk estimate).

There are several categories of uncertainties associated with baseline risk assessments. These include:

- sampling data adequacy,
- selection of contaminants of potential concern,
- exposure assessment variables, and
- toxicity values.

In each of these categories, Appendix C presents a discussion on the radiological risk characterization, chemical risk characterization, and uncertainties for ecological risk assessment.

3.7 SUMMARY OF HEALTH RISK CHARACTERIZATION

3.7.1 Radiological and Chemical Risks

At SIOU, radiological risk from sediment contaminants in the bottoms of the impoundments dominate the baseline risk assessment. In almost every future scenario, the EPA's target risk range is exceeded, making for an unacceptable future risk. In addition, the risk from radiological contamination as compared to the chemical risk is often several orders of magnitude

Table 3.11. Summary of chemical carcinogenic risks for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Location	Receptor	Risk	
		Mean	RME
Current use scenario			
SIOU	Employee	2×10^{-7}	1×10^{-6}
Future use scenario			
SIOU	Employee	5×10^{-7}	4×10^{-6}
White Oak Creek	Child wading	6×10^{-6}	4×10^{-5}
White Oak Creek	Resident	4×10^{-4}	2×10^{-3}
White Oak Dam	Resident	2×10^{-4}	9×10^{-4}

ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

Table 3.12. Summary of chemical noncarcinogenic hazards for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Location	Receptor	Hazard index	
		Mean	RME
Current use scenario			
SIOU	Employee	0.004	0.008
Future use scenario			
SIOU	Employee	0.005	0.009
White Oak Creek	Child wading	0.0005	0.001
White Oak Creek	Resident	0.003	0.01
White Oak Dam	Resident	0.002	0.007

ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

greater in both the current and future scenarios. If chemical risks were the only consideration at SIOU, the associated risk from the chemicals present would not necessitate a remedial action.

Currently, there is no unacceptable on-site or off-site risk to employees or the public. Energy Systems monitors and maintains the protective water covers on the impoundments and handles any compromise in the berms surrounding the impoundments expeditiously. All monitoring station data indicate that contamination is limited to the immediate SIOU area and is not significantly migrating off site. As reported, all current risks are well within the EPA's acceptable target risk range.

For comparison purposes only, hypothetical scenarios were developed to estimate future risk from SIOU. These scenarios are conservative and assume that DOE would return ORR to its original, unrestricted farming, residential, or commercial land uses. In every one of these scenarios, the risks that were estimated suggest that a corrective action be taken to protect both on-site and off-site employees and residents. Again, the majority of the risk occurs when the protective water cover is removed by a drought condition or a berm failure, exposing the sediments in the impoundments, thus releasing large quantities of contamination to White Oak Creek. When contamination is modeled to allow off-site migration, the risk from contaminated drinking water at all locations is unacceptable for the RME.

The baseline risk assessment concludes that, when radionuclides such as ^{239}Pu, ^{242}Am, or ^{60}Co and ^{137}Cs in the soil and sediment are exposed, the on-site future risk to the employees or residents is always unacceptable. The pathways contributing the majority of the risk are direct radiation, inhalation of airborne particulates, and incidental ingestion of soil and sediment. Strontium-90, which is readily mobilized by water, accounts for the majority of the risk that results from off-site migration. The drinking water pathway is the main contributor to this risk.

When the protective water cover is removed, the airborne pathway results in unacceptable risk at both White Oak Creek and Clinch River.

3.8 BASELINE ECOLOGICAL RISK ASSESSMENT SUMMARY

This section presents a summary of the baseline ecological risk assessment for SIOU; Appendix C includes supporting documentation. This baseline ecological risk assessment evaluates risks to populations and communities of nonhuman organisms that are currently on the site or may live there in the future. It also assesses the contribution of the site contaminants to off-site risks.

3.8.1 Ecological Problem Formulation

Ecological problem formulation defines the scope of the assessment, the sources being assessed, the endpoints of the assessment, and the site conceptual model. The objective of ecological risk assessment is to provide a basis for decisions on remediation as it concerns risks to nonhuman species. The relative risks to receptors are estimated by comparing environmental concentrations of contaminants to toxicological benchmarks provided by the Risk Assessment Council at ORNL and EPA Region IV.

3.8.1.1 Potentially affected habitat and potentially exposed species

SIOU, which is composed of four man-made impoundments, has minimal natural habitat; however, some species may visit the site on a limited basis.

Impoundments 3513 and 3524. Fish were introduced into these impoundments in May 1977 (Garten, Trabalka, and Bogle 1982). Species included goldfish (*Carassius auratus*), channel catfish (*Ictalurus punctatus*), mosquito fish (*Gambusia affinis*), and bluegill sunfish (*Lepomis macrochirus*). These fish species supplemented an existing vertebrate fauna consisting of frogs (*Rana catesbeiana* and *R. palustris*) and possibly some turtles. In addition to aquatic species, birds and small mammals may forage in and around the impoundments.

Impoundments 3539 and 3540. Impoundments 3539 and 3540 do not contain fish and presumably do not contribute to groundwater contamination because they have a clay liner. Therefore, they were not included in the determination of risks to off-site receptors from migration of contaminants from SIOU or for impacts to piscivorous wildlife.

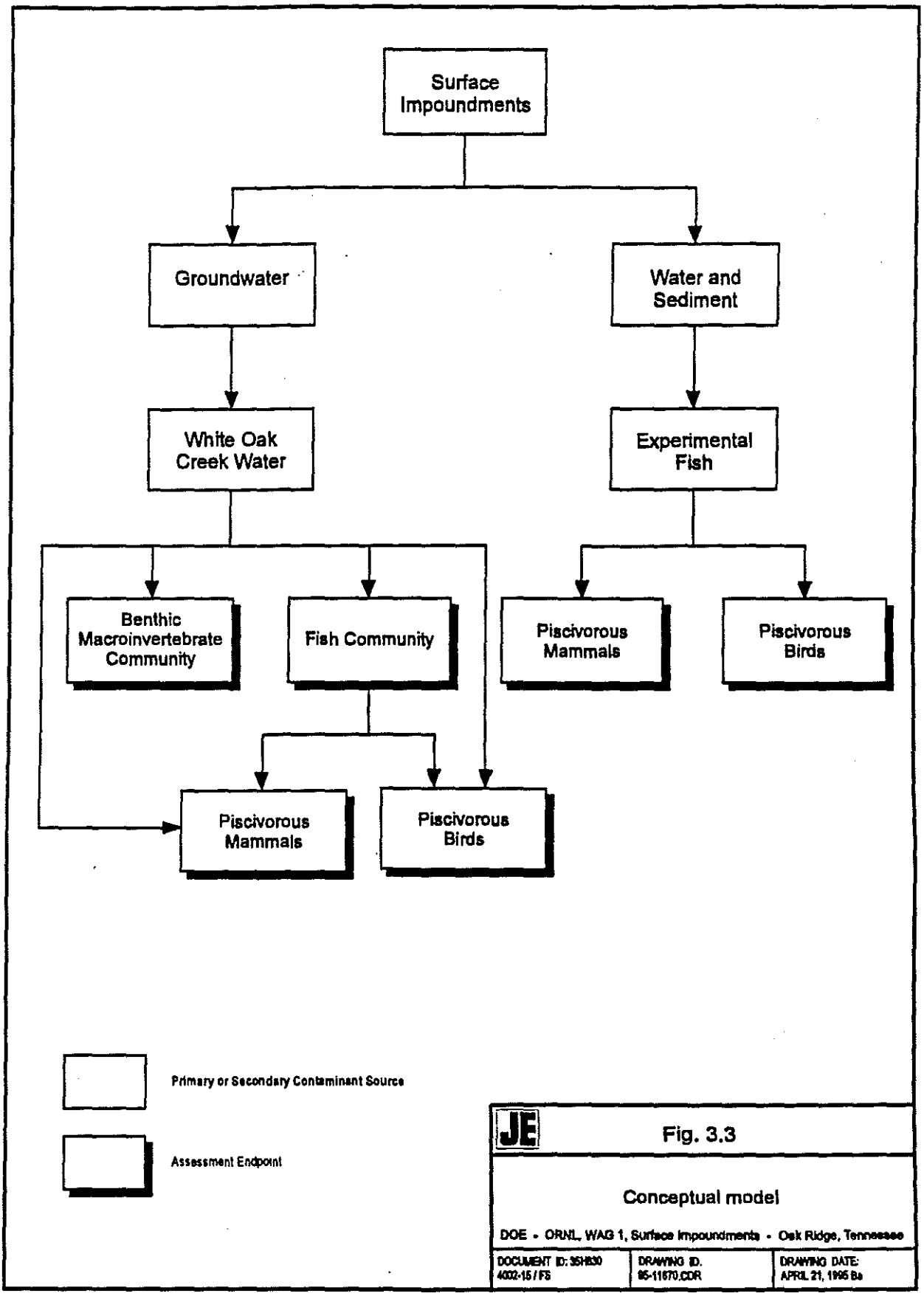
3.8.1.2 Ecological assessment endpoints

This baseline ecological risk assessment does not address aquatic receptors in SIOU. The surface impoundments are man-made, and the fish species that are present in the impoundments are experimental animals introduced several years ago. However, effects to fish and aquatic invertebrates were evaluated in White Oak Creek adjacent to SIOU, at White Oak Dam, and in Clinch River.

The belted kingfisher (*Ceryle alcyon*) and mink (*Mustela vison*) were selected as piscivorous endpoints.

3.8.1.3 Site conceptual model

The site conceptual model, which is illustrated in Figure 3.3, graphically represents the relationships between the contaminant sources and the endpoint receptors. It includes the SIOU


Surface Impoundments
Groundwater
Water and Sediment
White Oak Creek Water
Experimental Fish
Benthic Macroinvertebrate Community
Fish Community
Piscivorous Mammals
Piscivorous Birds
Piscivorous Mammals
Piscivorous Birds
Primary or Secondary Contaminant Source
Assessment Endpoint
JE
Fig. 3.3
Conceptual model
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DRAWING ID. 95-11670.CDR
DRAWING DATE: APRIL 21, 1995 Ba

sources, the receptors that are designated as assessment endpoint species, and the major routes that result in exposure.

3.8.2 Ecological Exposure Assessment

The only significant route of exposure for aquatic biota is respiratory uptake. Therefore, concentrations of contaminants in water constitute a complete model of exposure for aquatic biota.

The primary routes of exposure for terrestrial wildlife species are ingestion of food and surface water. Tables C5.3 through C5.16 present the total exposure of the endpoint receptors to contaminants of ecological concern in surface water and food items. Appendix C includes assumptions and equations for computing total exposure.

3.8.3 Ecological Effects Assessment

Effects assessment involves identifying known effects of contaminants on receptors using conventional and ambient toxicity data. These data will be used in the risk characterization section to evaluate risks to piscivorous wildlife at SIOU and White Oak Creek and aquatic biota in White Oak Creek and Clinch River. Contaminant concentrations and total estimated exposures are compared to benchmarks to compute a hazard quotient used in the risk characterization.

Appendix C includes toxicity information for the contaminants of ecological concern at SIOU.

3.8.4 Ecological Risk Characterization

The risk characterization in this assessment is performed for each assessment endpoint by (1) screening all measured contaminants against toxicological benchmarks, (2) estimating the effects of the contaminants retained by the screening analysis, and (3) discussing the uncertainties in the assessment.

3.8.4.1 Aquatic biota

Chemical Screening. Effects to aquatic biota were evaluated at White Oak Creek adjacent to SIOU, White Oak Dam, and Clinch River. In White Oak Creek adjacent to SIOU modeled concentrations of cadmium exceeded only the lowest chronic value for daphnids (hazard quotient = 1.3) (Table C5.14). Cadmium levels were below this benchmark at White Oak Dam (Table C5.15).

Modeled mercury concentrations (0.033 mg/L) exceeded several benchmarks for fish and daphnids in White Oak Creek (WCK 3.9) (Table C5.14) and at White Oak Dam (Table C5.15),

regardless of whether inorganic or methyl mercury was assumed to be the dominant form. However, in June 1994 measured mercury levels in White Oak Creek downstream of SIOU were 0.00002 mg/L (Hicks, personal communication), which exceeds only the Tier II chronic value for methyl mercury.

Modeled silver concentrations at WCK 3.9 (Table C5.14) and at White Oak Dam (Table C5.15) exceeded the secondary chronic value and the lowest chronic value for fish.

Effects Estimation. Weak evidence exists to support a risk to fish and benthic macroinvertebrate communities at WCK 3.9 resulting from exposure to cadmium. The lowest chronic value for daphnids (hardness = 53 mg/L) was exceeded only by a factor of 1.3. Sufficient dilution occurs in the creek at White Oak Dam to eliminate cadmium as a contaminant of concern.

Current mercury concentrations (< 0.00002 mg/L) in surface water in White Oak Creek adjacent to SIOU are not expected to impact the fish and benthic invertebrate communities. However, if the total mercury concentration is assumed to be methyl mercury, chronic toxicity could result. Chronic toxicity to methyl mercury was observed for cladocerans at values < 0.00007 mg/L (EPA 1984a).

Modeled mercury concentrations were estimated to be 0.0327, 0.0164 and 0.000065 mg/L in White Oak Creek (WCK 3.9), White Oak Dam, and Clinch River, respectively. Concentrations exceed the acute NAWQC, LC_{50}s for sensitive species of fish and invertebrates, and chronic values for most species (Tables C5.14 and C5.15), which suggests impacts to the fish and invertebrate communities, regardless of the mercury species present.

Modeled silver concentrations at WCK 3.9 and White Oak Dam were estimated at 0.0024 mg/L and 0.0012 mg/L, respectively. These values exceed the documented level that resulted in significant mortality for 18-month-old rainbow trout. Since silver concentrations are less than the acute toxicity values but are higher than the no-effect concentrations, the fish community may experience adverse effects.

Based on the model of Blaylock et al. (1993), radiation doses for small fish at WCK 3.9, White Oak Dam, and Clinch River were 0.024, 0.012, and 4.7×10^{-5} μGy/hour, which are below the NCRP benchmark of 400 μGy/hour considered protective of populations of aquatic organisms (NCRP 1991).

Ambient Toxicity Tests. The Biological Monitoring and Abatement Program (BMAP) has conducted aquatic toxicity tests on surface water downstream of SIOU (WCK 3.8) since 1986 using 7-d static renewal chronic toxicity tests based on the survival and growth of the fathead minnow (*Pimephales promelas*) larvae and the survival and reproduction of a daphnid (*Ceriodaphnia dubia*) (Ashwood, 1994). Toxicity test results from 1992 to 1994 suggest no evidence of toxicity to fathead minnow larvae or *Ceriodaphnia* (Stewart, personal communication).

Biological Surveys. The BMAP has conducted fish community surveys at WCK 3.9 for 7 years (Schilling 1994). The site has experienced substantial increases in fish densities since 1989 when no fish were found. The increase in fish population densities and biomass may be attributed to continued improvements in water quality from pollution abatement projects (Schilling 1993). Since the population of fish at WCK 3.9 has been substantially increasing over the past several years, there is no indication that predicted mercury concentrations from SIOU are affecting the abundance of the fish population.

Benthic macroinvertebrate surveys, which have been performed at WCK 3.9 since 1988, show adverse effects in the benthic invertebrate community there. A loss of sensitive Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa has occurred, and those present have low densities. These sensitive faunas are virtually absent at WCK 3.9, and total taxonomic richness is approximately one half of that typically observed in unimpacted streams. The invertebrate fauna at WCK 3.9 is dominated by midges (Chironomidae), which are more pollution tolerant. However, effects due to contaminants leaching from SIOU and many other factors, such as thermal discharges, residual chlorine, nutrient enrichment, and sediment loading, cannot be differentiated.

The future risks to fish and benthic invertebrate communities in White Oak Creek should not increase from current conditions.

3.8.4.2 Piscivorous wildlife

Chemical Screening. The contaminant exposure estimates for wildlife feeding from SIOU and White Oak Creek were compared to estimated NOAELs and LOAELs to determine if the contaminant exposure experienced by piscivorous wildlife is potentially hazardous. For this assessment, individual mink and kingfishers were assumed to feed at SIOU, WCK 3.9, White Oak Dam, and Clinch River. Risks for each location were evaluated by comparing the mean and maximum exposure estimates (using the mean and maximum bioconcentration factors) and the LOAEL. For any given contaminant, if exposure estimates for all sampling locations were below

LOAELs, adverse effects were assumed to be absent for populations; however, exposures exceeding the NOAELs could potentially cause effects to individuals.

Concentrations of mercury and PCBs (Aroclor-1254 and Aroclor-1260) in fish from SIOU exceeded NOAELs for mink and kingfishers (Tables C5.3 and C5.4).

Radiation exposures to kingfishers and mink at SIOU were estimated according to the methods of Blaylock et al. (1993). The total radiation dose to a kingfisher is 38.8 μGy/hour, which is below the IAEA benchmark of 42 μGy/hour considered to be protective of populations (IAEA 1992). However, the total radiation dose to a mink (44.8 μGy/hour) exceeds the IAEA benchmark.

The total exposures to Ag, Be, Cd, Cr, Aroclor-1254, and Aroclor-1260 for kingfishers and mink at WCK 3.9, White Oak Dam, and Clinch River were less than the estimated NOAELs. The mercury exposure to kingfishers, using fish collected downstream of SIOU, exceeded the NOAEL by eight times at WCK 3.9 (Table C5.8), and the total mercury exposure to mink at that site was equal to the methyl mercury NOAEL (Table C5.11). The most conservative exposure calculation for mink, using the maximum concentration potentially found in fish, resulted in cadmium exposures that exceed the NOAEL at WCK 3.9 and White Oak Dam by 2.4 and 1.2 times, respectively (Table C5.10). The total mercury exposure calculated from fish collected at WCK 3.9 was equal to the methyl mercury NOAEL (Table C5.11).

Effects Estimation. Mercury concentrations in the fish at SIOU resulted in unacceptable risk to mink. Acute effects are not expected in mink feeding from SIOU. However, exposures may be sufficiently high to produce chronic reproductive effects. Mercury concentrations in the fish in SIOU also resulted in risk to kingfishers. Exposure of kingfishers to mercury exceeded the NOAEL (hazard quotient = 33.6) and the LOAEL (hazard quotient = 3.4), suggesting acute or chronic adverse effects to the kingfisher population or individuals feeding from SIOU.

Aroclor-1254 concentrations in fish from SIOU resulted in risks to mink and kingfishers. Exposures from Aroclor-1254 exceeded the LOAELs (hazard quotient = 3 for kingfishers; hazard quotient = 2 for mink). No adverse effects from Aroclor-1260 in fish from SIOU are expected for the mink or kingfisher populations feeding there. However, there is a potential for adverse chronic effects to occur for individuals feeding from SIOU. Exposures of mink and kingfishers to Aroclor-1260 exceeded the NOAELs, but were only 47 and 69 percent of the respective LOAELs.

The total radiation dose to a mink at SIOU is 44.8 μGy/hour, which exceeds the IAEA chronic dose benchmark of 42 μGy/hour considered to be protective of populations (IAEA 1992).

Therefore, the potential exists for chronic effects to occur for mink feeding from the impoundments. Reproduction is the population attribute most sensitive to damage from chronic irradiation. The total dose to a kingfisher (39 μGy/hour) was similar to the chronic dose benchmark of 42 μGy/hour (IAEA 1992).

The maximum modeled exposure to mink resulted in cadmium exposure in excess of NOAELs at WCK 3.9 and White Oak Dam, but was only 18 percent and 10 percent of the estimated LOAEL at WCK 3.9 and White Oak Dam, respectively. Therefore, adverse effects from cadmium are possible, but not expected for mink feeding at these locations.

Estimated mercury exposure for kingfishers exceeded the NOAEL at WCK 3.9; however, the exposure estimate was 82 percent of the estimated LOAEL. Similarly, the mercury exposure for mink estimated from measured concentrations in fish in White Oak Creek was equivalent to the NOAEL and was 58 percent of the estimated LOAEL for methyl mercury. Because estimated exposures are less than the LOAEL, adverse effects from mercury are not expected among the kingfisher or mink populations feeding in White Oak Creek. However, the exceedence of the NOAEL suggests a potential for adverse effects to occur to individuals feeding from the stream.

Mercury exposures were not calculated at White Oak Dam and Clinch River because there was minimal risk to the kingfisher or mink found in White Oak Creek adjacent to SIOU (WCK 3.9). The concentrations currently found in fish at White Oak Dam and Clinch River may have accumulated mercury from multiple sources on the reservation. Therefore, the contribution of SIOU to mercury exposure at White Oak Dam and Clinch River cannot be assessed.

3.8.4.3 Preliminary remediation goals

The concentration of mercury in fish in SIOU (0.795 mg/kg) would have to be decreased to less than 30 percent of the current levels for there to be insignificant risks to piscivorous wildlife.

The concentration of Aroclor-1254 in fish in SIOU (23.8 mg/kg) would have to be decreased to less than one third of the current levels for risks to be insignificant to piscivorous wildlife.

Silver concentrations (0.0024 mg/L) in surface water at White Oak Creek (WCK 3.9) and White Oak Dam exceed the secondary chronic value and the lowest chronic value for fish. These modeled surface water concentrations appear to be conservative and may not truly be representative of the current surface water concentrations at WCK 3.9 or White Oak Dam.

However, if modeled concentrations are accurate, a preliminary remediation goal of 0.00012 mg/L (lowest chronic value for fish) would be established for silver.

The measured mercury (< 0.00002 mg/L) concentration at WCK 3.9 exceeded the secondary chronic value (0.000003) if methyl mercury is assumed. This value is considered an appropriate preliminary remedial goal; however, the value is below the practical quantitation limit for the analytical method.

The risk characterization for piscivorous wildlife feeding out of White Oak Creek (WCK 3.9) (Sect. 3.8.4.1) suggested no unacceptable risks for either piscivorous bird or mammal populations. Therefore, no PRGs are set for these endpoints.

3.8.4.4 Uncertainties

Appendix C includes uncertainties associated with this ecological risk assessment.

4. TECHNOLOGY AND ALTERNATIVE SCREENING AND ALTERNATIVE DESCRIPTIONS

This chapter identifies and screens remedial technologies and process options, then develops them into a range of remedial action alternatives for evaluation in Chapter 5. The potentially applicable technologies and options identified evolved from general response actions (developed during several meetings between DOE, Energy Systems, regulatory agencies, and consultants in 1993 and 1994) and from the remedial action objectives presented in this chapter. The meetings included observational approach and SAFER/Data Quality Objective workshops in November and December 1993 and February 1994 (CDM 1993, 1994).

Section 4.1 develops and presents the remedial action objectives selected to protect human health and the environment and identifies the general response actions that, alone or in combination, could meet those objectives. Section 4.2 screens the potential remedial technologies and identifies the representative process options retained for development into remedial alternatives. Section 4.3 assembles remedial action alternatives that meet the remedial action objectives from the representative process options, then screens those alternatives to select a reasonable range of alternatives to be carried forward for detailed analysis. Section 4.4 describes the selected alternatives in sufficient detail to allow evaluation against a set of established criteria in Chapter 5.

Note that the retained alternatives are representative and that the actual details of a remedial design could vary from those in the selected alternative. Also, combinations of the alternatives may be utilized, provided the remedial action objectives are met.

4.1 REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

This section identifies the remedial action objectives for remediation of SIOU and the general response actions that could be used, alone or in combination, to meet those objectives.

4.1.1 Remedial Action Objectives

The goal for remediation of this operable unit is to reduce to acceptable levels the risk to human health and the environment from the significant potential sources of contamination at SIOU. This will entail addressing the need for better environmental management of the contaminated sediments in the unlined impoundments (Impoundments 3513 and 3524). Accordingly, the operable unit includes contaminated sediment and surface water within the operable unit. Existing groundwater contamination is not included as part of SIOU.

Groundwater contamination has resulted from this or other sources within ORNL and will be considered in the Waste Area Grouping 1 Groundwater Operable Unit. Only the leaching of contaminants from the sediments into groundwater will be considered. Contaminated soils will be addressed consistent with other remedial actions, but remediation of soil is not an objective of remedial action for SIOU. Residual soil contamination will be considered under the Waste Area Grouping 1 3000 Area Soils Operable Unit.

The following remedial action objectives address protection of human health and the environment by reducing exposure to hazardous chemicals and radionuclides in the media of concern through pathways identified in the baseline risk assessment:

- minimize direct exposure, direct contact, inhalation, and ingestion by humans and animals with the contaminated sediments,
- reduce and/or control leaching of contaminants to drinking water sources,
- control potential future failure of the impoundments berm and embankments, and
- minimize the bioaccumulation of contaminants in sensitive ecological receptors.

The EPA target for remediation of CERCLA sites is to reduce risk from a site to within a range of 1×10^{-6} to 1×10^{-4}. Remedial actions can be developed to protect using engineering controls (e.g., removing the waste or isolating the waste from the environment in an engineered facility) or institutional controls (e.g., prohibiting access to the site). Depending on the extent of the institutional controls, the engineering controls can be designed to reduce risk to acceptable levels at different receptor locations. The locations selected for evaluation include on site, White Oak Creek, White Oak Dam, and off site at the Clinch River.

Sampling during closure, post-closure monitoring, and risk modeling based on the monitoring results will be used to verify that the remedial action objectives are met by establishing decision rules. Decision rules identifying specific cleanup levels, sampling plans, monitoring plans, and modeling requirements will be defined in the record of decision (ROD).

4.1.2 General Response Actions

General response actions that meet the remedial action objectives have been identified in the observational approach and SAFER/Data Quality Objectives workshops mentioned earlier and in EPA/TDEC/DOE working group meetings. The general response actions considered include:

- no action;
- institutional controls;
- containment;
- in situ treatment;
- removal;
- ex situ treatment;
- disposal; and
- liquids treatment and discharge.

These general response actions are used to develop the technology screening analysis in Section 4.2.

4.2 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGY TYPES AND PROCESS OPTIONS

For each general response action, potentially applicable technology types and process options are identified and screened in Figure 4.1. Among the more important references used to identify these technology types are:

- ORNL Remedial Action Technology Logic Diagram (ORNL 1993),
- ReOpt. Prepared for DOE (PNL 1990),
- Hazardous Waste Site Remediation (Grasso 1993), and
- Hazardous Waste Management (LaGrega, Buckingham, and Evans 1994).

As specified in EPA RI/FS guidance (EPA 1988), two steps are taken to reduce the number of technology types and process options that undergo detailed analysis. First, each process option is evaluated to determine if it is technically applicable at the site. To determine technical applicability, the capabilities of the process options are evaluated against the site conditions and the contaminant types and concentrations. Process options that are not technically applicable at the site or for the waste are eliminated from further consideration.

Figure 4.1 identifies and briefly describes each process option adopted for the general response actions under consideration. The discussion column in the figure identifies those process options screened out on the basis of technical applicability to site conditions or waste types.

General Response Action	Remedial Technology Type	Process Option	Description	Discussion
No Action	None	None	No actions	Carried through detailed analysis as required by NCP
Institutional Controls	Access and Use Restrictions	Physical Barriers	Fences, signs, or other barriers to limit site access	Potentially viable
		Shielding Barriers	Barriers of sufficient material and thickness to prevent penetration of β or γ radiation	Potentially viable
		Institutional Requirements	Institutional policies and procedures controlling employee access	Potentially viable
		Deed Restrictions	Covenants attached to a property deed prohibiting certain uses of the property	Potentially viable
	Maintenance and Monitoring	Surveillance and Maintenance	Inspections of facilities and performance of preventive or corrective measures to ensure proper operation	Potentially viable
		Monitoring	Sampling and characterization of waste, soils, surface water, groundwater, and air before to, during, and after remediation	Potentially viable

LEGEND

Screened out

Representative Process Option

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Fig. 4.1

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Results of process option screening

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General Response Action	Remedial Technology Type	Process Option	Description	Discussion
Containment	Surface Controls	Grading	Reshaping surface topography to manage storm water run-on and runoff	Carried forward as representative process option
		Revegetation	Systematic selection of suitable plant species, seedbed preparation, seeding/planting, mulching, fertilization, and maintenance	
		Diversion and Collection Systems	Trenches, berms, culverts, or other features to manage storm water run-on and runoff	
	Capping	Single-Layer Cap	Soil, clay, asphalt, synthetic membrane or other material used to contain waste and minimize infiltration of rainwater	Unlikely to provide adequate long-term protection
		Multilayered Cap	Appropriate combination of graded stones, native soils, clay, synthetic membranes and materials, asphaltic concrete, portland cements, or other materials used to contain waste, minimize infiltration of rainwater, and prevent intrusion	A containment option for use alone or in combination with other containment options
	Horizontal Subsurface Barrier	Injected Grout Sheet Barrier	Low-permeability barrier of chemical- or cement-based grout injected in a series of overlapping wells drilled horizontally or at an angle	The grout/clay barrier is considered more effective than a grout barrier and is representative of barriers for use in combination with in situ technolgies
		Injected Grout/Clay Sheet Barrier	Same as injected grout sheet barrier with addition of clay and other additives to enhance flow and retard setup of grout	
		Liner	Low permeability barrier placed in the bottom of an excavation. Barrier may include compacted clay layer, geomembrane, or other low-permeability materials. Liner may also include a drainage layer with a leachate collection system	A liner is considered more effective than an injected barrier and is retained as part of a containment system for relocated waste

LEGEND

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- Representative Process Option

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Fig. 4.1

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Results of process option screening

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General Response Action	Remedial Technology Type	Process Option	Description	Discussion
Containment *Continued...*	Vertical Subsurface Barrier	Sheet Pile Wall	Steel sheet piles driven until refusal to control shallow subsurface flow	Likely to leak at joints and at interface with bedrock - usually considered a temporary measure.
		Soil-Bentonite Slurry Wall	Trench excavated above and/or around contaminated area and filled with bentonite or soil-bentonite slurry to create a low-permeability barrier to shallow subsurface flow	The grout/clay misture sheet curtain is considered more effecive than the grout curtain and of comparable effectiveness as the slurry or composite walls. Because it is less costly and more implementable, the grout/clay curtain is selected as representative of vertical subsurface barrier
		Composite Sheet Pile and Grout Wall	Chemical or cement grout injected between parallel sheet pile walls to create a low-permeability barrier to shallow subsurface flow	
		Grout Sheet Curtain	Low permeability barrier of chemical- or cement-based grout injected in a series of overlapping vertical wells to create a low-permeability barrier to shallow subsurface flow	
		Grout/Clay Mixture Sheet Curtain	Same as grout sheet curtain with addition of clay and other additives to enhance flowability and retard setup of grout	
	Groundwater Suppression	Recovery Well Network	A well and pumping system used to extract contaminated groundwater or lower the water table	Because of ease of implementation, recovery wells are selected as representative of short-term groundwater suppression to enhance the effectiveness of removal or in situ treatment options
		Interceptor Trench (French Drain)	A trench filled with graded stone, possibly including a perforated pipe network or filter fabric. Used to intercept shallow subsurface flow or lower the water table	
		Ground Freezing/Cryogenic Barriers	Coolant pumped through piping loops freezes soil to form a barrier	Proximity to process waste treatment facility service lines prevents use due to probability of dislocating or freezing subsurface piping

LEGEND

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Representative Process Option

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Fig. 4.1

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Results of process option screening

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General Response Action	Remedial Technology Type	Process Option	Description	Discussion
In Situ Treatment	Physicochemical Treatment	Chemical Treatment	Addition of chemicals to waste in place to convert contaminants into less mobile species	Chemical treatment and permeable treatment beds may be considered as process modifications for other actions or contingency actions to correct poor performance. In situ stabilization/ solidification and drainage beds are representative of treatment processes that could be used in combination with containment options
		In Situ Stabilization/Solidification	Mixing stabilization and solidification materials into contaminated sediments and soils using large augers or soil mixing equipment. Intended to reduce mobility and leachability of waste	
		Permeable Treatment Beds	Downgradient trenches backfilled with ion exchange media remove contaminants from groundwater passing through the bed	
		Drainage Beds	Removal of excess water from sediments and soils by surcharging waste and collecting leachate	
		In Situ Soil Flushing	Phase separation process that uses solvents, water, or other agents to mobilize contaminants by dissolution or emulsification before extracting them from wellpoints	Because of the proximity of White Oak Creek, increasing the mobility of the contaminants would likely spread contamination before it could be extracted
	Thermal Treatment	In Situ Vitrification	Melting contaminated soils and solids in place using high-voltage electric current passed through electrodes in the ground. Produces a glass-like waste form of reduced volume and with low leachability. Produces gas waste stream from volatiles that requires treatment	Not applicable to site below water table or to cesium-contaminated media. Water cannot be driven off at a rate sufficient to allow vitrification
Removal	Solids Removal	Mechanical Excavation	Removal of soil or sediments with mechanically operated equipment such as backhoes, bulldozers, clamshells, draglines, etc.	Mechanical excavation will be necessary for relocation of any surface soil and could be used for sediment or subimpoundment soil
		Hydraulic or Pneumatic Dredge	Removal of bulk materials, sediments, granular materials, and liquids using barge or surface-mounted hydraulic pumps or air pressure to transport a slurry through a pipeline	The remotely controlled mobile dredge is considered the least costly, most effective, and safest method of moving radioactive sediments
		Remotely Controlled Mobile Dredge	Removal of sediments and possibly soils with a remotely operated, track-mounted dredge incorporating a cutter head and a hydraulic pump. The cutter head mobilizes submerged sediments toward the intake of the pump, which transports a sediment-water slurry via pipeline	

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- Screened out
- Representative Process Option

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Fig. 4.1

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Results of process option screening

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General Response Action	Remedial Technology Type	Process Option	Description	Discussion
Removal *Continued...*	Liquids Removal and Pretreatment	Pumping	Removal or relocation of surface water or extracted leachate or groundwater using conventional liquid movement technology	Pumping will be required for any liquid transfer processes
		Pretreatment	Preliminary removal of solids or other contaminants from liquid waste stream to meet waste acceptance criteria at treatment plant. Pretreatment processes could include settling filtration, ion exchange, carbon adsorption, etc.	Potentially viable, but only considered as a contingency if existing treatment plant cannot accept wastes
Ex Situ Treatment	Physicochemical Treatment	Sediment/Soil Washing	Agitating wastes with a mixture of water, solvents, surfactants, or chelating agents. Usually used to segregate less contaminated coarse particles from more contaminated fine particles. Sometimes used to segregate waste types	Because all contaminated materials are fine sediments, little volume reduction would result from soil washing. Segregation of the waste types at the operable unit would not be very effective and would not affect waste treatment or diposal options
		Mechanical Dewatering	Removal of excess water from sediments or soils using filter presses, vacuum belt filters, centrifuges, or other demonstrated technologies	Retained as representative technolgoy for volume reduction or as contingency for in situ dewatering
		Chemical Separation	Separation of mixed waste into chemical components for resource recovery of segregated disposal	Because of the high number of contaminants in the impoundments and their chemical behavior, a very complex treatment process requiring multiple extraction steps would be needed. Many extraction steps would have their own mixed or hazardous waste streams requiring additional treatment or disposal. The volumes of the chemical constituents are far too small to justify resource recovery

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Representative Process Option

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Fig. 4.1

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Results of process option screening

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General Response Action	Remedial Technology Type	Process Option	Description	Discussion
Ex Situ Treatment *Continued...*	Physicochemical Treatment *Continued...*	Stabilization/Solidification	Addition of stabilization and solidification chemicals and materials to contaminated media in a solidification facility. Transporting the mixture to containers or to a disposal facility for solidification into a low-leachability waste form	Representative of physicochemical and thermal ex situ treatment options
		Electrokinetic Removal	Low-level direct current applied to electrodes to create an acid front at the anode and mobilize contaminants toward the cathode for removal. Could be used as in situ or ex situ application	Technology is in pilot development. Uncertainties exist as to which contaminants will be mobilized and to what extent. Technology has not been proven effective on sites this large
		PCB Treatment	Removal or stabilization of PCBs using incineration, base-catalyzed destruction, or other technologies	Retained for alternatives that require treatment of PCBs in addition to hazardous and radioactive waste
	Thermal Treatment	Vitrification	Use of high-voltage electrical current or plasma arc heating to melt contaminated sediment and soil into a glass-like waste form. Requires secondary treatment of off-gasses from volatile contaminants	Potentially viable, but because of high cost for vitrification and limited effectiveness of thermal drying, neither thermal treatment option is selected as representative. The physicochemical treatment option of stabilization/ solidification adequately represents ex situ treatment
		Sediment/Soil Drying	Use of thermal heating (natural gas or other heat source), microwaves, or radio-frequency energy to volatilize liquids and reduce water content. Requires secondary treatment of off-gasses from volatile contaminants	

LEGEND

- Screened out
- Representative Process Option

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Fig. 4.1

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General Response Action	Remedial Technology Type	Process Option	Description	Discussion
Solids Disposal or Storage	Engineered Facility	Consolidation Cell	Consolidate wastes within an area of contamination within engineered barriers	Retained based on effectiveness, implementability, and cost
		Interim Waste Management Facility	Disposal at existing permitted, low-level waste disposal facility at ORNL	Facility has insufficient capacity for the volume of waste projected. Concentrations of contaminants exceed waste acceptance criteria
		Off-Site Disposal Facility	Packaging, transport, and disposal of waste at an existing off-site facility with adequate capacity and applicable waste acceptance criteria	Retained in the event that on-site management of the waste is not acceptable
	Storage	Long-Term on ORR	Packaging and transport of waste, placement of the waste in an adequate storage facility (new or existing), and long-term monitoring and maintenance of the facility	Retained in the event that no disposal options are available
Liquids Treatment and Discharge	Treatment/Discharge	ORNL Process Waste Treatment System	Pretreat (if necessary) surface water from impoundments and leachate or other waters resulting from treatment processes, treat at the existing Process Waste Treatment Plant and Nonradiological Wastewater Treatment Plant, then discharge at existing permitted NPDES point	The existing treatment system is selected as the representative liquids treatment option based on availability and cost
		New Treatment Facility	Design, obtain permit, and construct new facility to treat and discharge liquid wastes	

LEGEND

Screened out

Representative Process Option

JE

Fig. 4.1

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Results of process option screening

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Process options or technology types that do not pass this first screening step are not considered further, as indicated by a cross-hatched box in the figure.

In a second screening step, the remaining process options are evaluated more closely to determine which process options and technologies can be developed into remedial alternatives. The purpose of this evaluation is to select one or more process options to represent each technology type so an estimated cost can be developed for each alternative. The process option that appears to offer the best blend of effectiveness, implementability, and cost (at the conceptual level of investigation) is carried forward for development into remedial alternatives in Section 4.3. In some cases, process options in the same technology type are significantly different, and the analysis of one option may not accurately represent the other. In such a case, two or more process options in a technology type may be carried forward in Section 4.3 for alternative development. The representative process options carried forward to Section 4.3 are shown outlined by double boxes in Figure 4.1. Because the selected process options are representative of a technology type, options not carried forward may be reevaluated in the proposed plan, the ROD, or the remedial design process. Appendix D provides a discussion of the selection of representative process options from the retained options.

4.3 ASSEMBLY AND SCREENING OF ALTERNATIVES

The representative process options selected in Appendix D and indicated in Figure 4.1 are assembled in this section into a range of remedial action alternatives that, with the exception of the no action alternative, meet some or all of the remedial action objectives developed in Section 4.1.1. The range of alternatives begins with low-cost actions that protect human health by restricting public access to contaminated areas. Other alternatives add process options (and cost) to permit human access nearer to the existing contamination source areas. The range of alternatives ends with complete removal of the contamination from this source and allows for the least restrictive institutional controls.

Table 4.1 shows the alternatives assembled and the representative process options that would be used to implement the alternatives. After the assembly of technologies and process options into alternatives that would be protective, the alternatives are screened by comparing their effectiveness, implementability, and cost.

Effectiveness is indicated by the estimated preliminary risk levels provided on the table. As explained in Section 3.5, the EPA target for acceptable risk is between 1×10^{-4} and 1×10^{-6}. The risk levels indicated here are determined by simple modeling and conservative engineering judgment on the degree to which an alternative will reduce mobility of the source

Table 4.1. Alternative screening results for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

General Response Action	No action	Institutional controls	Containment						In situ treatment		Removal		Ex situ treatment			Solids disposal			Liquids treatment	Relative Cost	Preliminary Reasonable Maximum Exposure Risk			
Technology Group	No action	See note #1	Surface controls	Cap	Horizontal barrier		Vertical barrier	GW suppress.	Physicochemical treatment		Excavation		Physicochemical treatment			Engineered disposal facility		Storage	Treatment					
Representative Process Options / Remedial Action Alternatives	No action	See note #2	See note #3	Multilayered cap	Injected grout/clay sheet barrier	Liner	Grout/clay sheet curtain	Recovery well network	Drainage basin	In situ solidification	Mechanical excavation	Rail cart mobile dredge	Mechanical dewatering	Stabilize/solidify	PCB Treatment	Consolidation Cell	Offsite facility	Long-term at K-25	ORNL process waste treatment system		Clinch River	White Oak Dam	White Oak Creek	On-Site Resident
A No action — Water cover	●	T																		0	1E-04	7E-03	3E-02	No pathway
A No action — No cover																					5E-03	1E-02	6E-02	6E-02
B1 Multilayer cap and institutional controls		●	●	●							●								●	1	<1E-06	1E-04	2E-03	3E-03
B2 Multilayer cap, institutional controls, isolation		●	●	●	●		●				●								●	4	<1E-06	1E-04	1E-03	2E-03
C1 In situ treatment		●	●	●						●	●								●	2	<1E-06	1E-04	9E-04	1E-03
C2 In situ treatment and isolation		●	●	●			●			●	●								●	2	<1E-06	1E-04	7E-04	8E-04
D1 Consolidation cell		●	●	●		●		T	●		●	●				●			●	2	<1E-06	9E-05	3E-04	4E-04
D2 Consolidation cell with ex situ treatment		●	●	●		●		T			●	●		●		●			●	3½	<1E-06	9E-05	3E-04	3E-04
D3 Consolidation cell with ex situ treatment and subsurface vertical barrier		●	●	●		●	●	T			●	●		●		●			●	4	<1E-06	9E-05	2E-04	3E-04
E1 Removal and consolidation		●	●	●		●		T	●		●	●				●			●	2	<1E-06	<1E-06 [4]	<1E-06 [4]	<1E-06 [4]
E2 Removal, treatment, and off-site disposal			T					T			●	●		●	●		●		●	5½	<1E-06	<1E-06 [4]	<1E-06 [4]	<1E-06 [4]
E3 Removal, treatment, long-term storage, disposal			T					T			●	●	●				●	●	●	10	<1E-06	<1E-06 [4]	<1E-06 [4]	<1E-06 [4]

NOTES:
1. Technology groups: (a) Access and use restrictions and (b) Monitoring and maintenance
2. Process options: (a) Access and use restrictions - (1) Physical barriers; (2) Shielding barriers; and (3) Deed restrictions; (b) Maintenance and monitoring - (1) Surveillance and maintenance; (2) Long-term monitoring; and (3) 5-year CERCLA review
3. Surface control process options: (a) Grading, (b) Revegetation, and (c) Diversion and collection systems
4. Residual soil risk excluded. Risk is assumed to be adequately addressed by the soils and groundwater operable units.

ORNL = Oak Ridge National Laboratory SIOU = Surface Impoundments Operable Unit

Legend:

T Temporary – during remedial actions only

▨ Alternative not carried forward for detailed analysis

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contaminants and by applying that reduction in the source to the baseline risk assessment. In the detailed analysis of the alternatives in Chapter 5, the risk estimate is refined by more extensive modeling of anticipated site impacts after the remedial actions are in place.

Table 4.1 also shows estimated relative costs for the alternatives. These relative costs were based on a preliminary evaluation of fixed costs at the site plus the costs for the major process options. The costs are normalized such that the cost for the least expensive, action-based alternative (Option B1) is equal to 1, and the costs of the other alternatives are scaled relative to that alternative.

The purpose of this screening is to develop a reasonable number and range of alternatives to be retained for detailed analysis. Brief descriptions of the alternatives and justification for retaining an alternative or screening it from further consideration are provided below. Alternatives screened from further consideration in this FS are shown in shaded boxes in Table 4.1.

4.3.1 Alternative A—No Action

The no action alternative assumes that existing institutional controls, including actively maintaining the water cover on the impoundments, are maintained for a reasonable period of time, say 30–100 years. After the period of institutional control, the site is abandoned and this alternative becomes identical to the baseline risk assessment. During the period of institutional controls, this alternative is protective of human health to the receptor at Clinch River. This alternative is retained to provide a baseline for comparison with other alternatives as required by the National Contingency Plan.

4.3.2 Alternative B—Multilayer Cap and Institutional Controls

This alternative protects on-site workers through federal institutional controls and a cap that provides radiation shielding and prevents airborne contamination. The cap also protects human and ecological receptors from inadvertent intrusion. Although contamination of groundwater is likely to be unabated, institutional controls protect the public from exposure to groundwater and surface water contamination by restricting their access to these media. The alternative reduces the risk of failure of the existing containment system and of rapid release of contamination, particularly through the airborne pathway. Two variations of this alternative are considered.

4.3.2.1 Option B1

Option B1 includes removal and treatment of surface water; relocation of contaminated surface soils into impoundments as expedient; installation of a multilayer cap over the operable unit; and federal institutional controls, including (1) limiting access to the site, (2) prohibiting drilling of drinking water wells at the operable unit, and (3) prohibiting future residential, recreational, and agricultural land use within ORNL to the point where risk is acceptable. In this case, institutional controls would have to be maintained to Clinch River. Risks for receptors at any location closer than White Oak Lake are clearly unacceptable. This option is retained as a low-cost, easily implementable alternative that is protective, but requires the greatest level of institutional control.

4.3.2.2 Option B2

Option B2 adds horizontal and vertical barriers (injected grout/clay mixture sheet curtains and barriers) to the actions in Option B1. These barriers would reduce contaminant migration from the site for a limited period of time, but only minor reductions in risk on site and at White Oak Creek and no reduction in risk at White Oak Dam would be expected. Risk to receptors between the site and White Oak Lake would remain unacceptable. Installation of the horizontal barriers would be difficult to implement, and their effectiveness for reducing risk as predicted is questionable. The horizontal barriers also add significantly to the cost of this alternative. Because other alternatives are more protective at a lower cost, this alternative is screened from further consideration.

4.3.3 Alternative C—In Situ Treatment

In situ treatment protects on-site workers through institutional controls, waste stabilization, and capping. It provides radiation shielding, prevents airborne contamination, and protects human and ecological receptors from inadvertent intrusion with solidification and the cap. It protects the public from exposure to groundwater contamination by restricting their access with institutional controls. It reduces the risk of failure of the existing containment system and of rapid release of contamination. It reduces the rate of, but does not prevent, groundwater contamination. Two variations of the alternative are evaluated.

4.3.3.1 Option C1

Option C1 includes relocation of the surface soil (from within the radiological control boundary and contaminated above acceptable levels) to one or more of the ponds; removal and treatment of surface water; in situ stabilization/solidification (see Appendix D, Sect 1.4.1) of the sediment and contaminated soils in each pond; installation of a multilayer cap over the operable unit; and federal institutional controls. These institutional controls include (1) limiting access to

the site, (2) prohibiting drilling of drinking water wells at the operable unit, and (3) prohibiting future residential, recreational, and agricultural land use within ORNL to the point where risk is acceptable as determined by the degree of isolation of the waste and risk at the off-site receptor location, in this case, White Oak Dam.

There are three concerns regarding the effectiveness and implementability of this alternative. First, the mixing process used to stabilize the sediments and soil inherently mobilizes large amounts of airborne dust. Mobilization of the sediment in this fashion could create significant risk due to airborne plutonium and americium. The contamination could be contained using a high-efficiency particulate air-filtered structure around the stabilization process and by providing the operator with adequate personal protective equipment. However, this would significantly reduce productivity and increase cost. Second, the characteristics of the stabilized waste may not yield the risk reductions expected. Past studies show that in situ fixation is fairly effective in reducing the mobility of nonradioactive metals, but less effective for ^{90}Sr, which is the most mobile contaminant in the groundwater pathway. Third, QC of the in situ process is difficult to verify.

Assuming the actions can be implemented with reasonable effectiveness, the risk at White Oak Dam is estimated to be reduced to an equivalent degree as Option B1. On-site risk and risk in White Oak Creek are reduced, but remain unacceptable. The cost, not accounting for potential containment requirements and productivity losses, approximately doubles. This alternative is not carried forward for detailed analysis because (1) similar institutional controls are required as for the cap alone, (2) the cost is greater, and (3) there are significant uncertainties regarding implementability, effectiveness, and cost.

4.3.3.2 Option C2

Option C2 adds vertical barriers to reduce groundwater infiltration to the actions in Option C1. Preliminary risk estimates indicate the risk reductions on site and at White Oak Creek are improved, but remain outside the target risk range. The risk from this operable unit at White Oak Dam remains within the EPA target range. The concerns discussed above regarding effectiveness and implementability and the uncertainties regarding cost are sufficient to eliminate this option.

4.3.4 Alternative D—Consolidation Cell

The consolidation cell protects on-site workers through institutional controls, waste stabilization (if performed), and capping to provide radiation shielding and prevent airborne contamination. It protects human and ecological receptors from inadvertent intrusion with the cap, institutional controls and, if provided, solidification. The cell protects the public from

exposure to groundwater contamination by reducing migration of contamination and restricting access with federal institutional controls. It reduces risk of failure of the existing containment system and rapid release of contamination. Three options are considered.

4.3.4.1 Option D1

Option D1 includes removal and treatment of surface water; initial relocation of sediment from Impoundments 3524 to 3513; installation of an appropriate consolidation cell liner in the former location of Impoundment 3524; relocation of all sediment and pertinent contaminated surface soil within the operable unit to the consolidation cell; simple dewatering of the contaminated media through a leachate collection system in the consolidation cell; installation of a multilayer cap; and federal institutional controls. These institutional controls include (1) limiting access to the site, (2) prohibiting drilling of drinking water wells at the operable unit, and (3) prohibiting future residential, recreational, or agricultural land use within ORNL to a point determined by the degree of isolation of the waste and risk at the off-site receptor location. The risk at White Oak Dam would fall within the acceptable EPA target range. The risk on site and at White Oak Creek would be just outside the target range. This alternative is retained because it provides significant reduction in on-site risk at a reasonable cost.

4.3.4.2 Option D2

Option D2 adds to the actions in Option D1 ex situ treatment (stabilization/solidification) of sediment and possibly the soil (in lieu of dewatering) before placement in the consolidation cell. The addition of this treatment process could increase the likelihood that this alternative meets regulatory requirements for mixed waste. If hazardous constituents are sufficiently stabilized, the waste to be managed could be considered low-level waste, rather than mixed waste. This alternative would be more costly because the volume of waste (and the size of the cell) would be increased with the addition of stabilization materials, and new treatment equipment and operations would be needed. This alternative is also retained because there is a regulatory preference in the CERCLA cleanup standards [42 *United States Code* (USC) 9621, Sec. 121(b)(1)] for treatment to reduce toxicity, mobility, or volume of waste. It would be protective to a receptor at White Oak Creek.

4.3.4.3 Option D3

Option D3 adds vertical barriers to the actions in Option D2. This option is not retained for detailed analysis because vertical barriers would only add a small reduction in risk compared to the risk reduction offered by the liner and cap.

4.3.5 Alternative E—Removal, Treatment, and Disposal or Storage

This alternative protects on-site workers and human and ecological receptors by removing the majority of the contamination source from SIOU. It eliminates the risk of failure of the existing containment system and rapid release of contamination. It prevents additional contamination of groundwater from this source. Some residual contamination could remain despite best efforts to remove it. Also, as for all other alternatives, this alternative does not address existing contamination in soil outside SIOU or in groundwater (whether resulting from this operable unit or from other upgradient contaminant sources) or recontamination of the site from other sources. In other words, although no institutional controls would be needed after remediation at the SIOU site due to the operable unit sources as defined, federal institutional controls at SIOU and at downgradient receptor locations could still be needed due to other sources of contamination. Three variations of this alternative are considered.

4.3.5.1 Option E1

Option E1 is the construction of a consolidation cell outside the operable unit but within ORNL. The cell would be similar to Alternative D, Option D1 or D2, but would have three major advantages: (1) a site could be selected that is more hydrogeologically isolated from groundwater or surface water, (2) the site would be outside of the main working area of ORNL and remote from high employee concentrations, and (3) a cell complex could be designed to have sufficient capacity to accommodate wastes from other similar impoundments within ORNL. Transport of the treated or untreated waste from the SIOU site to the consolidation cell would add to the cost and technological difficulty. This option is retained because it could offer better isolation of the waste from the environment and, although more costly for SIOU, could offer economies of scale if remediation of other impoundments could be accomplished using the same equipment, methods, and contractor.

4.3.5.2 Option E2

Option E2 includes removal and treatment of surface water, removal of all sediments, removal of soils within the operable unit contaminated above acceptable limits, treatment of both sediments and soils as required to meet pertinent disposal facility waste acceptance criteria, containerization of treated wastes, and transport of all treated wastes to one or more off-site disposal facilities. Nevada Test Site is designated as the representative facility for disposal (see Appendix D, Sect. 1.7.1). Wastes would be segregated, if practical, treated to remove PCBs as necessary, and treated to meet land disposal restrictions, using stabilization/solidification as the representative process option so that waste no longer exhibits hazardous characteristics and can be classified as low-level waste. This option is retained for detailed analysis in the event that regulators or the public do not accept management of the wastes on ORR.

4.3.5.3 Option E3

Option E3 includes removal and treatment of surface water, removal of all sediments, removal of soils within the operable unit contaminated above acceptable limits, mechanically dewatering both sediments and soils to reduce waste volume and meet applicable storage facility waste acceptance criteria, containerization of treated wastes, and transport of all treated wastes to an interim storage facility on ORR. When a mixed-waste disposal facility that can accept the waste is available, the waste would be treated as required to meet the waste acceptance criteria, transported to the disposal facility, and disposed of. This option is not retained for detailed analysis because no mixed-waste disposal facility that could accept these wastes currently exists, the treatment requirements for such a facility are undefined, the interim costs for construction and operation of the storage facility would be high, and the duration of storage is unknown.

4.3.6 Summary of Retained Alternatives

Of the alternatives and options discussed above, six alternatives are retained for detailed description in Section 4.4 and detailed analysis in Chapter 5. Table 4.2 identifies the six alternatives and discusses how each alternative is intended to address the remedial action objectives developed in Section 4.1.1.

4.4 DETAILED DESCRIPTIONS OF ALTERNATIVES

The following descriptions of the remedial alternatives retained for detailed analysis by the screening process in Section 4.3 are intended to provide sufficient information for the detailed analysis and comparison of alternatives in Chapter 5. These detailed descriptions provide feasibility-level design criteria. Appendix F, "Alternative Cost Estimates," provides additional details that were assumed only for purposes of developing the cost estimate.

The level of detail provided is sufficient to assure that the remedial actions can be implemented. However, details regarding material quantities, construction techniques, locations of facilities and structures, use of representative process options, and other items may be revised during preparation of the proposed plan, the ROD, or the remedial design. Furthermore, the remedial alternative selected in the proposed plan or the ROD is not restricted to the actions proposed for a single alternative. Key elements from two or more proposed alternatives could be combined, if appropriate.

Each alternative description includes descriptions of (1) base remedial actions, which address probable site conditions and expected remediation results; (2) process modifications (if any) that could be developed during remedial design or remedial implementation activities and

Table 4.2. Addressing remedial action objectives for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Alternative	Remedial action objective			
	Minimize direct exposure, direct contact, inhalation, and ingestion of contaminants	Control leaching of contaminants to drinking water sources	Control potential future failure of the impoundments berm/embankment	Minimize bioaccumulation of contaminants in sensitive ecological receptors
Alternative 1—No action	Maintaining water cover and prohibiting access will meet objective during period of institutional control. Will not meet objective thereafter	Prohibits access to drinking water sources up to Clinch River during period of institutional control	Operational controls and monitoring moderately effective during period of institutional control. Not effective thereafter	Not effective
Alternative 2—Multilayer cap and institutional controls	Cap will minimize direct exposure, direct contact, and inhalation of contaminants for life of cap. Prohibiting access from the SIOU site to Clinch River will minimize ingestion from waterborne pathways	Prohibits access to drinking water sources up to Clinch River	Structural stability somewhat improved	Contaminated ponds are eliminated and fish in the impoundment are no longer in the food chain. Lesser contamination in White Oak Creek continues
Alternative 3—Consolidation cell with simple dewatering	Cap and liner will minimize direct exposure, direct contact, inhalation, and ingestion of contaminants for life of cap	Controls leaching with cap and liner	Structural stability improved	Isolates contamination from ecological receptors
Alternative 4—Consolidation cell with ex situ treatment	Cap and liner will minimize direct exposure, direct contact, inhalation, and ingestion of contaminants for life of cap. Treatment will reduce risk of inadvertent intrusion for a longer period	Controls leaching with cap and liner	Structural stability improved	Isolates contamination from ecological receptors
Alternative 5—Off-operable unit consolidation cell	Will minimize risk at SIOU site and all points downgradient. Risk at consolidation cell site will be the same as Alternative 3	Controls leaching with cap, liner, and geologic isolation	Structural stability improved	Isolates contamination from ecological receptors
Alternative 6—Removal, treatment, and off-site disposal	Removal will minimize all long-term risks. Short-term risks during removal, treatment, transport, and disposal will increase	Eliminates contamination source	Eliminates contamination source	Eliminates contamination source

ORNL = Oak Ridge National Laboratory
SIOU = Surface Impoundments Operable Unit

would not significantly affect effectiveness, implementability, or cost; and (3) contingency actions (if any) to address reasonable deviations to probable site conditions and expected remediation results that could have more significant implications. During implementation of the base actions or process modifications and during the life of the engineering controls, a monitoring plan would be implemented to determine if any deviations from the probable conditions occur. Results of the monitoring would indicate whether actions would be required to address the deviations.

Deviations from site conditions or alternative-specific regulatory or technology uncertainties (if any) that could demand the use of additional process options (e.g., require use of a new treatment process) and would significantly affect effectiveness, implementability, or cost are identified for each alternative. If such deviations occur, contingency actions required to address them are discussed. Early identification of potential deviations and development of appropriate contingency actions (1) allow preparation of a ROD based on probable conditions that can be readily implemented and (2) allow development of approved monitoring and contingency plans to avoid the need for additional document preparation and regulatory and public approval if identified deviations occur.

4.4.1 Alternative 1—No Action

In the no action alternative, existing institutional controls are assumed to be maintained for 30-100 years, after which all controls are eliminated and the site is returned to residential use. The costs of site-wide institutional controls, including requirements such as training, guards, and badges, are not included in the cost estimate. The cost of continuing to implement site-specific institutional controls (such as maintaining an adequate depth of water on the ponds for shielding and containment) is included for a 30-year period (the standard duration used for remedial costing purposes). No containment, treatment, removal, or disposal actions are taken in this alternative. No process modifications or contingency actions are considered for this alternative.

4.4.2 Alternative 2—Multilayer Cap and Institutional Controls

Alternative 2 would include a multilayer cap to protect against airborne contamination and direct exposure to the waste and institutional controls to limit access and exposure to groundwater contamination.

As described in Section 4.3.2.1, Option B1, contamination of groundwater from the impoundments would continue, and institutional controls would be required to the Clinch River due to the contamination from this source. Additional controls could be needed due to contamination from other sources and would be defined in the ROD for the Waste Area Grouping 1 soils and groundwater operable units.

4.4.2.1 Base actions for Alternative 2

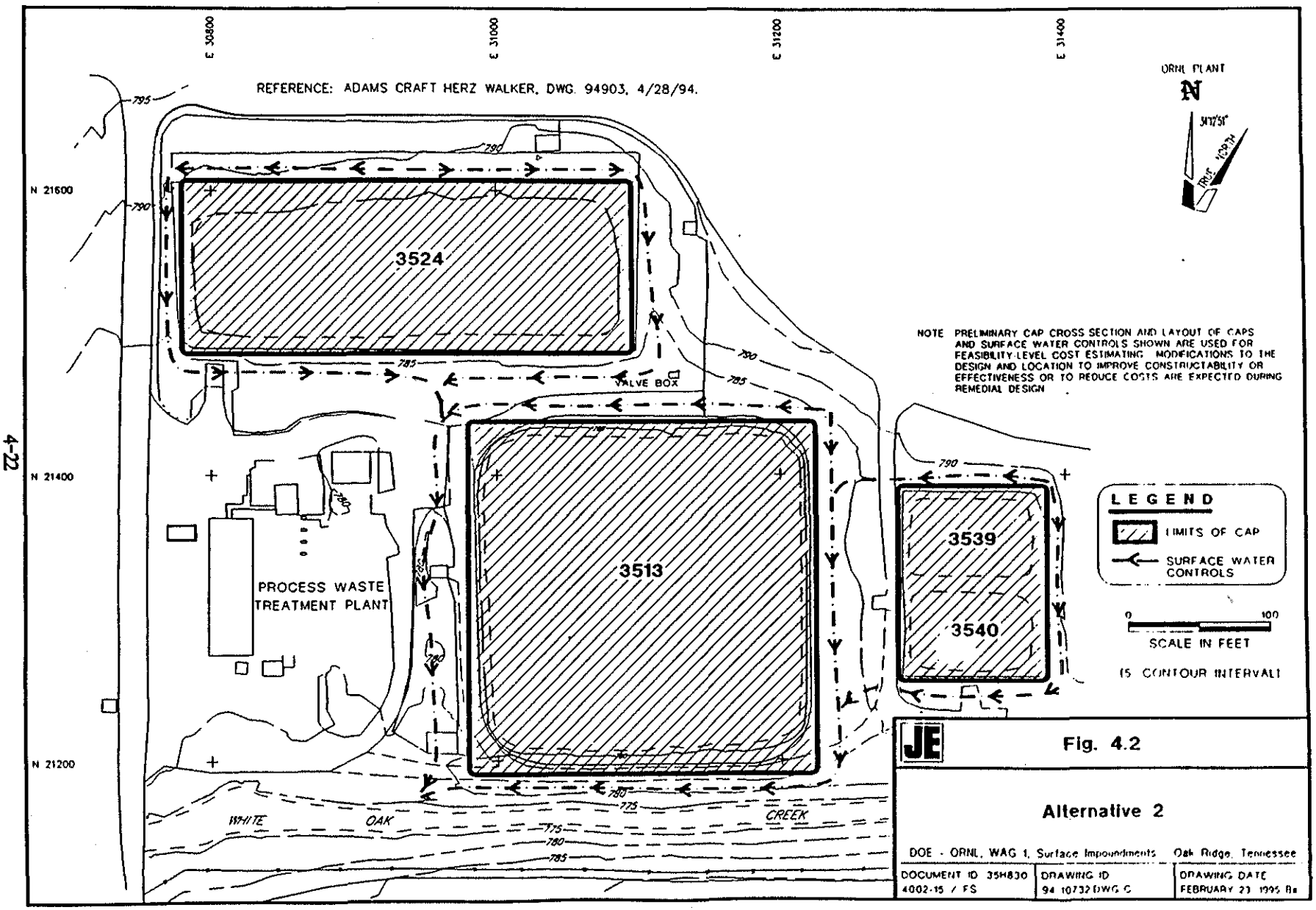
Figure 4.2 depicts the remedial actions for this alternative. A description of the sequence of events in implementing the actions follows.

1. **Initial actions and site preparation.** Mobilization activities could include installation of a construction office and equipment yard, a decontamination trailer, and a small, on-site laboratory to perform certain analyses required during remediation. Existing overhead power lines, steam lines, and other active utilities would be relocated as required. Barriers and signs would be installed and other institutional controls would be implemented during the construction period. Temporary surface water controls would be installed around the site to divert run-on away from the site and toward White Oak Creek, as required. Monitors for detection of airborne particulate matter would be installed, as necessary.

2. **Relocate contaminated surface soil.** Contaminated materials, including site-preparation-generated waste and soils as required, will be placed into one or more of the ponds with conventional excavation equipment. Decision rules would be developed and used during the closure verification sampling program as described in Section 4.1.1 to verify removal of contaminants required to meet the remedial action objectives for the Clinch River receptor.

3. **Install cap.** The cap for this alternative is intended to prevent airborne contamination and provide shielding to prevent direct radiation. The cap design and installation methods described here and shown in Figure 4.2 are used for cost estimating in this FS. Actual details of the cap design would be developed during remedial design to meet the objectives, if this alternative is selected.

   While maintaining the water shielding, fill and/or geotextile materials will be placed over the waste in the ponds to prevent displacement of the contaminated waste and provide a structural base for the cap. This will include a shielding and intrusion barrier. The shielding/intrusion material would be placed in the existing shielding water, which would gradually be removed as the new layer began to provide adequate shielding to the remediation workers. The shielding water would be pumped to the process waste treatment system. During placement of the cap and removal of the water, radiation levels would be monitored and material would be added until shielding is adequate. After placement of the intrusion and shielding barrier over all of the ponds and removal of water from the ponds to the greatest extent practical, an erosion


E 30800
E 31000
E 31200
E 31400
N 21600
N 21400
N 21200
REFERENCE: ADAMS CRAFT HERZ WALKER, DWG. 94903, 4/28/94.
ORNL PLANT
N
3524
3513
3539
3540
VALVE BOX
PROCESS WASTE TREATMENT PLANT
WHITE OAK CREEK
NOTE PRELIMINARY CAP CROSS SECTION AND LAYOUT OF CAPS AND SURFACE WATER CONTROLS SHOWN ARE USED FOR FEASIBILITY-LEVEL COST ESTIMATING. MODIFICATIONS TO THE DESIGN AND LOCATION TO IMPROVE CONSTRUCTABILITY OR EFFECTIVENESS OR TO REDUCE COSTS ARE EXPECTED DURING REMEDIAL DESIGN.
LEGEND
LIMITS OF CAP
SURFACE WATER CONTROLS
0
100
SCALE IN FEET
(5' CONTOUR INTERVAL)
JE
Fig. 4.2
Alternative 2
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control surface layer would be added. The cap would be graded to drain toward the surface water controls to reduce infiltration of surface water into the waste. Surface water controls would be upgraded for long-term use. A topsoil layer would be placed over the areas where contaminated surface soil had been removed, and the site would be seeded to establish vegetation. A fence and warning signs would be installed at the perimeter of the site.

4. **Long-term actions.** Institutional requirements would be implemented, and deed restrictions would be filed with the county clerk, prohibiting drilling of drinking water wells, excavation for building foundations or other purposes without permission, and residential, recreational, or agricultural land use for the SIOU site in perpetuity. A buffer zone would be established around the site, prohibiting construction of any permanent structures (without permission) that would interfere with future monitoring or remedial actions. Additional institutional requirements and deed restrictions would prohibit use of surface water for drinking in White Oak Creek, White Oak Lake, and the outfall from White Oak Dam to Clinch River. Additional restrictions may apply, resulting from other contamination sources. A long-term biannual inspection and maintenance program would be implemented to visually examine the cap and verify its integrity, the absence of burrowing animals and deep-rooted plants, and effectiveness of the surface water controls and to correct any deficiencies. A long-term monitoring program would be implemented to sample four groundwater monitoring wells, one located upgradient from the site and three located downgradient from the site. Modeling would be used to confirm that risk at the Clinch River receptor location would remain within acceptable levels. (Note that after installation of the cap, a temporary increase in migration of contamination out of the cell would be expected. The increase is not expected to cause excessive risk at the receptor location.) A 5-year CERCLA review of the continued effectiveness of the controls would be prepared, based on the inspection and monitoring results, and submitted for approval by regulatory authorities.

4.4.2.2 Monitoring and contingency actions for Alternative 2

Inadequate treatment capacity at process waste treatment system. This alternative assumes that all water removed from the impoundments will be treated at the existing ORNL process waste treatment system (for description, see Appendix D, Sect. 1.8.1). The treatment capacity at the Process Waste Treatment Plant is limited and may not be adequate to handle the volume of waste resulting from this remedial action at an acceptable rate. After wastewater is treated at the Process Waste Treatment Plant, it is further treated at the Nonradiological Wastewater Treatment Plant. The Nonradiological Wastewater Treatment Plant has ample

capacity for the waste resulting from this remedial action. If the ORNL Process Waste Treatment Plant cannot accept the remedial action wastewater, a package treatment plant containing filtration media and zeolite ion exchange canisters will be used to remove radiological contaminants. The wastewater will then be discharged to the Nonradiological Wastewater Treatment Plant.

4.4.3 Alternative 3—Consolidation Cell With Simple Dewatering

Alternative 3 would consolidate all wastes within SIOU in an engineered containment cell in the current location of Impoundment 3524. The final configuration of the consolidation cell would include a multilayer liner and a multilayer cap to isolate the waste from the environment.

As described in Section 4.3.4.1, Option D1, the consolidation cell would isolate the wastes sufficiently so federal institutional controls would only be required at the site of the consolidation cell and possibly at White Oak Creek. A receptor at White Oak Dam would not be exposed to unacceptable risk due to the contamination from SIOU. Additional institutional controls could be required to address other sources of contamination and would be defined in the ROD for the Waste Area Grouping 1 soils and groundwater operable units.

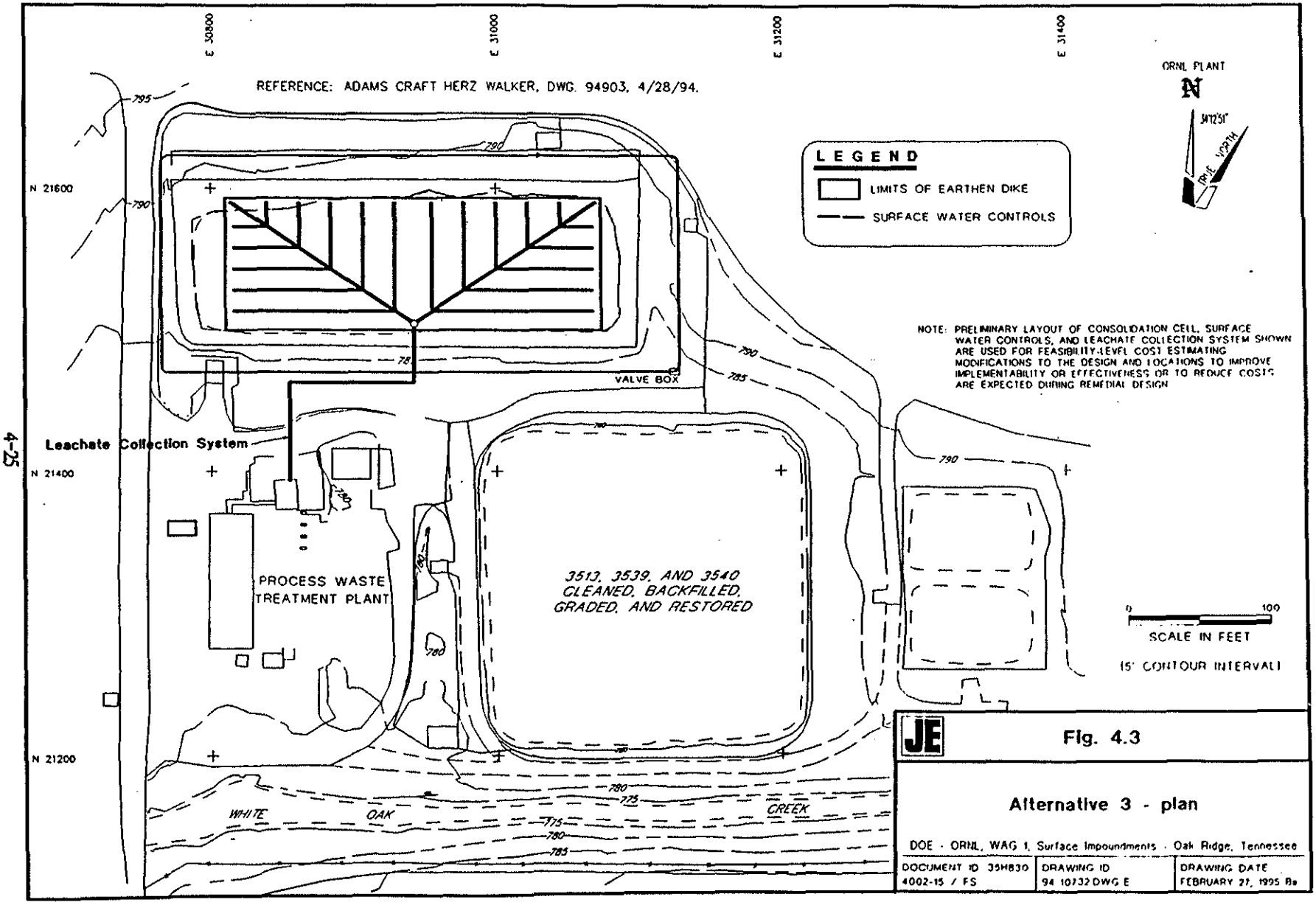
4.4.3.1 Base actions for Alternative 3

The sequence of events in implementing the remedial actions for this alternative follows. Figure 4.3 shows a plan view of the consolidation cell. Figure 4.4 shows a cross-section of the liner and the closure cap.

1. **Initial actions and site preparation.** Same as Alternative 2.

2. **Relocate contaminated materials from Impoundment 3524 to 3513.** By using a remotely operated hydraulic dredge (or other solids removal equipment, see Appendix D, Sect. 1.5.1), contaminated sediment and soils as required would be relocated from Impoundment 3524 to 3513. The dredge is expected to adequately remove almost all sediment and soil contaminated above acceptable levels. Silt screens or baffles could be placed around the dredge and discharge to Impoundment 3513. This will reduce mobilization of sediment suspended in the water by the dredging activities.

   All slurry pipelines would be designed to adequately contain and provide radiation shielding for untreated waste. A sufficient depth of water would be used for shielding of radiation emitted from the settled sediment in both ponds. To maintain water shielding when surface water is transferred with the slurry from Impoundment 3524 to 3513, excess water from Impoundment 3513 could be pumped back into


E 30800
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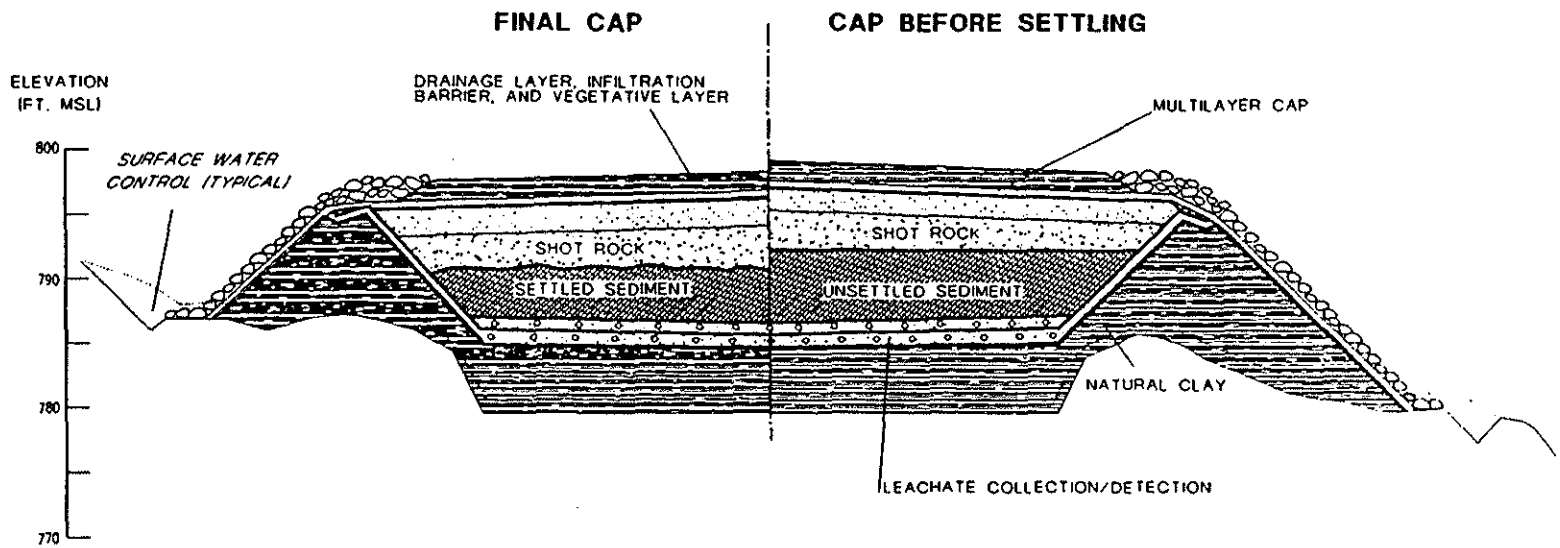
ORNL PLANT
N
34°12'51"
TRUE NORTH
LEGEND
LIMITS OF EARTHEN DIKE
SURFACE WATER CONTROLS
NOTE: PRELIMINARY LAYOUT OF CONSOLIDATION CELL, SURFACE WATER CONTROLS, AND LEACHATE COLLECTION SYSTEM SHOWN ARE USED FOR FEASIBILITY-LEVEL COST ESTIMATING. MODIFICATIONS TO THE DESIGN AND LOCATIONS TO IMPROVE IMPLEMENTABILITY OR EFFECTIVENESS OR TO REDUCE COSTS ARE EXPECTED DURING REMEDIAL DESIGN.
Leachate Collection System
VALVE BOX
PROCESS WASTE TREATMENT PLANT
3513, 3539, AND 3540 CLEANED, BACKFILLED, GRADED, AND RESTORED
WHITE OAK CREEK
795
790
785
780
775
0
100
SCALE IN FEET
(5' CONTOUR INTERVAL)
JE
Fig. 4.3
Alternative 3 - plan
DOE - ORNL, WAG 1, Surface Impoundments - Oak Ridge, Tennessee
DOCUMENT ID 35H830 4002-15 / FS
DRAWING ID 94 10732 DWG E
DRAWING DATE FEBRUARY 27, 1995 Rev



PROCESS WASTE POND 3524 - CONSOLIDATION CELL

NOTE: PRELIMINARY CAP CROSS-SECTION SHOWN IS USED FOR FEASIBILITY-LEVEL COST ESTIMATING MODIFICATIONS TO THE DESIGN TO IMPROVE CONSTRUCTABILITY OR EFFECTIVENESS OR REDUCE COSTS ARE EXPECTED DURING REMEDIAL DESIGN

0 30
HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION 2X

JE

Fig. 4.4

Alternative 3 - section

DOE - ORNL, WAG 1, Surface Impoundments Oak Ridge, Tennessee

DOCUMENT ID 35H830 4002-15 / FS	DRAWING ID 94-10999 DWG C	DRAWING DATE FEBRUARY 23, 1995 Re

Impoundment 3524. While the slurry is being transferred to Impoundment 3513, the solids will remain suspended in the water for a period of time. No special shielding requirements due to the suspended materials are necessary; however, administrative or operational controls should be implemented to maintain dose rates ALARA. For example, a flocculent could be added to the slurry to increase the settling rate, thereby reducing the amount of contamination suspended in the water. Likewise, transfer operations could be suspended for a period of time to allow settling and reduce the levels of suspended material, or a header could be used at the pipe outlet to more evenly distribute the slurry and reduce its discharge velocity. Silk curtains or baffles could also be used.

Small amounts of debris, stones, and other contaminated solid materials are expected to be found in the ponds. Appropriate procedures will be in place to remove sediment in the presence of such material. The solid material will be handled as addressed in Step 4.

3. **Relocate surface water from Impoundment 3524.** Surface water could be pumped from Impoundment 3524 to 3513, 3539, and 3540. Water could also be transferred to the process waste treatment system. Specific water management procedures will be defined during remedial design. As the water is removed from Impoundment 3524, radiation levels would be monitored to ensure that exposure due to residual contamination is within acceptable limits with the water shielding removed. If radiation levels are unacceptable, either the water shielding or local shielding for the remediation workers would be maintained during subsequent liner installation (Step 5 actions), and surface water would be removed following those actions.

4. **Relocate remaining contaminated materials from Impoundment 3524.** During this step, some amount of groundwater infiltration into Impoundment 3524 is expected. An appropriate level of water (based on shielding requirements, see Step 3) would be maintained during final cleanup of the pond by pumping excess water to the other ponds, to the storage tank, or to the process waste treatment system, as required.

   As required, residual contaminated solid materials would be removed from Impoundment 3524 using conventional excavation equipment. If radiation levels are acceptable, the solids could be stored in a stockpile with suitable protection. Otherwise, these materials could be placed in a corner of one of the other impoundments such that the water in the impoundments would provide adequate shielding.

When bedrock is encountered during waste removal, a visual inspection would be performed to determine if any karst features are present that would require sealing. If such features are detected, conventional techniques could be used to stabilize them.

5. **Install liner and leachate collection/detection system.** The open excavation at Impoundment 3524 would be enlarged to provide adequate waste storage capacity in the consolidation cell. Using clean borrow from within an 8-km (5-mile) radius of the operable unit, a compacted clay liner would be installed in the consolidation cell. Some dewatering during construction of the clay liner should be anticipated. Collected groundwater would be stored on site or sent to the process waste treatment system. The top of the clay liner would be above the seasonal fluctuation of the groundwater table. The upper surface of the clay liner would be sloped as required for leachate collection.

   The leachate collection/detection system will be designed per current practice. The drainage system would discharge to a sump area, where a pipe extended to the surface would allow placement of a pump to remove any leachate. However, special design provisions will need to be made to accommodate the added load of in situ dewatering.

6. **Install temporary shielding at consolidation cell.** Water would be used for temporary radiation shielding to protect workers during placement of waste in the consolidation cell and would be installed as follows.

   a. Close valves on leachate collection system so that liner is watertight.

   b. Pump water from Impoundments 3513, 3539, 3540, and/or the storage tank to Impoundment 3524, maintaining sufficient water depth in all ponds for shielding.

   c. Add water from other sources, if necessary, to account for evaporation and other losses.

Note: The sequence of Steps 7, 8, 9, and 10 are representative scenarios. The details of the steps and the representative process options used could be modified, as appropriate, during remedial design.

7. **Consolidate pumpable contaminated materials in cell.** Using procedures described in Steps 2, 3, and 4, all pumpable contaminated materials would be transferred from

Impoundments 3513, 3539, and 3540 to the new consolidation cell. Contaminated solid material from the stockpile or the other ponds (including riprap lining the sides of Impoundments 3539 and 3540) would be directed into the cell through the water shielding and into the sediment. Water could be pumped between the consolidation cell and the ponds, as required, to maintain adequate shielding and sufficient water to mobilize sediment for the dredging operations. Excess surface water and any groundwater infiltrating into the ponds or the cell could be pumped to the process waste treatment system.

8. **Remove and consolidate contaminated solids.** Contaminated surface soil, as required, and construction-generated waste within the operable unit but outside the impoundments or embankments would be removed as described for Alternative 2, Step 2. The closure inspection program would be implemented to verify removal of all contamination required to meet the remedial action objectives for the White Oak Dam receptor. The contaminated material would be consolidated into the cell with the sediment in an arrangement expedient to the design.

9. **Replace water shielding with rock.** Using conventional equipment, a geocomposite layer for filtration and structural stability could be placed on top of the settled sediment and soil. This layer will allow solid material to be placed in the cell without displacing the sediment and will also allow the use of lightweight conventional equipment in placing additional layers.

   Clean shot rock would be placed on top of the geocomposite, using a dragline or similar equipment. After placement of adequate rock for radiation shielding, water would be removed to the top of the rock surface. The leachate collection system would begin operation to remove water from the cell.

10. **Install and maintain cap.** The shot rock will be capped with an appropriate design to prevent run-on and enhance gravity surcharge dewatering of the waste. Operation of the leachate collection system would continue until the contaminated materials within the cell were sufficiently dewatered and no additional settling was expected. It has been assumed that sufficient surcharge will be added to complete the consolidation in two years. Process modifications described in Section 4.4.3.2 address additional actions that could be used to consolidate the waste if engineering support studies indicate the need.

11. **Redress cap.** After monitoring for verification of removal of all sediment and solid materials contaminated above cleanup levels, the excavated ponds would be backfilled with clean soil, covered with topsoil, and seeded with grass or native plants. A topsoil layer would be placed over the areas where contaminated surface soil had been removed, and the site would be seeded to establish vegetation.

    The final cap details will be developed during remedial design, and performance will equal or exceed the guidelines provided in EPA 625/4-89/022. After the waste is sufficiently dewatered in the consolidation cell so that settlement will not affect the final cap, the cover will be redressed as required for a permanent arrangement. A permanent fence and warning signs would be installed at the perimeter of the site.

12. **Long-term actions.** Long-term actions would include those described for Alternative 2, Step 4, except that prohibitions on the use of surface water due to contamination from this operable unit would extend only to White Oak Creek and would not include White Oak Lake and points downstream. Note that additional restrictions due to contamination from other sources could still apply.

4.4.3.2 Process modifications for Alternative 3

Before and during implementation of the remedial actions for the probable conditions addressed previously, engineering support studies and other monitoring of the site conditions and the effectiveness of the actions would be performed. The following is a discussion of minor process modifications for Alternative 3 that could be implemented to address any observed effects.

Poor sediment and soil dewatering characteristics. Engineering support studies performed before the remedial actions would indicate if the sediment and soil would retain excessive water and if the consolidation cell would not become structurally stable after implementation of the base actions for a reasonable period of time. If surcharging the waste with the temporary cap and collecting the leachate were shown to be inadequate, the remedial design could include the following process modifications. (1) After placement of the temporary cap, additional clay, stone, or other material could be added to the cap to further surcharge the waste and drive the water into the leachate collection system. (2) After placement of the temporary cap, a vacuum could be drawn on the leachate collection system to enhance recovery of interstitial water. (3) During placement of the waste, enhanced permeability zones could be included to provide a route for water to flow through relatively impermeable layers of waste to the leachate collection system. The enhanced permeability zones could consist of wicks, or horizontal or

vertical layers of sand and gravel or geocomposite. (4) Structural or chemical stabilization materials could be added to the waste in situ during and after placement into the consolidation cell. Structural materials could include sand to displace water or dry bentonite to absorb water. Chemical materials could include sulfide ions to precipitate mercury into a less leachable waste form, zeolite to adsorb ^{90}Sr, and/or lime or cement to absorb water, lower the pH, and add structural stability. Such addition of materials would increase the volume of the waste and the size required for the consolidation cell. The viability of such options would be assessed in the engineering support studies.

4.4.3.3 Monitoring and contingency actions for Alternative 3

Following is a discussion of the monitoring requirements for identification of deviations from probable site conditions and expected technology performance. Contingency actions to address any deviations detected by the monitoring program are also discussed.

Excessive volume of sediment and soil. The consolidation cell will be designed to accommodate the maximum volume of contaminated wastes anticipated.

In situ dewatering not practical. If engineering support studies indicate that the in situ dewatering methodology described would not be effective even with appropriate process modifications, then ex situ mechanical dewatering (see Appendix D, Sect. 1.6.1) could be used before placing waste in the cell. The steps of the remedial action would be similar to those described for Alternative 4, except that mechanical dewatering would be used instead of stabilization/solidification in the treatment steps. Material handling and placement systems would be designed to provide adequate shielding to protect remediation workers before the cap is in place. Also, structural stabilization could be utilized to supplement the design.

Cell Breaches. If monitoring or visual observation of the cap indicates an unacceptable condition in the consolidation cell, the following actions could be performed. Note that an initial transient surge of groundwater contamination would be expected from surcharging the residual soils and would not indicate cell leakage. Breaches in the cap and liner would be identified and repaired, if possible. A stone-filled lateral recovery trench could be installed downgradient from the cell and upgradient from the monitoring wells, and collected groundwater would be sampled and treated, as required. Alternately, a zeolite-filled, permeable treatment bed could be installed in the same location.

Inadequate treatment capacity at process waste treatment system. See Section 4.4.2.2.

Karst. This potential deviation is addressed in the base actions, Step 4. No additional monitoring or contingency actions are required.

4.4.4 Alternative 4—Consolidation Cell with Ex Situ Treatment

Alternative 4 would treat all of the pumpable contaminated constituents within the operable unit and consolidate them in an engineered containment cell in the current location of Impoundment 3524. The representative treatment process option described here is stabilization/solidification (see Appendix D, Sect. 1.6). Other treatment options, such as mechanical or thermal dewatering or ex situ vitrification, could also be used. Contaminated surface soil, as required, could be placed in the consolidation cell with or without treatment. If this alternative is selected, selection of the treatment process would be determined in the ROD or remedial design process based on engineering support studies. The final configuration of the consolidation cell would include a liner and a multilayer cap for isolation as described in Alternative 3, but adds an ex situ treatment step to stabilize the waste.

As described in Section 4.3.4.2, Option D2, the consolidation cell would isolate the wastes sufficiently such that federal institutional controls would only be required at the location of the consolidation cell, and a receptor at White Oak Creek would not be exposed to unacceptable risk due to contamination from SIOU. Additional institutional controls could be required to address other sources of contamination and would be defined in the ROD for the Waste Area Grouping 1 soils and groundwater operable units.

4.4.4.1 Base actions for Alternative 4

The sequence of events in implementing the remedial actions for this alternative is described here. Actions and detailed descriptions for Steps 1–4 are the same as for Alternative 3, Section 4.4.3. An engineering support study would determine the type and amount of stabilization and solidification material needed for treatment and the volume increase that would occur.

1. Same as Alternative 3.

2. Same as Alternative 3.

3. Same as Alternative 3.

4. Same as Alternative 3.

5. **Relocate contaminated pumpable material and solid material from Impoundments 3539 and 3540.** Using the methods described in Alternative 3, Steps 2–4, the contaminated sediment, subimpoundment soil, as required, and solid material from Impoundments 3539 and 3540 would be removed and stored in Impoundment 3513 or stockpiled, as appropriate. Surface water would also be removed from Impoundments 3539 and 3540 when no longer necessary for shielding and would be sent to the process waste treatment system.

6. **Construct treatment facility.** After backfilling Impoundments 3539 and 3540 with clean fill, a temporary stabilization/solidification facility would be constructed at their former location or another suitable nearby location. The treatment facility would be shielded and remotely operated. The facility would be designed, based on engineering support studies, to create a structurally stable and low leachability waste form. It will include a stabilized waste curing, storage, and testing area. A temporary storage yard with adequate shielding and containment features will hold the waste for a sufficient curing period until it solidifies.

7. **Install liner and leachate detection system.** A compacted clay liner and leachate collection system would be installed in the consolidation cell in a similar manner as described in Alternative 3, Step 5.

8. **Treat pumpable contaminants.** The pumpable contaminants from Impoundment 3513 would be relocated to the new treatment facility using a remotely operated hydraulic dredge or other appropriate equipment. If the treatment process units described in Step 5 are used (as determined during remedial design), the following treatment steps would be taken.

   The waste would be thickened, mixed with stabilization and solidification agents, and placed and consolidated in shielding/containment forms. The waste would be sampled at various points in the process, and appropriate quality assurance (QA) controls would be implemented.

   The filled forms would be transferred to the storage yard and allowed to cure. After curing, the solidified waste would be tested for structural integrity. Improperly solidified waste would be recycled for additional treatment. The stabilization/ solidification process is assumed to double the volume of the contaminated material.

When no longer required for shielding, the surface water in Impoundment 3513 would be removed and treated at the process waste treatment system. As required, solid materials from Impoundment 3513 would be stockpiled with the solid materials from the other ponds.

9. **Transfer waste into consolidation cell.** After the waste is solidified within the forms, the forms would be moved with the waste into the consolidation cell. Standard construction equipment would be used to move the solidified waste into the cell. The waste would be carefully placed to preserve the integrity of the liner and would be stacked in arrays to minimize void spaces. Voids could be filled with contaminated surface soil, sand, clay, bentonite, or similar material to provide additional structural stability of the waste in place and to reduce preferred pathways for flow of any water introduced into the cell. The additional volume of waste due to the stabilization/solidification process and the shielding containers would be accommodated by increasing the volume of the cell above the ground surface. This will increase the length of the side slopes and decrease the length of the top slope.

10. **Place contaminated solids in cell.** Remaining contaminated solid materials would be placed over the solidified sediment in the consolidation cell using mechanical excavation equipment. The solids would be placed in lifts, and each lift would be compacted before placing additional soil.

11. **Install closure cap.** After all solid waste material is in the consolidation cell, the closure cap would be installed. It would be similar in design to the cap described for Alternative 3 (Sect. 4.4.3.1, Step 12). The elevation of the top of the cap would be higher because the solidified waste volume for this alternative would be greater than the dewatered waste volume in Alternative 3.

12. **Demobilize treatment facility and restore empty ponds and remainder of site.** After completion of treatment, the treatment facility would be demobilized, decontaminated to the extent possible, removed from the site, and dispositioned appropriately. The excavated ponds would be backfilled with clean soil, covered with topsoil, and seeded with grass or native plants.

13. **Long-term actions.** The long-term actions described for Alternative 3 (Sect. 4.4.3.1, Step 12) would be implemented.

4.4.4.2 Monitoring and contingency actions for Alternative 4

Following is a discussion of the monitoring requirements for identification of deviations from probable site conditions and expected technology performance. Contingency actions to address any deviations detected by the monitoring program are also discussed.

Cell Breaches. The likelihood that the consolidation cell will release unacceptable levels of contamination is less for this alternative than for Alternative 3. However, similar monitoring and identical contingency actions as described for this deviation for Alternative 3 could be implemented.

Inadequate treatment capacity at process waste treatment system. See Section 4.4.2.2.

Karst. This potential deviation is addressed in the base actions. No additional monitoring or contingency actions are required.

4.4.5 Alternative 5—Off-SIOU Consolidation Cell

Alternative 5 would remove all sediments, all contaminated soils as required, and the surface water from the operable unit. Pumpable solids would be treated as appropriate and transported to a consolidation cell located in a hydrogeologically suitable area within ORNL. Surface water would be treated to acceptable levels and discharged.

As described in Section 4.3.5.1, Option E1, after closure of the SIOU site, no federal institutional controls would be required due to contamination from SIOU. Institutional controls at the site could be required to address other sources of contamination and would be defined in the ROD for the Waste Area Grouping 1 soils and groundwater operable units. Institutional controls would be required at the site of the new consolidation cell.

A major advantage of this alternative is that there would be no restrictions on the size of the off-SIOU consolidation cell. Therefore, other impoundments at ORNL but outside of SIOU could also be remediated, using the consolidation cell for management of the wastes by constructing subcells in phases. A preliminary screening of impoundments within ORNL has identified several other impoundments that might be compatible with the wastes and the remediation technologies proposed for SIOU. This issue is currently being investigated separately from this RI/FS. The cumulative estimated volume of sediment in these other impoundments is less than one third of the total sediment volume in SIOU.

For cost estimating purposes, a potential location of the off-SIOU consolidation cell is near the Waste Area Grouping 5 Process Waste Sludge Basin, one of the candidate impoundments. If this alternative is selected, a final location for the consolidation cell will be designated in the proposed plan or the remedial design.

The off-SIOU consolidation cell could be modeled after Alternative 3, which includes simple dewatering, or Alternative 4, which includes an ex situ treatment process (stabilization/ solidification). If treatment is selected, the treatment plant could either be centrally located (i.e., at the site of the consolidation cell) or located at the remediation site. If the plant were located at the remediation site, the main advantage would be that treated waste would be transported to the consolidation cell; the main disadvantage would be that the treatment plant would have to be demobilized, partially decontaminated, and transferred to each new remediation site. For simplicity, the only option receiving detailed description and analysis is the off-SIOU consolidation cell with simple dewatering. The waste transport requirements for raw sludge would be identical to those required for a centrally located treatment plant. The differences in cost and effectiveness for simple dewatering versus treatment can be surmised by comparing Alternatives 3 and 4.

4.4.5.1 Base actions for Alternative 5

The sequence of events necessary to implement the remedial actions for Alternative E, Option E1, is described below.

1. **Initial actions and site preparation.** Same as Alternative 2 for SIOU. Additionally, the site selected for the consolidation cell would be cleared and grubbed as necessary. An equipment yard, a decontamination trailer, and a waste transfer station could be established as needed at the site. Adequate roadways would be provided between the operable unit and the consolidation cell site. Fencing and signs would be installed and other institutional controls implemented at the consolidation cell site. Temporary surface water controls would be installed to divert run-on away from the site.

2. **Construct off-SIOU consolidation cell.** At the designated location, an adequately sized consolidation cell would be excavated, a liner and leachate collection/detection system would be installed (similar to that described in Alternative 3, Step 6), and clean water would be placed in the cell for temporary shielding, as required. The cell could be constructed in phases or subcells to accommodate waste from other sources.

3. **Transfer pumpable contaminated materials from all ponds to consolidation cell.** Using equipment such as a remotely operated hydraulic dredge, contaminated sediment and soil from an impoundment would be pumped into a tanker truck or other waste transfer system. The transfer equipment and systems would be designed to adequately shield and contain the slurry for transport to the consolidation cell. The slurry would be discharged into the consolidation cell using the methods described for Alternative 3, Step 2. If necessary, water from the consolidation cell could be pumped into the waste transfer system, transported, and discharged into the impoundment being dredged to replace any shielding water used to mobilize the sediment and soil into a slurry. This process would be repeated until all dredgable media contaminated above acceptable levels is removed from the four impoundments at the operable unit.

4. **Remove surface water from impoundments.** Surface water could be pumped from the impoundments to the process waste treatment system. As described in Alternative 3, Step 3, radiation levels would be monitored and adequate shielding would be maintained.

5. **Transfer remaining contaminated solid materials to consolidation cell.** The remaining solid materials would be decontaminated as practical, reduced in size if necessary, and transported to and placed in the consolidation cell. No grouting of karst features would be required since the contamination source would be removed.

6. **Remove contaminated solid materials and place in off-SIOU cell.** Same as Alternative 3, Step 8. The closure monitoring program would be implemented to verify removal of contaminants required to meet the remedial action objectives for the White Oak Creek receptor. After monitoring the operable unit for verification, the excavated ponds would be backfilled with clean soil, covered with topsoil, and seeded with grass or native plants.

7. **Replace water shielding at off-SIOU consolidation cell with rock.** Same as Alternative 3, Step 9.

8. **Install and maintain cap at off-SIOU cell.** Same as Alternative 3, Step 10.

9. **Redress cap at off-SIOU cell.** Same as Alternative 3, Step 11.

10. **Long-term actions.** After verification that SIOU is cleaned up to acceptable levels, the site would be incorporated into the Waste Area Grouping 1 soils and groundwater operable units and would be subject to their monitoring requirements, institutional controls, and subsequent remedial actions.

4.4.5.2 Process modifications for Alternative 5

The process modifications described for Alternative 3 are also applicable to this alternative. Another process modification would be the addition (in Step 3) of thickening tanks at the operable unit site before transferring the slurried sediment or soil to the transport system. Thickening the slurry would permit transport of a much smaller volume of higher solids-content material. The clarified water decanted from the thickener could be returned to the pond being dredged and used for shielding.

4.4.5.3 Monitoring and contingency actions for Alternative 5

The monitoring and contingency actions described for Alternative 3 are also applicable to this alternative.

4.4.6 Alternative 6—Removal, Treatment, and Off-Site Disposal

Alternative 6 includes removal and treatment of surface water, sediments, and soils as required within the operable unit contaminated above acceptable levels, containerization of treated solid wastes, and transport of all treated wastes to one or more off-site disposal facilities. The Nevada Test Site is designated as the representative facility for disposal (see Appendix D, Sect. 1.7.1). Wastes would be segregated, if practical, and sediments and soils would be treated as required to meet the Nevada Test Site waste acceptance criteria. Such treatment could include removal of PCBs, as necessary, and stabilization/solidification as the representative process option to meet Toxicity Characteristic Leaching Procedure (TCLP) requirements so that waste no longer exhibits hazardous characteristics and can be classified as low-level waste. Other treatment options, such as mechanical or thermal dewatering or ex situ vitrification, could also be used. Contaminated surface soil and other solids may not need treatment to meet the Nevada Test Site waste acceptance criteria. If this alternative is selected, selection of the treatment process would be determined in the ROD or remedial design process, based on engineering support studies.

As described in Section 4.3.5.2, Option E2, this alternative protects on-site workers and human and ecological receptors by eliminating the contamination source. It eliminates the risk of failure of the existing containment system and rapid release of contamination. It prevents additional contamination of groundwater from this source. As for all other alternatives, this alternative does not address existing contamination in soil outside the operable unit or in

groundwater or recontamination of the site from other ORNL sources. In other words, it does not eliminate the need for federal institutional control at the site due to other sources of contamination.

4.4.6.1 Base actions for Alternative 6

The sequence of events in implementing the remedial actions for this alternative is described here.

1. **Initial actions and site preparation.** Same as Alternative 2, Step 1.

2. **Relocate contaminated subimpoundment soil, sediment, and solid material from Impoundments 3539 and 3540 (optional).** If necessary to provide adequate space for construction of the treatment facility, the following actions could be performed. Using the methods described in Alternative 3, Steps 2–4, the contaminants from Impoundments 3539 and 3540 would be removed and stored in Impoundment 3513 or stockpiled, as appropriate. Surface water would also be removed from Impoundments 3539 and 3540, when not required for shielding, and would be sent to the process waste treatment system. The ponds would be backfilled with clean fill.

3. **Construct treatment facility.** A temporary treatment facility would be constructed at the former location of Impoundments 3539 and 3540 or another suitable location. The treatment facility would be as described for Alternative 4. If necessary to meet regulatory requirements or the Nevada Test Site waste acceptance criteria, an additional treatment train to remove PCBs from the waste would be added. Base-catalyzed decomposition is the PCB treatment process used to develop the cost estimate. A typical treatment train used for this process could include material handling systems, a dry additive (e.g., $NaHCO_3$) mixing tank, a heated rotary reactor, and an extensive off-gas treatment system.

4. **Treat contaminated materials.** Using methods previously described, sediment, applicable subimpoundment soil, and applicable surface soil would be removed and transferred to the treatment facility. PCB-contaminated sediment could be treated in the PCB treatment train, then transferred to the stabilization/solidification treatment system described for Alternative 4. Any materials containing radioactive or hazardous contamination above acceptable levels and with PCBs below acceptable levels would bypass the PCB treatment train and be fed directly to the stabilization/solidification process. The stabilization/solidification process is assumed to double the waste volume. The treated material would be placed in shielded containers that meet

shipping and disposal requirements. Note that the final treatment processes, sequence, and design would be determined during remedial design, based on the results of engineering support studies.

When no longer required for shielding, the surface water in the ponds would be removed and treated at the process waste treatment system. Applicable solid materials from Impoundment 3513 would be stockpiled with the solid materials from the other ponds.

5. **Place contaminated solids and surface soil in containers.** Stockpiled contaminated surface soil and solid materials removed from the impoundments would be treated only if necessary.

6. **Transport treated and packaged waste to the Nevada Test Site and dispose of waste.** After the waste is treated and packaged as required, the waste would be transported to the Nevada Test Site. The waste would be disposed of according to the regulatory and facility requirements applicable at the Nevada Test Site.

7. **Demobilize treatment facility and restore empty ponds and remainder of site.** After completion of treatment, the treatment facility would be demobilized, decontaminated to the extent possible, removed from the site, and dispositioned appropriately. The excavated ponds would be backfilled with clean soil, covered with topsoil, and seeded with grass or native plants.

8. **Long-term actions.** After verification that the SIOU site is cleaned up to acceptable levels, the site would be incorporated into the Waste Area Grouping 1 soils and groundwater operable units and would be subject to their monitoring requirements and institutional controls. No other long-term actions would be necessary.

Other than revising the design based on engineering support studies and addressing inadequate treatment capacity at the Process Waste Treatment Plant (see Sect. 4.4.2.2), no process modifications or contingency actions are associated with this alternative.

5. DETAILED ANALYSIS OF ALTERNATIVES

The assembled and screened remedial action alternatives presented in Chapter 4 represent a range of distinct management strategies for addressing the contamination at SIOU. Each alternative is intended to protect human health and the environment. Chapter 5 presents a detailed analysis of those alternatives that remain after screening. The detailed analysis is presented in the following sections:

- Section 5.1—This section describes the evaluation criteria used in the detailed analysis.
- Section 5.2—This section presents an evaluation of each alternative relative to each criterion.
- Section 5.3—This section compares the relative strengths and weaknesses of the alternatives regarding each evaluation criterion.

5.1 EVALUATION CRITERIA

Sections 5.2.1 through 5.2.6 provide evaluations of individual alternatives. Appendix C contains risk evaluations for each alternative. Appendix E contains a detailed description of the ARARs referenced in the compliance-with-ARARs discussions. Appendix F contains the feasibility-level design calculations and Automated Estimating System summary reports that support the capital costs and operation and maintenance (O&M) costs presented in this analysis.

This section describes the specific evaluation criteria used in conducting the detailed analyses. These criteria are taken from *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988) and include the following:

Threshold criteria. Developed alternatives (except the no action alternative) must meet these threshold criteria:

- overall protection of human health and the environment and
- compliance with ARARs.

Primary balancing criteria. The effectiveness of an alternative in meeting these criteria is evaluated in sufficient detail so that decision makers understand the significant aspects of each alternative and any uncertainties associated with the evaluation. These criteria are:

- long-term effectiveness and permanence,
- reduction of contaminant toxicity, mobility, and volume through treatment,
- short-term effectiveness,
- implementability, and
- cost.

Modifying criteria. These modifying criteria will be addressed following review of this document and the proposed plan by regulatory agencies and the public:

- state acceptance and
- community acceptance.

The seven criteria (the modifying criteria are excluded) addressed in this detailed analysis are discussed here.

Overall Protection of Human Health and the Environment. This evaluation criterion assesses each alternative's ability to protect human health and the environment in accordance with the remedial action objectives established in Section 4.1. All alternatives except the no action alternative must satisfy this criterion. The scope of this criterion is broad, and it reflects assessments discussed under other evaluation criteria, especially long-term effectiveness and permanence and short-term effectiveness. This criterion evaluates how site risks associated with each pathway are eliminated, reduced, or mitigated through treatment, engineering controls, or institutional controls. It also evaluates impacts to the site resulting from the remedial action itself.

Estimated human health carcinogenic risks indicate the increased probability that an individual exposed to the contaminants in SIOU could develop cancer over the course of a lifetime. The EPA target range for incremental increase in lifetime cancer incidence risk to an individual is 1×10^{-6} to 1×10^{-4} or one in one million to one in ten thousand. Risks greater than 1×10^{-4} are not acceptable. Incremental risk is evaluated rather than total risk because cancer risk is contributed from sources other than the site. For example, one in three Americans will develop cancer from all sources, and an estimated 60 percent of these will be fatal (EPA 1989a). Therefore, the average American faces a 1 in 5 (2×10^{-1}) risk of fatal cancer.

The pathways to potential receptors considered in the risk assessment models for each alternative are as follows. At the Clinch River and at White Oak Dam, airborne contamination and waterborne contamination of drinking water are considered. At White Oak Creek, in addition to those pathways, contaminated water is assumed to be used for plant irrigation and

livestock watering. Plant uptake of contaminated water is modeled, and humans ingest plants and animals grazing on those plants. For the on-site resident, the above pathways are considered and direct radiation is also modeled. The on-site resident is not assumed to come into direct contact with the sediment for extended periods of time. Such exposure would cause a clearly unacceptable risk (near unity) of cancer or other adverse toxicological effects.

Sediment is the major source of contamination at SIOU and is considered in all risk models. Groundwater entering the site is already contaminated from other off-SIOU sources, and only the contribution to groundwater contamination resulting from leaching from SIOU is considered in the alternative risk assessments. Groundwater contaminated from other sources will be considered under the Waste Area Grouping 1 groundwater operable unit.

Noncarcinogenic human health risk from exposure to chemicals is evaluated using the hazard index. A hazard index of less than 1 indicates that no adverse effects are expected to occur. The baseline risk assessment indicated that the hazard index is less than 1 for each present and future modeled condition. For this reason, noncarcinogenic human health risk is not considered for any alternative.

The ecological baseline risk assessment (see Section 3.8) indicates that the only significant risk to nonhuman organisms from the SIOU site is due to piscivorous species eating contaminated fish and invertebrates from Impoundments 3513 and 3524. No significant risks are expected from any SIOU contributions to off-SIOU contamination. Therefore, ecological risks are considered acceptable when the impoundments no longer serve as a food source for sensitive species.

Compliance with ARARs. This criterion addresses compliance with promulgated federal and state environmental requirements. ARARs consist of two types of requirements: those that are legally applicable and those that are relevant and appropriate. In certain cases, regulatory standards may not exist that address the proposed action or the COCs. In such cases, nonpromulgated advisories, criteria, or guidance developed by EPA, other federal agencies, or states can be designated as potential requirements to be considered (TBCs).

Other requirements that do not fall within EPA-established criteria for ARARs include DOE orders that pertain only to DOE facilities. Atomic Energy Act requirements for management of DOE's waste are incorporated into DOE Orders, developed under DOE's Atomic Energy Act authority. The substantive requirements of DOE Orders are TBC requirements, which, when specifically incorporated in a DOE CERCLA ROD, are legally binding. EPA's guidance, "Compliance with Other Laws Manual" (Office of Solid Waste and Emergency

Response Directive 9234.1-01) states, "...DOE orders are not promulgated requirements and are not potential ARARs." The manual further states that, "To the extent that DOE orders are more stringent or cover areas not addressed by existing ARARs, they should be considered when necessary to develop a protective remedy."

Appendix E discusses all ARARs and potential ARARs. ARARs for nonradioactive components of a remedial action are derived from RCRA and the Toxic Substances Control Act regulations. Table 1 in Appendix E identifies the chemical-specific and location-specific ARARs and TBCs. Tables 2-6 present the action-specific ARARs and TBCs for each action-based alternative (i.e., Alternatives 2-6). Table 7 in the appendix identifies the action-specific ARARs pertinent to the possible contingency actions for Alternatives 2-6.

This section discusses the ability of each alternative to meet the pertinent ARARs. If an alternative cannot meet a requirement, a determination can be made per 40 CFR 300.430(f)(1)(ii)(C) that a waiver under CERCLA may be appropriate. In this event, a basis for justifying the waiver is presented. Each remedial action alternative can meet most or all of the requirements of potential ARARs and TBCs, provided adequate attention is given to these requirements during design and implementation of the remedial actions. The categories of ARARs for which compliance is readily achievable are only briefly discussed in the sections below. This chapter discusses in detail the RCRA and Toxic Substances Control Act ARARs for which compliance is questionable or for which waivers are clearly needed.

Radiation protection standards can be found under promulgated NRC requirements. Tennessee is an NRC agreement state and TDEC implements the NRC regulations. DOE radiation protection requirements are implemented through DOE Orders designated as TBCs and through regulation such as 10 CFR 835, "Occupational Radiation Protection." DOE is exempt from TDEC NRC licensing and regulatory requirements under TDEC 1200-02-10-.06. The TDEC/NRC regulations are therefore not applicable, although they are potentially relevant and appropriate. DOE, TDEC, and EPA will concur on which of these regulations are ARARs, and those regulations will be incorporated into the ROD for SIOU. Table 8 of Appendix E identifies which potential TDEC/NRC requirements may be relevant and appropriate for each alternative, and whether a waiver would be required. Again, the remedial action alternatives presented in this FS can meet most of the substantive requirements of the TDEC/NRC regulations. As with the potential RCRA and Toxic Substances Control Act ARARs, the TDEC/NRC potential ARARs that can be readily met (as indicated in Table 8 of the appendix) are briefly discussed below. Those that could require waivers (if carried through as relevant and appropriate in the ROD) are discussed in detail.

Long-Term Effectiveness and Permanence. This criterion evaluates the extent to which an alternative achieves an overall reduction in risk to human health and the environment after the remedial action objectives (see Sect. 4.1.1) have been met. It considers the degree to which the alternative provides sufficient long-term engineering, operational, and institutional controls; the reliability of those controls to maintain exposures to human and environmental receptors within protective levels; and the uncertainties associated with long-term operations, maintenance, and institutional controls. The magnitude of residual risks is discussed under the overall protection of human health and the environment criterion and is briefly reviewed under this criterion. This criterion also addresses:

- the adequacy and reliability of controls,
- irreversible and irretrievable commitment of resources,
- sensitive resources, and
- cumulative effects.

Reduction of Toxicity, Mobility, and Volume Through Treatment. This criterion considers the following:

- treatment processes used and materials treated;
- quantities of hazardous material destroyed or treated;
- degree of expected reductions in contaminant toxicity, mobility, and volume;
- degree to which treatment is irreversible; and
- type and quantity of residuals remaining after treatment.

Short-Term Effectiveness. This criterion considers the following:

- community protection during remedial actions,
- worker protection during remedial actions,
- short-term and long-term environmental effects of remedial actions,
- estimated time until remedial action objectives are achieved,
- potential for sudden failure to occur, and
- direct or indirect socioeconomic impact.

Implementability. This criterion considers the technical and administrative feasibility as well as the availability of services and materials by addressing:

- ability to construct and operate a given technology;
- reliability of technology;

- ease of undertaking additional remedial actions, if necessary;
- ability to monitor effectiveness of remedial action;
- ability to obtain regulatory agency approvals;
- activities needed to coordinate with other offices and agencies;
- availability of necessary permitted facilities (e.g., disposal facility);
- availability of necessary equipment, technologies, and specialists; and
- effect of reasonable deviations on implementability.

Cost. Appendix F presents detailed cost estimates, projected project schedules, and the major assumptions used to develop the cost estimate. The estimates are based on feasibility-level scoping and are intended to aid in comparisons between alternatives. EPA guidance states that estimates should have an accuracy of +50 percent to −30 percent. These estimates attempt to achieve this level of accuracy; however, due to uncertainties in regulatory requirements, technology performance, availability of disposal capacity, and other items, such accuracy (particularly for the high-end alternatives) may not be possible at this time. Regardless, sufficient study has been performed and detail has been evaluated so that the comparison of costs between alternatives should provide valuable information.

This criterion summarizes the costs for each alternative and includes the following:

- capital costs,
- O&M costs,
- present worth costs, and
- contingency action costs.

Capital costs are defined as those expenditures required to initiate and perform a remedial action. These are short-term costs and exclude costs required to maintain the action throughout the project lifetime. Capital costs consist of direct and indirect costs. Direct costs include construction (e.g., material, labor, and equipment), service equipment, process buildings, utilities, and waste disposal. Indirect costs include Title I and Title II engineering, Title III inspection, project integration, project administration and management, and contingencies. Contingency costs are included in each alternative, based on the degree of difficulty of particular actions, technology status, and the uncertainty level of the scope of the action.

O&M costs are long-term costs that occur after construction and installation of components of a remedial action are complete. These costs include labor, materials, utilities, and services required to monitor, operate, and maintain the facilities. EPA Guidance (EPA 1988) indicates that "the period of performance for costing purposes should not exceed 30 years for the purpose

of the detailed analysis" because the present value of funds expended after that period is negligible. Therefore, although O&M activities may continue indefinitely, the cost calculations only consider the first 30 years of institutional controls and monitoring.

The cost estimate for each activity is escalated, based on the projected schedule for performance of that activity and approved DOE escalation rates. Escalation rates used are 2.8 percent for Fiscal Year (FY) 1994, 3.0 percent for FY 1995, and 3.2 percent for FY 1996 and thereafter. The estimated present worth of each alternative is determined based on a discount rate of 6 percent.

For alternatives that have contingency plans to address reasonable deviations from the probable conditions, an analysis is made of the likelihood of the deviation occurring. This report provides the potential cost of contingencies for deviations that have a high probability of occurring.

References such as EPA (1987), Means (1992a, 1992b), and Energy Systems (1993) are used to develop unit costs for alternative components and as guidance in determining appropriate costing procedures. Vendor quotes are also used to determine costs of alternatives and alternative components. Appendix F includes automated Estimating System cost information for each alternative.

5.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES

5.2.1 Alternative 1—No Action

Consideration of the no action alternative is required by the National Contingency Plan and NEPA. This alternative serves as a baseline for comparison with the other alternatives. In this study, Alternative 1, the no action alternative, makes no provisions for containment, removal, treatment, or disposal of wastes. Existing monitoring and institutional controls are assumed to remain in place during the period of DOE control, say 30–100 years, after which the site is assumed to be abandoned.

5.2.1.1 Overall protection of human health and the environment

Under Alternative 1, the existing environmental monitoring program, operational controls, and institutional controls would be continued as long as ORR remains under DOE control. However, after loss of DOE control, this alternative assumes unrestricted use of ORR. Before loss of DOE control, this alternative is considered protective of human health, but not protective of the environment.

Section 4.4.1 describes existing institutional and operational controls. During the period of institutional control, the modeled RME risk (see Appendix C) to the off-site receptor at Clinch River would be 1×10^{-4} from all pathways. The modeled future employee RME risk during the institutional control period would be acceptable at 6×10^{-5}. There is a small risk that the water cover over the impoundments could be lost during the period of institutional control due to continuing, long-term human error or to natural disaster. In this event, off-site RME risk at Clinch River would approach that for the baseline condition (5×10^{-3}).

Under the no action scenario, regardless of institutional controls, the surface impoundments would continue to act as a source of PCB, zinc, and mercury surface water contamination, presenting environmental risks to birds and mammals eating contaminated fish from the impoundments.

After loss of DOE control, this alternative is not considered protective of human health or the environment. Potential exposure pathways of direct radiation, inhalation, and ingestion of contaminated soil and sediment and ingestion of contaminated drinking water would exist and likely increase over time as the current control measures, such as access restrictions and the protective water cover, deteriorate. Exposure to contaminants and the size of the contaminated area could increase over time as the result of disturbances by humans and natural processes and the subsequent movement of contaminants by erosion, surface water transport, and leaching to groundwater. The majority of the risk occurs for the scenario that assumes that the protective water cover is removed by a drought condition, a berm failure, or another unforeseen event, exposing the sediments in the impoundments. Environmental risks would also increase as contamination releases became more widespread.

After the period of institutional control, human health risk for the on-site resident would revert to the baseline risk of 3×10^{-2} due primarily to the airborne pathway for plutonium and americium. The risk from groundwater and surface water pathways would be slightly reduced from today's baseline risk due to natural radioactive decay of ^{90}Sr (half-life of 29 years) for the duration of institutional control. Note that this risk assumes that the resident does not directly contact the exposed sediment. The risk of cancer and other radiation-related illnesses from continued exposure to the sediments is a near certainty.

There would be no adverse short-term effects due to implementation of this alternative.

5.2.1.2 Compliance with ARARs

There are no ARARs under CERCLA for Alternative 1, the no action alternative. However, the no action alternative does not meet the CERCLA requirement for protection of human health and the environment.

5.2.1.3 Long-term effectiveness and permanence

During the period of DOE control, continuation of existing operational and institutional controls would meet three of the four remedial action objectives developed in Section 4.1.1. Direct exposure, direct contact, inhalation, and ingestion of contaminants in the sediments would be minimized by maintaining the water cover and by restricting access through institutional control. Operational controls, monitoring, and maintenance would control potential future failure of the berms and embankments. Although contamination of groundwater would continue, leaching of contaminants to drinking water sources would be controlled by prohibiting use of groundwater at the site and surface water in White Oak Creek and White Oak Dam for drinking. Bioaccumulation of contaminants in sensitive ecological receptors would continue.

After loss of DOE control, none of the remedial action objectives would be met.

Magnitude of Residual Risks. Under the no action alternative, continued migration of contaminants from the surface impoundments to the surrounding soil and groundwater would be expected. This could influence White Oak Creek, located just south of the project area. Increased concentrations of contaminants in the environmental media and surrounding area would pose additional overall risks to environmental receptors. Continual exposure of biota to contamination originating at the site could lead to bioaccumulation of contaminants in aquatic biota, birds, and insects that use the area. Over time, these contaminants could migrate up the food chain into other organisms as well. Exposure to radiological contaminants also has the potential for adverse mutagenic effects on local biota over a long-term period.

Adequacy and Reliability of Controls. The no action alternative would maintain controls as they currently exist for the period of DOE control. These controls are intended to protect the worker population by shielding them from radiation with water on top of the pond sediments and off-site populations by prevention of releases of airborne contamination. This lends incidental protection to nearby biota as well. But, the existing level of protection depends on maintaining the ponds in their current state and results in no reduction of current risk levels. Maintenance of the water levels in the ponds is a straightforward process of monitoring and transferring water using readily available and easily maintainable equipment. Loss of some of the water would reduce shielding and increase direct radiation to nearby employees. The expected short duration

of such reduction in controls, combined with employee monitoring, would limit risk to acceptable levels. Loss of all of the water in one or more impoundments could lead to release of the dried sediment to the air. This would cause very serious increases in exposure to on- and off-site employees and residents. Such a loss could occur due to either long-term human error, vandalism, sabotage, or natural disaster. None of these scenarios is likely, but there is a remote possibility of such loss of the water cover during the period of institutional control.

After loss of DOE control, no controls would be in place and the likelihood of a release would be increased.

Irreversible and Irretrievable Commitment of Resources. Maintaining institutional and monitoring controls under the no action alternative would imply an irretrievable commitment of very small amounts of fuel and materials used to maintain the ponds in their current state. The institutional controls are a part of the overall security program on ORR, and the non-renewable resources used for this may be considered as already committed and not attributable to this project alone.

Sensitive Resources. An architectural/historical survey of ORNL was conducted in 1994. The 3513 Settling Basin and Process Waste Treatment Plant and the 3524 Process Waste Systems Basin/Equalization Basin, within the boundary of ORNL Historic District, are eligible for inclusion in the National Register of Historic Places. Since no action would be taken, Alternative 1 would have no adverse effect on these historic resources.

The operable unit is not located in a 100-year or 500-year floodplain, and no wetlands are present at the site (Rosensteel 1993).

Cumulative Effects. The no action alternative has the highest, long-term, cumulative risk to human health and environment of any alternative. These risks are presented as part of the risk assessment (see Chapter 3). The potential for negative effects to the environment as a result of implementing the no action alternative could increase over time as the likelihood of uncontrolled releases of the contaminants to White Oak Creek could increase. Contaminants could enter the surface water system in higher concentrations and more rapidly than at present. This could contribute to cumulative negative effects on surface water quality in these water bodies and to White Oak Lake.

5.2.1.4 Reduction of toxicity, mobility, and volume through treatment

No treatment of the contaminated material is proposed for this alternative. Therefore, there is no reduction in toxicity, mobility, or volume through treatment.

5.2.1.5 Short-term effectiveness

Under Alternative 1, the no action alternative, no uncontrolled exposure risks would result to workers, the community, or the environment from remediation activities, transportation, or disposal since no such actions would take place. During implementation of the pond level maintenance and other maintenance activities, workers would be adequately protected by compliance with existing, standard operating procedures at ORNL. No short- or long-term effects on ambient noise levels, ecological habitats, or cultural resources would be anticipated. However, cumulative human health and environmental risks from the no action alternative at the impoundments could be unacceptable, according to the results of the baseline risk assessment.

Estimated Time until Remedial Action Objectives are Achieved. Existing maintenance, monitoring, and institutional and operational controls are presently meeting three of the four remedial action objectives, i.e., (1) minimizing exposure to sediments with the water cover, (2) controlling drinking water sources with institutional controls, and (3) controlling potential failure of the berms with maintenance and monitoring. Minimizing bioaccumulation of contaminants in sensitive ecological receptors would not occur.

Potential for Sudden Failure. The existing berms and embankments are structurally stable, according to stability analyses performed in 1985 and 1994 (see Section 2.3). Burrowing animals and potential future seeps could compromise the integrity of the berm between Impoundment 3513 and White Oak Creek. There is a low probability of sudden failure due to natural disaster.

Direct or Indirect Socioeconomic Impact. Since the no action alternative is the baseline condition, the socioeconomic conditions of this alternative are those against which other alternatives will be compared. Land use under the no action alternative would remain unchanged and use restrictions would continue.

5.2.1.6 Implementability

Since no new actions would be taken, the technical aspects of this alternative would be readily implementable.

Obtaining regulatory agency approvals and coordinating with other offices and agencies is expected to be difficult.

5.2.1.7 Cost

As described in Section 4.4.1, the cost for this alternative only includes institutional and operational controls at the site for maintaining the water level in the impoundments and periodic maintenance of the SIOU site. The present worth of these O&M costs is estimated to be $5.569 million. There are no capital costs necessary for implementing this alternative. Table 5.1 is a summary of the main cost drivers for Alternative 1.

5.2.2 Alternative 2—Multilayer Cap and Institutional Controls

Alternative 2 includes a multilayer cap to protect against airborne contamination and direct contact with or direct exposure to radiation from the waste and institutional controls to the outfall from White Oak Dam to limit access and exposure to groundwater contamination.

5.2.2.1 Overall protection of human health and the environment

The cap in Alternative 2 protects current and future employees and potential on-site residents from direct radiation. In addition, airborne migration of contaminated soil particulates is minimized, and sediments from the impoundments are prohibited from becoming airborne. This significantly reduces the major contributor of potential risk at White Oak Dam and off site at Clinch River. Contamination of potential drinking and irrigation water sources would continue at a reduced rate. This contributes to unacceptable RME risks (see Appendix C) for residents at the site and on White Oak Creek of 3×10^{-3} and 2×10^{-3}, respectively. It is important to remember that this risk evaluation assumes that a resident does not build a home directly on the cap and penetrate the protective cover.

For Alternative 2, the RME risks modeled at White Oak Dam and off site at Clinch River (1×10^{-4} and $< 1 \times 10^{-6}$ respectively) are within the EPA's target risk range and are therefore acceptable at those locations. Note that if risk from residual soil contamination is discounted, the risk at White Oak Dam would be 1×10^{-5}. This alternative is also protective to the future on-site employee with an RME risk of 1×10^{-6}. Because institutional controls will be designed to restrict access to White Oak Creek and to the site and to prohibit residential or agricultural use, the alternative is considered protective of human health for the period of institutional control. It minimizes direct exposure to, direct contact with, and inhalation and ingestion of contaminated sediments. It provides some level of control of leaching to groundwater and surface water and prohibits use of those waters with unacceptable levels of contamination as drinking water sources. It structurally stabilizes the impoundments to control future failure of the berms and embankments.

Table 5.1. Alternative 1 cost estimate for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Project cost item	Costs (Thousand dollars)	
Capital cost		
Direct cost		
Direct total cost		0
Indirect cost		
Indirect total cost		0
Total capital cost		0
O&M costs		
O&M costs (1-30 years)		
Administration cost	3,348	
Institutional controls	8,111	
1-30 years O&M cots		11,459
Total O&M contingency		2,865
Total O&M costs		14,324
Total project cost in escalated dollars		14,324
Present worth costs		
Total Alternative 1 present worth costs: [Per BLCC analysis (version 4.20-95)]	5,569	

[a]Per Guidance Document EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*
[b]Escalated (average 3.7% escalated rate per DOE guidance)

BLCC = Building Life-Cycle Cost
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
O&M = operation and maintenance
ORNL = Oak Ridge National Laboratory
SIOU = Surface Impoundments Operable Unit

In the long term after loss of institutional control, on-site residents and residents at White Oak Creek could be exposed to the risks described. Intruders into the cap contacting the waste for extended periods would have a near certain risk of developing cancer or other radiation-induced illness.

Because the impoundments will be filled and capped, they will no longer serve as a source of contaminated food for piscivorous species of birds and mammals, eliminating bioaccumulation of contaminants in sensitive ecological receptors.

Implementation of good, standard construction practices and health and safety programs would adequately mitigate any adverse short-term effects to the community, remediation workers, and the environment during remedial actions.

5.2.2.2 Compliance with ARARs

Alternative 2 would be able to meet all of the potentially relevant and appropriate TDEC/NRC regulations listed in Appendix E, Table 8, with the following exceptions. A waiver would be required for the annual dose radiation protection requirements of TDEC 1200-2-11-.16(2), if the receptor is assumed to be on site. This requirement is met for a receptor at Clinch River. A waiver would also be required for the long-term design and isolation requirements of TDEC 1200-2-11-.17(1)(a) as this alternative does not isolate the wastes from groundwater and requires continued, active maintenance. The cap design for Alternative 2 does not meet all of the requirements in TDEC 122-2-11.17(d). Finally, TDEC 1200-2-11-.17(f) requires minimization of contact between the waste and standing or percolating water. Since implementation of this alternative does not isolate the waste from groundwater, a waiver would be required.

The objective of this alternative is to prevent off-site risk from airborne contamination with engineering controls (i.e., the cap) and to prevent exposure to groundwater and surface water contamination with institutional controls. If DOE and the regulatory agencies concur that these regulations are relevant and appropriate, waivers from the above requirements would be needed. If this alternative is selected, per 40 CFR 300.430(f)(1)(ii)(C) waivers would be requested on the following basis: (1) the alternative could be considered an interim measure such that, after the period of institutional control, additional actions would attain the ARARs or (2) the alternative would attain a standard of performance equivalent to the ARARs through use of another method or approach. In this case, the results of limiting risk and exposure through institutional controls could be considered equivalent to limiting groundwater contamination to allow unrestricted use of the site.

5.2.2.3 Long-term effectiveness and permanence

Alternative 2 would meet the remedial action objectives developed in Section 4.1.1. Direct exposure, direct contact, inhalation, and ingestion of contaminants in the sediments would be minimized by isolation of the waste with the cap. The cap would be designed to provide structural stability and control potential future failure of the berms and embankments. Although contamination of groundwater would continue, the availability of contaminants leached to potential drinking water sources would be controlled by prohibiting use of groundwater at the site and surface water in White Oak Creek and possibly in White Oak Dam for drinking. Bioaccumulation of contaminants in sensitive ecological receptors would be significantly reduced

by filling the ponds and eliminating contaminated fish and invertebrates as a food source for those receptors.

After loss of DOE control, the drinking water pathway could be a source of human health risk. There would also be an increased likelihood of intrusion into the cap and direct contact with the waste.

Magnitude of Residual Risks. The multilayer cap, institutional controls, and deed restrictions would minimize direct exposure to the contaminants for on-site workers and most biota. However, while the cap would isolate the contaminated surface waters and sediments from the air, it would not protect soil and groundwater. Thus, risks would be reduced, but not eliminated, as contaminant exposure pathways to aquatic and terrestrial organisms through continued migration would remain.

Adequacy and Reliability of Controls. The cap will need to be maintained to provide adequate and reliable containment controls. Institutional controls would be needed to prevent intrusion into SIOU. Management of the site would be required for as long as the contaminated media under the cap remains.

Irreversible and Irretrievable Commitment of Resources. Implementation of Alternative 2 would require some irretrievable commitment of resources, e.g., fuel, cap materials, and other materials. Also, the habitat provided by the impoundments would be lost, together with any biota living in or around them. However, this habitat is man-made, has been contaminated since its construction, is not unique, and similar areas are present nearby.

Sensitive Resources. Because the 3513 Settling Basin and the 3524 Process Waste Systems Basin/Equalization Basin are eligible for inclusion in the National Register of Historic Places (see Sect. 5.2.1.3) and capping the impoundments would physically alter the property, consultation with the State Historical Preservation Officer would be required before initiating any action. The State Historical Preservation Officer would specify any mitigation necessary and concur with the project through a memorandum of agreement.

As for Alternative 1, neither floodplains, wetlands, nor endangered or threatened species or critical habitat would be affected by this alternative.

Cumulative Effects. Replacement of the ponds with a grass-covered cap would result in an incremental loss of open water available to the local fauna. If other open waters were also lost in the area, this could affect local biota. However, White Oak Creek provides an alternate

source of drinking water to local wildlife, and other losses of open water in the immediate vicinity are not anticipated. Allowing contamination to remain below the ground could contribute incrementally to long-term cumulative risk for human health and environment on ORR. The acceptability of this risk is determined during the CERCLA process, and its incremental effect is considered during the risk assessment process.

5.2.2.4 Reduction of toxicity, mobility, and volume through treatment

The contaminated surface water would be removed and treated at the existing process waste treatment system. Most of the water would be discharged through a National Pollutant Discharge Elimination System-permitted outfall. The residual contamination extracted from the surface water would be concentrated and stored in existing, permitted facilities for future disposal. The concentrated residuals would represent a significant reduction in volume compared to the original volume of contaminated water. Residuals resulting from treating contaminated water at the process waste treatment system would include concentrated radioactively and chemically contaminated sludge, spent zeolite and resin from ion exchange processes, and dewatered sludge containing mostly cations such as calcium and magnesium. These residuals are similar to those produced at the process waste treatment system from treatment of ORNL process waste generated from research activities. The ORNL waste management system is set up to handle these residuals. The remedial actions for this alternative would be designed to avoid overloading the capacity of the system.

No treatment of contaminated sediment or soil is proposed for this alternative. Therefore, there is no reduction in toxicity, mobility, or volume through treatment for these media.

5.2.2.5 Short-term effectiveness

Implementation of Alternative 2 would involve removing and transferring the ponds' water to the Process Waste Treatment Plant for treatment. Relocation of power lines, steam lines, and other utilities as well as temporary set up of trailers and decontamination equipment could also be necessary. Following is a discussion of the short-term effectiveness of these activities.

Community Protection. Installation of the cap for Alternative 2 would not adversely affect the surrounding community. Ambient noise levels near the site would increase as at any small construction site, but would not be excessive in an industrial area. The activities could also result in a potential for off-site migration of dust or other airborne contaminants. Impacts would be monitored, and standard construction practices (e.g., to prevent erosion and control dust) during remedial actions would be adequately protective.

Worker Protection. Occupational injury and inhalation of dust and waste [e.g., volatile organic compounds (VOCs)] could pose slight risks to remediation workers, but should be controlled with conventional ALARA procedures. Installation of the cap and treatment of the contaminated pond water present accident risks. A health and safety program would be implemented to protect remediation workers from standard occupational risks as well as from excessive exposure to radiation. The remedial actions for removal of surface water and installation of the cap are limited in nature. The construction methods would not require many workers to enter the contamination zone. Those who do would be equipment operators situated in a shielded (if necessary) cab. Well-developed occupational safety, radiation protection, and equipment and personnel decontamination procedures are standard practice at ORNL. Development of a project-specific health and safety plan would include training requirements, personnel protective equipment requirements, shielding requirements, and other safety procedures. Overall, worker exposure would be held to reasonable levels through compliance with Occupational Safety and Health Administration (OSHA) requirements, DOE Orders, and ORNL procedures.

Short-Term and Long-Term Environmental Effects. Short-term disturbance of vegetation surrounding the ponds and some loss of habitat would result from activities associated with Alternative 2. Adverse effects to surface water quality could result from siltation in White Oak Creek if erosion control measures for construction traffic and runoff were not implemented. A sedimentation barrier upgradient of the creek would be constructed to keep any soil from washing down the slope into the creek. When construction and excavation are completed, disturbed areas would be revegetated with grasses.

Handling and processing pond waters could also result in potential exposure of workers and local biota to the contaminants. The most likely environmental accident scenario would occur during the surface water removal process if there were an uncontrolled release of contaminated water. Contaminant loading to White Oak Creek would be the primary concern. However, engineering controls would be implemented to mitigate this concern.

The effects of these remedial actions on a cumulative basis would depend on the timing and location of other actions at ORNL and on ORR. ORNL is likely to undertake many actions in the area, remedial and otherwise, over the next 20 years. The increase in traffic, noise, and dust levels anticipated during implementation of this alternative would not be significant compared to other actions at the large industrial site. The destruction of individual organisms and habitat would add incrementally to other such similar losses or degradation. However, the organisms and habitat at SIOU are neither unique nor large in scope. The overall environmental effect of this action would be positive, since releases of contamination to the environment and resulting

exposures would be reduced. Cumulative effects from this and other remedial actions would also be positive.

Estimated Time until Remedial Action Objectives are Achieved. The total duration of construction activities would be approximately 2 years, after which maintenance, monitoring, and institutional controls would be initiated.

Potential for Sudden Failure. Burrowing animals and potential future seeps could compromise the integrity of the berm between Impoundment 3513 and White Oak Creek. The cap would be designed to enhance the stability of the site and reduce the potential for sudden failure or release of contamination. Displacement of the water in the impoundments with the cap materials would reduce the potential for seeps, although the waste in Impoundment 3513 would remain saturated below the water table. Standard design parameters for the location regarding earthquake, flooding, and wind and water erosion would be considered in the design.

Direct or Indirect Socioeconomic Impact. No change would be expected in local population or nearby industrial and commercial operations. Although implementation of Alternative 2 would provide some jobs, the existing labor force would be used for the most part. No long-term or future expenditures should be associated with this alternative other than the need for monitoring, maintenance, institutional controls, and access control. Implementation of Alternative 2 would not substantially affect socioeconomics or the light-industrial land-use classification of the site. DOE is expected to retain ownership of the facility, and thus continued institutional controls are feasible for the foreseeable future.

5.2.2.6 Implementability

SIOU is in the midst of a highly active area of ORNL with a large employee population. Any heavy construction activities would have logistical difficulties in obtaining access to the site, controlling remediation-related and plant-related traffic flow, and protecting active utility service.

Standard construction equipment would be used to place the cap materials and remove the surface water from the ponds. No special equipment, technologies, or specialists would be necessary. Once in place, the cap would be very reliable in preventing airborne contamination.

The only contingency action considered for Alternative 2 is treatment of surface water in a package treatment plant rather than at the Process Waste Treatment Plant (see Sect. 4.4.2.2). The materials, equipment, and expertise needed for this contingency action are readily available.

No other contingency plans have been developed to address reasonable deviations because the cap would reliably prevent airborne contamination and the institutional controls would reliably prevent exposure to groundwater or surface water contamination. If this alternative is selected, additional remedial actions would only be necessary if policies developed in the future determined that more protective requirements were necessary. If removal actions would be required after the cap is in place, they would be significantly more difficult, first, due to the additional volume of materials to be handled, and second, because much of the cap material could become contaminated and require special handling and disposal.

Monitoring the effectiveness of the cap would be simple. The visual inspection program described in Section 4.4.2.1 would verify the absence of burrowing animals and deep-rooted plants and the effectiveness of the surface water controls. The surveys on settling would confirm the integrity of the cap. The groundwater sampling program would verify that the surface impoundments were not releasing contamination in excess of the predicted worst case amounts.

As described in Section 5.2.2.2, regulatory agencies would have to waive the requirements of certain ARARs before approving this alternative. Because the site is owned and regulated by DOE, only limited coordination with other offices and agencies would be required after regulatory approval of the proposed plan. No additional permitted facilities would be necessary.

5.2.2.7 Cost

Capital costs for implementing Alternative 2 are estimated to be $19.028 million. Although O&M costs are expected to continue indefinitely, costs for the maintenance and monitoring programs are projected at approximately $7.011 million total over a 30-year duration (per EPA guidance). The present worth of those costs is $21.23 million.

Table 5.2 is a summary of the main cost drivers for the base actions and the contingency actions for Alternative 2. Appendix F provides a detailed analysis of the cost, including assumptions.

5.2.3 Alternative 3—Consolidation Cell with Simple Dewatering

Alternative 3 would relocate the sediment and contaminated soil from Impoundment 3524 to Impoundment 3513; install a liner and leachate collection system in the location of the upper impoundment; transfer all of the wastes from Impoundments 3513, 3539, and 3540 to the lined cell; dewater the wastes in place; and install a multilayer cap over the consolidation cell to isolate the waste from the environment.

Table 5.2. Alternative 2 cost estimate for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Project cost item	Costs (Thousand dollars)[b]	
Capital costs		
Direct Cost:		
Support facilities	1,176	
Site preparation	444	
Multilayered cap	3,210	
Decontaminate and remove support facilities	206	
Mobilize and demobilize	312	
Training and medicals	330	
Deed restrictions	5	
Construction management	1,604	
Direct total cost		7,287
Indirect cost:		
Engineering expenses	2,248	
Administration costs	4,558	
Contingency (indirect and direct)	4,935	
Indirect total cost		11,741
Total capital cost		19,028
O&M costs		
O&M costs (first year):		
Administration cost	104	
Surveillance and maintenance	217	
First year O&M costs		321
O&M costs (2–30 years):		
Administration cost	3,012	
Surveillance and maintenance	1,741	
5-year periodic reports	120	
O&M costs (2–30 years)		4,873
Total O&M contingency		1,817
Total O&M costs		7,011
Total project cost in escalated dollars		26,039
Present worth costs		
Total Alternative 2 present worth costs: [Per BLCC analysis (version 4.20-95)]	21,230	

[a]Per Guidance Document EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*
[b]Escalated (average 3.7% escalated rate per DOE Guidance)

BLCC = Building Life-Cycle Cost
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
O&M = operation and maintenance
ORNL = Oak Ridge National Laboratory
% = percent
SIOU = Surface Impoundments Operable Unit

As described in Section 4.4.3, Alternative 3 would isolate the wastes sufficiently such that federal institutional controls would only be required at the site of the consolidation cell and possibly at White Oak Creek, and a receptor at White Oak Dam would not be exposed to unacceptable risk due to contamination from SIOU. Additional institutional controls could be required to address other sources of contamination not associated with SIOU.

5.2.3.1 Overall protection of human health and the environment

As for Alternative 2, Alternative 3 protects future employees and on-site residents from direct radiation, minimizes airborne migration of contaminated soil particulates, and prevents airborne migration of sediments from the impoundments. Risks at White Oak Dam and off site at Clinch River are 9×10^{-5} and $<1 \times 10^{-6}$, respectively, and are within the acceptable EPA target range. Contamination of potential drinking and irrigation water would be significantly reduced by the cap and liner. The modeled RME risks (see Appendix C) for residents at the site and on White Oak Creek are 4×10^{-4} and 3×10^{-4}, respectively. The risk evaluation assumes that a resident does not build a home directly on the cap and penetrate the protective cover. Implementation of good, standard construction practices and health and safety programs would adequately mitigate any adverse short-term effects to the community, remediation workers, and the environment during remedial actions.

Institutional controls will be designed to restrict access to the consolidation cell and, if required by regulatory agencies, to the remainder of the site and to White Oak Creek. Note that additional institutional controls at the site, the creek, and White Oak Lake could be required due to contamination from other sources. The extent of these controls would be specified in the RODs for the soils and groundwater operable units. This alternative meets all of the remedial action objectives stated in Section 4.1.

After closure of the impoundments, ecological risks will be negligible. The wastes will be isolated from the environment, and additional contamination of groundwater and surface water from SIOU will be significantly reduced.

In the long term after loss of institutional control, on-site residents and residents at White Oak Creek could be exposed to the nearly acceptable risks described above. Intruders into the cap contacting the waste for extended periods would have a near certain risk of developing cancer or other radiation-induced illness. In the very long term, the effective life of the liner and cap (on the order of a few hundred years) would be exceeded and releases could gradually begin to increase.

5.2.3.2 Compliance with ARARs

Alternative 3 would be able to meet TBCs for radionuclide exposures at the designated receptor location at White Oak Dam, the TBCs for PCBs and lead, and the location-specific ARARs (see Appendix E, Table 1).

Alternative 3 would be able to meet the requirements for institutional controls; stormwater runoff; fugitive emissions from construction activities; treatment of surface water; and closure of Impoundments 3513, 3539, and 3540 listed in Table 3 of Appendix E. It would also meet the RCRA and Toxic Substances Control Act requirements and DOE Orders regarding installation of a liner at the consolidation cell site. A waiver would be required for the chemical waste landfill general design requirements [40 CFR 761.75(b)] to locate the landfill 16.7 m (50 ft) above the historical high water table. This waiver would be requested per 40 CFR 300.430(f)(1)(ii)(C), because it will attain an equivalent standard of performance by conforming to RCRA siting and design standards. The final closure and capping requirements under RCRA, Toxic Substances Control Act, and DOE could all be met. The postclosure maintenance and monitoring requirements (Table 3 of Appendix E) could be met.

A possible contingency action would be use of mechanical dewatering (e.g., using a filter press) rather than the base action of in situ dewatering in the consolidation cell. Such movement of waste to a RCRA treatment unit and back to the consolidation cell would trigger land disposal restrictions for those RCRA characteristic wastes for which land disposal restrictions have been promulgated (see Appendix E, Table 7). A waiver from this requirement in 40 CFR 268.48 would be needed. Such a waiver would be requested per 40 CFR 300.430(f)(1)(ii)(C) because the alternative will attain an equivalent standard of performance through use of another method or approach (i.e., containment rather than treatment and storage, or disposal or reuse rather than closure).

In addition, if the mechanical dewatering contingency is used, a waiver could be needed from the tank requirements for closure of the treatment facility under TDEC 1200-1-11-.06(10)(h). It would be unlikely that all contaminants could be removed and inappropriate to close the temporary, aboveground tanks in place. The facility would be demobilized, packaged, and either stored or disposed of appropriately, or transported for reuse at another contaminated facility. Unless the less stringent technology requirements for temporary units under 40 CFR 264.553 are applied, a waiver could be required.

Alternative 3 would meet all of the potentially relevant and appropriate TDEC/NRC regulations listed in Appendix E, Table 8, if approved per TDEC 1200-2-11-.17(5).

5.2.3.3 Long-term effectiveness and permanence

Alternative 3 would meet the remedial action objectives developed in Section 4.1.1. Direct exposure, direct contact, inhalation, and ingestion of contaminants in the sediments would be eliminated by isolation of the waste with the cap and liner. The consolidation cell would be structurally stable, and waste contained within existing berms would be removed. Leaching of contaminants to drinking water sources would be controlled by the cap and liner and, if necessary, by prohibiting use of groundwater at the site and surface water in White Oak Creek for drinking. Bioaccumulation of contaminants in sensitive ecological receptors would be significantly reduced by filling the ponds and eliminating contaminated fish and invertebrates as a food source for those receptors.

After loss of DOE control, the drinking water pathway could be a source of human health risk. There would also be an increased likelihood of intrusion into the cap and direct contact with the waste.

Magnitude of Residual Risks. The consolidation cell would prevent migration of the contaminants and, combined with institutional controls and deed restrictions, would cut off exposure pathways to workers and local biota. The consolidation cell would remove contaminated surface water and isolate sediment through engineered controls. Implementation of this alternative would not reduce the hazard of exposure to the contaminants. However, since the contamination sources are isolated from human and environmental receptors, this alternative should result in a long-term, positive effect on the environment through a reduction in exposures.

Adequacy and Reliability of Controls. The cap for Alternative 3 will need to be maintained for adequacy and reliability of controls. Maintenance would include erosion repair and vegetation maintenance. Institutional controls would be needed to prevent intrusion into the consolidation cell. In addition, the leachate collection/detection system would need to be maintained and operated for an indeterminant period of time. In principle, management of the site would be required for as long as the contaminated media under the cap remains. These controls are considered very reliable as long as the site remains under federal control.

Thereafter, reliability of the necessary controls could be less assured. The cap and liner would have a finite effective life span on the order of a few hundred years. As the isolation features deteriorate, releases of strontium to groundwater could increase to present levels. This would be mitigated in part by radioactive decay of ^{90}Sr, which has a half-life of 28 years. If the cap erodes, direct radiation would also be somewhat mitigated due to the decay of ^{137}Cs, which has a 30-year half-life. Erosion of the cap to a degree that would permit sediment to become

airborne could create a significant risk due to the very long half-lives of alpha-emitting plutonium and americium.

Irreversible and Irretrievable Commitment of Resources. Implementation of Alternative 3 would require some irretrievable commitment of resources, e.g., fuel, cell construction materials, and other materials. Also, the habitat provided by the impoundments would be lost, together with any biota living in or around them. The present habitat is contaminated, is not unique, and similar areas are abundant and present nearby.

Sensitive Resources. As for Alternative 2, consultation with the State Historical Preservation Officer would be required before initiating of any action. The State Historical Preservation Officer would specify any mitigation necessary to protect the resources that are eligible for inclusion in the National Register of Historic Places and concur with the project through a memorandum of agreement.

As for previous alternatives, neither floodplains, wetlands, endangered or threatened species, nor critical habitat would be affected by this alternative.

Wildlife and aquatic biota might be subject to indirect exposures through contact with contaminated subsurface water and vegetative litter remaining at the site, but this potential would decrease and disappear over time as the water was moved and diluted with other waters and the vegetative litter was dispersed. This would result in a net long-term benefit to the environment through reduced contaminant exposure.

Cumulative Effects. Same as for Alternative 2.

5.2.3.4 Reduction of toxicity, mobility, and volume through treatment

In Alternative 3, the contaminated surface water and any collected leachate or groundwater would be removed and treated at the existing process waste treatment system. The concentrated residuals would represent a significant reduction in volume compared to the original volume of contaminated water. The type, quantity, and handling of treatment residuals would be as described for Alternative 2, Section 5.2.2.4.

In situ dewatering in drainage beds within the consolidation cell is the only treatment proposed in the base actions for Alternative 3. Before relocating the sediment into the consolidation cell, the sediment from all ponds would have been mobilized into a slurry and transferred between ponds. A 30 percent volume reduction of the dewatered sediment compared

to the in situ volume is expected. No reduction from the in situ volume of other contaminated solids is expected due to dewatering.

Potential process modifications to the base actions include addition of structural or chemical stabilization materials to the waste during and after relocation to the consolidation cell. These process modifications would be based on the results of engineering support studies. Addition of these materials could increase the contaminant volume. Structural materials such as sand would displace water and increase structural stability of the consolidation cell, but would not reduce toxicity or mobility of the contaminants. Addition of bentonite could improve structural stability by absorbing water and could also provide additional sorption sites for certain metals and radionuclides. This would reduce the mobility of those contaminants; however, they are not very mobile within the sediment, the existing natural clay, or the proposed compacted clay liner. The mobility of ^{90}Sr and mercury would not be significantly reduced by bentonite addition. Chemical stabilization materials could be used, if practical, to reduce the mobility of ^{90}Sr and mercury, the two most significant groundwater contaminants. Addition of stabilization materials could increase the volume by 5-50 percent.

Neither the dewatering nor the potential modifications in treatment processes will destroy any contaminants. Although no reduction in absolute toxicity of the material is expected, a significant reduction in mobility would be attained by reducing infiltration of water into the wastes and contaminant migration through the basal clay liner.

5.2.3.5 Short-term effectiveness

In addition to the actions required for Alternative 2, Alternative 3 would require transferring the most highly contaminated waste (i.e., the sediment) twice and would require installation of a liner as well as a cap. The size of the consolidation cell would be smaller than the area under the caps for Alternative 2, but the overall scope of activities for this alternative would be greater. Following is a discussion of the short-term effectiveness of the actions proposed for Alternative 3.

Community Protection. As described for Alternative 2, hazards to the community (e.g., noise and dust) resulting from the remedial actions would be small, and standard construction practices would adequately protect the surrounding community.

Worker Protection. Same as for Alternative 2.

Short-Term and Long-Term Environmental Effects. As described for Alternative 2, erosion control measures, sedimentation barriers, and revegetation would mitigate any short-term environmental effects from normal construction activities.

Concerns for surface water and groundwater also involve runoff and infiltration from accidental leakage or spills of engine fuels, oils, hydraulic fluids, and coolants from equipment and vehicles used during the action. Air quality would be temporarily degraded by emissions and potential fugitive dust. An increase in noise levels from equipment and humans could affect wildlife populations at the operable unit and surrounding areas during implementation of this alternative. Standard construction management practices can mitigate these impacts to a large extent.

Removal and replacement of the contaminants and associated media present unique accident risks. The most likely accident scenario that could present risks to human health and the environment would be a release of sediment during transfer between ponds. A risk of airborne contamination could ensue. Additional contaminant loading to White Oak Creek would be another concern. Properly designed containment, operational procedures, and construction contingency plans would be developed during remedial design for mitigation of this factor.

The effects of these remedial actions on a cumulative basis would be similar to those described for Alternative 2. The small losses of individual organisms and habitat would be offset by a significant reduction in releases of contamination to the environment. Cumulative effects from this and other remedial actions would be positive.

Estimated Time until Remedial Action Objectives are Achieved. As for previous alternatives, existing controls presently meet three of the four remedial action objectives, and the remedial design would assure that these objectives continue to be met during remedial actions. Bioaccumulation of contaminants in sensitive ecological receptors will be mitigated when the impoundments are emptied, approximately 4.5 years after beginning remedial actions. The total duration of construction activities would be approximately 7.3 years, after which maintenance, monitoring, and institutional controls would be initiated.

Potential for Sudden Failure. Relocation of the waste from Impoundment 3524 to 3513 before constructing the consolidation cell at the location of Impoundment 3524 would increase the stress on Impoundment 3513. Preliminary stability analyses indicate that the berm between Impoundment 3513 and White Oak Creek would be structurally stable during the remedial actions; however, a more detailed analysis would be performed during remedial design, and, if necessary, stabilizing features could be constructed at the Impoundment 3513 berm. There is a

somewhat more likely possibility that seepage through the berm would increase. A seep control and management plan would be required before temporarily placing additional sediment in the impoundment. An appropriate design (including consideration of earthquake, flooding, and wind and water erosion design parameters) and proper construction of the consolidation cell would minimize the potential for sudden failure and releases of contamination during and after the remedial actions.

Direct or Indirect Socioeconomic Impact. Socioeconomic and land-use issues would be as described for Alternative 2. There would be a small increase in the number of jobs created by the revised scope of work for this alternative.

5.2.3.6 Implementability

As for Alternative 2, logistical difficulties would be expected due to the location of the operable unit in the most active area of ORNL.

Remotely controlled mobile dredges for transferring sediment between impoundments are readily available. Standard pumps would be used to transfer water between ponds or to treatment facilities, and standard construction equipment would be used to support the remedial activities. Specialists to operate the standard and the remotely controlled equipment are available in the local work force. Other specialists, including radiation protection, health and safety, construction management, and other personnel are also available in the local labor pool. Specialized training of qualified individuals would acquaint them with project-specific requirements.

The key technologies required to implement this alternative include contaminant mobilization and relocation, radiation shielding, dewatering of sediment and soil, and isolation. All of these technologies are readily available within industry or are commonly used at ORNL. The reliability of each technology is addressed below.

Sediment Mobilization and Relocation. Use of the remotely controlled mobile dredge is expected to be very effective in mobilizing most of the sediments and subimpoundment soil from the bottoms of the impoundments. Various designs are available that provide adequate maneuverability inside restrictive spaces.

Radiation Shielding. Shielding from radiation emitted from the waste could take several forms. Steel, concrete, or other shielding material could be used to shield small sources, e.g., the slurry pipeline. Water shielding of the sediment within the ponds will be used, as it is for existing conditions, during intermediate processing steps. The cap materials (including earth and stone) would be used as a final shield when water is removed. Determination of the types,

activity levels, and radiation levels; the acceptable occupational dose rates; and the thicknesses of various shielding materials necessary to meet those dose rates will be determined by engineering support studies. Operational procedures will be determined to ensure that doses received by remediation workers are ALARA. This combination of engineering and operational controls is expected to be very reliable in adequately shielding remediation workers.

Dewatering of Sediment and Soil. The reliability of dewatering the sediment and soil using the drainage beds and leachate collection system described in the base actions (Section 4.4.3.1) is unknown. An engineering support study is required to develop a reliable method of dewatering the waste. Some combination of the base actions and process modifications (Section 4.4.3.2) is expected to adequately dewater waste as required for structural stability of the consolidation cell.

Isolation. The liner and cap system for isolating the waste from the environment is expected to be very reliable. The discussion of long-term effectiveness for this alternative provides additional detail regarding the reliability of the isolation system.

The contingency actions for minimizing cell leakage are considered readily implementable. Once the consolidation cell is in place, certain other remedial actions could also be taken to correct deficiencies or to enhance the performance of the cell. Such additional remedial actions could include additional containment elements such as horizontal or vertical barriers. Vertical barriers would be fairly easy to implement, but their effectiveness would be questionable. Subsurface horizontal barriers would be very difficult to implement, but could be installed either in the bottom of the liner or in the overburden between the liner and the bedrock. Because bedrock extends to the bottom of the west end of the existing upper impoundment, installation of a horizontal barrier in that location would be difficult and not very effective. If removal actions would be required after the consolidation cell is in place, they would be significantly more difficult, first, due to the additional volume of materials to be handled, and second, because much of the cap and liner material could become contaminated and require special handling and disposal.

The materials, equipment, and expertise needed for the contingency action of using a package liquid waste treatment plant are readily available.

Monitoring the effectiveness of the consolidation cell could be readily performed. The visual inspection program and surveys on settling would confirm the integrity of the cap as described for Alternative 2 (Section 5.2.2.6). The leachate detection system would provide an early indication of any problems with the liner. The groundwater sampling program would verify

that the consolidation cell was not releasing contamination in excess of the predicted worst case amounts.

As described in Section 5.2.3.2, the consolidation cell meets most ARARs, and the results of the risk assessments indicate that performance requirements can be met without full compliance with some of the siting requirements. It is reasonable to expect that regulatory agencies would waive the requirements of the remaining ARARs if no other combinations of remedial actions provide significantly better protection of human health and the environment. Because the site is owned and regulated by DOE, only limited coordination with other offices and agencies would be required after regulatory approval of the proposed plan. No additional permitted facilities would be necessary.

5.2.3.7 Cost

Capital costs for implementing Alternative 3 are estimated to be $51.36 million. The 30-year estimate for O&M costs is projected at approximately $5.804 million total. The present worth of those costs is $45.65 million. Table 5.3 is a summary of the main cost drivers for the base actions and the contingency actions for Alternative 3.

5.2.4 Alternative 4—Consolidation Cell with Ex Situ Treatment

Alternative 4 would relocate the sediment and contaminated subimpoundment soil from Impoundments 3524, 3539, and 3540 to Impoundment 3513, construct a treatment facility for stabilization and solidification of the waste, install a liner and leachate detection system (part of a consolidation cell) in the former location of Impoundment 3524, transfer all of the sediment within the operable unit to the treatment facility, treat the sediment (stabilization/solidification is the representative treatment process analyzed), place the solidified waste in the lined cell, place contaminated subimpoundment and surface soil (treated as appropriate) over the solidified sediment, and install a multilayer cap over the consolidation cell and clean soil over the excavated surface soil areas to isolate the waste from the environment.

As described in Section 4.4.4, Alternative 4 would isolate the wastes sufficiently such that federal institutional controls would only be required at the site of the consolidation cell, and a receptor at White Oak Creek would not be exposed to unacceptable risk due to contamination from SIOU. Additional institutional controls could be required to address other sources of contamination.

Table 5.3. Alternative 3 cost estimate for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Project cost item	Cost (Thousand dollars)[b]	
Capital costs		
Direct cost:		
Support facilities	1,266	
Site preparation	311	
Consolidation cell	11,895	
Dewatering	324	
Closure cap	719	
Decontaminate and remove support facilities	245	
Mobilize and demobilize	840	
Training and medicals	774	
Deed restrictions	5	
Construction management	4,029	
Direct total cost		20,408
Indirect cost:		
Engineering expenses	3,937	
Administration costs	13,696	
Contingency (indirect and direct)	13,319	
Indirect total cost		30,952
Total capital cost		51,360
O&M costs		
O&M costs (first year):		
Administration cost	112	
Surveillance and maintenance	235	
First year O&M costs		347
O&M costs (2–30 years):		
Administration cost	2,460	
Surveillance and maintenance	1,373	
5-year periodic reports	120	
O&M costs (2–30 years)		3,953
Total O&M contingency		1,504
Total O&M costs		5,804
Total project cost in escalated dollars		57,164
Present worth costs		
Total Alternative 3 present worth costs: [Per BLCC analysis (version 4.20-95)]	45,650	

[a]Per Guidance Document EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*
[b]Escalated (average 3.7% escalated rate per DOE Guidance)

BLCC = Building Life-Cycle Cost
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
O&M = operation and maintenance
ORNL = Oak Ridge National Laboratory
% = percent
SIOU = Surface Impoundments Operable Unit

5.2.4.1 Overall protection of human health and the environment

Alternative 4 protects against direct radiation, minimizes airborne soil particulates, and prevents airborne sediment migration as described for Alternative 3. Modeled risks at White Oak Dam and off site at Clinch River are 9×10^{-5} and $< 1 \times 10^{-6}$, respectively (see Appendix C), and are acceptable. The cap, the liner, and treatment of the waste would reduce the RME risks for residents both at the site and on White Oak Creek to 3×10^{-4}. The risk evaluation assumes that a resident does not build a home directly on the cap and penetrate the protective cover.

Institutional controls will be as described for Alternative 3 for SIOU and for other operable units. Alternative 4 meets all of the remedial action objectives stated in Section 4.1.

Ecological risks will be negligible as described for Alternative 3.

In the long term after loss of institutional control, on-site residents and residents at White Oak Creek could be exposed to the risks described above. Intruders into the cap contacting the waste for extended periods would have a near certain risk of developing cancer or other adverse toxicological effects. However, because the waste would be containerized and shielded before placement, such inadvertent intrusion would require a significant effort for the effective life (several hundred years or more) of the solidified waste and containers. Eventually, perhaps in several hundred years or more, the consolidation cell, the waste containers, and the waste form could deteriorate, and environmental releases could approach today's levels.

Implementation of good, standard construction practices and health and safety programs would adequately mitigate any adverse short-term effects to the community, remediation workers, and the environment during remedial actions. There is a substantial increase in the scope of the remedial actions compared to previous alternatives and, even with the best management practices, an increase in short-term risk to remediation workers would be expected.

5.2.4.2 Compliance with ARARs

Alternative 4 would comply with the TBCs for radionuclide exposures at the designated receptor location at White Oak Creek, the TBCs for PCBs and lead, and the location-specific ARARs (see Appendix E, Table 1).

Alternative 4 would meet the requirements for institutional controls; stormwater runoff; fugitive emissions from construction activities; treatment of surface water; closure of Impoundments 3513, 3539, and 3540; installation of a liner; and final closure and capping listed in Table 3 of Appendix E.

The movement of waste to the RCRA treatment unit (i.e., the stabilization/solidification facility) and back to the consolidation cell would trigger land disposal restrictions for those RCRA characteristic wastes for which land disposal restrictions have been promulgated (see Appendix E, Table 4). Depending on the results of the engineering support studies regarding the effectiveness of the treatment processes, a waiver from this requirement in 40 CFR 268.48 could be needed. If the treatment tanks cannot be classified as temporary units under RCRA, 40 CFR 264.553, a waiver may be required for clean closure [TDEC 1250-1-11-.06(10)(h)]. Such waivers would be requested per 40 CFR 300.430(f)(1)(ii)(C) because the alternative will attain an equivalent standard of performance through use of another method or approach.

Alternative 4 would meet all of the potentially relevant and appropriate TDEC/NRC regulations listed in Appendix E, Table 8, if approved per TDEC 1200-2-11-.17(5).

5.2.4.3 Long-term effectiveness and permanence

As for previous alternatives, Alternative 4 would meet the remedial action objectives developed in Section 4.1.1 by treating and isolating the contaminants, eliminating contaminated fish as a food source for ecological receptors and, if necessary, prohibiting use of groundwater at the site and surface water in White Oak Creek for drinking.

After loss of DOE control, the drinking water pathway could be a source of human health risk. There would also be an increased likelihood of intrusion into the cap and direct contact with the waste, although treatment and containerization of the waste could reduce both the likelihood and the effects of such intrusion.

Magnitude of Residual Risks. This alternative should result in essentially the same long-term positive effect on the environment through a reduction in exposures as described for Alternative 3. Because the waste is solidified and less likely to leach within the cell, a slight reduction in risk is expected as discussed in Sections 5.2.3.1 and 5.2.4.1.

Adequacy and Reliability of Controls. The same institutional and operational controls described for Alternative 3 would be applied for this alternative. These controls are considered very reliable as long as the site remains under federal control. Thereafter, intrusion by human or ecological receptors through the cap would still present hazards. Because the most highly contaminated waste would be solidified, the likelihood of intrusion and the probability of widespread releases of contamination would be greatly reduced. After the effective life of the consolidation cell is exceeded in perhaps several hundred years or more, releases and subsequent risks would increase toward the baseline risk assessment risks. Radioactive decay of ^{137}Cs and ^{90}Sr would partially mitigate those risks as described for Alternative 3.

Irreversible and Irretrievable Commitment of Resources. As for previous alternatives, Alternative 4 would require irretrievable commitment of resources of fuel and materials and minor losses of habitat and biota.

Sensitive Resources. Same as for Alternative 3.

Cumulative Effects. Cumulative effects would be as described for Alternative 3.

5.2.4.4 Reduction of toxicity, mobility, and volume through treatment

Treatment of the contaminated surface water and any collected leachate or groundwater at the existing Process Waste Treatment Plant would significantly reduce the volume of liquid waste, but create manageable residual waste streams as described for Alternative 2, Section 5.2.2.4.

The solidification/stabilization process developed for the sediment (and possibly the subimpoundment soils) would be designed to reduce the mobility of the contaminants by first stabilizing (reducing the solubility or mobility in water), then solidifying the waste by adding portland cement, lime, fly ash, zeolite, sulfide, and/or other additives and allowing the mixture to harden. The volume of contaminated material would increase (approximately double) due to the addition of stabilization and solidification materials. The reduction in mobility would lead to a reduction in toxicity since the contaminants would no longer be biologically available.

The effectiveness of the stabilization/solidification process would vary for the different contaminants in the mixed waste. Most of the metals and radionuclides are already relatively immobile in the sediment and soil; major exceptions are ^{90}Sr and mercury. In the existing sediment-soil-groundwater environment, mercury is apparently mobile, as indicated by elevated mercury concentrations in groundwater. All common species of strontium (with the exception of $SrTiO_3$) are soluble in water, and thus, highly mobile.

Stabilization agents are available that can precipitate most heavy metals, including mercury, into relatively immobile sulfide species. The contaminants that are currently relatively immobile and the sulfide-stabilized species can be tightly bound in a cement-solidified waste matrix. The mobility of ^{90}Sr is not reduced by the same stabilization agents. Certain salts, organic materials, clays (i.e., zeolite), and other additives have been suggested as possible ^{90}Sr-stabilization agents. The effectiveness of these additives, their interaction with other waste constituents and stabilization and solidification agents, and the chemical environment that would maintain ^{90}Sr in an immobile phase is not known. An engineering support study would be required to develop the most effective additives for the desired reduction in contaminant mobility.

Neither the solidification/stabilization process nor the water treatment processes would destroy any contaminants. The entire volume of contaminated free water removed would be treated. The entire volume of contaminated sediment would be treated. The base actions for Alternative 4 (Sect. 4.4.4.1) assume that soil contamination is minimal and no treatment of the soil is proposed.

The stabilization/solidification process is relatively irreversible. Although the expected life of the solidified waste matrix is not known and radiation is known to accelerate degradation of a cement-based matrix, durations of hundreds of years or more could be required for natural processes to completely break down the solidified waste form. Extensive human intervention would be required to remobilize the contaminants. Although absolute toxicity of the waste constituents would not be reduced, significant reductions in mobility would limit the biological availability of the contaminants. This would effectively reduce toxicity as well as mobility.

5.2.4.5 Short-term effectiveness

In addition to the actions required for Alternatives 2 and 3, this alternative would require construction of a temporary, on-site treatment unit. The overall scope of activities for this alternative would be greater than for previous alternatives. Following is a discussion of the short-term effectiveness of the actions proposed for Alternative 4.

Community Protection. As described for Alternative 2, hazards to the community (e.g., noise and dust) resulting from the remedial actions would be small, and standard construction practices would adequately protect the surrounding community.

Worker Protection. Short-term effects to workers during construction and other remedial efforts would be controlled through compliance with OSHA requirements, DOE Orders, and ORNL procedures. For normal construction practices and for transfer of untreated water, sediments, and soils, the health and safety plan described for Alternative 3 would be developed and implemented. Additional elements of the health and safety plan would address construction and operation of the treatment facility and handling and placement of the treated waste. Again, proper adherence to the safety requirements would provide an adequate level of protection for remediation workers, but the increased scope of the work would increase the probability of an industrial accident.

Short-Term and Long-Term Environmental Effects. Same as for Alternative 3, except the duration of construction will be 5 years.

5.2.4.6 Implementability

Same as for alternative 3, except for the additional action of stabilization/solidification, described below.

Stabilization/Solidification. To develop a reliable stabilization/solidification process, an engineering support study would be required to investigate the proper mix of additives for the specific waste being treated. At present, the sediment is assumed to have been deposited in layers with different characteristics, since different processes at ORNL were generating the waste that was discharged to the ponds over the years of operation. The characterization of the wastes within different ponds also varies, and there is horizontal variability of the waste characteristics within a pond. Relocation of the wastes with the mobile dredge from the upper impoundment and the two small impoundments to the lower impoundment, then from the lower impoundment to the treatment facility will combine the wastes in a more homogeneous mixture. Regardless, there will be some variability in the chemical content and water content of the waste arriving at the treatment facility. Also, there is a limitation on the percent organic content of a waste to be successfully solidified. Because there are actively growing biota within the ponds, the organic content within dredged sediment and soil is unknown, but may be high. The engineering support study would determine the range of waste characteristics that would be expected and develop either (1) a recipe of stabilization and solidification additives that would be effective over the entire range of waste characteristics or (2) a flexible fixation recipe that would be adjusted, based on sampled waste characteristics in batches.

Remotely handling the waste, adding the stabilization/solidification agents, mixing the ingredients, and curing the mixture is considered a reasonably reliable technology. Although several attempts at ex situ stabilization/solidification have been unsuccessful or only partially successful (e.g., the K-25 Pond Waste Management Project), proper studies, testing, and QC could provide reasonable assurance of a reliable process. Provisions would be made for repairing the equipment, and redundant systems would safely handle the waste in the event of process upset.

The reliability of the stabilization/solidification technology for reducing the mobility of the currently mobile contaminants, particularly ^{90}Sr, is not known (see Sect. 5.2.4.4). In addition, because radiation is known to degrade concrete, the long-term effectiveness of a cement-based stabilization/solidification process is not known (see Sect. 5.2.4.3).

5.2.4.7 Cost

Capital costs for implementing Alternative 4 are estimated to be $93.634 million. The 30-year estimate for O&M costs is projected at approximately $6.509 million total. The present worth of those costs is $87.243 million. Table 5.4 is a summary of the main cost drivers for the base actions and the contingency actions for Alternative 4.

5.2.5 Alternative 5—Off-SIOU Consolidation Cell

Alternative 5 includes removal of all sediments, contaminated soils and the surface water from the operable unit; treatment of the surface water in the existing process waste treatment system; possible treatment of the sediment and soil (simple dewatering with in situ drainage beds is the representative process option receiving detailed analysis); transport of the sediment and soil to a newly constructed, off-SIOU consolidation cell; consolidation of the waste into the lined cell; and capping the cell when the contents have sufficiently stabilized. The potential benefits of this alternative include (1) the opportunity to select a site that is hydrogeologically more suitable, (2) location of the consolidation cell away from the most active areas of ORNL, and (3) the ability to incorporate wastes from other impoundments within ORNL into the same consolidation cell.

As described in Section 4.4.5, Alternative 5 would require institutional controls at the site of the consolidation cell. No institutional controls would be needed at the SIOU site because all contamination (water and sediment) would be removed; however, such controls could be needed to address contamination from other off-SIOU sources (i.e., the soils and groundwater operable units).

5.2.5.1 Overall protection of human health and the environment

At the SIOU site, Alternative 5 protects against direct radiation, minimizes airborne soil particulates, and prevents airborne sediment migration by removing the waste. At the off-SIOU consolidation cell site, protection for these pathways is provided by the cap and liner as described for Alternative 3. Modeled risks at all receptor locations from the contamination at SIOU are less than 1×10^{-6} (see Appendix C). Risk at the consolidation cell site is difficult to evaluate since the site has not been designated. If risks from residual soil contamination were included, the risks on site and at White Oak Creek would both be 3×10^{-4}, the same as for Alternative 4. It is assumed that the site will be selected based on suitable hydrogeologic features and that the engineered barriers in conjunction with the site characteristics and institutional controls at the consolidation cell site will prevent unacceptable risk levels near the consolidation cell site and at

Table 5.4. Alternative 4 cost estimate for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Project cost item	Costs (Thousand dollars)[b]	
Capital costs		
Direct cost:		
Support facilities	1,266	
Site preparation	311	
Consolidation cell	4,287	
Treatment facility	6,536	
Treat, dispose, and cap	7,976	
Decontaminate and decommission treatment facilities	1,784	
Decontaminate and remove support facilities	245	
Mobilize and demobilize	1,273	
Training and medicals	760	
Deed restrictions	5	
Construction management	5,876	
Direct total cost		30,319
Indirect cost:		
Engineering expenses	7,038	
Administration costs	29,529	
Contingency (indirect & direct)	26,748	
Indirect total cost		63,315
Total capital cost		93,634
O&M costs		
O&M costs (first year):		
Administration cost	112	
Surveillance and maintenance	234	
First year O&M costs		346
O&M costs (2–30 years):		
Administration cost	2,682	
Surveillance and maintenance	1,501	
5-year periodic reports	120	
O&M costs (2–30 years)		4,303
Total O&M contingency		1,860
Total O&M costs		6,509
Total project cost in escalated dollars		100,143
Present worth costs		
Total Alternative 4 present worth costs: [Per BLCC analysis (version 4.20-95)]	87,243	

[a]Per Guidance Document EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*
[b]Escalated (average 3.7% escalated rate per DOE Guidance)

BLCC = Building Life-Cycle Cost
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
O&M = operation and maintenance
ORNL = Oak Ridge National Laboratory
% = percent
SIOU = Surface Impoundments Operable Unit

all remote locations. As for all previous alternatives in the long term after loss of institutional control, intrusion into the off-SIOU consolidation cell for extended periods would entail extreme risk of cancer or other adverse toxicological effects.

Institutional controls necessitated by the SIOU remedial actions would only be required at the site of the consolidation cell. Institutional controls for other sources of contamination will be as described for Alternative 3 for other operable units. Alternative 5 meets all of the remedial action objectives stated in Section 4.1.

Ecological risks will be negligible at the SIOU site because the contamination source is removed and at the consolidation cell site because the waste is isolated from the environment.

Implementation of good, standard construction practices and health and safety programs would adequately mitigate any adverse short-term effects to the community, remediation workers, and the environment during remedial actions. The increase in the scope of the remedial actions (particularly regarding transport of sediment between the impoundments and the consolidation cell site), even with the best management practices, would be expected to increase short-term risk to remediation workers. The risk of a spill that could result in environmental damage would also be increased. In the very long term after the effective life of the consolidation cell, risks at that location would be as described for Alternative 3.

5.2.5.2 Compliance with ARARs

Alternative 5 would be able to comply with the TBCs for radionuclide exposures for all receptors outside of the consolidation cell site, the TBCs for PCBs and lead, and the location-specific ARARs (see Appendix E, Table 1).

Alternative 5 would be able to meet the requirements for institutional controls, stormwater runoff, fugitive emissions from construction activities, treatment of surface water, installation of a liner, final closure and capping, closure of SIOU, and transport of contaminated sediment and soils listed in Table 5 of Appendix E. As described for Alternative 3, a waiver would be needed for the chemical waste landfill general design requirements to locate the landfill 16.7 m (50 ft) above the water table.

As for Alternative 3, the land disposal restriction Federal Facility Compliance Agreement and the Toxic Substances Control Act Federal Facility Compliance Agreement that permit storage of solid mixed waste that would be generated from the contingency action of treating liquid wastes in a zeolite package treatment plant (see Appendix E, Table 7) would be required and would be justified. If the contingency action of mechanical dewatering is used, waivers from

land disposal restrictions and tank closure requirements would be needed and justified as described for Alternative 3. Alternative 5 would meet potentially relevant and appropriate TDEC/NRC regulations listed in Appendix E, Table 8, if approved per TDEC 1200-2-11-.17(5).

5.2.5.3 Long-term effectiveness and permanence

As for Alternatives 3 and 4, Alternative 5 would meet the remedial action objectives developed in Section 4.1.1 by isolating the contaminants and eliminating contaminated fish as a food source for ecological receptors.

After loss of DOE control, there would be an increased likelihood of intrusion into the off-SIOU consolidation cell and direct contact with the waste.

Magnitude of Residual Risks. Removal of contaminants included in the operable unit would eliminate risks from those contaminants at the SIOU site. Some risk would remain at the site due to contamination from other sources, which will be addressed in other operable units. At the site of the consolidation cell, Alternative 5 would exhibit risks similar to those described for Alternative 3. Because the site for the consolidation cell would be selected to have better hydrogeologic characteristics than the operable unit site, the risk of migration of contamination by groundwater to off-site receptors would be reduced. This alternative should result in a net long-term positive effect on the environment through a reduction in exposures as described for Alternative 3.

Adequacy and Reliability of Controls. Same as for Alternative 3.

Irreversible and Irretrievable Commitment of Resources. As for previous alternatives, Alternative 5 would require an irretrievable commitment of resources and minor losses of habitat and biota. In addition, the consolidation cell site would be affected by changing the nature of the available habitat to a vegetated cap over the consolidation cell. Although the location of the consolidation cell has not been determined, the site selection criteria would include an assessment of existing resources to avoid unacceptable losses.

Sensitive Resources. Same as for Alternative 3.

Cumulative Effects. Construction of an off-SIOU consolidation cell would represent an incremental loss of habitat in addition to the losses at the operable unit site. If other impoundments are remediated and the waste placed in the same consolidation cell (see Sect. 4.4.5), then there would be a beneficial cumulative effect since a single site would be used for management of the waste.

5.2.5.4 Reduction of toxicity, mobility, and volume through treatment

The reduction of toxicity, mobility, and volume through treatment for Alternative 5 would be the same as described for Alternative 3.

5.2.5.5 Short-term effectiveness

In addition to the actions required for Alternative 3, this alternative would require transport of slurried waste to the off-SIOU consolidation cell. Following is a discussion of the short-term effectiveness of the actions proposed for Alternative 5.

Community Protection. Same as described for Alternative 2.

Worker Protection. Short-term effects to workers during construction and other remedial efforts would be controlled through compliance with OSHA requirements, DOE Orders, and ORNL procedures. For normal construction practices and for transfer of untreated water, sediments, and soils, the health and safety plan described for Alternative 3 would be developed and implemented. Additional elements of the health and safety plan would address spill prevention and emergency response during transport of the waste. Again, proper adherence to the safety requirements would provide an adequate level of protection for remediation workers, but a large scope of the work would increase the probability of an industrial accident.

Short-Term and Long-Term Environmental Effects. Construction activities for Alternative 5 would occur on both the SIOU site and the consolidation cell site. Transport activities would increase the potential for accidents and spills. Because of these increased activities, short-term effects would be as described for previous alternatives, but would be increased in magnitude.

Removal, transport, and placement of the contaminants and associated media present accident risks. The most likely accident scenarios would be a release of sediment during transfer to or from the transport tanker (or pipeline, if used) or during transport. Such a spill could lead to a release of airborne contamination if not properly contained. Properly designed containment, operational and safety procedures, and contingency plan would be developed during remedial design for mitigation of this factor.

The effects of these remedial actions on a cumulative basis would be similar to those described for Alternative 2, except that transport of the waste to the off-SIOU cell, if by truck, would increase traffic and noise within the ORNL complex.

Estimated Time until Remedial Action Objectives are Achieved. As for previous alternatives, existing controls presently meet three of the four remedial action objectives and the remedial design for Alternative 5 would assure that these objectives continue to be met during remedial actions. Again, minimizing bioaccumulation of contaminants in sensitive ecological receptors would occur when the impoundments are emptied, approximately 4.5 years after beginning remedial actions. The total duration of construction activities would be approximately 7.4 years, after which maintenance, monitoring, and institutional controls would be initiated.

Potential for Sudden Failure. Waste would be removed from the existing impoundments and relocated to a properly designed and constructed consolidation cell. The potential for sudden failure at the impoundments (e.g., erosion of a berm) and release of contamination would be lessened as remedial actions progress. Because of the transportation requirements, there is a risk that a sudden release from a truck or pipeline could occur. Such a release, while serious, would be of a smaller volume than a potential catastrophic release from an impoundment. A spill prevention, containment, control, and cleanup plan would be developed before transporting any contaminated liquids or sludges.

Direct or Indirect Socioeconomic Impact. Other than an increase in the number of jobs created by the revised scope of work for this alternative, socioeconomic and land-use issues would be as described for Alternative 3.

5.2.5.6 Implementability

Logistical difficulties for Alternative 5 would be expected due to the location of the operable unit in the most active area of ORNL and the need to transport the waste between the operable unit site and the off-SIOU consolidation cell site.

The technologies required to implement Alternative 3 are also required for this alternative. These technologies include sediment mobilization and relocation, soil moving, radiation shielding, dewatering of sediment and soil, and isolation and are discussed in Section 5.2.3.6. Monitoring for the effectiveness of the remedial actions could also be readily performed as described for Alternative 3.

Transport. The additional technology required to implement Alternative 5 is the transport of a mixed waste sludge from the operable unit to the site of the consolidation cell. Tanker trucks are available in various sizes that could handle the waste. Modifications could be required to provide adequate shielding. Precautions would be required to prevent accidents or spills. Alternately, installation of a pipeline for slurry transport could be considered. If treatment of the waste (as described for Alternative 4) is required before placement in the consolidation cell, then

a solid waste container transport system could be used. The selection of the most cost-effective, safe system of waste transport would be made during remedial design. The actions required to safely transport the waste are considered reasonably implementable.

5.2.5.7 Cost

Capital costs for implementing Alternative 5 are estimated to be $54.297 million. The 30-year estimate for O&M costs is projected at approximately $5.996 million total. The present worth of those costs is $48.252 million. Table 5.5 is a summary of the main cost drivers for the base actions and the contingency actions for Alternative 5.

5.2.6 Alternative 6—Removal, Treatment, and Off-Site Disposal

Alternative 6 includes removal and treatment of surface water, removal of all sediments, removal of contaminated soils within the operable unit, construction of a treatment facility, treatment of both sediments and soils as required to meet ARARs and applicable disposal facility waste acceptance criteria, containerization of treated wastes, and transport of all treated wastes to Nevada Test Site. The representative treatment processes include base-catalyzed destruction of PCBs followed by stabilization/solidification to meet U.S. Department of Transportation (DOT) transport and RCRA land disposal restriction requirements.

As described in Section 4.4.6, no institutional controls would be needed at the site due to contamination from SIOU. However, residual contamination at the site would be addressed under the Waste Area Grouping 1 soils and groundwater operable units, and institutional controls could be required to protect human health and the environment from those sources.

5.2.6.1 Overall protection of human health and the environment

At the SIOU site, Alternative 6 protects against direct radiation, minimizes airborne soil particulates, and prevents airborne sediment migration by removing the waste, treating and packaging the waste, and transporting it to an off-site disposal facility. Long-term risk would be transferred to the disposal facility, assumed to be Nevada Test Site. Modeled risks at all receptor locations from the residual contamination at SIOU are less than 1×10^{-6} (see Appendix C), assuming no contribution to risk from residual soil contamination. If such risk is considered, risks for the on-site resident and at White Oak Creek would both be 3×10^{-4}.

There would be no risk for an inadvertent intruder at the SIOU site since all waste would be removed. Risk at the disposal facility is assumed to be acceptable, although intrusion would have to be prohibited.

Table 5.5. Alternative 5 cost estimate for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Project cost item	Costs (Thousand dollars)[b]	
Capital costs		
Direct cost:		
Support facilities	1,527	
Site preparation	353	
Consolidation cell construction	1,006	
Relocate and cap contaminated material	11,783	
Dewatering	305	
Closure cap	682	
Decontaminate and remove support facilities	319	
Mobilize and demobilize	894	
Training and medicals	624	
Deed restrictions	5	
Construction management	4,296	
Direct total cost		21,794
Indirect cost:		
Engineering expenses	4,137	
Administration costs	14,288	
Contingency (indirect and direct)	14,078	
Indirect total cost		32,503
Total capital cost		54,297
O&M costs		
O&M costs (first year):		
Administration cost	112	
Surveillance and maintenance	380	
First year O&M costs		492
O&M costs (2–30 years):		
Administration cost	2,460	
Surveillance and maintenance	1,370	
5-year periodic reports	120	
O&M costs (2–30 years)		3,950
Total O&M contingency		1,554
Total O&M costs		5,996
Total project cost in escalated dollars		60,293
Present worth costs		
Total Alternative 5 present worth costs: [Per BLCC analysis (version 4.20-95)]	48,252	

[a]Per Guidance Document EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*
[b]Escalated (average 3.7% escalated rate per DOE Guidance)

BLCC = Building Life-Cycle Cost
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
O&M = operation and maintenance
ORNL = Oak Ridge National Laboratory
% = percent
SIOU = Surface Impoundments Operable Unit

No institutional controls necessitated by the SIOU remedial actions would be required at ORR. Institutional controls for other sources of contamination will be as described for Alternative 3 for other operable units. Alternative 6 meets all of the remedial action objectives stated in Section 4.1.

Ecological risks will be negligible because the contamination source will be removed.

Implementation of good, standard construction practices and health and safety programs would mitigate adverse short-term effects to the community, remediation workers, and the environment during remedial actions. However, the scope of these remedial actions is significantly greater than for previous alternatives. Construction and operation of a complex treatment facility and interstate transport of solidified and containerized waste are the key actions that, even with the best management practices, could increase risk to remediation workers and the public.

5.2.6.2 Compliance with ARARs

Assuming that the removal, treatment, and transportation technologies selected for implementation of this alternative are effective, Alternative 6 will be able to meet all chemical- and action-specific ARARs as well as location-specific ARARs for the SIOU site as listed in Appendix E, Tables 1 and 6. Alternative 6 would meet potentially relevant and appropriate TDEC/NRC regulations listed in Appendix E, Table 8, if approved per TDEC 1200-2-11-.17.

5.2.6.3 Long-term effectiveness and permanence

Alternative 6 would meet the remedial action objectives developed in Section 4.1.1 by removal, treatment, and off-site disposal of all accessible contamination. No institutional controls would be required due to the residual contamination originating from SIOU. Institutional controls at the site and at other locations could be required due to other sources of contamination, but these controls would be associated with the soils or groundwater operable units.

Magnitude of Residual Risks. Alternative 6 would provide a long-term solution that is effective and permanent, assuming that the disposal site at Nevada Test Site remains effective and in compliance with present and future regulatory requirements. Removal, treatment, and off-site disposal would prevent exposure to the waste for the on-site workers and biota. Implementation of this alternative will eliminate the risk associated with the sources of contamination after the contaminated surface water, sediment, and soil are removed, treated, and disposed of. No continuing migration of contaminants from SIOU to the surrounding soil, groundwater or surface water at White Oak Creek would occur. This alternative would be effective in the long term for protection of human health and the environment.

The risks at the disposal site are considered to be acceptable since the site is already permitted to accept low-level waste, and environmental effects and residual risk have already been addressed for this facility. Therefore, only residual risks at the operable unit site are considered here. Since Alternative 6 removes all of the wastes defined to be in this operable unit, no residual risk will remain that will not be addressed by the soils and groundwater operable units. Note, however, that other contamination sources addressed in those operable units may create risk at the same location.

Adequacy and Reliability of Controls. Because the waste would be removed from the site, no controls would be necessary to address the waste at this operable unit. Controls at the licensed disposal facility are presumed to be adequate.

Irreversible and Irretrievable Commitment of Resources. As for previous alternatives, Alternative 6 would require some irretrievable commitment of resources and minor losses of certain habitat and biota.

Sensitive Resources. Same as previously described in Alternative 5.

Cumulative Effects. Filling the ponds would result in a small loss of open water as habitat. The habitat that would be lost has been contaminated since its creation, other sources of open water are available, and no other significant losses are anticipated. After excavation, treatment, and off-site disposal, risks from SIOU to human health and the environment will no longer contribute to cumulative risks at ORR or nearby areas. These risks will have been transferred to the permitted disposal site at Nevada Test Site. Exposure pathways are monitored and controlled at the disposal site. It is assumed that the risks from placing the contaminants at the disposal site are much less than risks from leaving the contaminants in situ. The area will recover from the disturbance from construction. It will be revegetated and could support animal population. The site will remain in a highly utilized area of ORNL and, once remediated, could be subject to other industrial uses, for example, a parking lot. Some risk to human health and the environment from potential leachate generation from other sources still exists in this geographical region.

5.2.6.4 Reduction of toxicity, mobility, and volume through treatment

The representative treatment process of stabilization/solidification will significantly increase waste volume and will reduce contaminant mobility and toxicity as described for Alternative 4.

The additional treatment process of base-catalyzed destruction of PCBs will reduce the toxicity of those constituents. It will have little effect on volume. Once most of the PCBs are destroyed, their mobility is not an issue. The reliability of the process in treating the PCBs in this complex mixed waste stream is unknown. Engineering support studies would be required to properly design the system and evaluate the potential effectiveness.

5.2.6.5 Short-term effectiveness

Alternative 6 includes all of the actions required for Alternative 4 with the exception of constructing a consolidation cell on the operable unit. A treatment component for PCB removal would be added to the stabilization/solidification process. Long-distance transport and disposal in an off-site facility are also included. The scope of the activities, particularly the treatment and transport activities, would be much greater than for previous alternatives. Following is a discussion of the short-term effectiveness of the actions proposed for Alternative 6.

Community Protection. Same as described for Alternative 5.

Worker Protection. Short-term effects to workers during construction and other remedial efforts would be controlled through compliance with OSHA requirements, DOT requirements, DOE Orders, and ORNL procedures. The health and safety plan described for Alternative 4 would be developed and implemented. Additional elements of the health and safety plan would address transport requirements and emergency response during transport. Proper adherence to the safety requirements would provide an adequate level of protection for remediation workers, but the significantly increased scope of work, particularly regarding waste handling and transport, would increase the probability of an industrial accident.

Short-Term and Long-Term Environmental Effects. As described for previous alternatives, standard construction management practices would mitigate any short-term environmental effects from normal construction activities.

Removal, treatment, and transport of the contaminants and associated media present accident risks. The likely accident scenarios would include a release of sediment during transfer from the ponds to the treatment facility or a vehicular accident during transport. Properly designed containment, operational procedures, and an accident analysis and contingency plan would be developed during remedial design for mitigation of this factor.

The cumulative effects of the remedial actions for Alternative 6 would be similar to those described for Alternative 2.

Estimated Time until Remedial Action Objectives are Achieved. As for previous alternatives, existing controls presently meet three of the four remedial action objectives, and the remedial design for Alternative 6 would assure that these objectives continue to be met during remedial actions. Again, minimizing bioaccumulation of contaminants in sensitive ecological receptors would occur when the impoundments are emptied, approximately 3.6 years after beginning remedial actions. The total duration of construction activities would be approximately 4.3 years.

Potential for Sudden Failure. Waste would be removed from the existing impoundments and relocated to a treatment facility. The potential for sudden failure at the impoundments and release of contamination would be lessened as remedial actions progress. There is a risk that a sudden release of contamination from the treatment facility could occur. Such a release, while serious, would be a smaller volume than a potential catastrophic release from an impoundment. Safety features would be developed for the treatment facility. Releases during a transportation accident would not be dangerous to remediation workers or the public because the waste would be solidified and contained and could be effectively cleaned up.

Direct or Indirect Socioeconomic Impact. Implementation of Alternative 6 would provide a greater number of jobs to the local and regional economy than previous alternatives, commensurate with the increased scope and cost of the remedial actions. Although the existing labor force would be used, the construction and operation of the treatment facility could provide additional employment opportunities. The facility could continue operation or be relocated to address wastes from other operable units. Future expenditures could be associated with such continued operation. Implementation of Alternative 6 is not expected to have any substantial effects on socioeconomics or land use until all contaminated operable units are cleaned up or the owner of the property and the total land use of ORNL are changed.

5.2.6.6 Implementability

Implementing this alternative would be extraordinarily difficult, both technically and administratively. Obtaining a disposal contract with Nevada Test Site (or another disposal facility) would be difficult and time-consuming. Obtaining the necessary shipping permits and meeting the transport requirements would also be problematic. Because the waste would be prepared for final disposal, the most stringent regulatory requirements would be applicable.

The logistical problems described for Alternative 4 due to locating and operating a treatment plant and performing the remedial actions within the active portion of ORNL would also be applicable for Alternative 6.

As for previous alternatives, the construction equipment required for removing the waste and transferring it to the treatment facility is readily available. In addition to the representative stabilization/solidification treatment process described in Section 5.2.4.6 for Alternative 4, a representative treatment train for base-catalyzed destruction of PCBs would be required. Once transportation issues are resolved, staging the solidified and containerized waste, loading it onto appropriate vehicles, transporting it from Tennessee to Nevada, and unloading and placing the waste would be technically and logistically implementable. Assuming the treatment process can be adequately developed, the specialists necessary to operate the equipment are available.

The key technologies required to implement Alternative 6 include sediment mobilization and relocation, soil moving, radiation shielding, stabilization/solidification of sediment (and possibly soil), base-catalyzed destruction of PCBs, transport, and disposal. The reliability of sediment mobilization and relocation, soil moving, and radiation shielding is discussed in Section 5.2.3.6. Stabilization/solidification is addressed in Section 5.2.4.6. Base-catalyzed destruction of PCBs, transport, and disposal are discussed below.

Base-Catalyzed Destruction of PCBs. This process is an emerging technology described in *EPA Engineering Issue, Technology Alternatives for Remediation of PCB-Contaminated Soil and Sediment* (Dávila, Whitford, and Saylor 1993). None of the disposal sites investigated will currently accept waste containing greater than 50 ppm PCBs and, because the concentration of PCBs in all sediments and possibly some of the soils is greater than this level, treatment to remove or destroy some of the PCBs will be required. The demonstrated technology of incineration is not applicable to the highly radioactive waste. Base-catalyzed destruction appears to have the best chance of being effective on this waste when compared to other established, demonstrated, or emerging technologies. The pilot projects performed to date have treated simple PCB-contaminated soils. There have been no demonstrations on mixed, radioactive, hazardous, and PCB-contaminated waste. For this reason, the reliability of this process is unknown, and an engineering support study would be required to confirm the applicability of and to develop a design basis for this treatment process. Because of the radiation hazard, remote handling, containment, and shielding features would have to be incorporated into the process design. These features would increase the complexity and cost of the process. Finally, linking the process to the stabilization/solidification process would be required. It is believed that adding a PCB treatment train to the stabilization/solidification process is feasible, but extensive study, design, and demonstrations could be necessary before implementation. Implementing this technology would be very time-consuming and difficult. Adequate destruction of PCBs in the waste is likely possible, but the reliability is unknown at this time.

Transport. For Alternative 6, transport of the waste includes staging of the containerized, solidified waste, loading the containers onto trucks, possibly transferring the wastes to a train or barge, transporting the waste to Nevada Test Site, and unloading the waste. All of these operations are technologically reliable. The only concern is safety and the possibility of accident. Well over 2,000 truckloads and over 700 railroad cars (if used) would be needed to transport approximately 5,000 containers of waste. Because the waste would be solidified and containerized, exposures resulting from an accident would be limited, depending on the severity of the accident.

An increase in truck traffic, both on ORNL roads and on public roads, would occur during the disposal phase of Alternative 6. It is assumed that no new paved roads would be needed. A substantial increase in traffic on local roads would occur. The increase in interstate truck or rail traffic would not be significant. Local traffic delays could be partially mitigated by scheduling truck movement during nonpeak traffic flow times. Haul traffic would result in more wear and tear to road surfaces, reducing their life span. The increased potential for roadway accidents in the local area could be lessened by posting warning signs and signals and by scheduling transport during off-peak hours.

Disposal. Assuming regulatory requirements and waste acceptance criteria can be met, Nevada Test Site would reliably manage the waste upon receipt. Nevada Test Site has all the necessary permits to dispose of low-level waste.

Other Issues. Other than addressing other sources of waste under the soils and groundwater operable units, no additional remedial actions would be necessary. Monitoring the effectiveness of the actions would be limited to verifying adequate removal of the waste sources and would be readily implementable. Coordinating with Nevada Test Site and other offices and agencies and obtaining federal and state regulatory agency approval for the removal and treatment actions in Tennessee, the disposal in Nevada, and transport in the states in between would be time-consuming and difficult. Assuming technical issues could be resolved, such coordination and regulatory approval would likely be possible. The materials, equipment, and expertise needed for the contingency action of using a package liquid waste treatment plant are readily available.

No existing permitted facilities can accept mixed waste from the operable unit without treatment to eliminate RCRA hazardous characteristics and PCBs in excess of 50 ppm. A few facilities are permitted to accept low-level waste. The treatment processes discussed above are designed to meet the applicable waste acceptance criteria.

5.2.6.7 Cost

Capital costs for implementing Alternative 6 are estimated to be $162.693 million. The 30-year estimate for O&M costs is projected at approximately $1.335 million total. The present worth of those costs is $148.673 million. Table 5.6 is a summary of the main cost drivers for the base actions and the contingency actions for Alternative 6.

5.3 COMPARATIVE ANALYSIS

For each of the seven CERCLA evaluation criteria below, the relative success of the five alternatives in meeting those criteria are compared. In addition to the comparative analysis of the alternatives in addressing the probable conditions, a comparative analysis is also made of the contingency plans that address reasonable deviations from those conditions. Table 5.7. shows a summary of the comparative analysis.

5.3.1 Overall Protection of Human Health and the Environment

This criterion addresses protection of human health and the environment. Each is discussed separately below.

Currently, human health risks are acceptable for all receptors because existing institutional and operational controls prevent releases of contamination beyond the ORNL boundary, and access to contaminated media within ORNL is restricted to prevent unacceptable levels of exposure. Potential future risks to human health are indicated by modeled RME risks based on the following:

- RME contaminant levels at the SIOU site based on sampling data,
- reasonable maximum potential releases from any contamination sources remaining after remedial actions,
- modeled contaminant levels resulting from those releases to future receptor locations,
- pathways for exposure of receptors to contamination, and
- models of risk associated with exposure to the level of contamination by the available pathway.

Table 5.6. Alternative 6 cost estimate for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

Project cost item	Costs (Thousand dollars)[b]	
Capital costs		
Direct cost:		
Support facilities	1,347	
Site preparation	433	
Relocate material from Impoundments 3539 and 3540	1,513	
Treatment facility	9,578	
Remove and treat	9,957	
Decontamination and decommission treatment facility	1,760	
Decontaminate and remove support facilities	239	
Mobilize and demobilize	1,442	
Training and medicals	1,029	
Transport and dispose of waste	24,928	
Construction management	6,557	
Direct total cost		58,783
Indirect cost:		
Engineering expenses	7,584	
Administration costs	49,844	
Contingency (indirect and direct)	46,482	
Indirect total cost		103,910
Total capital cost		162,693
O&M costs		
O&M costs (first year):		
Administration cost	112	
Surveillance and maintenance	210	
First year O&M costs		322
O&M costs (2-5 years):		
Administration cost	448	
Surveillance and maintenance	165	
5-year periodic reports	20	
O&M costs (2-5 years)		633
Total O&M contingency		380
Total O&M costs		1,335
Total project cost in escalated dollars		164,028
Present worth costs		
Total Alternative 6 present worth costs: [Per BLCC analysis (version 4.20-95)]	148,637	

[a]Per Guidance Document EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*
[b]Escalated (average 3.7% escalated rate per DOE Guidance)

BLCC = Building Life-Cycle Cost
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
O&M = operation and maintenance
ORNL = Oak Ridge National Laboratory
% = percent
SIOU = Surface Impoundments Operable Unit

At each step, conservative assumptions are used in the risk assessments for each alternative. The results are expressed in the risk of additional incidence of cancer and are compared to the EPA target range of 1×10^{-6} to 1×10^{-4}. There are no expected human health risks other than additional incidence of cancer. Table 5.7 indicates the modeled future risk levels.

For all alternatives, it is assumed that no direct contact with the waste for extended periods of time occurs in the future. Such inadvertent intrusion at an on-site or off-site waste management facility would entail a near certain risk of cancer or other toxicological effects.

The risk to future employees for Alternatives 2-6 is 1×10^{-6} or less. For Alternative 1, employee risk is acceptable at a level of 6×10^{-5} during the period of institutional control, but would be unacceptable (4×10^{-3}) if such controls were abandoned.

Off-site risk at Clinch River is less than 1×10^{-6} for Alternatives 2-6. For Alternative 1, there is an acceptable modeled RME risk of 1×10^{-4} at Clinch River during the institutional control period and an unacceptable risk of 5×10^{-3} thereafter.

For residential receptor locations within the current ORNL boundary, each alternative depends on institutional controls to restrict access to media that potentially could be contaminated by SIOU wastes. Alternative 1 would not be protective for any residential receptor within the existing ORNL boundary, either during or after the institutional control period. Alternative 2 would be protective at White Oak Dam and would require institutional controls restricting access to and use of water from White Oak Creek or from the SIOU site.

Alternatives 3-6 would meet EPA target risk goals for residential receptors at White Oak Dam. These alternatives could also be protective at White Oak Creek and on site if the risk from residual soil within the SIOU boundary and outside of the consolidation cell is discounted. Discounting residual soil contributions to risk may be acceptable for the following reasons. First, these soils are not included within the definition of SIOU. Residual soil risk will be addressed by the soils and groundwater operable units for Waste Area Grouping 1. Second, the contribution to risk from the residual soils of 3×10^{-4} on site and at White Oak Creek may be overly conservative.

Alternatives 3, 4, and 5 would need institutional controls to restrict access to the consolidation cell. Adequate institutional controls are assumed to be in place at the off-site disposal facility proposed for Alternative 6.

Table 5.7. Summary of comparative analysis of alternatives for CERCLA criteria, Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

CERCLA criteria	Alternative 1 No Action: During institutional Control	Alternative 1 No Action: Loss of institutional control	Alternative 2 Multilayer cap, institutional controls		Alternative 3 Consolidation cell with simple dewatering		Alternative 4 Consolidation cell with ex situ treatment		Alternative 5 Off-SIOU consolidation cell		Alternative 6 Removal, treatment, and off-site disposal		CERCLA criteria
Overall protection of human health and the environment													Overall protection of human health and the environment
Future RME Risk			Total risk	Residual soil risk[a] excluded	Total risk	Residual soil risk excluded	Total risk	Residual soil risk excluded	Total risk	Residual soil risk excluded	Total risk	Residual soil risk excluded	Future RME Risk
Future employee	6×10^{-5}	4×10^{-3}	1×10^{-6}		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		Future employee
Clinch River	1×10^{-4}	5×10^{-3}	$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		$<1 \times 10^{-6}$		Clinch River
White Oak Dam	7×10^{-3}	1×10^{-2}	1×10^{-4}	1×10^{-5}	9×10^{-5}	1×10^{-6}	9×10^{-5}	$<1 \times 10^{-6}$	9×10^{-5}	$<1 \times 10^{-6}$	9×10^{-5}	$<1 \times 10^{-6}$	White Oak Dam
White Oak Creek	3×10^{-2}	6×10^{-2}	2×10^{-3}	2×10^{-3}	3×10^{-4}	1×10^{-6}	3×10^{-4}	1×10^{-6}	3×10^{-4}	$<1 \times 10^{-6}$	3×10^{-4}	$<1 \times 10^{-6}$	White Oak Creek
On-site resident	No pathway	6×10^{-2}	3×10^{-3}	3×10^{-3}	4×10^{-4}	1×10^{-4}	3×10^{-4}	1×10^{-6}	3×10^{-4}	$<1 \times 10^{-6}$	3×10^{-4}	$<1 \times 10^{-6}$	On-site resident
Human health risk discussion	Risk to human health from migration of contamination to groundwater and White Oak Creek. Moderately protective off site at Clinch River while DOE maintains institutional controls	If water cover over sediment is lost, airborne contamination resulting in widespread human health risk is possible	Protective to receptor at White Oak Dam. Possible risk to human health from migration of contamination to groundwater and White Oak Creek. Protective while DOE maintains institutional controls		Protective to receptors at White Oak Dam, and possibly at White Oak Creek and at the site while DOE maintains institutional controls		Protective to future employees, residential receptors at White Oak Dam, and possibly at White Oak Creek while DOE maintains institutional controls		Protective to all receptors while DOE maintains institutional controls		Protective to all receptors due to removal of source material		Human health risk discussion
Ecological risk discussion	Risk to environmental receptors from consumption of fish in impoundments. Small risk from consumption of fish in White Oak Creek		No risk to environmental receptors		No risk to environmental receptors		No risk to environmental receptors		No risk to environmental receptors		No risk to environmental receptors		Ecological risk discussion
Compliance with ARARs	No ARARs under CERCLA. Not protective as required by CERCLA		Several waivers required		A few waivers required		A few waivers required		A few waivers required		Meets all ARARs		Compliance with ARARs
Short-term effectiveness	No increase or reduction in short-term effects on human health and environment		Potential for small, adverse short-term effects		Potential for moderate, adverse short-term effects		Potential for moderately high, adverse short-term effects		Potential for moderately high, adverse short-term effects		Potential for very high, adverse short-term effects		Short-term effectiveness
Long-term effectiveness	Not effective		Effective for period of institutional control		Very effective for period of institutional control		Very effective for period of institutional control		Very effective for period of institutional control		Very effective at site		Long-term effectiveness
Reduction of toxicity, mobility, or volume through treatment	None		None		Small reduction in volume		Significant increase in volume. Some decrease in mobility of most contaminants		Small reduction in volume		Significant increase in volume. Some decrease in mobility of most contaminants		Reduction of toxicity, mobility, or volume through treatment
Implementability	Very easy to implement		Easy to implement		Somewhat difficult to implement		Difficult to implement		Fairly difficult to implement		Extremely difficult to implement, both technically and administratively		Implementability
Present worth cost	$5,569,000		$21,230,000		$45,650,000		$87,243,000		$48,252,000		$148,637,000		Present worth cost

[a]Risk associated with soils to be remediated as part of the 3000 Watershed Soil Operable Unit.

ARAR = applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = U.S. Department of Energy
ORNL = Oak Ridge National Laboratory
RME = reasonable maximum exposure
SIOU = Surface Impoundments Operable Unit

Alternative 1 continues to expose sensitive environmental receptors to the risk of ingestion of contaminated fish and invertebrates from the impoundments, both during and after institutional controls. Alternatives 2–6 prevent such ecological exposures by closing the ponds and eliminating the contaminated food source.

5.3.2 Compliance with ARARs

Compliance with ARARs is also a threshold criterion that must be met to consider an alternative for implementation. Selection of an alternative that does not meet ARARs can be justified under 40 CFR 300.430(f)(1)(ii)(C) under certain specified conditions. The action-based alternatives meet most of the substantive ARARs listed in Appendix E. The waivers potentially required for each alternative are discussed below.

Alternative 6 is the only alternative that could potentially comply with all ARARs. Such compliance would be contingent on development of a treatment process that would meet the applicable land disposal restrictions, eliminate PCBs, and treat the waste such that it can be designated as low-level waste rather than mixed waste. The sections on implementability and reduction of toxicity, mobility, and volume discuss the uncertainties associated with the technologies required for this alternative. This alternative is subject to the greatest number of and most restrictive regulatory requirements, and compliance would be difficult, costly, and time-consuming. With the possible exception of the treatment requirements, the remaining ARARs are achievable.

Alternative 5 would need waivers from the Toxic Substances Control Act siting criteria [i.e., landfill must be located 16.7 m (50 ft) above groundwater]. For contingency actions, waivers could be needed for storage of solid mixed waste if a zeolite package water treatment plant is needed and for tank closure requirements if mechanical dewatering is used. Alternative 3 would need the same waivers as Alternative 5.

Alternative 4 would need the same waivers as Alternatives 3 and 5, except that the stabilization/solidification treatment process would definitely trigger land disposal restrictions, whereas mechanical dewatering is only a contingency action for Alternatives 3 and 5. Whether Alternative 4 could meet the land disposal restrictions would be determined in engineering support studies regarding the effectiveness of the treatment process. A waiver from some of the land disposal restrictions and tank closure requirements could be necessary.

For Alternative 2, waivers could be needed for the zeolite package treatment plant contingency and possibly for the TBC cleanup level for lead. If TDEC/NRC regulations are ARARs, inadvertent intrusion requirements and environmental monitoring in a contaminated area

would need waivers. Waivers would also be needed for the requirements to eliminate free liquids from the wastes and, if TDEC/NRC regulations are ARARs, for allowing waste to remain within a zone of groundwater fluctuation and discharge, for requiring continuing active maintenance, for not minimizing infiltration through the cover, and for not minimizing contact of water with the waste.

There are no ARARs for Alternative 1, but it would not comply with the CERCLA requirement to protect human health and the environment.

5.3.3 Long-Term Effectiveness and Permanence

In the long term, Alternative 1 cannot effectively reduce risks to human health. Estimated future risks exceed EPA's target risk range, and there is no reduction in risk to the environment for either the long or short term.

Alternatives 2–5 all effectively reduce human health risk as necessary to meet EPA targets and eliminate ecological risks during the period of institutional control. Because receptors must be prevented from intruding into the waste and from long-term exposures (e.g., building a house with a basement penetrating the cap), the effectiveness after institutional controls are abandoned would be reduced. In the very long term, degradation of the engineered containment facilities would reduce long-term effectiveness. The caps for Alternative 2, the cap and liner for Alternatives 3 and 5, and the cap, liner, waste containers, and waste form for Alternative 4 would eventually degrade. These containment elements would have an expected effective life on the order of a few hundred years for Alternatives 2, 3, and 5, and of perhaps 1,000 years for Alternative 4. The off-site disposal facility for Alternative 6 would need the same controls as required for Alternative 4. Presumably these controls are in place and considered effective. If the assumed disposal site at Nevada Test Site is selected, the hydrogeologic conditions in the Nevada desert are expected to offer more effective long-term isolation of the long-lived radionuclides than any on-ORNL consolidation cell location.

Magnitude of Residual Risks. Assuming that residual risk at the Nevada Test Site disposal site is negligible, Alternative 6 has the lowest residual risk since no contamination from the operable unit remains on ORR. (Note that residual risk at the site due to soil and groundwater contamination is addressed in other operable units.)

Alternatives 3, 4, and 5 have similar residual risks. Containment within the consolidation cell provides the most significant reduction in risk for all three alternatives. Alternative 4 provides additional risk reduction because the waste within the consolidation cell is solidified and less likely to leach if water infiltrates into and out of the cell. Alternative 5 has the advantage

of allowing selection of a site that is more hydrogeologically suitable than either of the on-operable-unit consolidation cell options. The off-SIOU consolidation cell site would be farther above the normal groundwater table, farther above the deep bedrock aquifer, and more distant from surface water (i.e., White Oak Creek).

The risk from Alternative 2 is reduced to acceptable levels by preventing airborne contamination and using institutional controls to prevent access to contaminated media. Hypothetical receptors using groundwater from the site or surface water from White Oak Creek would be subject to unacceptable risks, although an order of magnitude less than for the no action alternative. Alternative 1 uses operational controls (maintaining the water level in the impoundments) to prevent airborne contamination and institutional controls to prevent access. Residual risk for Alternative 1 for hypothetical on- and off-site receptors would be as described in the baseline risk assessment for the scenario with the water cover in place and would be similar to Alternative 2. There is an unquantified risk for Alternative 1 that human error or natural disaster could cause the loss of the water cover, and widespread airborne contamination could result. After the period of institutional control, this risk would increase.

Irreversible and Irretrievable Commitment of Resources. All alternatives would cause a small, irretrievable commitment of resources such as fuel and construction materials. The scope of this commitment would be roughly comparable to the scope of the alternative. The scopes increase in the order of Alternatives 1, 2, 3, 5, 4, and 6. Some losses of habitat would also occur. Loss of man-made, contaminated aquatic habitat, which is identical for Alternatives 2–6 and would not occur for Alternative 1, would be offset by preventing exposure of biota to the contamination in the impoundments. The off-SIOU consolidation cell for Alternative 5, depending on its final location, could cause an additional, small loss of habitat compared to the other alternatives.

Sensitive Resources. The site is eligible for inclusion in the National Register of Historic Places. All alternatives except Alternative 1 would require consultation with the State Historical Preservation Officer, mitigation specified by the State Historical Preservation Officer (most likely in the form of photographic and written documentation), and concurrence from the State Historical Preservation Officer through a memorandum of agreement. No floodplains, wetlands, endangered or threatened species, or critical habitat would be affected by Alternatives 1, 2, 3, 4, or 6. The final location of the off-SIOU consolidation cell for Alternative 5 would also be selected to prevent adverse effects on these resources. Alternatives 2–6 would result in a small loss of habitat for neotropical migrant birds, but this would be offset by reduction of their exposure to contamination.

Cumulative Effects. Alternatives 2–6 would cause small, incremental losses of habitat that are similar in scope and are considered negligible. Alternative 5 would have an increase in habitat loss at the site of the off-SIOU consolidation cell. However, if other impoundments at ORNL are remediated and their wastes consolidated at the same site, then the cumulative effect could be positive.

5.3.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 1 offers no reduction of toxicity, mobility, or volume of the contaminated media in the operable unit. Alternative 2 requires removal and treatment of surface water from the ponds at the existing ORNL process waste treatment system. This treatment will reduce the volume of contaminated water and will result in a small volume of concentrated contaminants to be managed along with similar wastes from historical and continuing research and production processes at ORNL. If the Process Waste Treatment Plant does not have sufficient capacity, a zeolite package treatment system would be used as a contingency to remove most radionuclides before the surface water is treated at the Nonradiological Wastewater Treatment Plant and discharged. The spent zeolite would be stored or disposed of as appropriate.

Alternatives 3 and 5 would treat the surface water as described for Alternative 2. The in situ dewatering process for the consolidation cell in Alternatives 3 and 5 would reduce the volume of the sediment by an estimated 30 percent. No volume reduction is expected for the soil. No reduction in toxicity or mobility would result from treatment in this alternative. Some potential process modifications to improve dewaterability or structural stability of the waste could include additives that could increase the volume of the dewatered waste somewhat.

Alternative 4 would treat the surface water as described for Alternative 2. The stabilization/solidification process would significantly increase (approximately double) the volume of treated sediment and soils. Although there would be no inherent reduction in the toxicity of the contaminants within the solidified matrix, limiting mobility would reduce biological availability of the contaminants and thus the effective toxicity. Mobility of many of the contaminants would be reduced. However, engineering support studies would be required to evaluate the effectiveness of the treatment process in reducing mobility of particular constituents. The treatment process is relatively irreversible. Note that treatment processes other than the representative process of stabilization/solidification could result in different reductions in toxicity, mobility, or volume. For example, thermal soil drying and ex situ vitrification would reduce volume and the latter would also reduce mobility. Implementability and cost considerations resulted in the selection of stabilization/solidification as the representative treatment process option for detailed analysis as discussed in Section 4.2.6.

Alternative 6 would use the same surface water treatment as described for Alternative 2 and the same stabilization/solidification process as described for Alternative 4. In addition, base-catalyzed destruction of PCBs would be added to the treatment processes. If implementable and effective, this process would reduce the toxicity of the PCBs within the waste. There would be no reduction in the toxicity of the other contaminants and little reduction in the overall toxicity of the waste. Little effect on the volume of the waste form or the mobility of the other contaminants would result.

5.3.5 Short-Term Effectiveness

This criterion refers to effects on human health and the environment during implementation of remedial actions. In general, the more involved an alternative is, the lower the short-term effectiveness.

Community Protection. For all alternatives, hazards to the surrounding community would be small and standard construction practices would be adequately protective.

Worker Protection. For all alternatives, short-term effects to workers during construction and other remedial efforts would be controlled through compliance with OSHA requirements, DOT requirements, DOE Orders, and ORNL procedures. Appropriate health and safety plans would be developed and implemented. Proper adherence to the safety requirements would provide an adequate level of protection for remediation workers. Risk to workers would increase as the scope of the remedial actions increased. The risks for Alternative 1 would be negligible, Alternative 2 would be small, and Alternative 3 would be moderate. Alternative 4 would include construction and operation of a treatment facility, thus increasing accident risk over that for Alternative 3. Alternative 5 would add risks for transport of slurried waste within ORNL and thus would be greater than Alternative 3. Alternative 6 would include the additional risk from construction and operation of a more complex treatment facility, as well as long-haul transport of the wastes from Tennessee to Nevada. Although risks would be controlled through project design, safety plans, and compliance with regulations as for other alternatives, Alternative 6 would result in the greatest worker risk.

Short-Term and Long-Term Environmental Effects. Standard construction practices would be used to mitigate short-term environmental effects from normal construction activities and would be similar for all alternatives. There is little risk of accident from Alternatives 1 or 2. Relocation of slurried sediment and soil would cause a risk of accidental spillage for the remaining alternatives. Alternatives 3 and 5 require transfer of slurried waste between impoundments and to the consolidation cell twice, therefore increasing that risk. Alternative 5 also requires transport of slurried waste by tanker or pipeline from the operable unit to the new

consolidation cell site with an associated spillage risk. Alternative 6 requires interstate transport of waste. Because the waste would be solidified and containerized, this would not cause a significant risk of contaminant release and environmental insult, but the risk of accident and injury would be increased. Cumulative long-term environmental effects for all of the action-based alternatives would be positive, since less exposure to contamination from the SIOU site would result.

Estimated Time until Remedial Action Objectives Are Achieved. For current conditions, existing maintenance, monitoring, and institutional and operational controls are meeting the remedial action objectives of (1) minimizing exposure to sediments with the water cover, (2) controlling drinking water sources with institutional controls, and (3) controlling potential failure of the berms with maintenance and monitoring. For all alternatives, remedial actions would be designed to ensure that all of these objectives continue to be met during implementation of the actions. Therefore, no time would be required to meet these objectives.

Alternative 1 would never meet the objective of minimizing bioaccumulation of contaminants in sensitive ecological receptors. The remaining alternatives would meet that objective as soon as the impoundments no longer serve as a source of food for piscivorous species. Initiation of construction activities would make the site less attractive to those species. Draining the impoundments would eliminate the contaminated food source. The impoundments would be emptied in about 1.5 years for Alternative 2, 4.5 years for Alternatives 3–5, and 3.6 years for Alternative 6.

The estimated time required to complete construction of the engineering controls would be as follows: Alternative 1, 0 months; Alternative 2, 2 years; Alternative 3, 7.3 years; Alternative 4, 5 years; Alternative 5, 7.4 years; and Alternative 6, 4.3 years. Maintenance, monitoring, and institutional controls specific to each alternative would ensure that remedial action objectives continue to be met.

Potential for Sudden Failure. Under current conditions and for Alternative 1, the existing berms and embankments are structurally stable according to the stability analyses reported in Section 2.3. Burrowing animals and potential future seeps could compromise the integrity of the berm between Impoundment 3513 and White Oak Creek, and additional analyses are recommended. The caps for Alternative 2 would be designed to enhance berm stability, and seeps would be somewhat reduced.

Relocation of waste from other impoundments into Impoundment 3513 for Alternatives 3 and 4 would increase the stress on the Impoundment 3513 berm. Although preliminary

analyses indicate that the berm would be stable, (1) more detailed analyses would be needed, (2) if necessary, stabilizing features would be designed and constructed, and (3) a seep control and management plan would be developed and implemented as required.

The consolidation cell for Alternatives 3, 4, and 5 would be designed and constructed to minimize the potential for sudden failure. The treatment facilities for Alternatives 4 and 6 would be designed to prevent unacceptable releases. A spill prevention, containment, control, and cleanup plan would be developed for transporting liquid wastes to the off-SIOU consolidation cell for Alternative 5.

Direct or Indirect Socioeconomic Impact. There would be no difference between the socioeconomic impact of the alternatives other than the short-term number of jobs as a result of the scope and cost of the project. That scope increases in the order of Alternative 1, 2, 3, 5, 4, and 6. All alternatives are expected to use the existing work force and infrastructure. The more complex and costly the alternative, the more time will be required for completion.

5.3.6 Implementability

This criterion addresses the technical feasibility, the administrative feasibility, and the availability of required services and materials associated with implementing an alternative. As with short-term effectiveness, in general, the more involved an alternative is, the more difficult it is to implement.

5.3.6.1 Constructability, operability, reliability, and monitoring

All of the alternatives are considered readily constructable and operable. Complexity of the actions, which increases particularly for Alternatives 4 and 6 which require construction and operation of an ex situ treatment plant, will affect constructability and operability. The on-ORNL transport requirements for Alternative 5 and the interstate transport requirements for Alternative 6 will also complicate operations.

Monitoring for all alternatives could be readily performed. Monitoring would consist of preclosure monitoring to confirm that remedial action objectives have been met and long-term monitoring to confirm that engineering controls remain reliable. Monitoring requirements for all alternatives are similar in scope.

Maintaining the water cover in the impoundments and the institutional controls required for Alternative 1 would be reasonably reliable while DOE maintains control of ORNL. Only the small risk of natural disaster or continued human error could affect the reliability of this alternative.

The cap for Alternative 2 would be reliable in preventing airborne contamination, but contamination of groundwater would continue. Institutional controls required to restrict access and prevent exposure to the contaminants are also in place and would be reliable as long as DOE maintains control of ORNL.

Sediment mobilization and relocation and soil moving are required for Alternatives 3-6. The technologies considered to implement these actions are considered reasonably reliable. Modifications to equipment and adjustments in technique would be expected in the field, but these would be similar for these alternatives.

Radiation shielding during the above activities would also be similar for Alternatives 3-6. Shielding using surface water during the slurry transfer and in situ dewatering process for Alternatives 3 and 5 would likely be reliable. Proper monitoring, procedures, and operational controls would be used to maintain exposures ALARA. Shielding for the treatment facilities required for Alternatives 4 and 6 add significantly to the complexity of the design and to the cost of the facility, but could be incorporated as needed. Shielding of the treated waste during transport and placement of the waste would also be costly. The transport system to relocate the slurry to the off-SIOU consolidation cell for Alternative 5 would also require adequate shielding.

Alternatives 3 and 5 depend upon in situ dewatering using drainage beds and leachate collection systems. The reliability of this process for the wastes in question is unknown and would be predicted by an engineering support study. Some combination of the base actions and process modifications described in Section 4.4.3 is expected to perform as required.

In addition to a cap as proposed for Alternative 2, Alternatives 3-5 include a liner for isolation of the wastes from the environment. The engineered multilayer liners and caps proposed should reliably reduce migration of contaminants from the consolidation cells to negligible amounts. The consolidation cell would be effective for the duration of DOE control and maintenance and could be designed to be reliable for 100-500 years or more, barring inadvertent intrusion.

For treatment of the wastes as proposed for Alternatives 4 and 6, an engineering support study would be required to develop effective processes. The reliabilities of the representative process options of stabilization/solidification (for both alternatives) and base-catalyzed destruction of PCBs (for Alternative 6) are unknown for this waste stream. It is expected that some recipe of additives could be developed to adequately stabilize and solidify the waste and that base-catalyzed destruction could be effective. QC and monitoring in the field would be essential to assuring that treatment processes and results meet specifications. Whether the treatment processes

will result in a waste form that meets land disposal restrictions, eliminates the RCRA toxicity characteristics of the waste, or acceptably reduces PCB concentrations is unknown. The success of the treatment process will determine whether the waste meets ARARs (for Alternatives 4 and 6) and disposal facility waste acceptance criteria (for Alternative 6).

Alternative 5 would also require an adequate transport system to move solid and slurried materials from the operable unit site to the off-SIOU consolidation cell. Because of radiation-protection requirements, the transport system would require adequate shielding and monitoring. Otherwise, it would be expected to be reliable if adequate safety precautions are in place. An interstate transport system would be required to move treated waste and other solids for Alternative 6. Again, except for the risk of vehicular accidents, the transport system would be reliable.

5.3.6.2 Availability of equipment, technologies, specialists, and permitted facilities and coordination with other offices and agencies

All equipment, personnel, and procedures required to maintain the water level in the impoundments for Alternative 1 are in place. The equipment, technologies, and specialists for implementation of Alternative 2 are readily available. For the remaining alternatives, specialists are available and equipment is either available or can be fabricated.

The dewatering technology for Alternatives 3 and 5 requires development in an engineering support study, but the necessary materials and techniques are available. The study would determine the appropriate combination of techniques that would provide the greatest overall effectiveness.

The treatment technologies for Alternatives 4 and 6 would require a more extensive engineering support study for development. Neither the stabilization/solidification nor the base-catalyzed destruction of PCBs technology has been demonstrated at greater than a pilot level study. The behavior of these technologies with mixed hazardous, radioactive, and chemical waste must be investigated thoroughly.

With the exception of concurrence of regulatory agencies through the CERCLA process, coordination requirements with other offices and agencies will be minimal for Alternatives 1-5. No other permitted facilities are required for these alternatives.

Alternative 6 will require significant coordination with the disposal facility, regulatory agencies in other states, and with DOT. Permitted facilities are available that can accept low-level waste. Assuming that treatment can meet the applicable waste acceptance criteria, disposal

facility capacity would be more of an administrative problem than a technical availability problem. If treatment cannot eliminate PCBs and hazardous characteristics from the waste, there is no disposal facility in the United States that can accept the waste.

5.3.6.3 Ease of undertaking additional remedial actions

There are two key issues regarding the ease of undertaking additional remedial actions. The first regards future actions taken on the waste from this operable unit to meet future requirements or to correct deficiencies in the remedial actions already taken. The second regards the effect of these remedial actions on other nearby operable units, for example, the Waste Area Grouping 1 soils and groundwater operable units.

Alternative 1 would have no effect on other operable units, except that additional contamination of groundwater from this source would continue. Similarly, there would be no impediments to taking additional corrective actions at this operable unit.

Alternative 2 would also permit continued contamination of groundwater. Selection of Alternative 2 would indicate that institutional controls and restricting access to White Oak Creek and White Oak Lake down to the Clinch River would be acceptable. This would set a precedent for the level of remediation appropriate for other operable units. If more stringent isolation or removal actions were required at this or other operable units, the cap and the residual contamination would limit the remediation options available. The cap materials placed into each of the ponds would become contaminated. If additional actions were undertaken at the site, a significant increase in contaminated material would have to be addressed. A limited action to remove nearby contaminated soils or groundwater would have to avoid the area covered by the cap, therefore leaving a significant potential source of contamination in place. Alternately, a major action would be required to remove the original contaminated media and the additional volume of contaminated cap materials. If the waste were removed, none of the actions taken for Alternative 2 would preclude additional treatment as required. Additional containment features (e.g., vertical isolation barriers) are not considered appropriate since prevention of groundwater contamination is not an objective of this alternative. If future requirements necessitated such containment barriers, the actions of Alternative 2 would not preclude their installation. However, the expected effectiveness of such barriers is limited.

The consolidation cell in Alternative 3 would virtually stop migration of contamination into groundwater for a reasonable period of time (greater than 100 years). A small, additional volume of filtration materials would become contaminated and would increase the volume of waste to be addressed if future removal actions are required. If removal actions were required, additional material handling would be necessary to access the waste, but the remedial actions

taken would not preclude any potential future treatment process. If monitoring indicated that the cell did not effectively contain the wastes as predicted, installation of contingency isolation features could be readily performed, as discussed in Section 4.4.3.3. Remedial actions taken for nearby soils or groundwater would not be adversely affected, provided that they do not disturb the integrity of the cap or liner.

The Alternative 4 consolidation cell would also stop groundwater contamination, allow installation of contingency isolation features, and have little effect on nearby remedial actions. If stabilization/solidification is the treatment process used (as expected), there would be a significant increase (approximately double) in the volume of treated waste. If removal actions are required in the future, the increased volume would have to be addressed. If the waste form and shielding container has maintained its integrity, then handling the waste could be simple. If significant deterioration of the waste or containers occurred, future handling and treatment of the waste could be much more difficult. The stabilization/solidification process would preclude many alternate treatment processes, should additional treatment be required in the future.

Alternative 5, the off-SIOU consolidation cell, would be similar to Alternative 3 in the ease of undertaking additional remedial actions. An advantage of this alternative would be that wastes from other operable units could be consolidated into the same cell. This could greatly simplify the remediation of certain other contamination sources. At SIOU, there would be no impediments to remediation of adjacent contamination.

Removal of the waste, treatment, and disposal off site per Alternative 6 would preclude the need for any additional actions regarding this operable unit. There would also be no impediments to remediation of nearby operable units.

5.3.6.4 Ability to obtain regulatory agency approvals

Administrative implementability for Alternative 1 could be difficult, since regulatory agencies are unlikely to accept the status quo for this site. Because of the continued groundwater contamination, regulatory agencies may not approve of Alternative 2.

5.3.6.5 Effect of reasonable deviations on implementability

No reasonable deviations would adversely affect implementation of Alternatives 1 or 2. If the projected volumes of in situ, slurried, or dewatered waste are significantly greater than projected, the required size of the consolidation cell for Alternative 3 may require added modification of the storage space on the operable unit site. Because the solidified waste for Alternative 4 can be stacked above ground level, additional waste volume should not pose a

problem. There are no size restrictions on the Alternative 5 off-SIOU consolidation cell. Only cost and schedule would be affected by volume considerations for Alternative 6.

5.3.7 Cost

Table 5.8 compares the total capital, operating, and present worth costs for each of the alternatives. The potential costs of contingency actions and the assumed probability that such actions would be necessary is also provided. An alternative with a higher base cost and a low probability of requiring contingency actions may be more attractive than an alternative with a lower cost but a higher probability of needing one or more costly contingency actions.

Table 5.8. Alternatives cost summary for Waste Area Grouping 1 SIOU, ORNL, Oak Ridge, Tennessee

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Direct cost (FPSC)	0	7,287	20,408	30,319	21,794	58,783
Indirect cost	0	6,806	17,633	36,567	18,425	57,428
Total capital cost	0	14,093	38,041	66,886	40,219	116,211
First year O&M costs	382	321	347	346	492	322
O&M 2-30 years	11,077	4,753	3,833	4,183	3,830	613
O&M 5-year report	0	120	120	120	120	20
Total O&M cost	11,459	5,194	4,300	4,649	4,442	955
Total contingency[a]	2,865	6,752	14,823	28,608	15,632	46,862
Total cost[b]	14,324	26,039	57,164	100,143	60,293	164,028
Present value[c]	5,569	21,230	45,650	87,243	48,525	148,637

[a]Total contingency is conclusive of direct, indirect, and all O&M-associated contingencies.
[b]Total cost includes all capital costs, direct and indirect with O&M and associated reports for the 30-year term of comparison in each alternative.
[c]Present value based on present worth analysis is calculated using the NIST BLCC computer software. This application complies with ASTM standards related to building economics as well as FEMP and OMB circular A-94 guidelines for economic analysis of federal building projects (ASTM E917). BLCC complies with the "Life-Cycle Costing Manual for the Federal Energy Management Program." A discount rate of 7 percent is used per the guidance in OMB A-94 for discount rate policy relevant to "external" versus "internal" costs (per R. Lyon, OMB January 5, 1995, OMB Section 8c.3, "Cost Effectiveness.")

This estimate is consistent with EPA guidance recommending a level accuracy of +50-30% for feasibility studies. A cost evaluation based on detailed scope is recommended upon acceptance of an alternative and detailed engineering.

ASTM = American Socitey for Testing and Materials
BLCC = Building Life-Cycle Cost
EPA = U.S. Environmental Protection Agency
FEMP = Fernald Environmental Management Project
FPSC = fixed-price subcontractor
NIST = National Institute of Standards and Technology
O&M = operation and maintenance
OMB = Office of Management and Budget
ORNL = Oak Ridge National Laboratory
SIOU = Surface Impoundments Operable Unit

6. SUMMARY AND KEY DECISIONS

Chapter 6 summarizes the RI/FS and identifies some key decisions that stakeholders (DOE, regulatory agencies, and the public) must make before remediation of SIOU.

6.1 SUMMARY OF THE RI/FS

The RI identified a number of radioactive and hazardous constituents in the sediment, soils, and surface water in and around the four surface impoundments within SIOU. The baseline risk assessment determined which of these constituents were COCs for human health risk and for ecological risk for existing conditions and for projected future conditions. The baseline risk assessment then evaluated the mean risk and the RME risk for human health and determined the potential for adverse ecological effects.

Currently, there is no de minimus on-site or off-site risk to employees or the public. Energy Systems monitors and maintains the protective water covers on the impoundments, and any compromise in the berms (e.g., seeps) surrounding the impoundments is handled expeditiously. All monitoring station data indicate that contamination is essentially limited to the immediate SIOU area and is not significantly migrating off site. As expected, all current risks are well within the EPA's target risk range.

For every hypothetical future scenario developed to estimate future risk, the risks that are estimated suggest that a corrective action be taken. The majority of the risk occurs when the protective water cover is removed by a drought condition or a berm failure, exposing the sediments in the impoundments. In addition, when contamination is modeled to estimate off-site migration of contaminated water, the risk from contaminated drinking water is also unacceptable for the RME.

The range of remedial alternatives developed and analyzed in the FS includes actions to protect human health and the environment. At the low end of the range, low cost alternatives with limited scope, protection of human health relies primarily on institutional controls that limit access to contaminated areas and caps to prevent airborne contamination and reduce direct radiation exposure. At the high end, contaminants are removed from the site and the operable unit is fully restored. A brief discussion of each alternative follows.

6.1.1 Alternative 1—No Action

In the no action alternative, existing institutional controls (including controlling access within ORR to Clinch River and maintaining the water shielding and containment integrity of the impoundments) are assumed to be preserved for at least 100 years, after which all controls are eliminated and the site reverts to residential use. No treatment, removal, or disposal actions are taken in this alternative. Regulatory requirements regarding prevention of pollution to groundwater would have to be waived for selection of this alternative. The present-worth cost of site-specific institutional controls is estimated to be $5.569 million. Selection of this alternative would require CERCLA reviews every 5 years to ensure site conditions are still controlled and maintained.

6.1.2 Alternative 2—Multilayer Cap and Institutional Controls

Alternative 2 would include a multilayer cap to protect against airborne contamination and direct exposure to the waste and to limit percolation of water into the wastes. Leaching of contaminants from the impoundments into groundwater would continue, and institutional controls would need to be maintained to Clinch River (i.e., ORR) due to the contamination from this source. Additional controls (e.g., fencing, signs, etc.) could be needed due to contamination from other ORNL source areas. Regulatory requirements regarding prevention of pollution to groundwater would have to be waived for selection of this alternative. The present-worth cost of this alternative is estimated to be $21.23 million. Selection of this alternative would require CERCLA reviews every 5 years to ensure site conditions are still controlled and maintained.

6.1.3 Alternative 3—Consolidation Cell with Simple Dewatering

Alternative 3 would consolidate the wastes within SIOU in an engineered consolidation cell in the current location of Impoundment 3524. Wastes would be dewatered within the cell using a leachate collection system. The final configuration of the consolidation cell would include a liner and a multilayer cap to isolate the waste from the environment.

The consolidation cell would isolate the wastes sufficiently such that federal institutional controls would only be required at the site of the consolidation cell, and receptors at White Oak Dam and possibly at White Oak Creek would not be exposed to unacceptable risk due to the contamination from SIOU. Additional institutional controls could be required to address other ORNL sources of contamination.

Because the most highly contaminated waste would be relocated and handled during implementation of this alternative, there would be a greater risk to remediation workers for this alternative than for Alternatives 1 or 2. Use of remotely operated equipment, radiation shielding,

and other controls would help manage, but not eliminate these short-term risks. Engineering support studies would be needed to properly design the remedial actions, but there are no expected uncertainties that would preclude use of this alternative.

The present-worth cost of this alternative is estimated to be $45.65 million. Monitoring would be required after closure of the site to verify that the consolidation cell performs as expected. CERCLA reviews would be required every 5 years.

6.1.4 Alternative 4—Consolidation Cell with Ex Situ Treatment

Alternative 4 would treat the wastes within SIOU using stabilization/solidification techniques and consolidate them in a consolidation cell in the current location of the upper impoundment. The final configuration of the consolidation cell would include a liner and a multilayer cap to isolate the waste from the environment.

The consolidation cell would isolate the wastes sufficiently such that federal institutional controls would only be required at the site of the consolidation cell, and receptors at White Oak Creek would not be exposed to unacceptable risk due to the contamination from SIOU. Additional institutional controls could be required to address other ORNL sources of contamination.

The stabilization/solidification treatment process would reduce the likelihood of contaminants being leached from the cell, but probably would not meet land disposal restrictions, if applicable. Land disposal restrictions for mercury and treatment requirements for PCBs would still have to be waived. Again, because of waste handling actions of this alternative, the short-term risk to remediation workers would be greater than that for Alternatives 1 or 2 and could be managed, but not eliminated. Engineering support studies would be needed to properly design the remedial actions. The long-term effectiveness of the stabilization/solidification process and the degree to which some contaminants are contained by the process are uncertain, but there are no expected uncertainties that would preclude use of this alternative.

The present-worth cost of this alternative is estimated to be $87.243 million. Monitoring would be required after closure of the site to verify that the consolidation cell performs as expected. CERCLA reviews would be required every 5 years.

6.1.5 Alternative 5—Off-SIOU Consolidation Cell

Alternative 5 would be similar to Alternative 3 except that waste would be transported to a consolidation cell located in a more hydrogeologically suitable area within ORNL. Since all wastes would be removed from the SIOU site, residual risks would be essentially eliminated and

no institutional controls would be required, except to control exposures from other ORNL sources.

Because of waste handling actions of this alternative, particularly increased transport requirements, the short-term risk to remediation workers would be greater than that for the preceding alternatives. The risk could be managed, but not eliminated. Engineering support studies would be needed to properly design the remedial actions, but there are no expected uncertainties that would preclude use of this alternative.

The present-worth cost of this alternative is estimated to be $48.252 million. Monitoring and CERCLA reviews every 5 years would be required at the site of the consolidation cell to verify that it performs as expected.

6.1.6 Alternative 6—Removal, Treatment, and Off-Site Disposal

Alternative 6 would remove from SIOU all surface water, soil, and sediment contaminated above acceptable levels; treat the sediment and, if necessary, the soil with stabilization/solidification (or other treatment options as determined by an engineering support study); dewater the remaining soil, if possible; package the solids in acceptable containers; and transport the containers to appropriate off-site disposal facilities. The treated sediment and soil is expected to meet the waste acceptance criteria for final disposal at the Nevada Test Site.

No federal institutional controls would be required at the site due to contamination from SIOU. Institutional controls could be required to address other ORNL sources of contamination.

No regulatory requirements would have to be waived for selection of this alternative, provided that waste transportation and disposal requirements are met at the off-site facilities. Because of waste handling actions of this alternative, the short-term risk to remediation workers would be greater than that for the other alternatives. The risk could be managed, but not eliminated. In addition, transport of the waste to the appropriate storage or disposal facility would significantly increase the short-term risk to remediation workers and to the public. Engineering support studies would be needed to properly design the remedial actions.

The present-worth cost of this alternative is estimated to be $148.637 million. No long-term monitoring would be required for this alternative because waste would be removed. However, monitoring requirements at the site would be determined by the RODs for other operable units (i.e., the soils and groundwater operable units).

6.1.7 Risk Versus Cost Summary

Figure 6.1 illustrates cost versus risk reduction for the range of alternatives at various receptor locations. This summary helps illustrate the need for handling the residual soil contamination in the adjoining operable unit for a resident to be considered on site or at White Oak Creek.

6.2 KEY DECISIONS

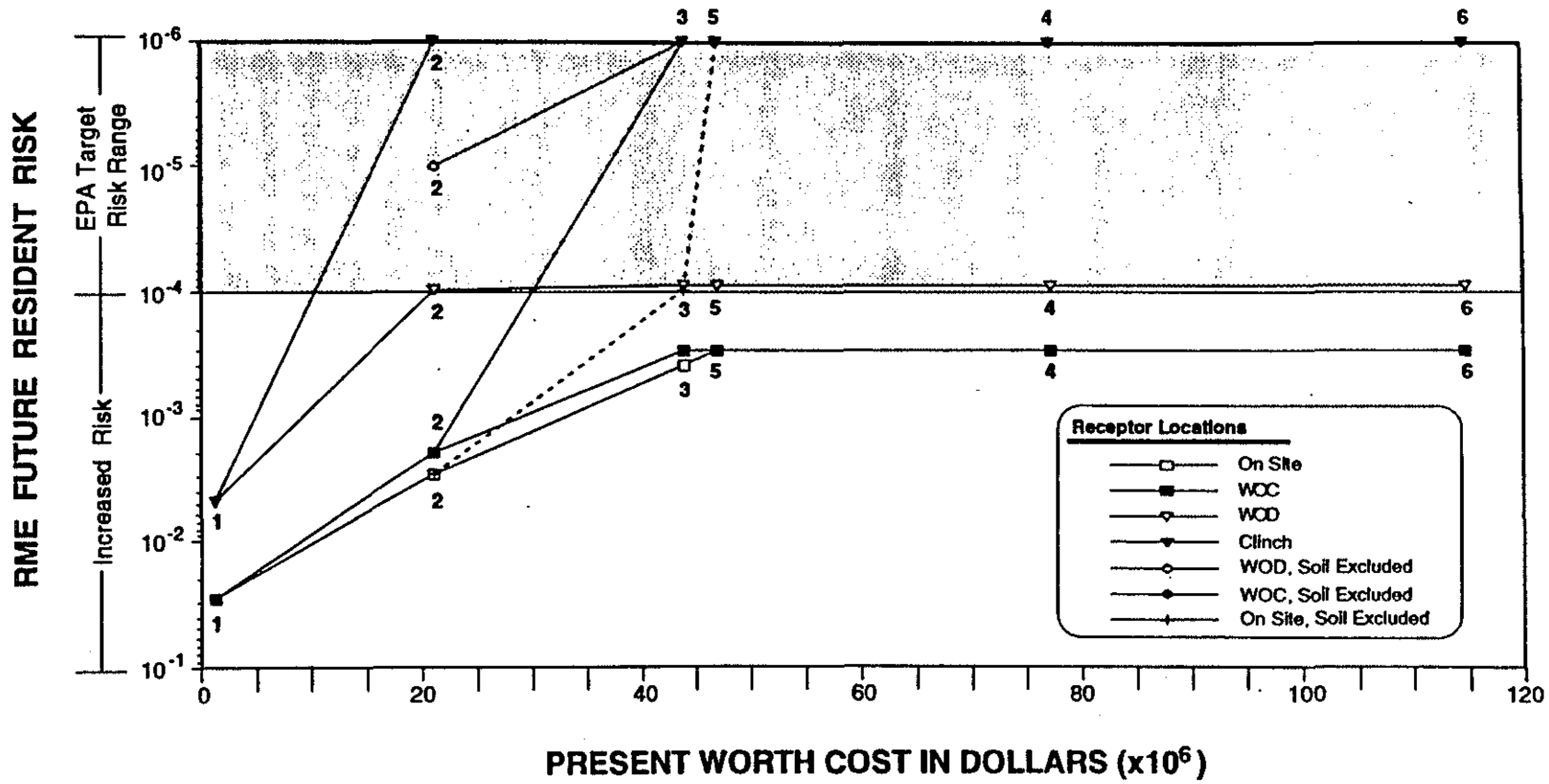
To select remedial actions that are acceptable, regulators and decision makers must consider the following key issues:

- compatibility with remedial actions for adjacent operable units;
- determination of future land use and location of the receptor that needs to be protected by the remedial action;
- combining waste from other operable units into an off-SIOU consolidation cell (Alternative 5); and
- availability of treatment, storage, and disposal capacity for mixed waste at ORNL, ORR, and nationally.

A discussion of each of these issues follows. A summary of the decisions to be made is included in Section 6.4.

6.2.1 Combining Waste from Other Operable Units into Off-SIOU Consolidation Cell (Alternative 5)

In June 1994, at the request of EPA and TDEC, an additional remedial alternative was added that allowed for an off-SIOU consolidation cell to be evaluated. It was determined early in the evaluation process that this would be a more costly alternative than the on-site cell, but could be attractive from a long-term planning standpoint because it allowed for one controlled cell to be constructed in a preferred location with potential to be expanded for placement of other ORNL waste. For this reason a long-range planning effort has been initiated by ORNL ER Program to evaluate the feasibility of an off-SIOU consolidation cell.



NOTE: Number on graph (1 to 6) indicates remedial alternative number.

JE	Fig. 6.1	**Cost versus risk reduction** DOE — ORNL, WAG 1, Surface Impoundments — Oak Ridge, Tennessee	DOCUMENT ID: 35H830 4002-15 / RI/FS	DRAWING ID 95-11412 PD0	DRAWING DATE FEBRUARY 22, 1995 Ba

Other strategies to be considered include placement of waste from other ORNL impoundments with like contaminants using an expedited RI/FS process with a presumptive remedy based on the SIOU as the example.

A value engineering team led by Energy Systems personnel with the support of Jacobs ER Team, CDM Federal, and SEG have developed a set of strategies for optimizing the closure of additional surface impoundments at ORNL. The specific strategy would depend on resolving certain regulation issues, identifying whether remedies developed for the Waste Area Grouping 1 SIOU would be presumed adequate to address other individual impoundments or groups of impoundments, and selecting the preferred remedy or remedies. The strategies may also be applicable to other surface impoundments on ORR; however, the value engineering session only considers impoundments at ORNL in detail. The section summarizes the data collected, the background information considered, the review process, the results of the review, and the proposed strategies for optimizing impoundment closure. Findings include:

- DOE should determine whether optimization of other impoundments within ORR should be pursued according to the methods described here for ORNL;

- the regulatory questions regarding designation of transuranic waste and the acceptability of waivers required for Waste Area Grouping 1 SIOU RI/FS alternatives be presented to regulators at the earliest opportunity;

- the Waste Area Grouping 1 SIOU alternatives be presented to the public at the earliest opportunity, and the preferred alternative selected;

- a grouping strategy consistent with the regulator and public input be developed;

- a regulatory/administrative framework be selected; and

- a budget and schedule to implement the appropriate studies, reports, and documentation be prepared.

6.2.2 Compatibility with Remedial Action for Adjacent Operable Units

Remediation activities at SIOU could significantly influence actions or decisions to be made regarding other ORNL activities. Conversely, both national and local decisions and actions outside the scope of this remedial action will affect the SIOU remediation effort.

The main plant area of ORNL surrounding SIOU is characterized by contaminated soils; contaminated groundwater; miles of contaminated piping; other impoundments; and inactive low-level, transuranic, and mixed waste storage tanks. The lack of safe and effective remedial technologies and high cost associated with attempts to remediate this area for unrestricted use suggest that the remedial strategy for the remainder of the plant area will be limited and clean closure of the overall site, if possible, will not occur within the next several decades.

6.2.3 Determination of Future Land Use and Location of Receptor for Risk Assessment

Each remedial alternative will protect human health and the environment; however, some remedial strategies include restrictions on the use of the site to prevent unacceptable exposure to contaminants through institutional controls. Remedial actions that include restricting the SIOU area to industrial use would likely not be compatible with unrestricted use of adjacent areas. Each of the remedial alternatives, except for Alternative 6, includes institutional controls as specified per alternative in Section 6.2.

6.2.3.1 Risk assessment

One key area regarding assessment of off-site risk is a matter of policy rather than engineering calculations. This issue, location of the receptor, is discussed below.

Location of Receptor. Four potential receptor locations were evaluated for determination of off-site risk as indicated in Figure 6.1. They are (1) at the SIOU site, (2) at White Oak Creek adjacent to the site, (3) at White Oak Dam, and (4) in the Clinch River below White Oak Creek embayment. Currently, DOE maintains ORNL as a federally controlled industrial facility with existing institutional controls (fencing, access and use restrictions, and continued monitoring and maintenance) extending to the Clinch River. The determination of future land use will dictate to a large degree the likelihood of exposures at these levels. If land use on ORR remains industrial with institutional controls restricting use of surface water and groundwater, then the nearest off-site resident would be at the Clinch River, about 2.4 km (1.5 miles) from the impoundments. Because of dilution, entrainment of contamination in the sediment of White Oak Lake, and continued radioactive decay due to the longer period of time before the contamination reaches the receptor, risk at this location is reduced to acceptable levels under current conditions.

Land use at ORNL will continue to be DOE-controlled for the foreseeable future. DOE requests that TDEC and EPA accept the designation of ORNL as federally controlled industrial land use, or identify another appropriate land use. Alternative land use options are discussed below.

Residential/Agricultural Land Use. To designate the land use as residential or agricultural, SIOU would have to be completely remediated and the contamination in all remaining operable units within ORNL would have to be remediated to the same degree. Limitations of the existing technologies for remediation and waste disposal result in unacceptably high costs for remediation of small areas. The federal government does not have sufficient resources to remediate all of the contaminated federal sites over the next few decades to allow unrestricted use of those sites. There is little benefit in terms of risk reduction to an off-site resident if a site is remediated for unrestricted use compared to the less costly remedial actions that require site use restrictions. Complete restoration of some of the adjacent operable units is not considered reasonable, and returning the site to residential/agricultural land use is not considered a viable option.

Restricted Industrial Land Use. If waste remains on site, certain industrial uses could be acceptable if institutional controls prohibiting excavation, extended occupancy of a contaminated area, extraction of groundwater or surface water, and other uses could be assured. Deed restrictions would be one method for implementing the institutional controls. However, if any contamination remains on site, it is unlikely that the federal government would relinquish control of the site. Since ensuring adequate institutional control of commercial industries is questionable, and since the federal government will be reluctant to relinquish control, designation of the site for restricted industrial land use is considered inappropriate.

Federally Controlled Industrial Land Use. Regardless of the remediation alternative selected, there will be a period of institutional control during which DOE retains ownership of the site and dictates the uses and restrictions that apply to areas within ORR. It is reasonable to expect that DOE will continue to control the site for the foreseeable future. New construction of laboratory facilities with 50-year or greater design lives is underway. The Advanced Neutron Source continues to be funded and development of this major, long-term project is underway.

Designation of the site for federally controlled industrial land use in perpetuity is considered reasonable and appropriate because of the following: (1) the federal government has long-term plans to continue to use the site as a national laboratory, (2) the federal controls in place and projected for the future are adequate to minimize the risk of exposure of employees to residual contamination remaining after remediation, (3) adjacent areas will likely require similar use restrictions, and (4) the federal government cannot legally release control of a contaminated site.

For SIOU, remedial alternatives are presented that allow waste to be left in place and still meet risk reduction objectives in White Oak Creek and points downstream. Other alternatives

will not be protective at White Oak Creek, but will be protective at White Oak Dam. All alternatives are protective to the off-site receptor at the Clinch River as long as institutional controls are maintained.

6.2.4 Availability of Treatment, Storage, and Disposal Capacity for Mixed Waste at ORNL, ORR, and Nationally

Removal of the contaminated sediment and soil from SIOU, as discussed in Alternative 6, may be viewed as desirable in the sense that contamination is removed from the shallow subsurface environment to a much more controlled setting. However, disposal capacity for mixed, low-level, and hazardous wastes is limited. A more detailed description of the status of appropriate waste treatment, storage, and disposal systems follows.

All of the alternatives require treatment of the surface water and any collected leachate from the impoundments, storage of the residual materials, and eventual disposal of the stored wastes. Existing treatment and storage facilities at ORNL would be used for the liquids; however, significant modifications to the existing facilities are required to provide the treatment rate and storage capacity required to handle the wastes generated by the proposed remedial actions. Some of the actions and modifications to the waste management system required before implementation of the remedial actions include:

- solidification of liquids presently in the Melton Valley Storage Tanks to provide additional storage capacity;
- additional storage for sludges and concentrates currently stored in the Low-Level Liquid Waste Evaporator Facility feed tanks;
- replacement of one of the two liquid low-level waste evaporators; and
- installation of surge tanks for additional storage capacity.

The alternatives that allow the sediments and soils to be disposed of in situ (Alternatives 2–5) do not need additional on-site storage, handling, or packaging facilities or off-site transportation and disposal capabilities. Alternative 6, which includes actions to remove the sediments and soils, depends upon the future availability of adequate mixed waste treatment, storage, and disposal facilities, as well as shipment of the waste through several states.

The ORNL Waste Management and Remedial Action Division has developed long-range plans for adequate storage, treatment, packaging, and disposal facilities, but final approval and

funding are not in place at this time and are outside the scope of the SIOU remedial actions and this FS. Some of the remedial action alternatives; however, cannot be accomplished until some or all of these facilities are available, or the planned modifications are complete.

6.3 SUMMARY

EPA and TDEC regulators and DOE decision-makers must decide on the following matters for remediation of SIOU to proceed.

Adjacent Operable Units. DOE requests that TDEC and EPA recognize the relationship of the SIOU and adjacent operable units and confirm that the level of remediation selected for this operable unit will be consistent with the likely remediation alternatives to be selected for the other operable units.

Land Use. DOE requests that TDEC and EPA accept the designation of ORNL as federally controlled industrial land use, or identify another appropriate land use.

Risk Assessment. DOE requests that EPA and TDEC accept the Clinch River as the receptor location for calculation of off-site risk, or designate another acceptable location.

Significant cost inefficiency could result if the selection of an alternative proves inconsistent with the selection of remedial actions for adjoining operable units. Selecting an alternative will dictate a future land use for the site. National policy on future land use of DOE facilities is not established, increasing the potential that the selected action and resulting land use may be inconsistent with land uses stipulated by policy later. Since the investment in remediation is likely to be in the range of tens of millions of dollars and this operable unit represents only a small portion of potential remediation at ORR, selecting and implementing an alternative without the resolution of these issues entails extreme economic risk.

While it is necessary to proceed with actions at the operable unit, extreme care should be given to selecting an approach that will limit the negative effects of these uncertainties. Proposed future land use and effects on adjacent operable units should be determined in conjunction with the development of the proposed plan.

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