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Remedial Investigation/Feasibility Study for the David Witherspoon, Inc., 901 Site, Knoxville, Tennessee

Volume I

DOE/OR/02-1503/V1&D1

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Volume I

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PREFACE

This *Remedial Investigation/Feasibility Study for the David Witherspoon, Inc., 901 Site, Knoxville, Tennessee* (DOE/OR/02-1503/V1,V2&D1) reports the results of a site characterization and an analysis of remedial alternatives for public review. This work was performed under Work Breakdown Structure 1.4.12.3.1.03 (Activity Data Sheet 9303, "Non-FFA Projects"). This document provides the Environmental Restoration Program with information about the results of the investigations performed at the David Witherspoon, Inc., 901 Site, the analysis of remedial alternatives developed for the site based on existing information, and the need for more data. The document also includes risk assessments of long-term effects on human health and the environment.

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ACRONYMS AND ABBREVIATIONS

Ac	actinium
ALARA	as low as reasonably achievable
AMSL	above mean sea level
ARAR	applicable or relevant and appropriate requirement
As	arsenic
Ba	barium
Be	beryllium
BEIR	biological effects of ionizing radiation
bgs	below ground surface
BHC	benzene hexachloride
Bi	bismuth
°C	degrees Celsius
Ca	calcium
$CaCO_3$	calcium carbonate
Cd	cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	*Code of Federal Regulations*
CLP	Contract Laboratory Program
cm	centimeter
COC	chemical of concern
COE	U.S. Army Corps of Engineers
COEC	chemical of ecological concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
Cr	chromium
Cs	cesium
Cu	copper
dL	deciliter
DOE	U.S. Department of Energy
DWI	David Witherspoon, Inc.
EDE	effective dose equivalent
EMWMF	Environmental Management Waste Management Facility
Energy Systems	Lockheed Martin Energy Systems
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
ERA	ecological risk assessment
ESI	expanded site investigation
°F	degrees Fahrenheit
Fe	iron
FFA	Federal Facility Agreement
FS	feasibility study
ft	foot

ACRONYMS AND ABBREVIATIONS (continued)

FY	fiscal year
g	gram
gpm	gallons per minute
ha	hectare
Halliburton	Halliburton NUS Corporation
Hg	mercury
HI	hazard index
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic
in.	inch
K	potassium
kg	kilogram
km	kilometer
L	liter
lb	pound
LDR	land disposal restriction
LLW	low-level waste
LOAEL	lowest observed adverse effect level
LTTD	low-temperature thermal desorption
m	meter
M&M	maintenance and monitoring
μg	microgram
mg	milligram
Mg	magnesium
Mn	manganese
MOU	memorandum of understanding
mph	miles per hour
μR	microroentgen
mrem	millirem
MW	monitoring well
NCP	National Contingency Plan
NEPA	National Environmental Policy Act of 1969
ng	nanogram
Ni	nickel
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
OU	operable unit
PA	preliminary assessment
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
pCi	picocurie
POTW	publicly owned treatment work
PPE	personal protective equipment
ppm	parts per million

ACRONYMS AND ABBREVIATIONS (continued)

PRC	PRC Environmental Management, Inc.
PRG	preliminary remediation goal
PRP	potentially responsible party
Pu	plutonium
QA	quality assurance
QC	quality control
Ra	radium
RA	remedial action
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act of 1976
RGO	remedial goal option
RI	remedial investigation
RME	reasonable maximum exposure
Rn	radon
ROD	record of decision
Sb	antimony
Se	selenium
SERA	site ecological risk assessment
SI	site investigation
Sr	strontium
SS	surface spring
SVOC	semivolatile organic compound
T&E	threatened and endangered
TAL	Target Analyte List
TBC	to be considered
TBD	to be determined
TCL	Target Compound List
TDEC	Tennessee Department of Environment and Conservation
TDRH	Tennessee Division of Radiological Health
TDSF	Tennessee Division of Superfund
TEQ	toxic equivalents
Th	thorium
Tl	thallium
TSCA	Toxic Substances Control Act of 1976
U	uranium
U_2O_3	uranium oxide
UCL_{95}	95 percent upper confidence level of the mean
UST	underground storage tank
VOC	volatile organic compound
WAC	waste acceptance criteria
WESTON	Roy F. Weston, Inc.
Zn	zinc
yd	yard

EXECUTIVE SUMMARY

This remedial investigation (RI)/feasibility study (FS) supports the selection of remedial actions for the David Witherspoon, Inc. (DWI) 901 Maryville Pike Site in Knoxville, Tennessee. Operations at the site, used as a recycling center, have resulted in past, present, and potential future releases of hazardous substances into the environment. The DWI 901 Site has been the subject of ongoing investigations by the Tennessee Department of Environment and Conservation (TDEC) and is a Tennessee Superfund site. This report documents the findings of several investigative efforts at this site and the feasibility of potential remedial action alternatives. This preliminary RI/FS will be used to determine a reasonable remedial action. Because of its preliminary nature, this document is also used to determine the information necessary to fully characterize the site.

The environmental restoration strategy for the DWI 901 Site was developed to investigate contaminated material that has current or possible future impacts on surrounding environmental media. A phased approach is planned to (1) gather existing data from previous investigations managed by TDEC; (2) perform a preliminary RI, including risk assessments, and an FS with existing data to identify areas where remedial action may be necessary; (3) gather additional field data, where needed, to adequately define the nature and extent of risk-based and/or regulatory-based contaminants that present identifiable threats to human and/or ecological receptors; and (4) develop remedial action alternatives to reduce risk to acceptable levels. Site risk assessment will use an iterative process where additional data will be incorporated as it is obtained. Where boundaries of known contaminants are poorly defined or previously undiscovered contaminants are detected, further data collection may be required to revise site models, risk assessments, and remedial alternative viability.

The baseline risk assessment contained in this report consists of a preliminary human health and ecological risk assessment (ERA). Both assessments assume no further action is taken at the site and institutional controls are removed. The assessments identify the risks associated with site contaminants and determine whether remedial actions are warranted. All conclusions are based on historical data.

Risk to human health was evaluated using pathways of exposure and receptors appropriate for current and hypothetical future land use scenarios. The pathways of exposure included (1) external exposure to radiation; (2) inhalation of radon and particulates; (3) ingestion of soil, groundwater, and sediment; and (4) dermal contact with chemicals in soil, groundwater, and sediment. Receptors evaluated for the DWI 901 Site included an employee, an adolescent trespasser, and an on-site and off-site resident. The human health risk assessment methodology is based on principles presented in *Risk Assessment Guidance for Superfund (RAGS)* (EPA 1989a). Sites with a cumulative cancer risk exceeding 1E-04 or a hazard quotient (HQ) of 1 (a measure of noncarcinogenic exposure) generally warrant remedial action.

Twenty-six chemicals of concern (COCs) were identified in DWI 901 Site soil. The COCs included radionuclides, metals, semivolatiles, polychlorinated biphenyls (PCBs), and dioxins/furans. Sediment COCs included six metals, two PCBs, and three semivolatiles. Groundwater COCs included nine metals and isotopic uranium.

Radiological risk exceeded 1E-04 for all receptors and approached 1 for a future resident living in the Candora Road Area. Uranium and ^{226}Ra contributed the majority of the calculated risks. Risk calculations were based on data suspected to be highly biased. However, even if the calculated risks are two orders of magnitude too high, contaminants in the Candora Road Area would still pose unacceptable risks (i.e., more that 1E-04) to a future resident.

The cumulative chemical risk exceeded 1E-04 for all exposure pathways evaluated for the reasonably maximum exposed individuals at the DWI 901 Site. Hazard indexes (HIs) exceeded 1.0. PCBs, mercury, and uranium are the major contributors to chemical risk and hazards associated with soil at the site.

The screening ERA estimated risk to nonhuman receptors. There is a potential for adverse effects to ecological receptors associated with the DWI 901 Site if conditions remain unchanged. Receptors include (1) small terrestrial mammals, (2) soil invertebrates, (3) vegetation, and (4) benthic macroinvertebrates. The primary chemicals of ecological concern (COEC) include metals and PCBs in the soil and sediment.

The remedial action objectives (RAOs) for the site are:

- Debris—To reduce contaminant contributions to environmental media through the removal or isolation of debris from the DWI 901 Site.

- Soil—To prevent current and future unacceptable risk ($> 1 \times 10^{-4}$ excess cancer risk or an HI of 1) to humans from exposure to contaminated soil and prevent contaminant migration to surface water and groundwater in excess of risk and regulatory levels.

- Sediment—To prevent current and future unacceptable risk (> 1 x 10^{-4} excess cancer risk or a HI of 1) to humans from exposure to contaminated sediment and prevent contaminant migration to surface water in excess of risk and regulatory levels.

- Surface water—To develop RAOs for surface water following analysis of planned surface water sampling.

- Groundwater—To develop RAOs for groundwater following analysis of planned groundwater sampling.

In the FS, a range of remedial action alternatives was developed to potentially meet these objectives. Alternatives developed in detail and analyzed included: Alternative 1—No Action, Alternative 2—Multilayer cap and monitoring, Alternative 3—Minimal treatment and disposal, and Alternative 4—Extensive treatment and disposal.

The detailed analysis is summarized in Table ES.1.

Table ES.1. Comparison of remedial alternatives, DWI 901 Site, Knoxville, Tennessee

Evaluation criteria	Alternative			
	1 No action	2 Multilayer cap and monitoring	3 Minimal treatment and disposal	4 Extensive treatment and disposal
Overall protection	None	Protection of employees and trespassers achieved. Future on-site residents not protected	Achieves protectiveness of all receptors	Achieves protectiveness of all receptors
Compliance with ARARs	None	Complies with all ARARs	Complies with all ARARs[a]	Complies with all ARARs[a]
Long-term effectiveness and permanence	No long-term effectiveness achieved	Long-term effectiveness achieved while institution control maintained	Long-term effectiveness achieved	Long-term effectiveness achieved
Reduction of toxicity, mobility, and volume through treatment	No reduction achieved since no treatment employed	No reduction achieved since no treatment employed	Toxicity of organics reduced through LTTD	Mobility of metals and radionuclide contamination, total waste volume, and toxicity of organics reduced through vitrification
Short-term effectiveness	No short-term effectiveness achieved. RAOs never achieved	Short-term effectiveness achieved with the use of BMPs and compliance with governing regulations. RAOs achieved in 36 months	Short-term effectiveness achieved with the use of BMPs and compliance with governing regulations. RAOs achieved in 41 months	Short-term effectiveness achieved with the use of BMPs and compliance with governing regulations. RAOs achieved in 50 months
Implementability	Readily implementable	Readily implementable	Readily implementable if EMWMF is developed	Implementable but complex
Present worth cost ($ millions)	0	7	20	33

[a]Assuming that surface water and groundwater ARARs can be met once data are available to demonstrate this.

ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
$ = dollar
DWI = David Witherspoon, Inc.
EMWMF = Environmental Management Waste Management Facility
LTTD = low-temperature thermal desorption
RAO = remedial action objective

1. INTRODUCTION

This remedial investigation (RI)/feasibility study (FS) supports the selection of remedial actions (RAs) for the David Witherspoon, Inc. (DWI) 901 Maryville Pike Site in Knoxville, Tennessee. Operations at the site resulted in past, present, and potential future releases of hazardous substances into the environment. The DWI 901 Site has been the subject of ongoing investigations by the Tennessee Department of Environment and Conservation (TDEC) and is a Tennessee Superfund Site. This document summarizes previous sampling activities and results of investigations conducted by TDEC. This preliminary RI/FS will be used in determining a reasonable RA. Because of its preliminary nature, this document also will be used to determine the information necessary to fully characterize the site.

The environmental restoration (ER) strategy for the DWI 901 Site was developed to investigate contaminated material that has current or possible future impacts on surrounding environmental media. A phased approach is planned to (1) gather existing data from previous investigations managed by TDEC; (2) perform a preliminary RI, including risk assessments, and an FS with existing data to identify areas where RA may be necessary; (3) gather additional field data, where needed, to adequately define the nature and extent of risk-based and/or regulatory-based contaminants that present identifiable threats to human and/or ecological receptors; and (4) develop RA alternatives to reduce risk to acceptable levels. Site risk assessment will use an iterative process where additional data will be incorporated as it is obtained. Where boundaries of known contaminants are poorly defined or previously undiscovered contaminants are detected, further data collection may be required to revise site models, risk assessments, and remedial alternative viability.

The 3.85-ha (9.5-acre) DWI 901 Site is situated in a mixed-use urban setting in the Vestal Community of South Knoxville, Tennessee (Fig. 1.1). It is bounded to the northwest by the CSX Railroad, to the northeast by Candora Road and the Tennessee Asphalt Company, to the southeast by Maryville Pike, and to the southwest by Alpha Industries and three parcels of residential property.

1.1 SITE HISTORY

In 1948, David Witherspoon, Sr., began DWI as a scrap metal processor. David Witherspoon, Jr., who succeeded his father, moved the business from an unknown location to the current 901 Maryville Pike location in 1968 (Fig. 1.1). The 901 Maryville Pike facility sorted and bulked

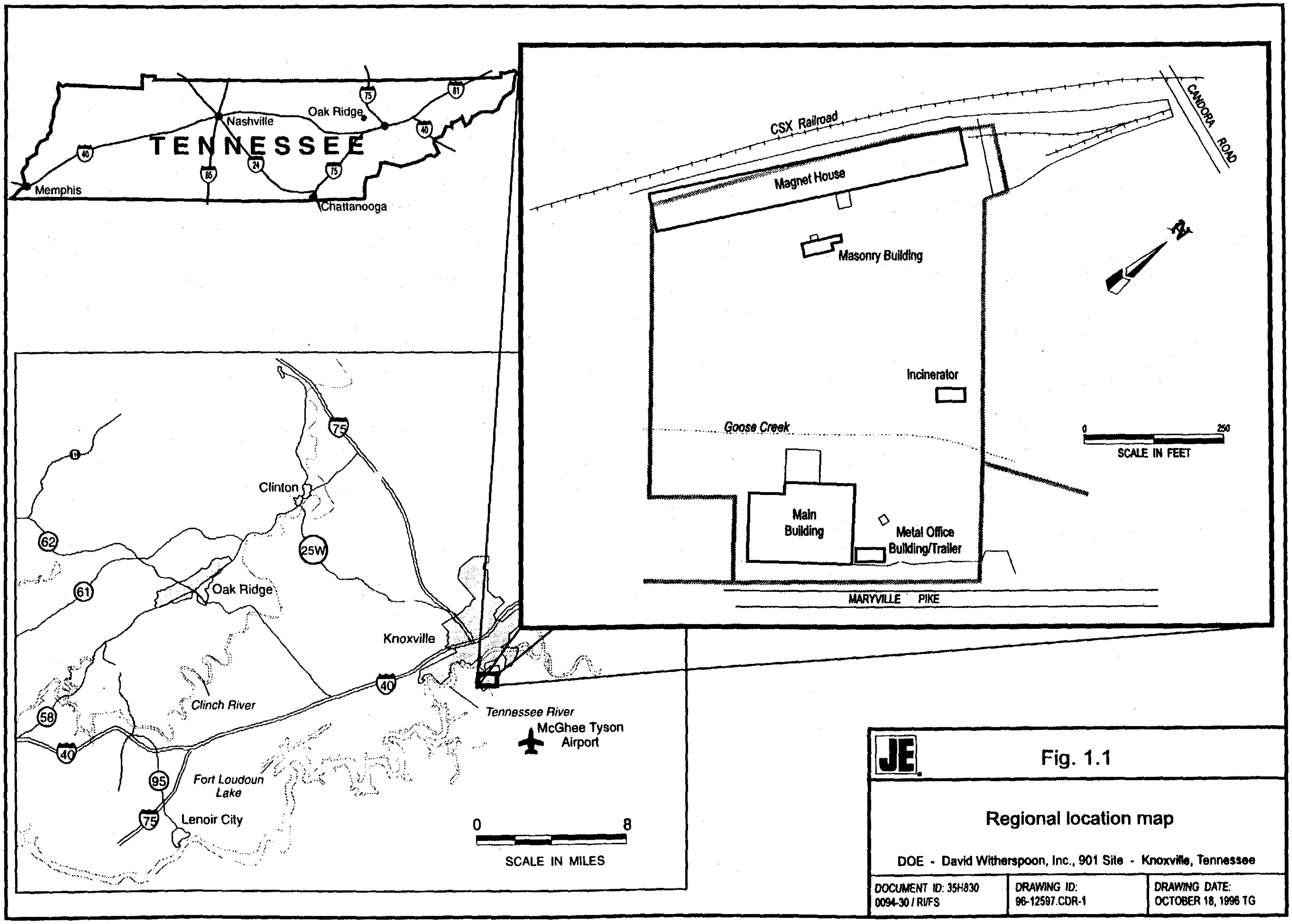


Fig. 1.1

Regional location map

DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-30 / RI/FS | DRAWING ID: 96-12597.CDR-1 | DRAWING DATE: OCTOBER 18, 1996 TG various types of scrap metal for resale. Currently, the facility is not in operation. Table 1.1 lists the buildings at the facility and identifies each building's function.

Table 1.1. Identification and function of DWI 901 Site buildings, Knoxville, Tennessee

Identification	Function
Main building	Part of overall scrap metal processing
Metal office building/office trailer	Probably used for DWI administrative functions
Magnet house	Part of overall scrap metal processing
Incinerator	Junk cars were burned and the scrap metal reclaimed for reprocessing
Masonry building	Not known

DWI = David Witherspoon, Inc.

In 1966, the Atomic Energy Commission issued a permit to DWI to accept low-level, uranium-contaminated scrap metal. The Tennessee Division of Radiological Health (TDRH) licensed the facility the same year. The license was renewed annually until 1981. In 1981 the Commissioner of TDRH issued an Order and Complaint for license violation. A 1982 Consent Agreement between DWI and TDRH transferred over 200 drums of mixed waste from a nearby DWI property (Rader or Screen Art Property, 1630 Maryville Pike) to the DWI 901 Site. In 1983, the TDRH commissioner issued an Order and Civil Penalty against DWI. The Order and Penalty were appealed by DWI, resulting in a reduction of penalties because of monies already spent. A 1985 Final Order forced the placement of more than 200 drums from the nearby Rader property in sea/land containers on the DWI 901 Site.

The Tennessee Division of Superfund (TDSF) began investigating three DWI-related sites in 1989, including the DWI 901 Site. Several sampling events have occurred at the DWI 901 Site since 1989. Each investigative effort has determined that the site is contaminated to some degree and that there is a need for further data collection; thus, successive sampling events have been initiated. Following is a list of the sampling events from 1987 to the present and the investigators:

- January 1987 — Analytical Chemical Division of Martin Marietta Energy Systems, Inc. [now known as Lockheed Martin Energy Systems (Energy Systems)], sampled drummed soils at the Candora Road Area. The drums have since been removed.

- March 1987 — Bechtel National, Inc., conducted a radiological walkover of the Candora Road Area and collected soil samples.

- August 1989 — Technical Laboratories, Inc., removed an underground storage tank (UST) and collected four excavation soil samples. There was no closure because no groundwater monitoring had been conducted.

- August 1989 — The TDSF collected two soil samples.

- March 1990 — TDRH conducted a radiological walkover survey and collected soil samples.

- August 1990 — TDSF collected soil and sediment samples from seven locations.

- April 1991 — CRU Inc., collected soil samples on behalf of CSX Transportation.

- April 1991 — TDSF collected three surface water samples and one off-site groundwater sample.

- May 1992 — PRC Environmental Management, Inc. (PRC), conducted a preliminary RI and wrote a draft technical memorandum.

- October 1992 — PRC produced an addendum to the preliminary RI.

- January 1993 — Ten open metal bins and 268 drums were removed and sent to the Oak Ridge K-25 Site for long-term storage.

- December 1993 — Roy F. Weston, Inc. (WESTON) produced a limited field investigation report.

- January 1995 — Characterization and disposal of Cincinnati Machine and related equipment.

- August 1995 — Halliburton NUS Corporation (Halliburton) produced a final expanded site inspection (SI) report.

On October 19, 1993, a court order forced the cessation of DWI operations at the 901 Maryville Pike location and the property was seized by TDSF. TDSF identified the U.S. Department of Energy (DOE) as a potentially responsible party (PRP) April 4, 1991.

1.2 REGULATORY INITIATIVES

The cleanup process, as mandated under state and federal regulations, begins with investigating and characterizing contamination at a site. The process continues by assessing the possibilities of site remediation, making cleanup decisions based on characterization and assessment, and implementing RA. The primary reporting documents generally published by the lead agency during the cleanup process are the RI/FS report and the record of decision (ROD), which presents the chosen method and/or technology for cleanup. Other documents, secondary in nature, may be published for some sites. Examples include, but are not limited to, treatability studies and proposed plan support documents. These documents become part of a project's administrative record.

DOE has agreed to undertake DWI 901 Site remedial activities specified under a Consent Order with the state of Tennessee (Consent Order No. 90-3443, April 4, 1991) and as further directed by a memorandum of understanding (MOU) between DOE and the state of Tennessee (*MOU Regarding Implementation of Consent Orders*, October 6, 1994). Unlike many remedial activities undertaken by DOE, activities at the DWI 901 Site are not subject to the Federal Facility Agreement (FFA) of January 1, 1994, but rather to the rules of the state Hazardous Substance Site Remedial Action Program directed by the TDEC Division of Superfund. According to the MOU and the Consent Order, DOE shall conduct these activities in a manner consistent with the terms and conditions of the FFA and Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and as approved by the commissioner.

Tennessee Rules 1200-1-13 and Section 121 of CERCLA specify that RAs for cleanup of hazardous substances must comply with requirements or standards under federal, state, and local regulations, whichever is more stringent, that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site. Inherent in the interpretation of applicable or relevant and appropriate requirements (ARARs) is the assumption that protection of human health and the environment is ensured.

The National Environmental Policy Act of 1969 (NEPA) requires all federal agencies to consider the possible effects (both adverse and beneficial) of all proposed activities or actions. DOE's NEPA requirements are found in 10 *Code of Federal Regulations* (CFR) 1021, "National Environmental Policy Act Implementing Procedures," and DOE Order 451.1, "National

Environmental Policy Act Compliance Program." DOE's policy for complying with the NEPA review and approval for CERCLA actions was presented in the Secretarial Policy Statement on NEPA (June 13, 1994). The policy 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. Although the DWI 901 Site is a state Superfund site and is not included in the FFA, DOE-Oak Ridge Operations (ORO) Office of Chief Counsel has stated that DOE has agreed to conduct remedial activities for non-FFA sites in a manner that is consistent with CERCLA and the FFA (Memorandum, June 12, 1996). Therefore, NEPA values have been incorporated into this RI/FS.

Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations," became effective February 11, 1994. The EO mandates that every federal agency make achieving environmental justice part of its mission. The intent is to avoid disproportionately high and adverse human health or environmental effects on minority or low-income populations. The DWI 901 Site is in an urban area of mixed residential and industrial zoning and has residential per capita income levels that are slightly lower than other nearby areas. DOE wishes to ensure that environmental justice issues are given appropriate consideration.

There are, as yet, no implementing regulations for EO 12898. The project that DOE is proposing is to remediate the DWI 901 Site, so the intent and result are anticipated to benefit local property owners, residential and industrial alike. However, decisions implicit in the selection of the remedial alternative (e.g., intended land use), will be of interest to local stakeholders. DOE will fulfill the mandate and intent of EO 12898 through enhanced use of public participation requirements for Superfund sites. In addition, DOE will work with TDSF to facilitate public participation through measures such as the distribution of informational briefs to local mailing addresses, holding a public meeting near the site, or other outreach measures TDSF might deem necessary.

1.3 DWI SITE ER

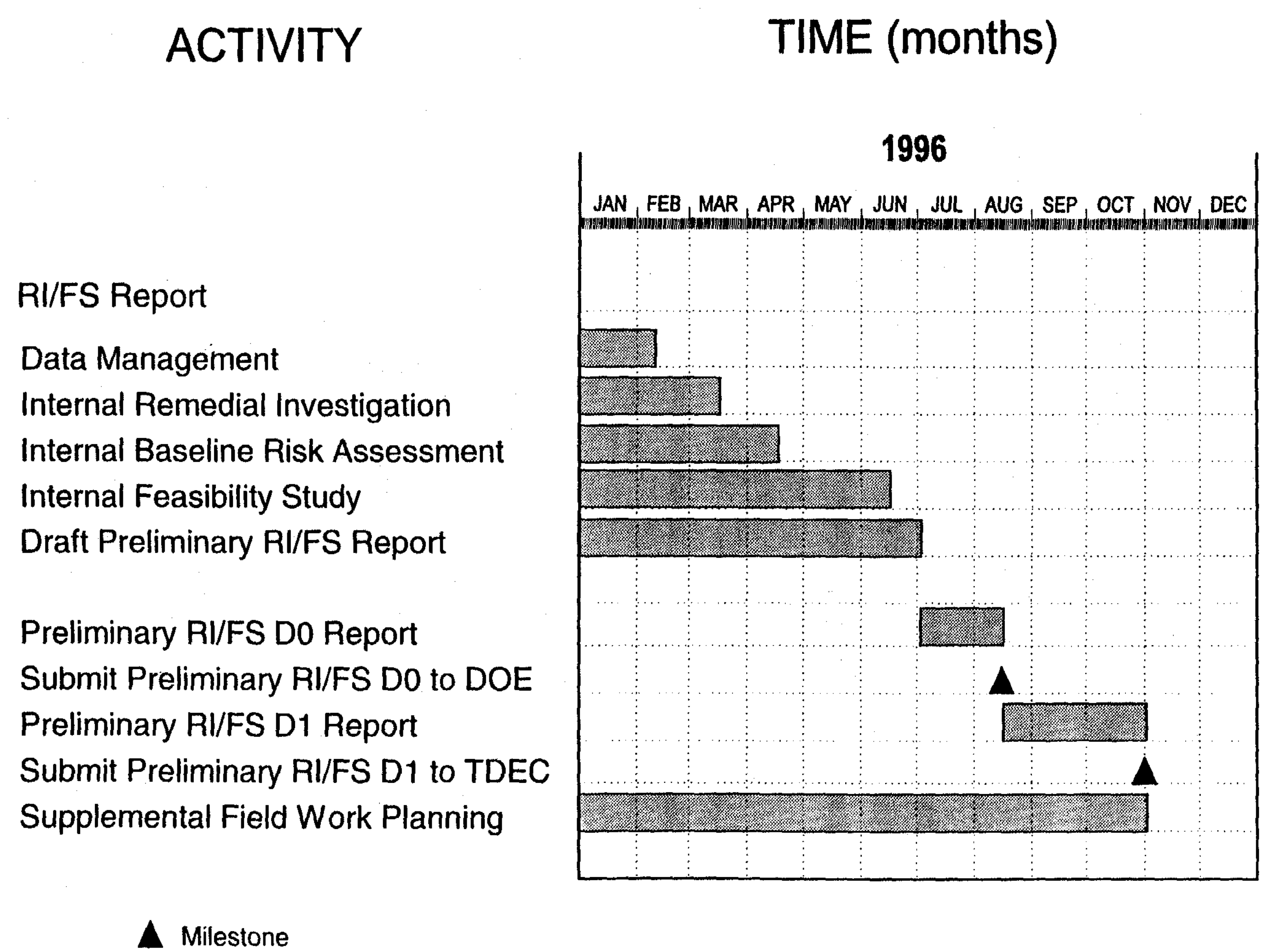
The ER strategy for the DWI 901 Site was developed to investigate contaminated material that has current or may have future impacts on surrounding environmental media. A phased approach is planned to (1) gather existing data from previous investigations managed by TDEC; (2) perform a preliminary RI, including risk assessments, and an FS with existing data to identify areas where RA may be necessary; (3) gather additional field data, where needed, to adequately define the nature and extent of risk-based and/or regulatory-based contaminants that present identifiable threats to human and/or ecological receptors; and (4) develop RA alternatives to reduce risk to acceptable levels. Site risk assessment will use an iterative process where additional data will be incorporated as it is obtained. Where boundaries of known contaminants are poorly defined or previously undiscovered contaminants are detected, further data collection may be required to revise site models, risk assessments, and remedial alternative viability.

Data gaps have been identified for potential buried debris, surface debris, surface soils, subsurface soils, surface water, groundwater, and off-site radiological characterization. Additional sampling is warranted and will be performed for these media to adequately characterize the site and support remedial alternative development. Appendix B, Chapter 2, describes the locations, sampling methods, and analytical procedures that will be used.

This RI/FS for the DWI 901 Site is presented in nine chapters. Chapter 1 explains the regulatory initiative for the RI/FS and provides background information on the DWI 901 Site. Chapter 2 summarizes the environmental setting. Chapter 3 summarizes the environmental data used to define the nature and extent of site contaminants. Chapters 4 and 5 assess the human and ecological risks associated with the site contamination. Chapter 6 summarizes previous work and lays the foundation for the FS. Chapter 7 identifies and screens potential remedial technologies. Chapter 8 builds these technologies into alternatives for RAs. Chapter 9 provides a detailed analysis of individual potential remedial alternatives.

1.4 SCHEDULE

The schedule for the RA program at the DWI 901 Site (Fig. 1.2) incorporates the investigation, documentation, and review requirements of the consent order. Submittal dates and document review times are proposed by DOE and negotiated with TDSF. DOE has committed to providing responses to regulatory comments within 60 calendar days.



JE	Fig. 1.2	Project schedule DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-12676.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

2. CHARACTERIZATION OF ENVIRONMENTAL SETTING

The environmental setting of the DWI 901 Site includes physical and cultural aspects of the facility and nearby areas.

2.1 PHYSIOGRAPHY

The DWI 901 Site lies in the Valley and Ridge Physiographic Province, Appalachian Rough Lands subdivision, Open Hills surface type in East Tennessee (Fig. 2.1) (Hammond 1964). The Valley and Ridge Physiographic Province lies between the Blue Ridge Province to the east and the Cumberland Plateau Province to the west. It extends for 1,900 km (1,200 miles) from the St. Lawrence Valley in New York to the Gulf Coastal Plain in Alabama. Knox County elevations range from 225 m (740 ft) at Clinch River to 649 m (2,128 ft) at House Mountain. Average topographic relief among Knox County ridges and valleys is 55–122 m (180–400 ft).

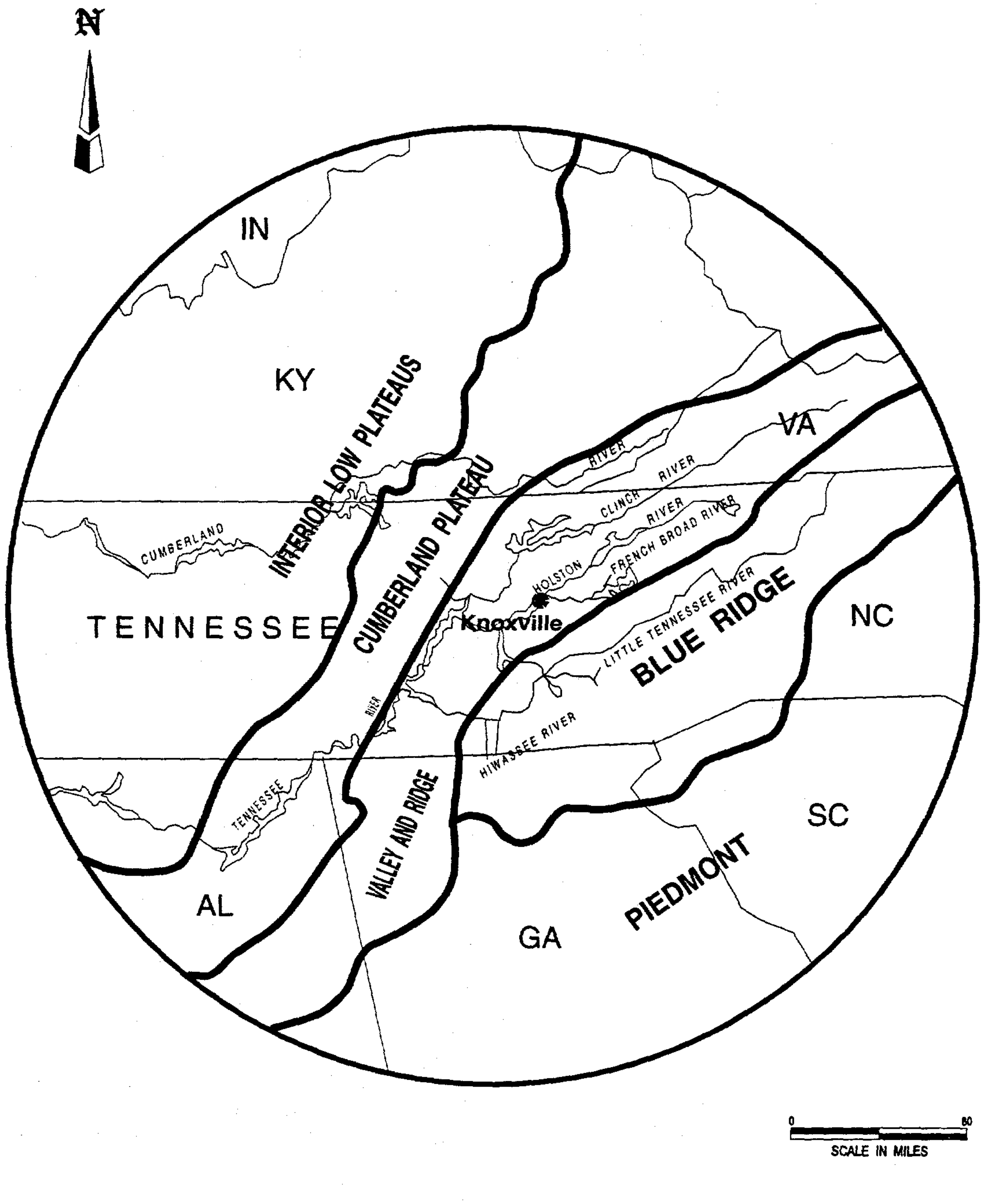
The Valley and Ridge Physiographic Province is a lowland or assemblage of valley floors surmounted by long, narrow, even-topped ridges. The uniform elevations of the ridge tops are a remnant of a former peneplain or erosion surface. Thrust faulting and folding of predominantly calcareous Paleozoic rocks coupled with differential erosion have generated elongated, subparallel ridges and valleys trending approximately N 55° E. The surface was uplifted following several events, and subsequent erosion cut the extensive valley system between the ridges (Fenneman 1938; King et al. 1968; Shimer 1972).

2.1.1 Site Topography

The DWI 901 Site topography is slightly rolling. Between Goose Creek and the CSX Railroad, the surface slope is moderately gentle at an approximate 9–10 percent grade with a southeast aspect. The portion of the site between Goose Creek and Maryville Pike slopes gently to the north-northwest at an approximate 2–5 percent grade. Alterations to original topography include road improvements along Maryville Pike, underground utilities, building construction, and drainage improvements (i.e., culverts and channelization). Elevation at the DWI 901 Site ranges from approximately 267–258 m (876–848 ft) above mean sea level (AMSL).

2.1.2 Wetlands/Floodplains

A review of the U.S. Department of the Interior, National Wetlands Inventory map of the Knoxville Quadrangle disclosed no wetlands on or adjacent to the DWI 901 Site. However,



JE	Fig. 2.1	
Physiographic regions in the vicinity of the DWI 901 Site		
DOE - David Witherspoon, Inc., 901 Site, - Knoxville, Tennessee		
DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-12675.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

since Goose Creek transects the site, a wetlands survey of the site and adjacent areas of potential off-site migration of contaminants will be performed to establish the presence or absence of wetlands (Fig. 2.2).

A floodplain delineation for Goose Creek at the DWI 901 Site has not been conducted. Approximately 150 m (500 ft) downstream of the site, established floodplain boundaries have been defined by the Federal Emergency Management Agency as part of mapping done for the Tennessee River Basin. The uppermost areas studied on Goose Creek are denoted Zone A4 on city of Knoxville Department of Engineering drawings. This area is bisected by Candora Road northeast of the site. The 100-year floodplain boundary for Zone A4 is 256 m (846 ft) AMSL (Fig. 2.3). According to 10 CFR 1022, a floodplain assessment will be conducted for any action proposed within the 100-year floodplain based on this elevational boundary.

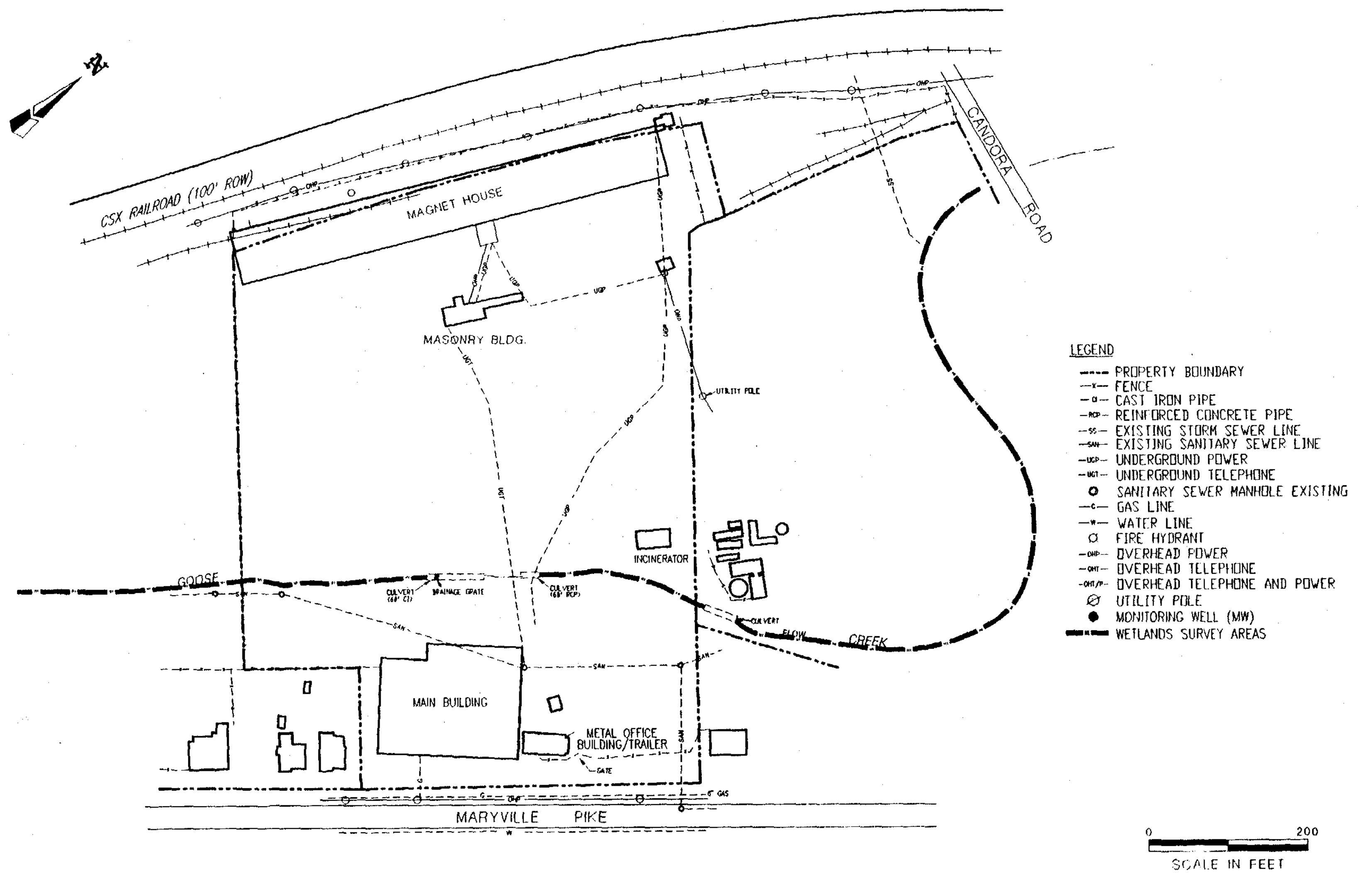
2.1.3 Cultural Resources

TDSF did not investigate cultural resources at the DWI 901 Site, according to four TDSF reports. A formal consultation will be conducted. However, since the site has been extensively disturbed, a cultural resources survey will be conducted only if any artifacts are observed during activities conducted at the site.

2.2 DEMOGRAPHY AND LAND USE

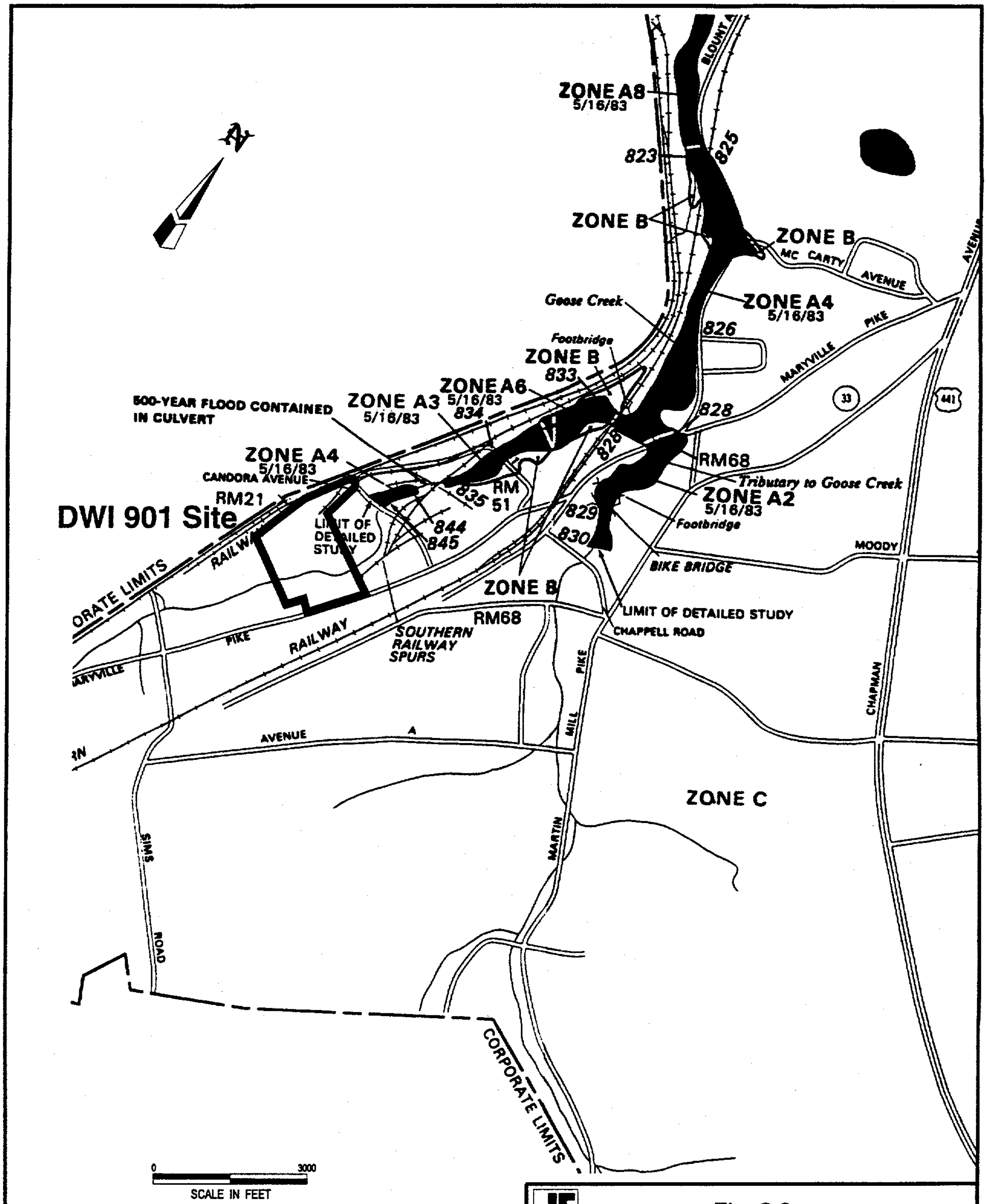
The DWI 901 Site is in the Vestal Community within the Knoxville South City Sector (Fig. 2.4). According to the 1990 Census, the South City Sector had 17,719 residents, which is a 12.2 percent decline over 10 years (MPC 1995). This decline is attributed to the overall aging of the sector's population. Statistics show that more children are leaving households to live outside of this sector and fewer new families are moving in. Countywide, the South City Sector has had the fewest new building permits between 1990 and 1994. The sector has 16.5 percent of its population age 65 or older, compared to 12.7 percent for the remainder of the county. Population density is 2.4 persons per acre. Overall population density for Knoxville and Knox County is 3.2 and 1.0, respectively. Eight churches and three public schools have been identified within a 1.6-km (1-mile) radius of the DWI 901 Site. Mary Vestal Park is a 6.4-ha (16-acre) community park approximately 0.8 km (0.5 miles) downstream of the site at 522 Maryville Pike.

The South City Sector has a mean annual household income of $24,492, which is lower than Knoxville and Knox County. The DWI 901 Site is within Census Tract 24. This tract has the lowest median annual income ($14,161) and lowest per capita income ($7,048) of all South City Sector Census Tracts. Census Tract 24 also has the highest percentage of population without a high school diploma (52 percent) or a college degree (92 percent) for the South City Sector



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	Fig. 2.2	DWI 901 Site wetlands survey areas DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0034-20 / RI/FS	DRAWING ID 96-13182 DWG A2	DRAWING DATE OCTOBER 21, 1996 TG



SOURCE: Knoxville City Engineers Office, Federal Emergency Management Agency Maps

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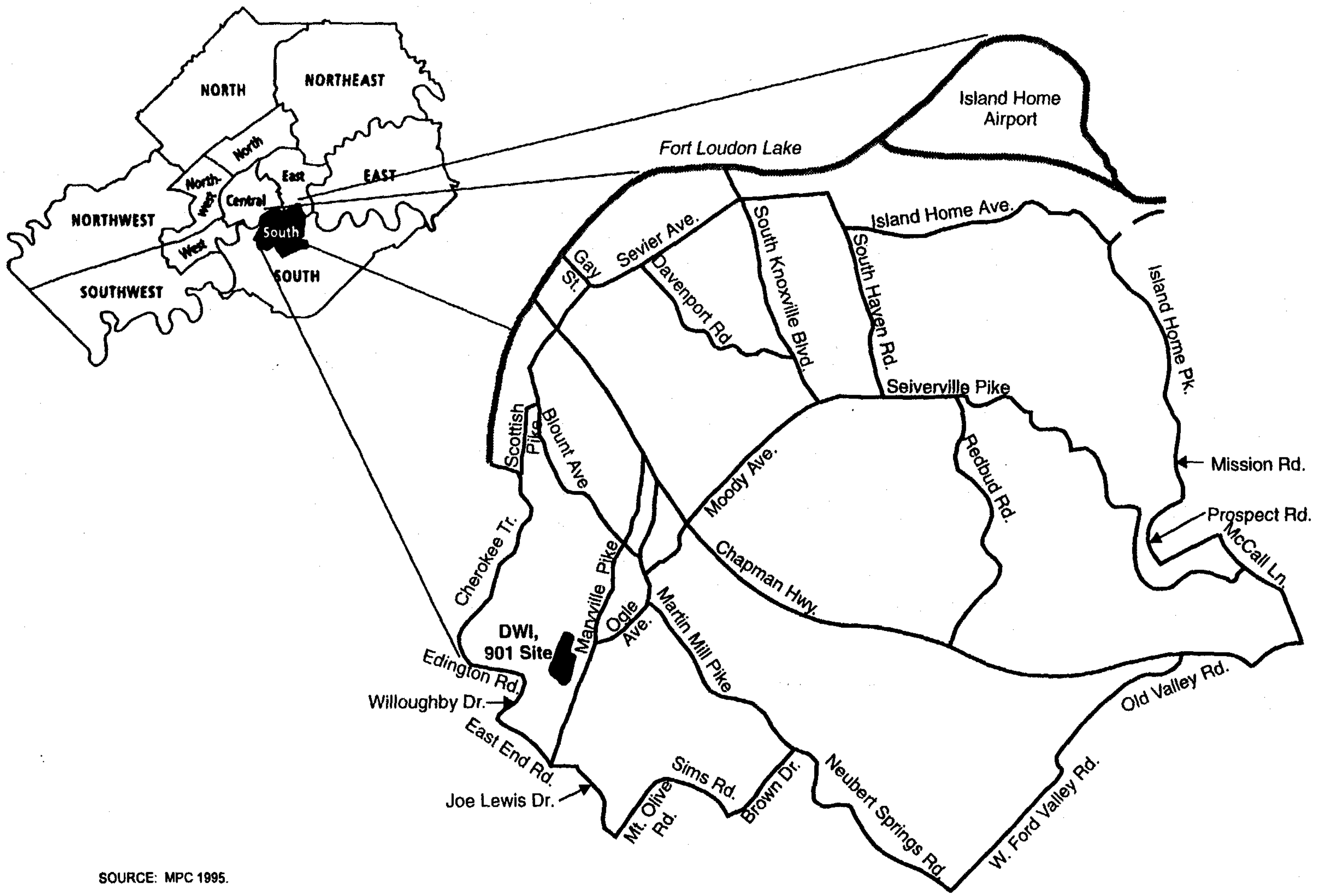
Fig. 2.3

Off-site floodplain boundary
(DWI 901 Site floodplain to be added)

DOE - David Witherspoon, Inc., 901 Site, - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-13139.CDR	DRAWING DATE: OCTOBER 18, 1996 TG



SOURCE: MPC 1995.

JE	Fig. 2.4	South city sector map DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-12680.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

(average of 31 and 83 percent, respectively). Census Tract 24 has the highest unemployment rate (10.7 percent) and one of the highest poverty rates (31.3 percent) in the South City Sector as compared to Census Tract 34, which is located directly east (3.2 and 7.4 percent, respectively) (MPC 1995).

The site's current land use classification is Industrial-wholesale and Manufacturing (MPC 1995). Since the October 1993 property seizure and termination of DWI operations, authorized use of the property has ceased. TDSF maintains control of the site, although gaps in the perimeter fence may allow trespassers to access the site.

This sector has a significant amount of land developed for industrial use. It ranks third in total industrial acres for all sectors and second only to the Central City Sector in percentage of land developed for industrial use. The sector has 37 ha (93 acres), representing 2.6 percent of the total land, identified as industrial. Most of the industrial development is pre-1960 and is scattered along rail lines and river banks. Several sites are still active and include some major employers. In the southern tip of the sector, there are some scattered industrial sites remote from the rail lines, but with access via Chapman Highway.

2.3 CLIMATE

The Valley and Ridge Province climate is classified as humid-forest, mesothermal. Rainfall is abundant in all seasons according to Thornwaite's classification system (Trewartha 1943). Winter temperatures average 4.7°C (40.5°F), and summer temperatures average 24.7°C (76.5°F) (U.S. Department of Commerce 1995). Precipitation in the region averages 121 cm (48 in.)/year. Most of the precipitation occurs in the winter and early spring seasons, with most of the precipitation in the form of rain. Snowfall averages 29 cm (12 in.)/year. Table 2.1 presents precipitation and temperature data for Knox County, Tennessee (U.S. Department of Commerce 1995). December through March is considered flood season. A secondary period of precipitation occurs midsummer as a result of shower and thunderstorm activity. Fall is the driest season of the year (Dickson 1978). The average date of the last killing frost is April 1, and the first fall frost is October 28. The average maximum annual depth of frost penetration is 18–25 cm (7–10 in.) with extreme depth from around [46–61 cm (18–24 in.)]. The growing season lasts from 180 to 220 days.

The winter weather pattern for Knoxville is variable because of frequent fronts, which are accompanied by alternating cold and warm air masses. Associated wind speeds average 13 km/hour (8 mph). Wind direction is greatly influenced by the northeast to southwest orientation of the ridges in the Valley and Ridge Province. Table 2.2 presents windspeed,

Table 2.1. Normal monthly, seasonal, and annual temperature and precipitation, Knoxville, Tennessee

Month	Temperature average °F	Precipitation	
		Rain average (in.)	Snow average (in.)
December	40.7	4.45	1.5
January	38.9	4.56	3.9
February	41.8	4.56	3.5
Winter	40.5	4.52	3.0
March	49.5	5.14	1.7
April	58.7	4.08	0.4
May	67.2	3.81	trace
Spring	58.5	4.34	0.7
June	74.8	4.02	0.0
July	77.8	4.50	0.0
August	76.8	3.67	0.0
Summer	76.5	4.06	0.0
September	71.4	2.85	0.0
October	59.7	2.64	trace
November	48.5	3.43	0.6
Fall	59.9	2.97	0.2
Year	58.8	47.70	11.7

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 1995. *Local Climatological Data and Annual Summary with Comparative Data, Knoxville, Tennessee (TYS)*. ISSN 0198-4802, National Climatic Data Center, Asheville, NC.

°F = degrees Fahrenheit
in. = inch

Table 2.2. Normal wind speed, direction, and moisture balance data, Knoxville, Tennessee

Month	Wind		Moisture balance		
	Mean speed (mph)	Prevailing direction	Precipitation (in.)	Evapotranspiration (in.)	Effective precipitation (in.)
December	7.2	NE	4.45	nd	nd
January	7.7	NE	4.56	nd	nd
February	8.1	NE	4.56	nd	nd
Winter	7.7		4.52	nd	nd
March	8.5	NE	5.14	nd	nd
April	8.4	WSW	4.08	4.90	-0.82
May	6.8	SW	3.81	5.88	-2.07
Spring	7.9		4.34	nd	nd
June	6.4	SW	4.02	6.77	-2.75
July	6.0	SW	4.50	6.90	-2.40
August	5.5	WSW	3.67	6.20	-2.53
Summer	6.0		4.06	6.62	-2.56
September	5.6	NE	2.85	4.55	-1.70
October	5.7	NE	2.64	3.03	-0.39
November	6.7	NE	3.43	nd	nd
Fall	6.0		2.97	nd	nd
Year	6.9	NE	47.70	nd	nd

Sources: Logan, J. and H. Fribourg. 1989. *Agroclimatology of the Knoxville Experiment Station, 1988 -vs- 1960–87.* The University of Tennessee Agricultural Experiment Station, Research Report 89-10, Knoxville, TN.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 1995. *Local Climatological Data and Annual Summary with Comparative Data, Knoxville, Tennessee (TYS).* ISSN 0198-4802, National Climatic Data Center, Asheville, NC. Observations based on data collected 1965–1994.

in. = inch
mph = miles per hour
nd = no data

NE = northeast
SW = southwest
WSW = west southwest

direction, and moisture balance for Knoxville, Tennessee (TVA 1980). Summer weather in the area is influenced by warm moist air influx from the Atlantic Ocean and the Gulf of Mexico. Summer winds are the lightest of the year averaging 8–11 km/hour (5–7 mph) (Table 2.2), and generally originate from west to southwest (30 percent) and north to northeast (25 percent) (TVA 1980).

2.4 GEOLOGY

The DWI 901 Site consists of sedimentary formations of differential weathering. The topography of this sedimentary basin was created by compressional tectonic force during the Appalachian Orogeny (200–290 million years ago) as older rocks were thrust on top of younger rocks. As this thrust faulting occurred, frictional drag-like forces deformed many of the valley and ridge rocks, producing folds and secondary faults. These folds and faults, combined with the differential erosion of the bedrock, created the existing topography. The more weatherable formations are in the valleys, and the more resistant formations are along the ridgetops. The DWI 901 Site lies within the more weatherable limestones and shales of the valley.

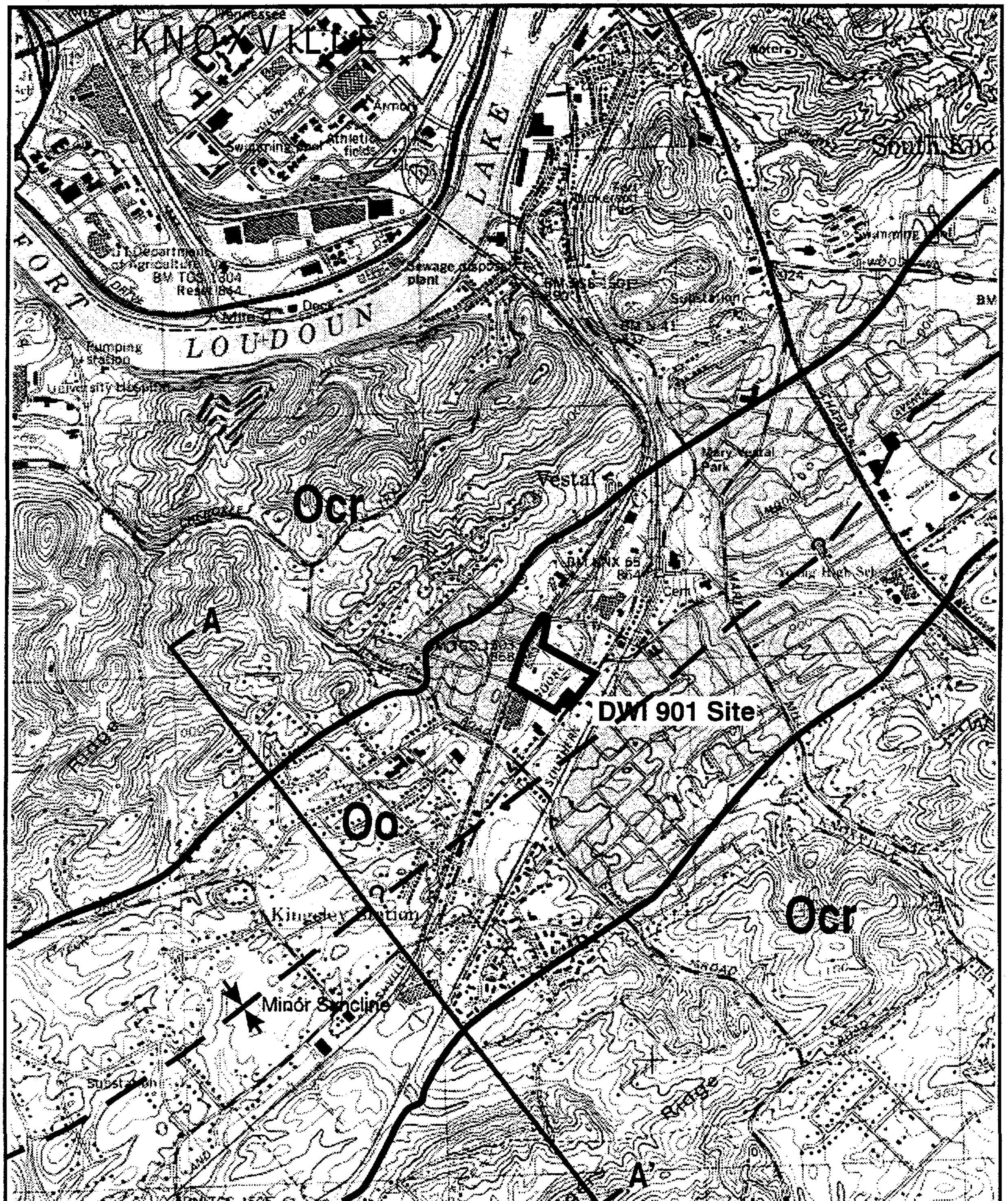
2.4.1 Geologic Setting

There is no faulting near the DWI 901 Site, but the site is situated on an unnamed syncline in the Ottosee Shale (Figs. 2.5 and 2.6). It is stratigraphically underlain by Ottosee Shale, a member of the Middle to early Upper Chickamauga Group.

Ottosee Shale is a heterogeneous mixture of fossiliferous shale, siltstone, sandstone, and carbonate rock (Fig. 2.7). Thicknesses range from 212 to 606-m (700 to 2,000-ft). The shales that comprise the unit are brown, grayish brown, or medium to dark gray and contain calcite crystals, pods, or laminated limestone beds. Limestone layers in Ottosee Shale range from coarse and clayey to aphanitic. Scattered pink beds of marble, similar in appearance to marble comprising the Holston Formation, occur throughout the formation and are up to 61 m (200 ft) thick (Tennessee Division of Geology—Bulletin 70, 1973). Ottosee Shale typically weathers into a yellowish residuum that ranges in thickness from 0.15 to 1.1 m (0.5 to 3.5 ft) (Roberts et al. 1955).

2.4.2 Soils

DWI 901 Site soils consist of six series in three distinct groupings: (1) residuum formed from shale, (2) alluvium, and (3) thin soils formed on weathered limestone.



N

0 2000
SCALE IN FEET

Oo = Ottosee Shale Ocr = Chapman Ridge Sandstone

MODIFIED FROM: U.S.G.S. Geologic Quadrangle of Knoxville, Tenn. (147-NW), 1958.

SOURCE: U.S.G.S. Topographic Quadrangle, Knoxville, Tenn. (147-NW), 1978.

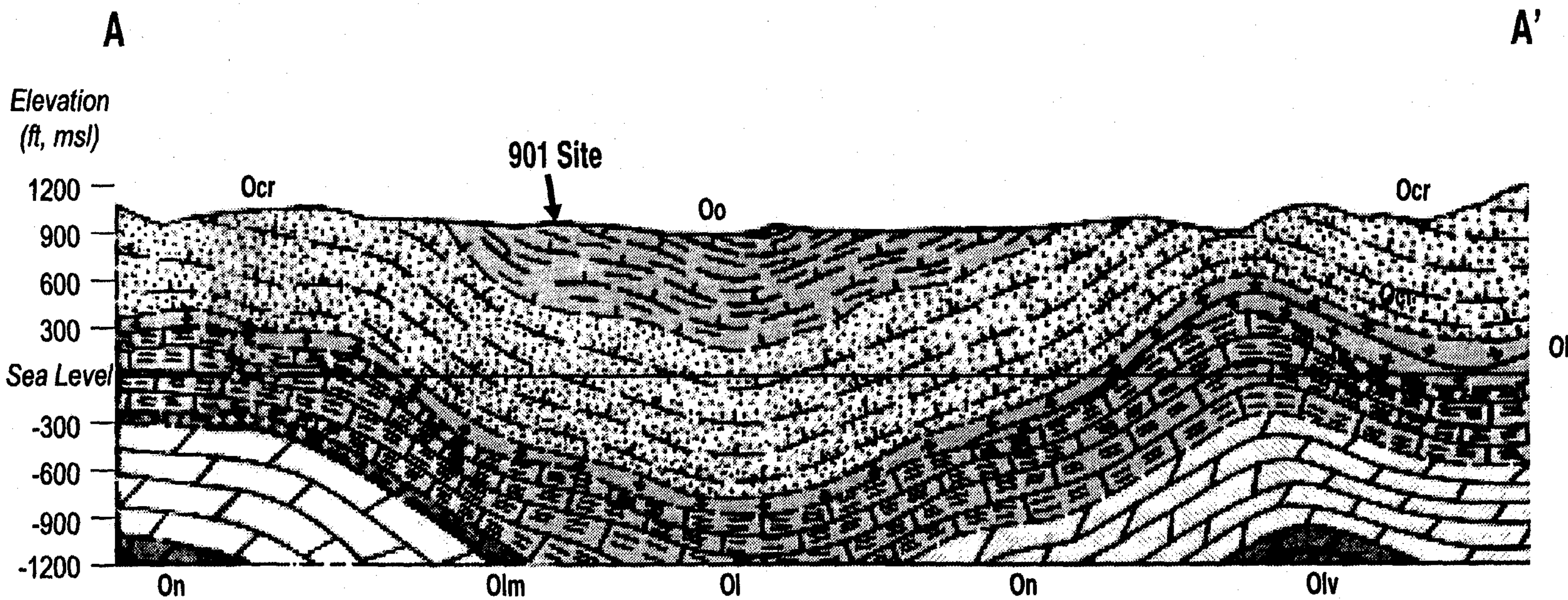
JE

Fig. 2.5

Geologic map

DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-12674.CDR-2	DRAWING DATE: OCTOBER 18, 1996 TG



(see Fig. 2.5 for location)

Ocr - Chapman Ridge Sandstone
Oo - Ottosee Shale
Oh - Holston Formation
Ol - Lenoir Limestone
Olm - Lenoir Limestone (Mosheim Member)
On - Newala Formation
Olv - Longview Dolomite

0 2000
APPROXIMATE SCALE IN FEET

SOURCE: USGS Knoxville Geologic Quadrangle Map 1958.

JE Fig. 2.6	Generalized geologic cross section DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-12677.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

Lithology	Thickness (ft)	Formation
UPPER ORDOVICIAN	450	SEQUATCHIE FORMATION (Os), Mudstone, siltstone and shale, grayish-red; and silty limestone, gray.
UPPER ORDOVICIAN	700++	MARTINSBURG SHALE, Shale and siltstone, sandy, calcareous, gray to greenish gray, and limestone, argillaceous, gray fossiliferous.
MIDDLE ORDOVICIAN; Chickamauga Group (Och)	700	BAYS FORMATION (Ob), Mudstones, silty, grayish-red; some with mud cracks; calcarous in upper part; with two thin zones of metabentonite in upper part.
MIDDLE ORDOVICIAN; Chickamauga Group (Och)	950	MOCCASIN FORMATION, Mudstones, calcarous grayish-red, greenish-gray; with shrinkage cracks, mudcracks, ostracod zones; with thick zones of fossiliferous gray limestones; with two thin metabentonites in upper part.
MIDDLE ORDOVICIAN; Chickamauga Group (Och)	700 - 2,000	OTTOSEE SHALE (Oo), Shale, siltstone, some sandstone and marble; shales and siltstones are brown, medium to dark gray, fossiliferous, calcareous; limestones are argillaceous to pure, gray; marble is pink to grayish red.
MIDDLE ORDOVICIAN; Chickamauga Group (Och)	up to 900	CHAPMAN RIDGE (Tellico) SANDSTONE, Sandstone, calcareous and calcarenite, arenaceous, fossiliferous, crossbedded, dark-greenish-gray to reddish brown; wiith some shale interbeds silimilar to those of the Ottosee, and some beds of marble.
MIDDLE ORDOVICIAN; Chickamauga Group (Och)	up to 525	HOLSTON LIMESTONE (Oh), Marble, calcarenite, fine-to coarse grained, shades of gray, pink, red,; thick-bedded; with some innerbeds of nodular gray limestone; fossiliferous.
MIDDLE ORDOVICIAN; Chickamauga Group (Och)	120 - 600	LENOIR LIMESTONE (Ol), Limestone, argillaceous or silty, gray, weathers nodular or cobbly, fossiliferous; with sedimentary breccias at base.
MIDDLE ORDOVICIAN; Chickamauga Group (Och)	up to 150	MOSHEIM MEMBER, Limestone, aphanitic, gray thick-bedded; with birdseyes.

REFERENCE: Tennessee Division of Geology, Bulletin 70, 1973.

JE

Fig. 2.7

Stratigraphic column

DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-13060.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

2.4.2.1 Shale residuum

Three soil series at the site form from weathered shales: Sequoia silty clay loam, eroded rolling phase; Sequoia silty clay loam, severely eroded phase; and Dandridge and Litz shaly silt loam, eroded hilly phase occur on the northwestern half of the property above Goose Creek partially extending northward to Candora Road (Fig. 2.8). These are residual products of interbedded shale and limestone and calcareous shale bedrock weathered in place.

Sequoia silty clay loam, eroded rolling phase (5–12 percent slopes) has low organic matter. It is medium to strongly acidic. Internal drainage is "somewhat impaired to slow," and the infiltration rate may be retarded by the "firm" subsoil (Roberts et al. 1955).

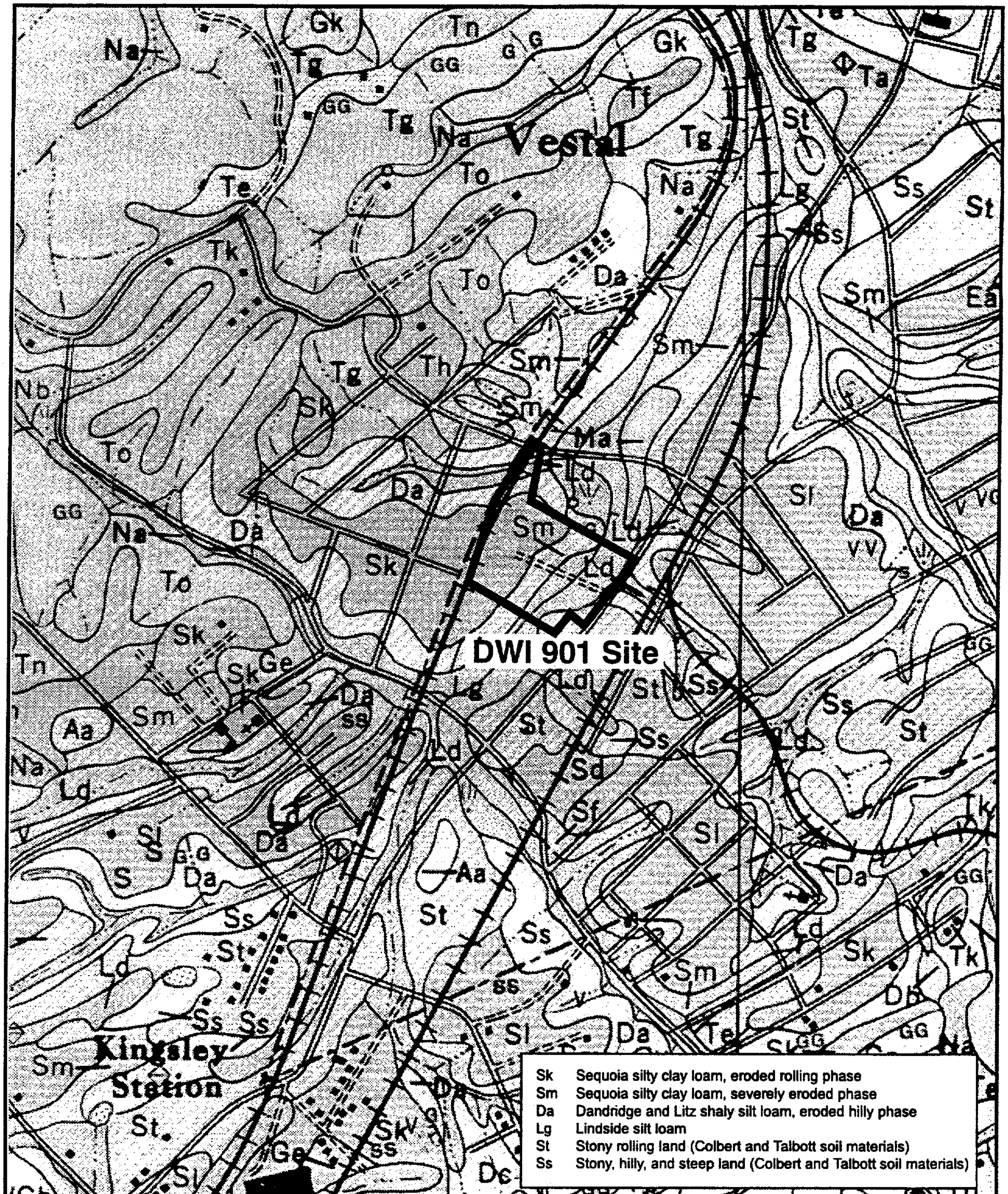
Sequoia silty clay loam, severely eroded phase (5–12 percent slopes) has very low organic matter because of a considerable loss of surface material caused by erosion. Its internal permeability is very low, and it has a medium to strong acidity (Roberts et al. 1955).

Dandridge and Litz shaly silt loam, eroded hilly phase (12–25 percent slopes) consists of undifferentiated Dandridge and Litz soils. The grade from Dandridge to Litz increases as calcium carbonate leaches from the parent material. This soil unit exhibits moderate internal drainage and has been materially eroded. Where shale is present at shallow depths, moisture movement may be further impeded if fractures are oriented unfavorably. Moisture-holding capacity is low due to the shallow nature of the bedrock. Organic content is low and fertility is moderate to low due to surface material erosion (Roberts et al. 1955).

2.4.2.2 Alluvium

Both sides of Goose Creek and a small area at the northern tip of the Candora Road Area contains Lindside silt loam. This is an alluvial material transported by surface drainage from sources on either side of the creek and/or from sources upstream within the watershed of the creek and deposited on the floodplain of the creek. Lindside soil in the Candora Road Area was deposited by a small tributary branch that periodically drained into Goose Creek at the confluence downstream of the site. Current topographical information does not show this feature.

Lindside silt loam (0–2 percent slopes) is alluvium derived from limestone or other calcareous-based parent material. This soil occurs widely in many area creeks underlain by limestone and shale. The soil is moderately acidic to moderately alkaline and has a high organic matter and a high moisture-holding capacity. The soil is permeable, but has variable internal



N

0 1000
SCALE IN FEET

SOURCE: U.S. Department of Agriculture Quadrangle, Knoxville, Tenn. (147-NW), Series 1942, No. 10.

JE

Fig. 2.8

Area soils map

DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-12679.CDR	DRAWING DATE: October 18, 1996 TG

drainage. Depth to limestone or shale bedrock varies from less than 1.5 m (5 ft) to as much as 10.6 or 12.1 m (35 or 40 ft). The soil is generally flooded during the wet season and the water table is about 1 m (3 ft) below the surface during the dry season (Roberts et al. 1955).

2.4.2.3 Thin limestone residuum

The southeastern portion of the site contains stony, rolling land (Colbert and Talbott soil materials) and stony, hilly, and steep land (Colbert and Talbott soil materials). These are typically thin soils of weathered limestone with much of the surface covered in rock outcrops. Slopes range from 7 to 45 percent (Roberts et al. 1955). However, site topographical information shows that existing slope is less than 5 percent, suggesting slope has been modified to some extent.

The stony, rolling land (7–15 percent slope) and the stony, hilly, and steep land (15–45 percent slope) are miscellaneous soil types marked by abundant limestone and loose rock outcrops covering 10–50 percent of the surface. Soil material is thin; usually 0.3 cm (12 in.), seldom exceeding 0.6 m (2 ft). The stony, hilly, and steep land has more relief (Roberts et al. 1955).

2.5 GROUNDWATER

Groundwater elevations, flow direction, and speed across the DWI 901 Site have not been established. It is unclear whether the water table is consistently above or below the soil-bedrock interface, whether it moves in and out of this interface, or what effect seasonal variation has on flow path and direction. There are nine private wells within a 3-km (2-mile) radius of the site (Halliburton 1995).

2.5.1 Unconsolidated Zone

Natural soil characteristics and the amount of alteration to its original fabric will strongly influence infiltration and runoff. Compaction on well-travelled areas of the site will lower the infiltration rate. Fill material across naturally occurring soil may alter the normal transmission rate and/or direction. Fill material may include natural soil brought from on- or off-site, crushed stone, metal parts, asphalt, concrete, or similar matter.

Groundwater elevations have not been fully determined. Groundwater has not been consistently encountered in the soil horizon. Sequoia soils have naturally slow percolation rates and can puddle easily when wet (Roberts et al. 1955). Lindside silt loam is the most permeable of the site soil types. Goose Creek flows over this material. It is not known if or how much water from surrounding soil flows into or out of Goose Creek. In general, it can be expected that the majority of the Sequoia soils will have lower infiltration rates than Lindside silt loam, which is located along Goose Creek.

Five groundwater monitoring wells were installed in the unconsolidated zone (Fig. 2.9). Groundwater was encountered in Monitoring Well 01 (MW-01) at 2.3 m (7.5 ft) below ground surface (bgs). Groundwater in MW-02 was encountered at 2.6 m (8.7 ft) bgs; however, the screened interval of the well extends into surface fill material. MW-03 had perched water in the fill material during drilling, but was dry on completion. MW-04 was installed to monitor an upper zone of water encountered at 2.1–3.9 m (7.0–13 ft) with the lower zone of water at the top of bedrock sealed off with bentonite. MW-04 was dry on completion. MW-05 was installed into bedrock in Soil Boring 7 (Fig. 2.10) (PRC 1994a).

2.5.2 Bedrock Zone

In Ottosee Shale, groundwater preferentially flows along limestone fractures. The relatively pure limestone lenses within shaly phases may have well-developed solution channels. Calcareous shales are prone to solutional weathering and are also water-bearing in places. Springs commonly occur in Ottosee outcrops. Well yields in the Ottosee Shale range from less than 10–450 gallons per minute (gpm) (DeBuchananne and Richardson 1956). Of 129 Ottosee Shale wells surveyed in East Tennessee, 70 wells (54 percent) had sufficient yields for residential use within the first 30 m (100 ft). Metals in water derived from Ottosee Shale include the following ranges: 0.8–0.15 parts per million (ppm) Fe, 23–32 ppm Ca, 4.1–9.3 ppm Mg. Water hardness ranges from 94 to 118 ppm $CaCO_3$ equivalent (DeBuchananne and Richardson 1956).

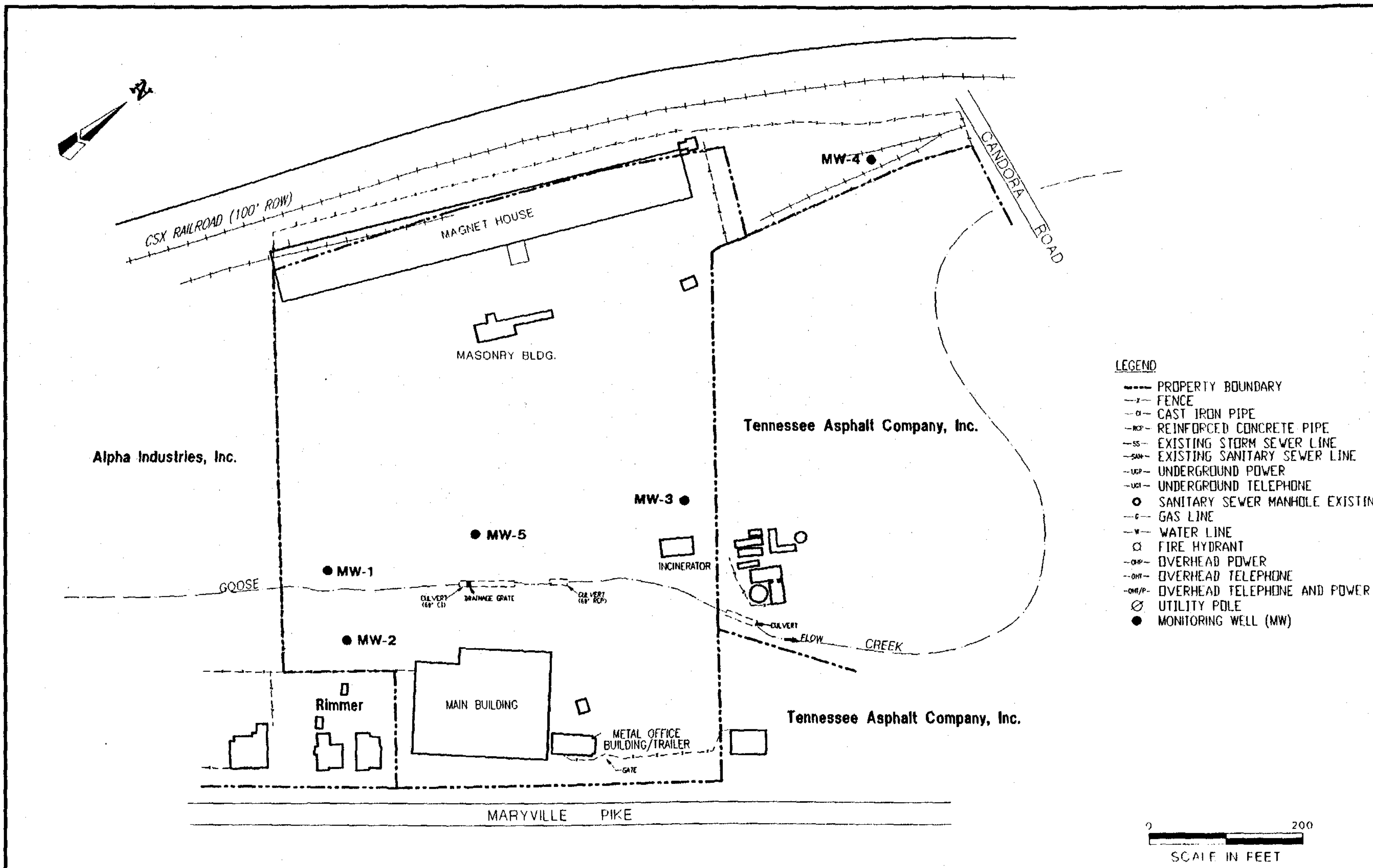
2.6 SURFACE HYDROLOGY

Surface hydrology is determined by surface water, landform, and groundwater flow paths. Surface water at the DWI 901 Site and its associated sediments are discussed below.

2.6.1 Surface Water

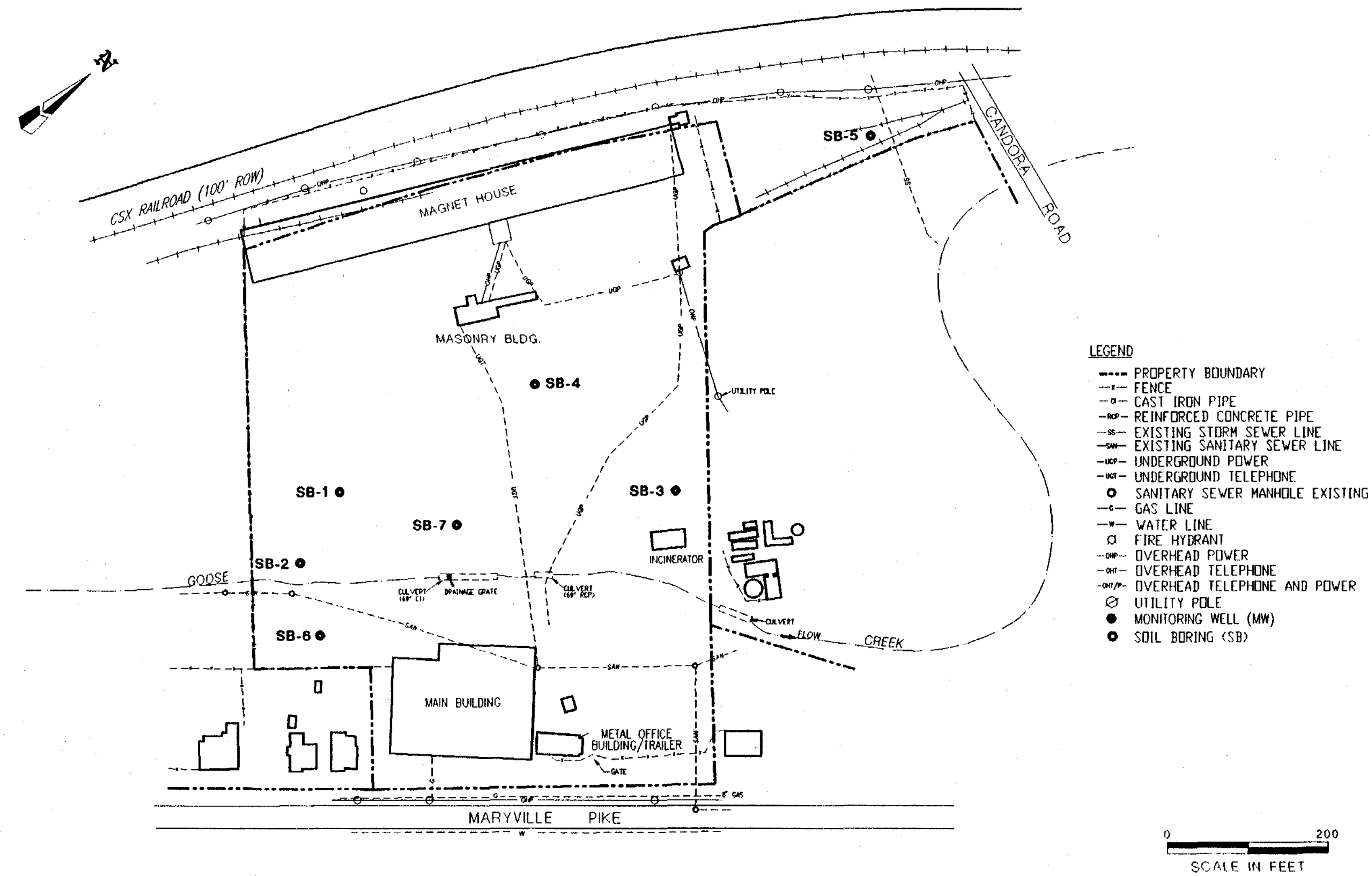
Goose Creek is formed by the drainage of five smaller unnamed tributary branches (Fig. 2.11). It flows southwest to northeast across the site and gradually flows in a northwesterly direction at Mary Vestal Park. It passes through a water gap in Chapman Ridge and empties at Fort Loudoun Lake.

All surface water runoff at the DWI 901 Site flows ultimately into Goose Creek. Runoff from the Candora Road Area appears to flow off site before entering Goose Creek. Other areas



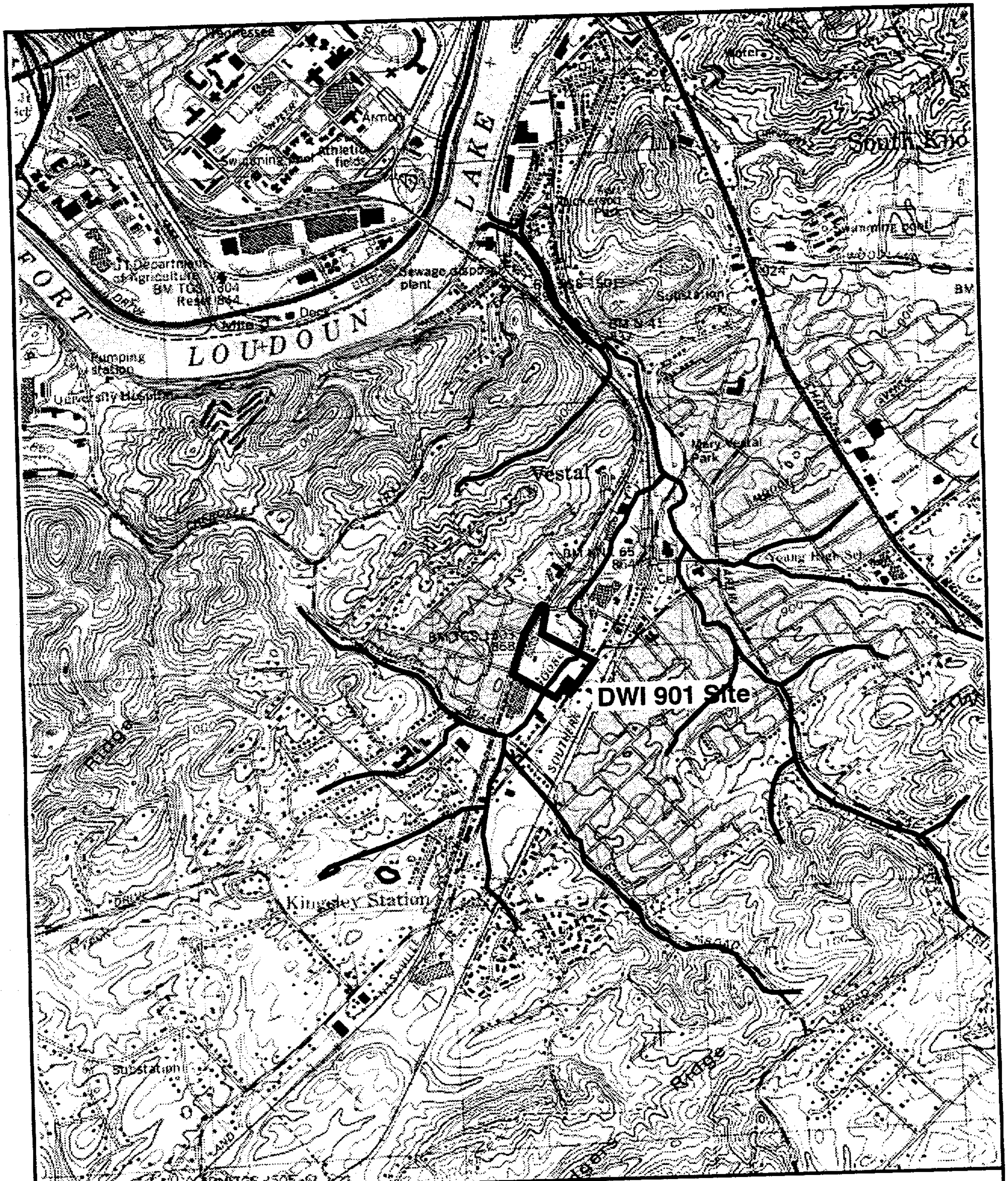
MODIFIED FROM Jesse Walker, RLS, PE, Survey, July 29, 1992

JE	**Fig. 2.9**	**Monitoring well locations** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID 96 131610WG 1	DRAWING DATE OCTOBER 18, 1996 TG



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE Fig. 2.10	**Soil boring locations** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96-13182 DWG-A1	DRAWING DATE: OCTOBER 18, 1996 TG



N

0 2000
SCALE IN FEET

SOURCE: U.S.G.S. Topographic Quadrangle, Knoxville, Tenn. (147-NW), 1978.

JE

Fig. 2.11

Goose Creek tributaries

DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-12674.CDR-3	DRAWING DATE: OCTOBER 18, 1996 TG

may also flow off the property before entering Goose Creek; however, the exact flow path is not known. DWI 901 Site topography is subtle, and existing topographic maps do not carry the level of detail sufficient to determine exact flow paths leading to Goose Creek.

Alterations to surface water flow have occurred at the DWI 901 Site and include a 1.5-m (5-ft) cast iron culvert with a surface drainage grate. The culvert reportedly drains surface runoff from undefined southwest, northwest, and eastern portions of the site (PRC 1993a). The culvert is approximately 36 m (120 ft) long and is located approximately 32 m (105 ft) northwest of the center of the Metal Office Building. A second alteration to Goose Creek flow is a 1.5-m-diameter by 9.1-m-long (5- by 30-ft) reinforced concrete pipe located approximately 14 m (45 ft) downstream of the cast iron culvert.

2.6.2 Sediment

Sediments are any unconsolidated, fragmented material derived from wind-blown or water-borne sources. Goose Creek sediment is comprised chiefly of material carried by surface water from site drainage and off-site drainage.

2.6.3 Groundwater Flow Paths

Water flow in the Ottosee Shale at the DWI 901 Site and its residual products will be governed largely by the number of solution channels in the limestone, the distribution of limey shale stringers, and the orientation and distribution of fractures.

Groundwater pathways on site in the upper aquifer probably have an overall trend toward Goose Creek. At progressively deeper intervals, the flow path probably becomes less influenced by Goose Creek, and large-scale features such as Fort Loudoun Lake, faults, fracture sets, and folds begin to play an increasingly important role in groundwater movement.

2.7 ECOLOGY

The DWI 901 Site lies within the Carolinian Biotic Province. This province is characterized by hardwood forest.

2.7.1 Terrestrial Flora

A mixture of urban and rural ecologies predominates the DWI 901 Site, which consists of buildings and paved and unpaved ground. The DWI 901 Site has been disturbed and is in a state of neglect, allowing adventitious plants to become well established on all bare ground areas. Vegetation is primarily herbaceous, graduating to scrub/shrubs by fence lines and property boundaries with mature trees lining Goose Creek. Goldenrod (*Soldago canadensis*) and Queen Anne's lace are the predominant herbaceous plants, while cottonwood (*Populus deltoides*) and sycamore (*Platanus occidentalis*) are the dominant woody species (Dickie, personal communication 1996).

2.7.2 Terrestrial Fauna

The nearby railroad track and the creek that runs through the site provide additional potential habitat for animals able to live in proximity to humans. Numerous birds such as crows, mockingbirds, mourning doves, flickers, robins, and chickadees were observed during a site visit. Other animals likely to use the site include raccoons (*Procyon lotor*); opossum (*Didelphis marsupialis*); field mice, meadow voles, salamanders, and snakes. Although fencing at the site has been breached, no evidence of deer (*Odocoileus virginianus*) has been observed (Dickie, personal communication 1996).

2.7.3 Aquatic Species

The types of aquatic life at the DWI 901 Site have not been determined. Goose Creek could provide habitat for amphibians and freshwater invertebrates.

2.7.4 Threatened and Endangered Species

No federally or state-listed species have been observed on the DWI 901 Site; a list of threatened and endangered (T&E) species obtained from TDEC in 1992 for the Knoxville 7.5' topographic quadrangle lists the following species:

- Invertebrates:
  - Anthony's River Snail (*Athearnia anthonyi*)
  - Dromedary Pearlymussel (*Dromus dromas*)
  - Tuberculed-blossum (*Epioblasma torulosa torulosa*)
  - Spiny Riversnail (*Io fluvialis*)
  - Ornate Rocksnail (*Lithasia geniculata*)
  - Varicose Rocksnail (*Lithasia verrucosa*)
  - Orange-foot Pimpleback (*Plethobasus cooperianus*)
- Plants:
  - Spreading Rockcress (*Arabis patens*)
  - Bitter Cress (*Caroamine flagellifera*)

- Golden Seal (*Hydrastis canadensis*)
- American Ginseng (*Panax quinquefolius*)
- Carey Saxifrage (*Saxifraga careyana*)

- Vertebrates

  - Peregrine Falcon (*Falco peregrinus*)
  - Tennessee Cave Salamander (*Gyrinophilus palleucus*)
  - Red-headed Woodpecker (*Melanerpes erythrocephalus*)
  - Yellowfin Madtom (*Noturus flavipinnis*)
  - Southeastern Shrew (*Sorex longirostris*)
  - Cumberland Slider (*Trachemys scripta troostii*)
  - Common Barn Owl (*Tyto alba*)

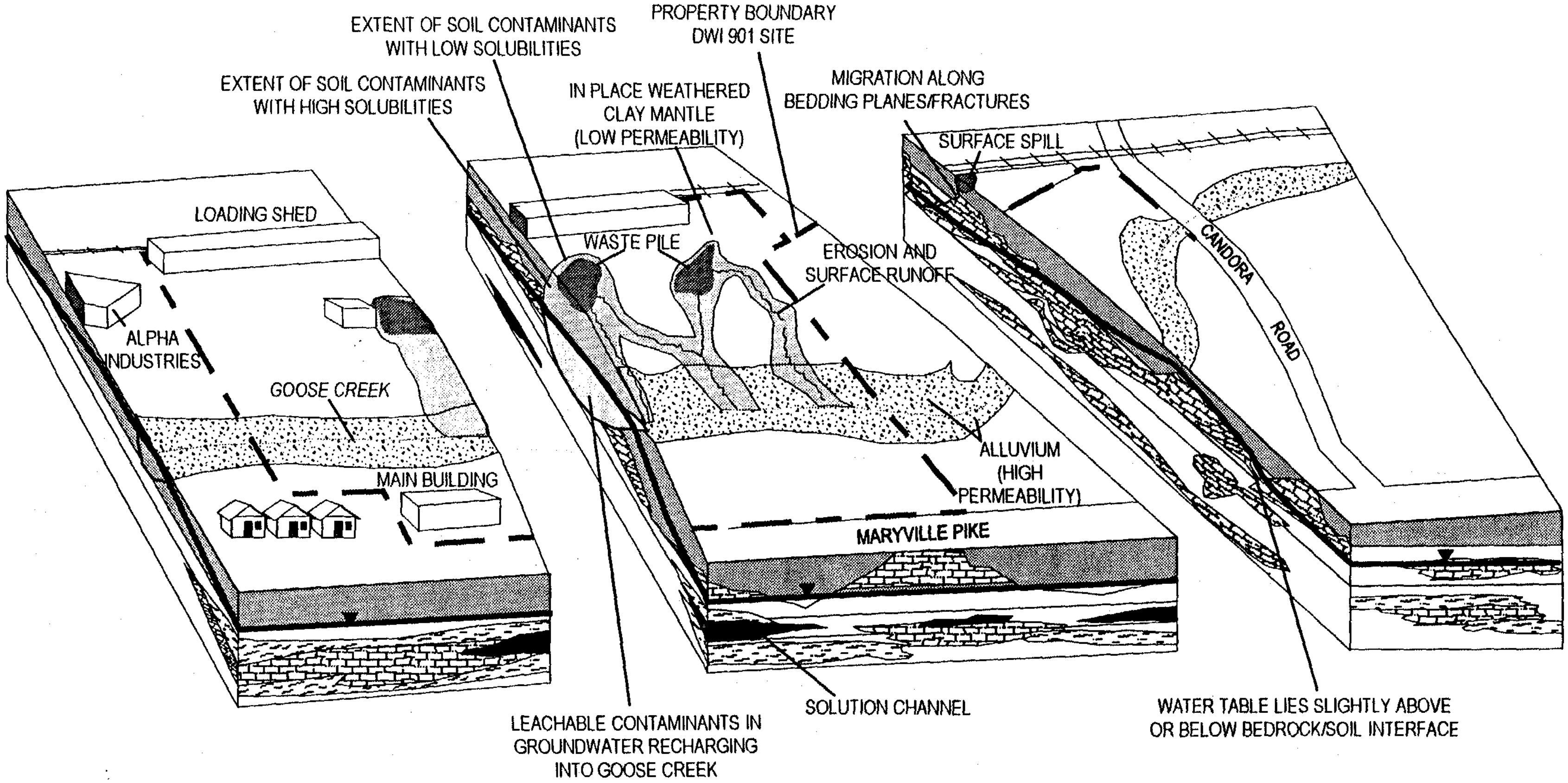
There are no designated critical or unique habitats on the DWI 901 Site. The state will be consulted to determine whether any sightings of these species have been reported at the DWI 901 Site.

2.8 SITE HYDROGEOLOGICAL MODEL

A hydrogeological model is a conceptualization that combines precipitative and potential source contaminant inputs; a matrix of surface, subsurface, and groundwater flow; evapotranspiration; and outputs (Fig. 2.12). A general discussion of the site hydrogeological conceptual model is presented to simplify and summarize the process in terms of relevance and applicability to the site. The conceptual model is a basic tool for developing additional working models that may evolve to describe particular areas within the site. Working conceptual models, like any hypotheses, require data to support their development. Site-specific data are used where available to support the development of the working conceptual model. This working model supports data collection activities at the site.

2.8.1 Site Hydrology

Hydraulic conductivities will probably range widely across the site. Hydraulic conductivity of Sequoia and Dandridge soils is typically around 1×10^{-5} to 1×10^{-7} cm/second. Hydraulic conductivity in Lindside soil and weathered limestone portions of the Ottosee Shale typically are 1×10^{-1} cm/second. These rates represent a minimum and maximum range. Site hydraulic conductivities are expected to be somewhere between these values. Low conductivities are likely to occur in portions of Ottosee Shale where shaly phases dominate. Sequoia soils with a network of fractures can have relatively high conductivities.



JE	Fig. 2.12	**Conceptual site model** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-30 RI/FS	DRAWING ID: 96-13312.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

The natural infiltration capacity of the soil and bedrock may be locally altered where fill is present. Depending on the degree of compaction, the fill may enhance or reduce the infiltration capacity of the soil/bedrock.

In situ hydraulic conductivity in MW-05 was tested by performing a slug test. Hydraulic conductivity was calculated to be between 3.32×10^{-2} and 1.01×10^{-1} cm/second using the Hvorslev and the Bouwer and Rice methods, respectively (PRC 1993b). This value represents the hydraulic conductivity of a small volume immediately around the well.

2.8.2 Water Budget

The moderately gentle to gentle slope on either side of Goose Creek should allow for runoff of an undetermined amount of water. Runoff will flow across the site, and in some areas across adjacent properties, into Goose Creek.

Soil properties of the Sequoia soil series will naturally enhance the amount of runoff due to the low amount of "internal drainage." Once surface water drainage passes onto the adjacent Lindside soil, rates of infiltration should increase substantially because of the relative increase of moisture-holding capacity of this soil. Surface water that does not infiltrate the soil and discharge into Goose Creek will remain.

The thinly covered rocky soil on the southeastern portion of the site should have a highly variable amount of infiltration. Drainage in typically thinly covered rocky soil follows any number of openings in soil to rock boundaries and rock fractures. This soil occurs adjacent to Maryville Pike. In many ways, the behavior of any disturbed and/or compacted soil will be different than it is in its natural state. Therefore, runoff will probably be greater on this soil than it would be naturally because of the amount of vehicular traffic that drives across this area of the site.

3. SUMMARY OF EXISTING DATA

Past site investigations detected numerous contaminants, including (1) heavy metals such as Pb, Hg, and Cd; (2) dioxins and furans; (3) polychlorinated biphenyls (PCBs); (4) semivolatile organics; and (5) radionuclides, including various isotopes of uranium, thorium, and associated radioactive decay products (daughters).

3.1 PREVIOUS INVESTIGATIONS

In January 1987, the Analytical Chemistry Division of Energy Systems sampled drummed soils at the Candora Road Area. These drums contained soils that had been excavated at the Screen Arts Site at 1630 Maryville Pike. The drums had been moved to 901 Maryville Pike so they could be controlled. Ten samples composited from the top 15–30 cm (6–12 in.) of each drum were obtained for analysis. The analytical results showed varying levels of Pb (400–9,600 mg/kg), U (108–1,488 mg/kg), Hg (8.16–96.2 mg/kg), and PCBs (18–7,415 mg/kg) (TDSF 1991).

In March 1987, Bechtel National, Inc., conducted a radiological walkover survey of the Candora Road Area. In addition, soil samples were collected and analyzed for isotopic uranium, ^{226}Ra, and ^{232}Th (TDSF 1991). Data were not provided.

In August 1989, the TDSF began investigating the DWI 901 Site. TDSF personnel collected two soil samples from the Candora Road Area near the drum storage area. Analyses showed that the area was contaminated with methylene chloride (1.9 μg/kg), delta benzene hexachloride (BHC) (317 μg/kg), dieldrin (56.7 μg/kg), and Aroclor-1260 (14,000 μg/kg) (TDSF 1990).

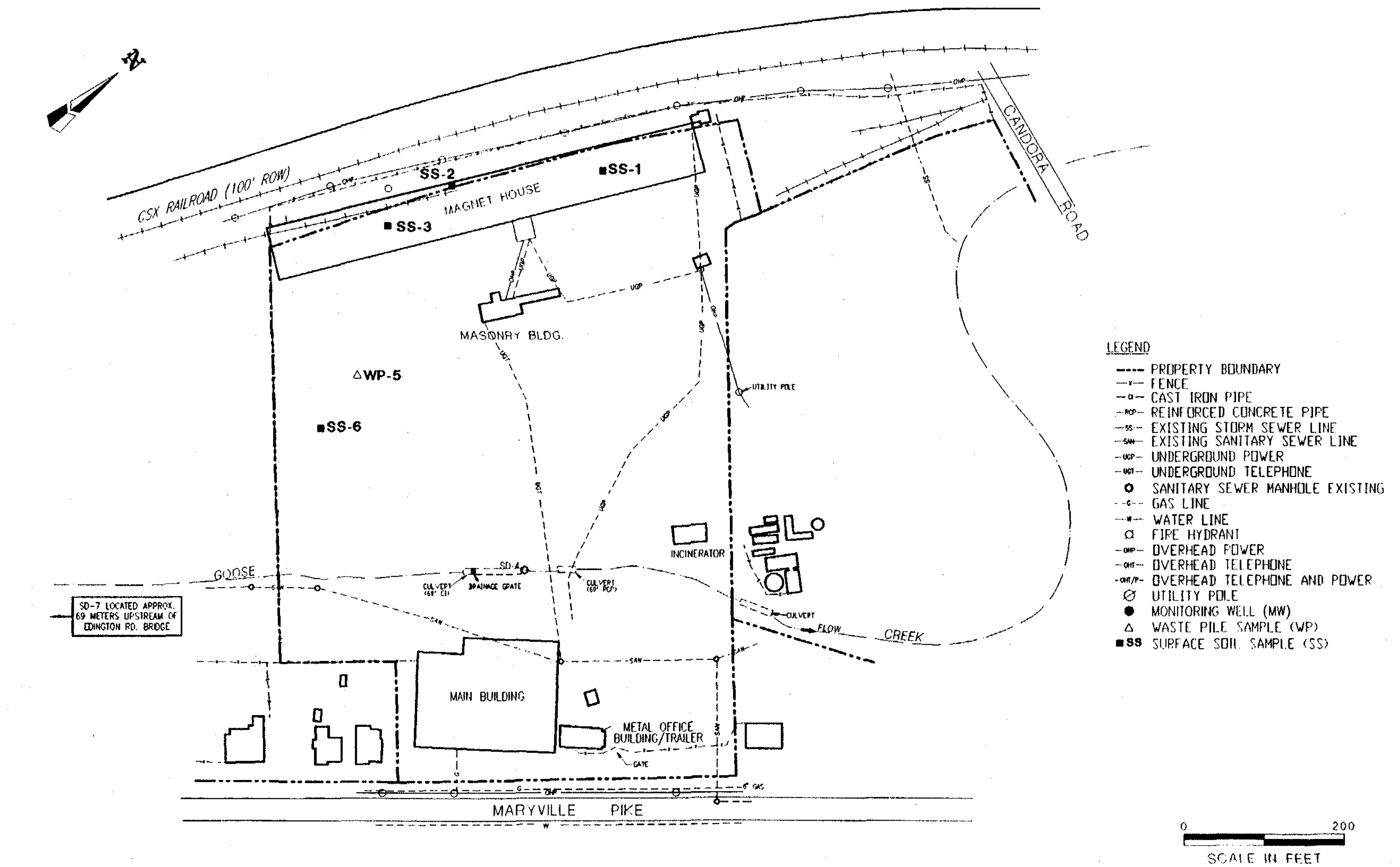
In August 1989, DWI submitted an application to the Tennessee Division of Underground Storage Tanks to remove two buried petroleum hydrocarbon tanks. Tennessee Technical Laboratories, Inc., conducted an UST removal from the eastern portion of the facility near the front gate and scales. Soils removed from the tank pit contained less than 10 mg/kg of benzene, toluene, ethylbenzene and xylene and 100 ppm of total petroleum hydrocarbons. Although soil levels were below regulatory standards, the site did not meet clean closure standards because no groundwater monitoring information was obtained (TDSF 1990).

In March 1990, TDRH conducted a radiological walkover survey of the Candora Road Area, extending from the extreme northwestern corner of the property bordered by the railroad tracks to the west, Candora Road to the north, the fenced area next to an asphalt plant to the east, and a large scrap separation shed to the south (TDSF 1990).

During August 1990, TDSF performed a preliminary assessment (PA) (Fig. 3.1). TDSF collected seven soil samples, including four composite surface soil samples, two sediment samples and one waste sample from a scrap pile in the western portion of the property. The composite soil samples were collected near the Magnet House and in the northwestern [Surface Spring 1 (SS-1)] and southwestern corners (SS-2) of the site. The other two samples were taken on the northwestern (SS-3) and southwestern corners of the property near a junk pile (SS-4). Samples were tested for U.S. Environmental Protection Agency (EPA) Contract Laboratory Program (CLP) Target Analyte List (TAL) metals, Extraction Procedure toxicity, and Target Compound List (TCL) volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) (TDSF 1990). These data were collected from biased sampling locations. No data quality assurance (QA) package was provided, and as a result, the uncertainty of these data may be considerable.

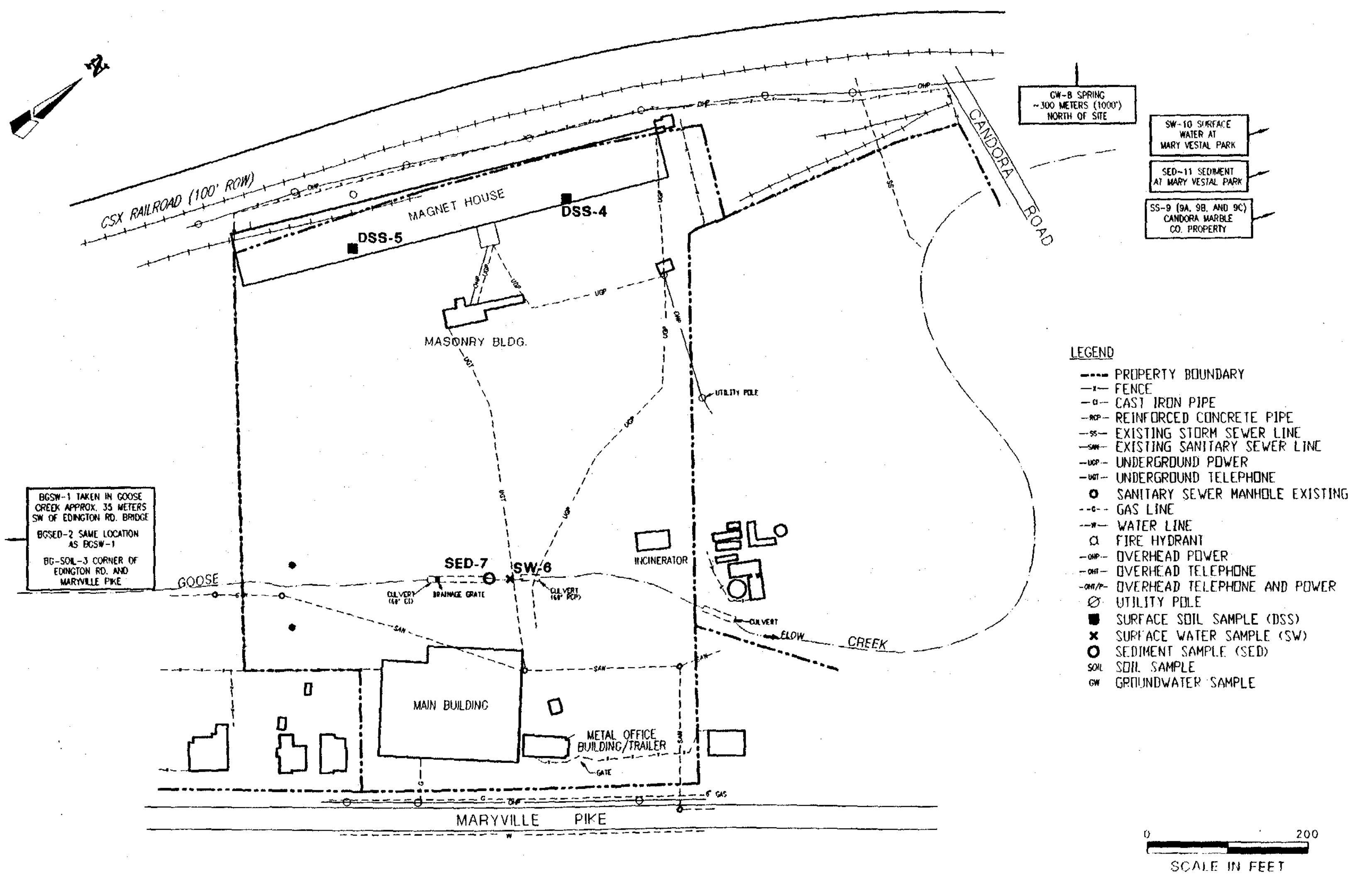
During an April 1991 sampling event in conjunction with TDSF, a SI collected 11 samples to define the types of contaminants present at the site, including 4 soil samples, 3 sediment and surface water samples, and 1 groundwater sample (Fig. 3.2). While on site, the investigators noted that soil throughout the site had been discolored and stained by oily and metallic substances. Background samples were collected for all matrices except groundwater. The surface soil background sample (BGSOIL-3) was collected at the corner of Edington Road and Maryville Pike at an old firehouse. The sediment background sample (BGSED-2) was collected from Goose Creek approximately 35 m (115 ft) southwest of Edington Road Bridge. The surface water background sample (BGSW-1) was collected from the same location as BGSED-2 (TDSF 1991). These data were collected from biased sampling locations. No data QA package was provided, and as a result, the uncertainty of these data may be considerable.

Also in April 1991, the CSX Corporation, which operates the railroad track spur adjacent to the DWI 901 Site facility, hired CRU, Inc., to conduct a soil survey in the area of the rail spur to determine the potential for train crew exposure to heavy metals or radioactivity while switching trains at the DWI 901 Site. CSX Corporation also was concerned about its workers entering the DWI 901 Site during the process of loading and unloading rail cars. Ten soil samples were collected within 3 m (10 ft) of the track starting 60 m (200 ft) from the inner fence on the DWI



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE **Fig. 3.1**	**TDSF PA sample locations** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13411DWG	DRAWING DATE: OCTOBER 18, 1996 TG



MODIFIED FROM. Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE Fig. 3.2	**TDSF SI sample locations** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13412 DWG-4	DRAWING DATE OCTOBER 17, 1996 TG

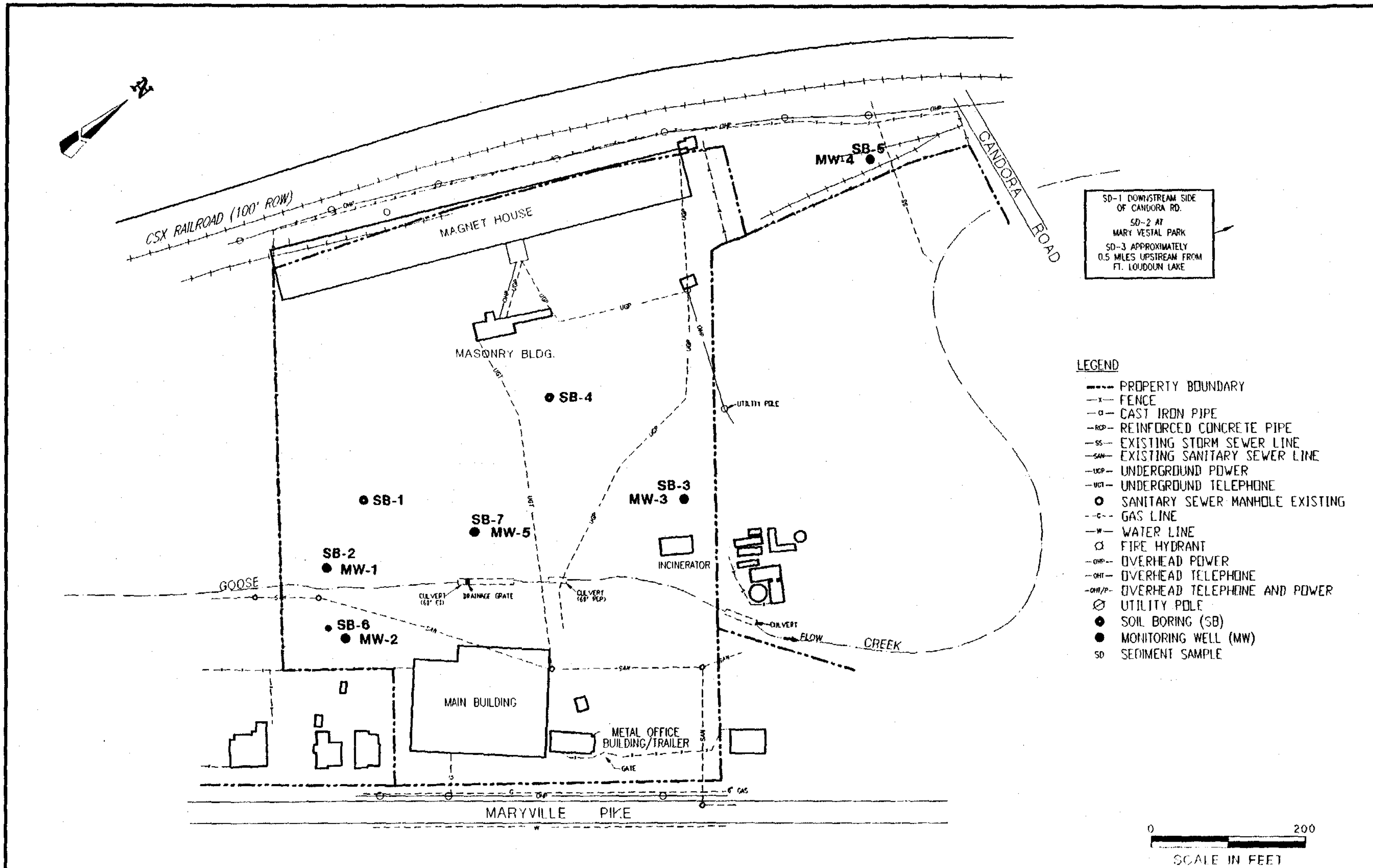
901 Site to the shed. The samples were collected by scraping approximately 0.45 kg (1 lb) of surface dirt in a 0.2–0.4 m^2 (2–4 ft^2) area. A composite soil sample was collected for heavy metals analysis (TDSF 1991).

In May 1992, PRC performed the Phase I RI under the direction of TDSF. The investigation defined contaminant concentrations and identified potential transport pathways. Data on (1) surface features, (2) stream sediments, (3) geology, (4) soil, and (5) groundwater were collected (Fig. 3.3). Surface features such as buildings, fencing, surface debris, utility and sewer lines, and property lines were documented and mapped. Four surface sediment samples [0–0.6 m (0–0.5 ft)] were collected from the Goose Creek floodplain. One sample was collected from a depth of 0.6 m (2 ft) at Mary Vestal Park. Sediment samples were analyzed for TCL VOCs, SVOCs, pesticides, and PCBs; and TAL metals and cyanide. The geologic investigation reviewed published materials and visually inspected cores during subsurface soil investigations.

Subsurface soil samples were collected from six boring locations. Samples were composited from a depth of 0.6–1.5 m (2–5 ft) and below; 1.5-m (5-ft) samples were composited at intervals of 1.5 m (5 ft) until auger refusal. Soil samples were analyzed for TCL VOCs, SVOCs, pesticides, PCBs; and TAL metals and cyanide.

The groundwater investigation consisted of installing a monitoring well in soil borings that encountered groundwater. Groundwater was located in four borings (Nos. 2, 3, 5, and 6). The wells were developed, purged, and sampled. Two groundwater samples were collected because two wells were dry and two additional wells were bailed to dryness. One water sample was analyzed for CLP TCL VOCs, SVOCs, pesticides, and PCBs; and CLP TAL metals. The other water sample was subjected to CLP TCL VOCs and CLP TAL metals only (PRC 1993a).

An addendum to the 1993 PRC report cited the investigation of an additional monitoring well on the DWI 901 Site. The well (MW-05) (Fig. 3.3) was installed with the aid of an air rotary drill rig, and no core samples were collected. The well was developed using a "trash pump." A slug test was performed to determine hydraulic conductivity (K) within the uppermost section of Ottosee Shale. Estimates of K using the Bouwer and Rice method and the Hvorslev method were between 3.32×10^{-2} cm/second and 1.01×10^{-1} cm/second, respectively. A groundwater sample was collected and analyzed for CLP TCL VOCs, SVOCs, pesticides, and PCBs; and CLP TAL metals and cyanide (PRC 1993b). These data were collected from a biased sampling location. No data QA package was provided, and as a result, the uncertainty of these data may be considerable.



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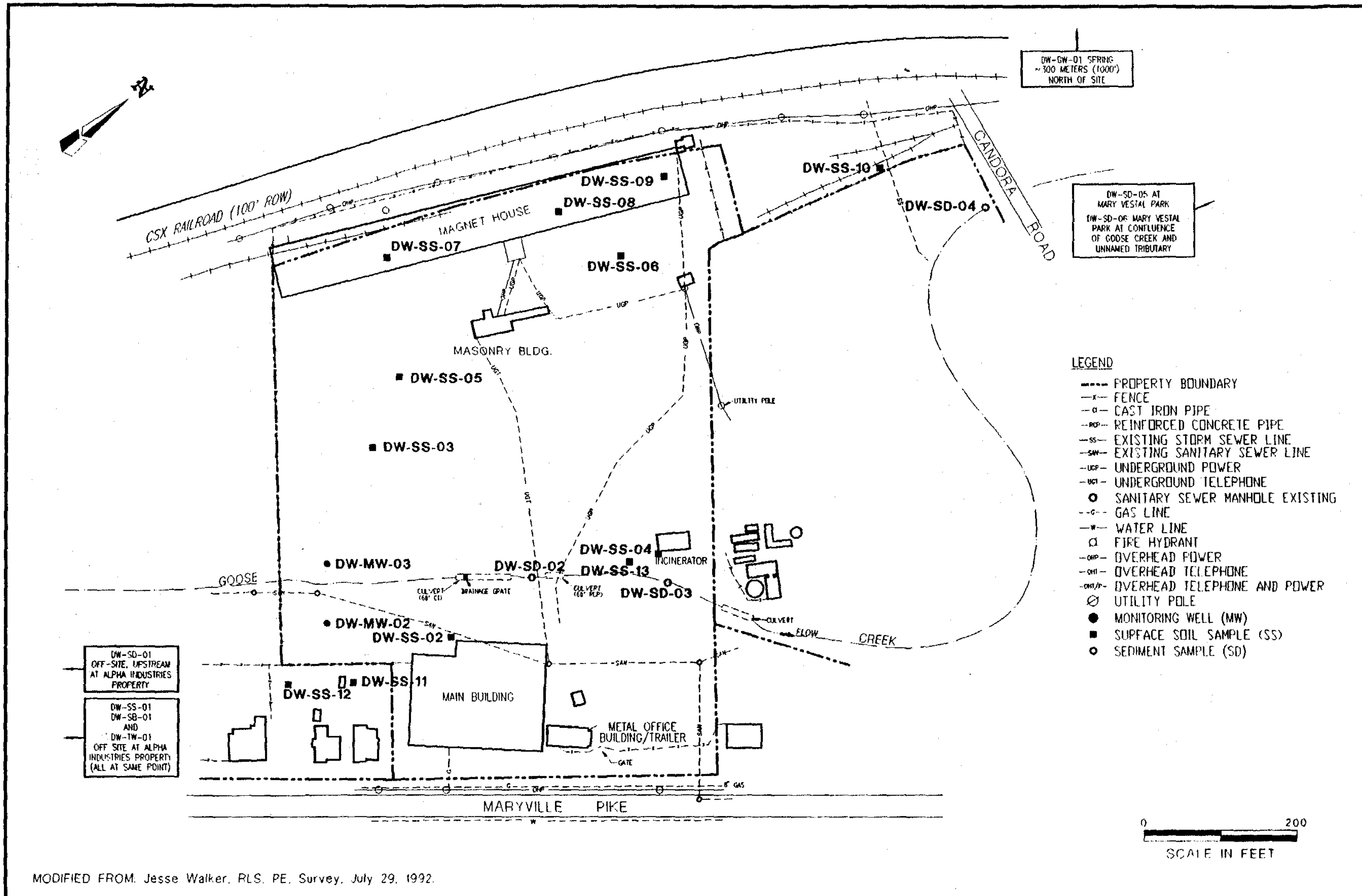
JE	Fig. 3.3	PRC Environmental sample locations DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96 13412 DWG-5	DRAWING DATE OCTOBER 21, 1996 TG

Field investigations for an expanded site investigation (ESI) were conducted by Halliburton during the week of January 25, 1994. Twelve surface soil samples were collected from 5 potential contaminant source areas: (1) the area near the DWI main building, (2) burned scrap piles, (3) Magnet House, (4) former incinerator, and (5) Candora Road Area (Fig. 3.4). Six sediment samples were collected to characterize the contaminants that may have migrated from the site. One sediment sample was collected upstream as a background sample. Two sediment samples were collected on site. Three sediment samples were collected off site; two of them were collected in Mary Vestal Park. Four groundwater samples were collected, including one background sample. Two on-site monitoring wells and one off-site spring were sampled. Samples were analyzed for all organic parameters listed in the TCL and all inorganic parameters in the TAL. The samples were also analyzed for ^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{234}Th, gross alpha, and gross beta. Analyses for dioxins/furans were performed on a select number of samples (Halliburton 1995). The Halliburton data were provided with data QA packages. These data are believed to be reliable.

In February 1994, TDSF authorized WESTON to conduct a limited field investigation of the DWI 901 Site. During Stage 1, a grid was placed over the site and samples of shallow surface soils were collected across the entire site (Fig. 3.5). These samples were analyzed for SVOCs, PCBs, metals, cyanide, gross alpha, and gross beta. As a part of Stage 1, WESTON performed an additional preliminary radiation survey to evaluate the extent of localized concentrations of radioactive contamination. Results of the Stage 1 sampling of SVOCs and PCBs were used to select locations for Stage 2 sampling of dioxins/furans. The results of Stage 1 gross alpha and gross beta analysis were used to select locations for Stage 2 radionuclide analyses (Fig. 3.6). Radionuclide analyses included isotopic uranium, isotopic thorium, isotopic plutonium, $^{89/90}Sr$, and gamma spectroscopy (WESTON 1994). The data collected during Phase I were from systematic random sampling data points and are unbiased for analytes detected in this stage. Phase II radiological samples are from the grids with greater than background readings. The data collection points were directed toward the area within each grid with the highest readings. These data have some degree of randomness and bias. Both phases of WESTON data were provided with QA packages. These data are believed to be reliable.

3.1.1 Soil

DWI 901 Site soil investigations primarily collected surface soils. There were limited deep soil investigations. Subsurface contamination is not fully assessed in these reports. Soil information concerning contamination peak levels are presented in Table 3.1, which represents the minimum and maximum values for important soil elements and compounds for the DWI 901 Site.



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

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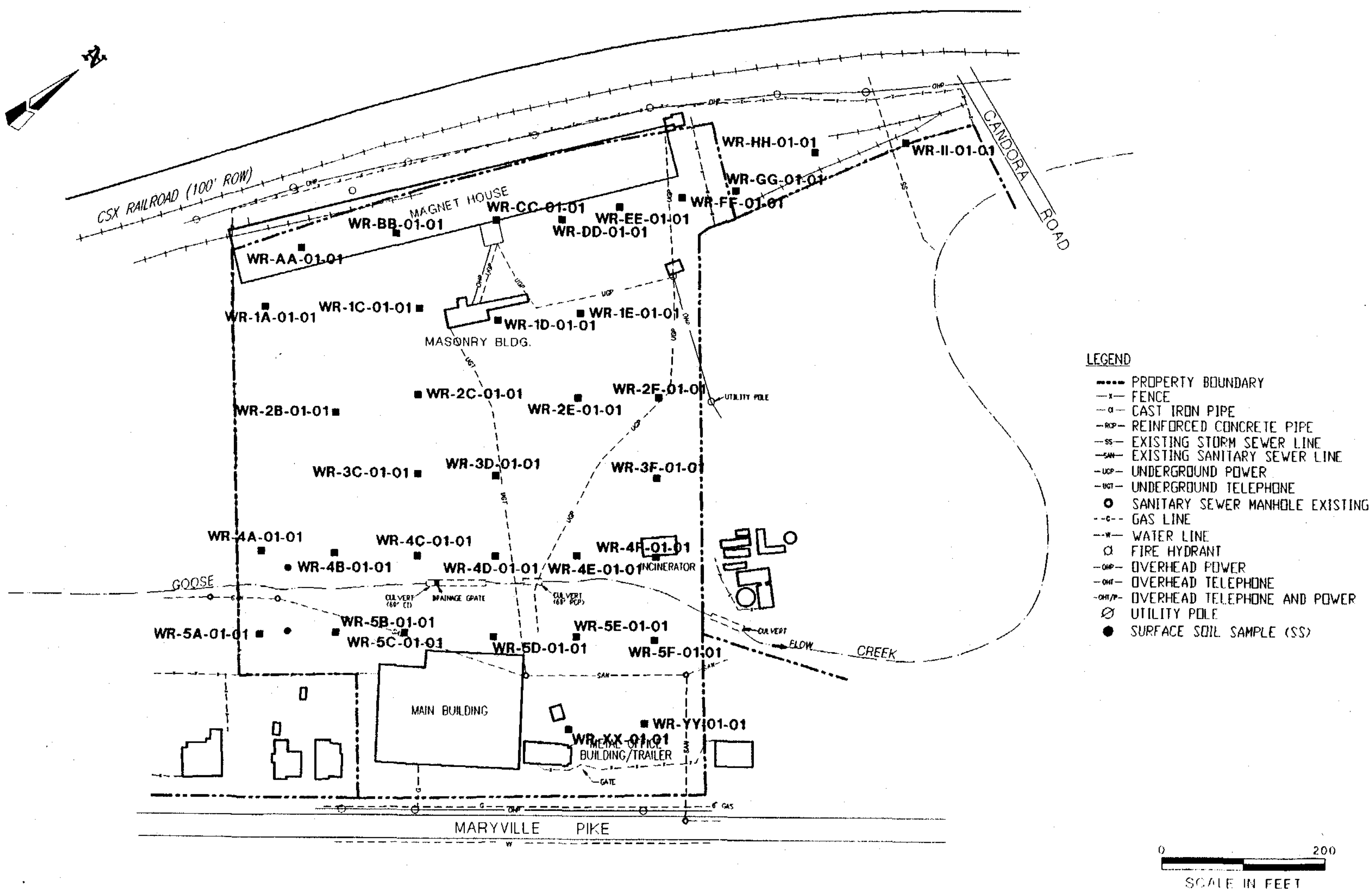
Fig. 3.4

Halliburton sample locations

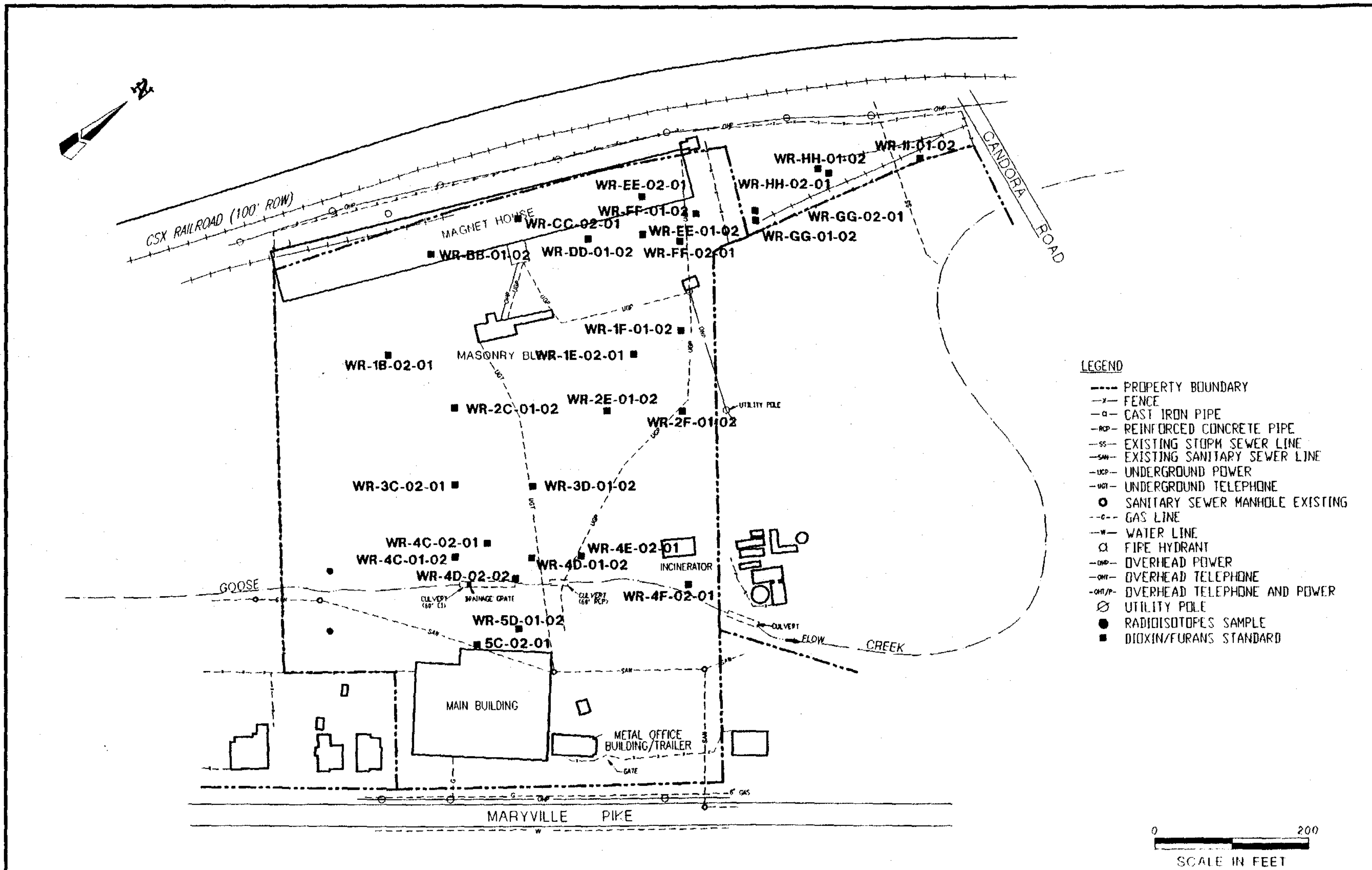
DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094.20 / RI/FS	DRAWING ID 96-13412DWG-3	DRAWING DATE OCTOBER 18, 1996 TG



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	**Fig. 3.5**	**Roy F. Weston Stage 1 sample locations** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13412 DWG-2	DRAWING DATE OCTOBER 18, 1996 TG



MODIFIED FROM. Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE® Fig. 3.6	**Roy F. Weston Stage 2 sample locations** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13412 DWG-1	DRAWING DATE OCTOBER 1, 1996 SR

Table 3.1. Surface soil parameters for detected analytes from the main DWI 901 Site, Knoxville, Tennessee

Analyte	Units	Minimum	Maximum
		Metals	
Antimony	mg/kg	6.6	162
Arsenic	mg/kg	2.7	30
Barium	mg/kg	28	986
Beryllium	mg/kg	0.55	1.5
Cadmium	mg/kg	1.3	45
Chromium	mg/kg	9.8	3,480
Lead	mg/kg	46.2	8,320
Manganese	mg/kg	260	14,600
Mercury	mg/kg	0.31	1,660
Zinc	mg/kg	95.5	16,000
		Dioxin/furans	
1,2,3,4,6,7,8-HpCDD	ng/kg	35	2,600
1,2,3,4,6,7,8-HpCDF	ng/kg	18	440
1,2,3,4,7,8-HxCDF	ng/kg	5.4	88
1,2,3,7,8,9-HxCDD	ng/kg	18	91
2,3,7,8-TCDD	ng/kg	4.6	4.6
2,3,7,8-TCDF	ng/kg	3.4	71
OCDD (total)	ng/kg	200	9,400
		PCBs	
Aroclor-1242	μg/kg	200,000	200,000
Aroclor-1248	μg/kg	3,800	140,000
Aroclor-1254	μg/kg	94	160,000
Aroclor-1260	μg/kg	120	43,000
		Radionuclides	
Lead-212	pCi/g	1	149
Protactinium-234	pCi/g	1,618	12,380
Plutonium-239	pCi/g	0.2	7.54
Radium-226	pCi/g	0.84	1,710
Radium-228	pCi/g	1.3	154
Thorium-232	pCi/g	0.87	73
Thorium-234	pCi/g	0.67	55,240
Uranium-234	pCi/g	3.8	92,530
Uranium-238	pCi/g	3.5	98,530
		Semivolatile organics	
Benzo(a)anthracene	μg/kg	74	44,000
Benzo(a)pyrene	μg/kg	42	43,000
Benzo(b)fluoranthene	μg/kg	67	42,000
Dibenzo(a,h)anthracene	μg/kg	61	570
Indeno(1,2,3-cd)pyrene	μg/kg	170	28,000

Sources: TDSF 1990, TDSF 1991, PRC 1993a, Halliburton 1995, WESTON 1994.

DWI = David Witherspoon, Inc.
g = gram
kg = kilogram
μg = microgram
mg = milligram
ng = nanogram
PCB = polychlorinated biphenyl
pCi = picocurie

Previous reports indicate that Soil Borings 3, 4, and 5 refused on limestone bedrock. Soil Boring 1 refused on calcareous shale. Soil Borings 2 and 6 were advanced to refusal, but no indication regarding lithology was recorded. These soil borings were advanced by means of hollow-stem augers and split-spoon sampling. This is recorded by the photo log and recorded blow counts on the boring logs (PRC 1993a).

Previous reports indicate that Soil Borings 3, 4, and 5 refused on limestone bedrock. Soil Boring 1 refused on calcareous shale. Soil Borings 2 and 6 were advanced to refusal, but no indication regarding lithology was recorded. These soil borings were advanced by means of hollow-stem augers and split-spoon sampling. This is recorded by the photo log and recorded blow counts on the boring logs (PRC 1993a).

Soil Boring 7 was installed by means of an air rotary drill rig. Change from weathered bedrock to unweathered bedrock, that normally causes split spoon refusal, can be missed by the more invasive and powerful air rotary method. Hence, the significantly greater depth to bedrock may be misleading when comparing the results of two technologies.

3.1.1.1 Metals in soil

During the August 1990 TDSF PA at the DWI 901 Site (Fig. 3.1), TDSF collected seven soil samples, including four composite surface soil samples. Two samples contained total metal concentrations of cadmium (2–181 mg/kg) and lead (602–7,650 mg/kg) (TDSF 1990).

The April 1991 TDSF soil samples contained elevated levels of heavy metals: Cr (254 mg/kg), Cu (200 mg/kg), Hg (26 mg/kg), Ni (248 mg/kg), and Zn (66.4 mg/kg) (TDSF 1991).

The composite soil sample from the April 1991 CRU, Inc., survey analyzed heavy metals by the Toxicity Characteristic Leaching Procedure method. Low levels of Cu (2.8 mg/kg), Zn (18.7 mg/kg), Ba (1.16 mg/kg), and Pb (1.53 mg/kg) were reported.

The May 1992 Phase I RI by PRC found higher than expected concentrations of As (26.5 mg/kg), Cu (46.6 mg/kg), Pb (51.2 mg/kg), Mn (4,930 mg/kg), Ni (69.3 mg/kg), and Zn (153 mg/kg). Distribution of these metals with depth was deemed inconclusive by the investigative team (PRC 1993a).

The January 1994 ESI by Halliburton found the greatest number of elevated toxic metals and cyanide (12) in the Candora Road Area. Elevated metal concentrations were also found in the east end Magnet House samples (DW-SS-08 and DW-SS-09), the burned scrap pile sample

(DW-SS-05), and the dirt pile sample (DW-SS-06). Inorganic analytes in soil samples exhibited concentrations above background in at least five samples: Cr (110–230 mg/kg), Pb (830–2,400 mg/kg), Hg (1.6–430 mg/kg), Cu (240–7,500 mg/kg), and cyanide (0.79–2 mg/kg). Other metals found at levels above background include Ni (20–410 mg/kg), Zn (130–14,000 mg/kg), Ba (40–830 mg/kg), and Cd (1.3–41 mg/kg) (Halliburton 1995).

The February 1994 WESTON limited field investigation (Fig. 3.5) found metals that exceeded residential preliminary remediation goals (PRGs) (see Appendix C, Table C.1), including As (2.3–44.1 mg/kg), Cd (0.54–77.5 mg/kg), Cr (10–3,480 mg/kg), Hg (0.14–1,660 mg/kg), Ni (10.9–4,880 mg/kg), and Pb (3–6,270 mg/kg) (WESTON 1994).

Soil contamination by metals most likely occurred as a result of poor housekeeping by the DWI 901 Site operation. Contamination by lead and mercury may be traced to handling of lead/mercury batteries. Elevated levels of Cd, Cr, Cu, Pb, Hg, and cyanide reflect the uncontrolled handling and processing of scrap metal and batteries that took place at the facility.

3.1.1.2 Dioxins/furans in soil

The Halliburton ESI reported dioxin in three Magnet House samples at 4.9J toxic equivalents (TEQ) (DW-SS-07), 43J TEQ (DW-SS-08), and 110J TEQ (DW-SS-09). Samples collected near a burned scrap pile showed elevated dioxin concentrations. Dioxins were detected at concentrations of 68J TEQ (DW-SS-03) and 46 TEQ (DW-SS-05). Sample DW-SS-04 collected near the incinerator exhibited levels of 2.9J TEQ (Halliburton 1995).

The February 1994 WESTON limited field investigation found four samples that showed dioxin/furan toxicity equivalents (4C, BB, 1B, and 4F) that exceeded the 1.0 ng/g threshold for total dioxins and furans (WESTON 1994).

Contamination by dioxins/furans at the DWI 901 Site is most likely a result of the mishandling of hazardous substances. Dioxins occur as the result of impurities in PCB compounds and as a result of burning these compounds.

3.1.1.3 PCBs in soil

TDSF personnel collected two soil samples from the Candora Road Area near the drum storage area in August 1989. Analyses showed that the area was contaminated with Aroclor-1260 (14,000 μg/kg) (TDSF 1990).

The PA performed by TDSF showed that Aroclor-1254 and Aroclor-1260 were in all four composited soil samples, and Aroclor-1248 was detected in one sample (SS-1) (TDSF 1990).

The Phase I RI by PRC detected Aroclor-1248 and Aroclor-1260 in subsurface soils. Boring 1 contained Aroclor-1248 (79 μg/kg) in the 0.6–1.5-m (2–5-ft) and 1.5–3-m (5–10-ft). intervals. Boring 2 contained Aroclor-1260 (340 mg/kg) in the 1.5–3-m (5–10-ft) interval. The duplicate sample in the 1.5–3-m (5-10-ft) interval of Boring 4 contained Aroclor-1260 (364 μg/kg); however, it was not detected above residential PRG of 83 μg/kg in the original sample (PRC 1993a).

The Halliburton ESI showed that sample DW-SS-10 (Fig. 3.4) in the Candora Road Area contained PCBs. The Magnet House had elevated levels of PCBs in all three samples, but especially in sample DW-SS-08. This sample exhibited high concentrations of Aroclor-1242 (200,000C μg/kg) and Aroclor-1248 (100,000C μg/kg). Two PCB compounds—Aroclor-1254 (1,200 μg/kg) and Aroclor-1260 (440 mg/kg)—were reported in a sample collected from a storm drain behind the main building. Soil sample DW-SS-03, collected from a burned scrap pile, contained two PCB compounds—Aroclor-1254 (1,500 mg/kg) and Aroclor-1260 (540 mg/kg) and sample DW-SS-05 had three PCB compounds—Aroclor-1248 (3,800 mg/kg), Aroclor-1254 (7,100 mg/kg, and Aroclor-1260 (3,700 mg/kg). Sample DW-SS-04 collected near the incinerator had one PCB compound Aroclor-1260 (340 mg/kg) above background. One PCB compound Aroclor-1254 (28,000 mg/kg) was detected from DW-SS-06, located near a scrap and dirt pile near the east end of the Magnet House (Halliburton 1995).

The WESTON limited field investigation showed that of the 41 grid samples, 16 exceeded the proposed PCB industrial cleanup level of 10 mg/kg. Samples with PCB concentrations over 10 mg/kg ranged between 10.9–203 mg/kg. Only three grid samples had no PCBs. The highest concentration was at Grid Center 4D, west of the loading dock (WESTON 1994).

PCB contamination at the DWI 901 Site is most likely the result of mishandling of hazardous materials. PCB compounds, formerly used as insulating material in transformers, were on site during normal operations. It was reported that PCB-containing transformers were stored and handled on site.

3.1.1.4 SVOCs in soil

Level IV analytical testing of subsurface soils during the PRC Phase I RI detected 2 butanone (17–33 μg/kg), 4,4'-DDE (3.3–14.8 μg/kg), acetone (31–950 μg/kg), butylbenzylphthalate (140–430 μg/kg), delta-BHC (1.7–3 μg/kg), gamma-chlordane (1.7–2.86 μg/kg), toluene (4–670 μg/kg), and xylene (4–62 μg/kg). Toluene was found in most of the soil samples collected at the site. The highest concentrations were found in Borings 1, 2, and 3. Toluene concentrations at Borings 1 and 2 (560 and 670 μg/kg, respectively) are higher in the 1.5–3-m (5–10-ft) interval than in the surface soils. Xylenes were indicated at very low levels in the near-surface soil of Boring 2 (4 μg/kg); 2-butanone (methylethyl ketone) was detected in Borings 1 (13 mg/kg), 2 (78 μg/kg), and in several intervals in Boring 5 (13–74 μg/kg) (PRC 1993a).

The Halliburton ESI indicated that soil collected from the Candora Road Area (DW-22-10) had detectable concentrations of 2-methylnaphthalene, phenanthrene, pyrene, chrysene, and benzo(b and/or k)fluoranthene, di-n-butylphthalate, benzyl butyl phthalate, bis(2-ethylhexyl)phthalate, and di-n-octylphthalate (Fig. 3.4). A surface soil sample from the western end of the Magnet House (DW-SS-07) contained phenanthrene, anthracene, carbazole, fluoranthene, pyrene, chrysene, benzo(b and/or k)fluoranthene, and benzo(a)pyrene. Results from soil samples from the eastern end of the Magnet House showed six polycyclic aromatic hydrocarbon (PAH) compounds in DW-SS-08 and three PAH compounds in DW-SS-09. The latter sample contained a high concentration of bis(2-ethylhexyl)phthalate (55,000 μg/kg). Soil from a storm drain behind the main building (DW-SS-02) contained phenanthrene, fluoranthene, pyrene, chysene, benzo(b and/or k)fluoranthene, and benzo-a-pyrene. Soil sample DW-SS-03, collected from a burned scrap pile, contained benzo(b and/or k)fluoranthene. Sample DW-SS-05 contained levels of phenanthrene, fluoranthene, benzo(b and/or k)fluoranthene, and benzo(a)pyrene. One soil sample collected near the incinerator contained phenanthrene, fluoranthene, pyrene, and benzo(b and/or k)fluoranthene. Another area of soil contamination was a scrap and dirt pile near the eastern end of the Magnet House (DW-SS-06). This sample had a number of compounds similar to the Magnet House samples, including phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benzo(b and/or k)fluoranthene, benzo-a-pyrene, indeno(1,2,3-CD)pyrene (Halliburton 1995).

The WESTON limited field investigation showed that there were two grid units where the soil exceeded the proposed 20 mg/kg cleanup level for SVOCs (WESTON 1994).

Contamination by SVOCs at the DWI 901 Site was likely due to mishandling of hazardous materials. Several reports indicate oils, greases, and solvents were observed on the ground surface at the site (TDSF 1991). Organics such as PAH compounds (constituents of petroleum products) and plasticizers (used to maintain the flexibility of resins) were used as part of the normal operation at the site.

3.1.1.5 Radionuclides in soil

The TDRH radiological walkover survey of the Candora Road Area showed that a round, stainless-steel fan housing in the area of the original scrap pile had the highest reading (600 μR/hour). A considerable amount of material resembling processed uranium ore (yellow cake) was observed in the fan housing. Gamma spectroscopy and spectrometry analysis revealed elevated levels of ^{235}U (3.25–30.84 pCi/g) and several daughter products such as ^{40}K, ^{212}Pb, ^{214}Pb, ^{228}Ac, and ^{234}Th (TDSF 1990).

The CRU, Inc., survey found low-level radioactive contamination in 10 samples ranging from 11.5 to 41.4 pCi/g. According to the CSX Corporation report, EPA requires that soil and water remediation be conducted when the total activity from any element exceeds 10 pCi/g. Each sample exceeded this threshold (TDSF 1991).

The Halliburton ESI initial radiological assessment indicated that the Candora Road Area was the most significant area of radiological concern. Sample DW-SS-10 contained radionuclides including alpha, beta, and gamma emitters such as U, Th, Bi, Cs, Pb, Ra, and Tl, at activity levels many times higher than at any other property location. The area of the Magnet House indicated a dose gradient extending from south to north. Samples DW-SS-08 collected in the Magnet House contained a significant level of ^{235}U (0.653 pCi/g). Sample DW-SS-09 contained high levels of alpha, beta, and gamma emitters, including ^{235}U (6.08 pCi/g), ^{214}Bi (33 pCi/g), and ^{214}Pb (35.5 pCi/g). Soil from a storm drain behind the main building (sample DW-SS-02) had notable levels of ^{235}U (0.190 pCi/g). Notable concentrations of ^{235}U (1.08 pCi/g) were detected in Sample DW-SS-05, and ^{235}U was also detected in Sample DW-SS-13 near the incinerator (0.318 pCi/g). Suspected soil contamination in the eastern end of the Magnet House (DW-SS-06) showed high activity levels of alpha, beta, and gamma emitters, including ^{235}U (1.3–13,000 pCi/g), Th (0.5–73 pCi/g), Bi (0.423–2.45 pCi/g), Pb (0.412–27.1 pCi/g), Ra (0.47–74.4 pCi/g), and Tl (0.123–8.81 pCi/g) (Halliburton 1995).

The WESTON limited field investigation showed that uranium was present on site as isotopes ^{234}U, ^{235}U, and ^{238}U, in activities as high as 129,700 pCi/g. These high activity areas were in isolated areas of the site. Ratios of ^{235}U to ^{238}U do not show substantial quantities of enriched uranium on site. A sample of "yellow cake" was collected from Grids 4E and 4C; the uranium concentration was calculated to be 40 percent by mass. Investigators concluded that the yellow substance was uranium oxide (U_2O_3). Four samples had ^{239}Pu at low activity levels. Analyses detected no ^{89}Sr in any samples; however, ^{90}Sr was detected in all samples analyzed for strontium. The highest activity was 260 pCi/g. Other isotopes detected include ^{228}Ac, ^{137}Cs, and ^{208}Tl. Measurement of thorium isotopes ^{234}Th and ^{230}Th show that the ratios of ^{238}U and ^{234}Th are essentially at equilibrium. The very low activity of ^{230}Th in the samples indicated that the uranium on site had been processed and was not enriched (WESTON 1994).

Contamination by radionuclides at the DWI 901 Site most likely occurred as a result of the mishandling of radionuclide-contaminated materials. The facility received, stored, and processed materials contaminated with enriched uranium and uranium mill tailings. There were essentially no radiological controls followed at the site, leading to the spread of these materials across the site.

3.1.2 Groundwater

Alterations to the land surface have occurred. Areas with fill will have variable infiltration rates according to the type of material, its degree of compaction, thickness, and the nature of the native soil it covered. Fill material has been noted on some of the soil boring logs, but no study of this subject has been done. Preconstruction maps of the area show that, from 1941 to 1978, topography was altered by the significant amounts of fill material placed on the property (PRC 1993a).

Five groundwater monitoring wells were installed in the unconsolidated zone. Of these, three had water at well completion, and one of those (MW-02) may have suspect construction, hence suspect water quality. No groundwater elevation measurements have been provided, and it is unclear whether the well elevations noted on existing site maps are the casing elevations or the ground surface elevations. The two "dry" wells may be installed above the water table, or soil conditions may deflect infiltration and groundwater into other preferred flow paths (e.g., flow in relict fractures) flanking these areas (PRC 1993a). Groundwater contaminants are summarized in Table 3.2. The constituents listed are considered important in characterizing the contamination in the groundwater of the DWI 901 Site.

3.1.2.1 Metals in groundwater

The May 1992 PRC Phase I RI groundwater sample analyses showed that PRGs were exceeded for Cr (124 μg/L), Pb (111 μg/L), and Hg (61.9 μg/L). Health-based criteria for carcinogens and systemic toxicants exceeded PRGs for beryllium (6.9 μg/L) and antimony (60.4 μg/L). Residential PRGs were exceeded for Ba (694 μg/L), Cu (572 μg/L), Ni (152 μg/L), and Zn (1,520 μg/L) (PRC 1993a).

The Halliburton ESI found mercury (0.29 μg/L) and zinc (370 μg/L) above background concentration in Sample DW-MW-02. No other inorganic analytes were detected above background in groundwater (Halliburton 1995).

Groundwater contamination by metals most likely occurred as a result of poor housekeeping. Contamination by lead and mercury may be traced to handling of lead/mercury batteries. Elevated levels of Cr, Pb, Hg, and Zn reflect the uncontrolled handling and processing of scrap metal and batteries that took place at the facility.

Table 3.2. Groundwater parameters for detected analytes from the DWI 901 Site, Knoxville, Tennessee

Analyte	Units	Mean[a]	Minimum detected	Maximum detected
Metals				
Antimony	μg/L	31.6	60.4	60.4
Barium	μg/L	282.75	48	694
Beryllium	μg/L	2.85	6.9	6.9
Chromium	μg/L	35.3	124	124
Manganese	μg/L	4,007.5	880	9,170
Mercury	μg/L	24.423	0.29	61.9
Nickel	μg/L	53.075	20.3	152
Vanadium	μg/L	37.25	9	130
Zinc	μg/L	601	11	1,520
Radionuclides				
Uranium-234	pCi/L	1.3	1.2	1.4
Uranium-238	pCi/L	1.1	1.1	1.1

Sources: PRC 1993a, PRC 1996, Halliburton 1995, WESTON 1994.

[a]Mean value detected using detected value(s) and half of nondetected values.

DWI = David Witherspoon, Inc.
L = liter
μg = microgram
pCi = picocurie

3.1.2.2 Dioxins/furans in groundwater

No dioxins/furans were analyzed for groundwater at the DWI 901 Site.

3.1.2.3 PCBs in groundwater

The Halliburton ESI did not detect PCBs in groundwater (Halliburton 1995).

3.1.2.4 SVOCs in groundwater

The Halliburton ESI did not detect SVOCs above background in groundwater (Halliburton 1995).

3.1.2.5 Radionuclides in groundwater

The Halliburton ESI found that temporary Background Well DW-MW-01 exhibited relatively high levels of gross alpha (0.9–24 pCi/g) and gross beta (2–18 pCi/g), although the levels were not out of the reported range of naturally occurring radioactive materials (Halliburton 1995).

3.1.3 Surface Water

Surface water at the DWI 901 Site consists of the waters of Goose Creek, an ephemeral stream that flows through the site from west to east and flows into the Tennessee River (Fort Loudoun Lake).

3.1.3.1 Metals in surface water

No metals were analyzed for surface water samples at the DWI 901 Site.

3.1.3.2 Dioxins/furans in surface water

No dioxins/furans were analyzed for surface water samples at the DWI 901 Site.

3.1.3.3 PCBs in surface water

No PCBs were analyzed for surface water samples at the DWI 901 Site.

3.1.3.4 SVOCs in surface water

The TDSF SI collected surface water Background Sample BGSW-1 from the same location as BGSED-2 (Fig 3.2). Bis(2-ethylhexyl)phthalate was detected in 6 of 11 samples, including groundwater (GW-8) collected from Chestnut Road Spring and the background surface soil sample. Surface water from the Sample SW-6 collected from Goose Creek contained trichlorofluoromethane (TDSF 1991).

SVOC contamination of surface waters is most likely a result of mishandling of these materials. It has been reported that oils, solvents, and greases have been observed on the surface. These liquids may have been deposited in the surface by runoff from upslope positions of the site into Goose Creek.

3.1.3.5 Radionuclides in surface water

No radionuclides were analyzed in surface water at the DWI 901 Site.

3.1.4 Sediment

Sediment is present at the DWI 901 Site in the form of overbank alluvium originating from Goose Creek. Some of this sediment on site and downstream is believed to be derived from surface wash from the site. Important contaminants in the sediment at the DWI 901 Site are summarized in Table 3.3.

3.1.4.1 Metals in sediment

The TDSF PA found that chromium (63.7 mg/kg) and manganese (1,450 mg/kg) exceeded residential PRGs (TDSF 1990).

The TDSF SI collected a background sediment sample (BGSED-2) from Goose Creek approximately 35 m (115 ft) southwest of Edington Road Bridge (Fig 3.2). Two sediment samples, one on Goose Creek and the other 0.8 km (0.5 miles) downstream in Mary Vestal Park, contained elevated levels of mercury (TDSF 1991).

The PRC Phase I RI showed that metals from Goose Creek sediments had As, Be, Cr, Mn, Ni, and Sb exceeding residential PRGs in at least one sample (PRC 1993a).

The Halliburton ESI found Hg (0.87–7 mg/kg), Pb (80–440 mg/kg), Cr (15–86 mg/kg), Cu (46–830 mg/kg), Cd (1.9–6.2 mg/kg), and Zn (250–1,900 mg/kg) above background in on-site sample DW-SD-02. Elevated Cd (1.9 mg/kg), Cu (100 mg/kg), and Hg (2.1 mg/kg) were found in on-site sediment sample DW-SD-03. Levels above background of Cd (4.1 mg/kg), Cu (59 mg/kg), Hg (1.3 mg/kg), and Zn (500 mg/kg) were found off site in Mary Vestal Park (Halliburton 1995).

Sediment contamination by metals most likely occurred as a result of erosion of soils contaminated due to poor housekeeping. Contamination by lead and mercury may be traced to handling of lead/mercury batteries. Elevated levels of Cd, Cr, Cu, Pb, Hg, and cyanide reflect the uncontrolled handling and processing of scrap metal and batteries at the facility. Transport of these metals likely occurred as a result of soil erosion from upslope positions, and they were deposited as alluvium in Goose Creek. These metals likely were transported as discrete sediments rather than redeposited and reprecipitated from soluble ions. Contamination of sediments downstream is represented by a suite of metals similar to soil contaminants of the DWI 901 Site.

Table 3.3. Sediment parameters for detected analytes, DWI 901 Site, Knoxville, Tennessee

Analyte	Units	Minimum	Maximum
Metals			
Antimony	mg/kg	14	14
Arsenic	mg/kg	5.8	12.5
Beryllium	mg/kg	0.74	1.1
Chromium	mg/kg	14.9	86
Manganese	mg/kg	570	12,200
Mercury	mg/kg	0.23	7
PCBs			
Aroclor-1254	μg/kg	300	4,000
Aroclor-1260	μg/kg	168	2,700
Semivolatiles			
Benzo(a)anthracene	μg/kg	630	1,600
Benzo(a)pyrene	μg/kg	280	1,700
Benzo(b)fluoranthene	μg/kg	1,200	4,600

Sources: TDSF 1990, TDSF 1991, PRC 1993a, Halliburton 1995, WESTON 1994.

DWI = David Witherspoon, Inc.
kg = kilogram
μg = microgram
mg = milligram
PCB = polychlorinated biphenyl

3.1.4.2 Dioxins/furans in sediment

The Halliburton ESI showed that dioxins were in on-site samples DW-SD-02 at 15 TEQ and DW-SD-03 at 5.8 TEQ. Dioxin analysis was not performed on off-site samples (Halliburton 1995).

3.1.4.3 PCBs in sediment

The TDSF PA showed that the composited sediment sample collected from Goose Creek contained elevated levels of Aroclor-1254, Aroclor-1260, and Aroclor-1248 in comparison to a background sediment sample (TDSF 1990).

The TDSF SI showed that the sediment sample from Mary Vestal Park contained detectable levels of Aroclor-1254 and Aroclor-1260 (TDSF 1991).

The Halliburton ESI showed that on-site sediment sample DW-SD-02 contained elevated levels of Aroclor-1254 (4,000C μg/kg) and Aroclor-1260 (2,700C μg/kg). These two compounds also were detected downstream at DW-SD-03 at lower concentrations (Aroclor-1254, 410 μg/kg, and Aroclor-1260, 250 μg/kg). Off-site sediment samples DW-SD-04 and DW-SD-05 showed elevated concentrations of Aroclor-1254 (300 μg/kg) and Aroclor-1260 (500 μg/kg) (Halliburton 1995).

The extent of PCB sediment contamination at the DWI 901 Site is most likely the result of mishandling of hazardous materials. PCB compounds, formerly used as insulating material in transformers, were on site during normal operations. Reportedly, PCB-containing transformers were stored and handled on site. PCBs may have been transported downslope from their source by erosion of the soil surface into Goose Creek. It is possible that the PCB compounds may have been miscible with other organic materials and were washed in as discrete sediments. These sediments may also have been deposited downstream where they were detected in Mary Vestal Park.

3.1.4.4 SVOCs in sediment

The PRC Phase I RI showed that sediments from Goose Creek contained detectable levels of acetone, benzo(a)pyrene, di-n-butylphthalate, ethylbenzene, and xylene (PRC 1993a).

The Halliburton ESI showed that on-site sediment sample DW-SD-02 contained bis(2-ethylhexyl)phthalate (6,700 μg/kg). Sample DW-SD-03 contained elevated levels of (3- or 4-)methyphenol (1,700 μg/kg). Five PAH compounds and the pesticide endrin were detected at levels above background in Sample DW-SD-06 in Mary Vestal Park. These compounds were not found in the sediment samples upgradient and are probably not related to the DWI 901 Site. An additional stream enters Goose Creek upstream from DW-SD-06, and this may be the source of contamination (Halliburton 1995).

SVOC sediment contamination at the DWI 901 Site was likely due to mishandling of hazardous materials. Several reports indicate oils, greases, and solvents spilled on the ground. Organics such as PAH compounds (constituents of petroleum products) and plasticizers (used to maintain the flexibility of resins) would have been used as part of the normal site operation. These organic compounds may have been spilled directly on the alluvial sediments at Goose Creek or were washed in from upslope. There is a similar suite of organic contaminants downstream; however, some organics found in Mary Vestal Park do not match compounds from the DWI 901 Site. It is possible that downstream contamination has also come from an alternate source, such as the tributary to Goose Creek, which converges with Goose Creek downstream of the DWI 901 Site.

3.1.4.5 Radionuclides in sediment

The Halliburton ESI showed notable levels of gross alpha (30 pCi/g) and gross beta (32 pCi/g) in on-site Sample DW-SD-02. Off-site Sample DW-SD-04 showed activity levels of gross alpha (22 pCi/g), gross beta (18 pCi/g), and uranium (0.1–2.8 pCi/g) above background levels (Halliburton 1995).

Radionuclide contamination in sediment at the DWI 901 Site most likely occurred as a result of the mishandling of radionuclide-contaminated materials. The facility received, stored, and processed materials contaminated with enriched uranium and uranium mill tailings. According to the 1990 TDSF investigation, there were essentially no radiological controls followed at the site, leading to the spread of these materials across the site. Sediments may have been contaminated by directly depositing radionuclide-contaminated materials or by erosion of these materials in particulate form into Goose Creek.

3.1.5 Radiation Survey

The March 1987 radiation walkover survey by Bechtel National, Inc., found some radiological contamination in the Candora Road Area. The highest concentration measured was 23,000 pCi/g of ^{238}U. Radiation levels in the areas covered by the walkover survey appeared to range from naturally occurring background levels to about 70 times the background level. The survey concluded that surface contamination apparently extended beyond the DWI 901 Site to the east and west, but appeared to be limited to the ditch lines that run along the site boundary (TDSF 1990).

In March 1990, TDRH conducted a radiological walkover survey of the Candora Road Area. At the entrance to the DWI 901 Site, readings were about 6–10 μR/hour, which TDRH considered as background measurements. About 230 drums were positioned along the fence to the west. Radiation readings from the drums ranged from 60 to 2,500 μR/hour. General readings of the area between the fence to the west and the fence line to the east next to the asphalt company ranged from 10 to 30 μR/hour. A large pile of debris in the center of the yard, near the southern end next to the crane shed, showed readings ranging from 400 to 600 μR/hour. The scrap exhibiting the highest reading was a round stainless steel fan housing in the area where the original scrap pile had been. A considerable amount of material resembling processed uranium ore (yellow cake) was observed in the fan housing (TDSF 1990).

Halliburton conducted field investigations the week of January 25, 1994, for the ESI. A site radiological survey was conducted. The findings were that general dose rates around the site were 1–2 times background dose rate (approximately 8–16 μR/hour). The western portion of the site had dose rates ranging from 20 to 210 μR/hour. Dose rates around the Magnet House were 2–3 times background (Halliburton 1995).

In February 1994, TDSF authorized WESTON to conduct a limited field investigation of the DWI 901 Site. As a part of Stage 1, WESTON performed an additional preliminary radiation survey to evaluate the extent of localized concentrations of radioactive contamination. Background measurements were determined and areas exceeding background were located in the Candora Road Area, the Magnet House, and north of the Main Building near the culvert at Goose Creek (WESTON 1994).

3.1.6 Debris

Debris piles, including sorted scrap metal, are in several locations on the DWI 901 Site. These piles are particularly conspicuous in the Magnet House and south and east of the Magnet House. Table 3.4 lists the types of debris piles and their relative volume estimates. Figure 3.7 shows relative locations of debris piles listed in Table 3.4.

3.1.6.1 Metals in debris

During August 1990, TDSF performed a PA at the DWI 901 Site (Fig. 3.1). TDSF collected one waste sample from a scrap pile in the western portion of the property. Metals detected in this debris sample included Ba, Cd, Pb, and Ni (TDSF 1990).

Contamination of debris by heavy metals is due to either the composition of the scrap metal or direct deposition of these metals onto the debris.

3.1.6.2 Dioxins/furans in debris

There were no dioxins/furans analyzed for debris samples.

3.1.6.3 PCBs in debris

The TDSF PA showed that all waste samples contained detectable levels of Aroclor-1254, Aroclor-1260, and Aroclor-1248 (TDSF 1990).

PCB contamination of the debris was likely due to the presence of these compounds on the scrap (e.g., insulation).

Table 3.4. Material type and volume estimates for debris piles, DWI 901 Site, Knoxville, Tennessee

Area	Area volume	Concrete slabs	Spooled wire	Temporary building	Loose tires	Catalytic converters	Equipment (refrigerant compressors, fan units)[a]	Electric meters	Heavy gauge (iron/steel) metal bins, dumpsters, roll-offs	Heavy gauge (iron/steel) pipes, rods, rollers	Drums	Sheet metal	Tanks, cylinders	Lumber, pallets	Plastic	Fines (ash, scraped soil, any material < 6 in.)	Thin (wire-like) metal
	yd^3																
A	31.6	0	0	0	0	0	0	31.3	0	0	0	0.3	0	0	0	0	0
B_1	399.3	0	0	0	0	0	159.7	0	99.8	59.9	0	39.9	0	39.9	0	0	0
B_2	20.0	0	0	0	0	0	1.0	0	10.0	2.0	0	4.0	2.0	1.0	0	0	0
C	157.3	0	0	0	0	0	23.6	0	78.7	15.7	0	0	0	39.3	0	0	0
D	23.4	0	0	0	0	0	0	0	14.0	0	9.3	0	0	0	0	0	0
E	79.0	0	0	0	0	0	0	0	0	0	0	0	0	79.0	0	0	0
F	5.7	0	0	0	0	0	0	0	0	0	5.7	0	0	0	0	0	0
G	1,591.9	0	0	0	0	0	0	0	79.6	318.4	79.6	238.8	0	159.2	79.6	318	318
H	0.9	0	0	0	0	0	0.8	0	0	0	0	0	0	0.04	0	0	0
I	4.8	0	0	0	0	0	0	0	1.4	0	0	0	3.4	0	0	0	0
J	0.0	0	0	0.0[b]	0	0	0	0	0	0	0	0	0	0	0	0	0
K	28.6	0	22.9	0	4.3	0	0	0	1.4	0	0	0	0	0	0	0	0
L	69.6	0	0	0	0	0	27.9	0	13.9	0	0	10.4	0	10.4	0	7	0
M	95.1	0	0	0	0	0	0	0	9.5	0	0	19.0	0	14.3	0	38	14
N	6.7	0	0	0	0.7	0	1.3	0	1.3	0	0	1.3	0.7	0.7	0.3	0	0.3
O	23.4	0	0	0	0	0	0	0	14.1	0	0	0	9.4	0	0	0	0
P	16.2	0	0	0	0	0	0	0	0	0	0	8.1	8.1	0	0	0	0
Q	11.7	0	0	0	0	0	0	0	5.8	4.7	0	1.2	0	0	0	0	0
R	41.0	0	0	0	0	0	8.2	0	20.5	8.2	4.1	0	0	0	0	0	0

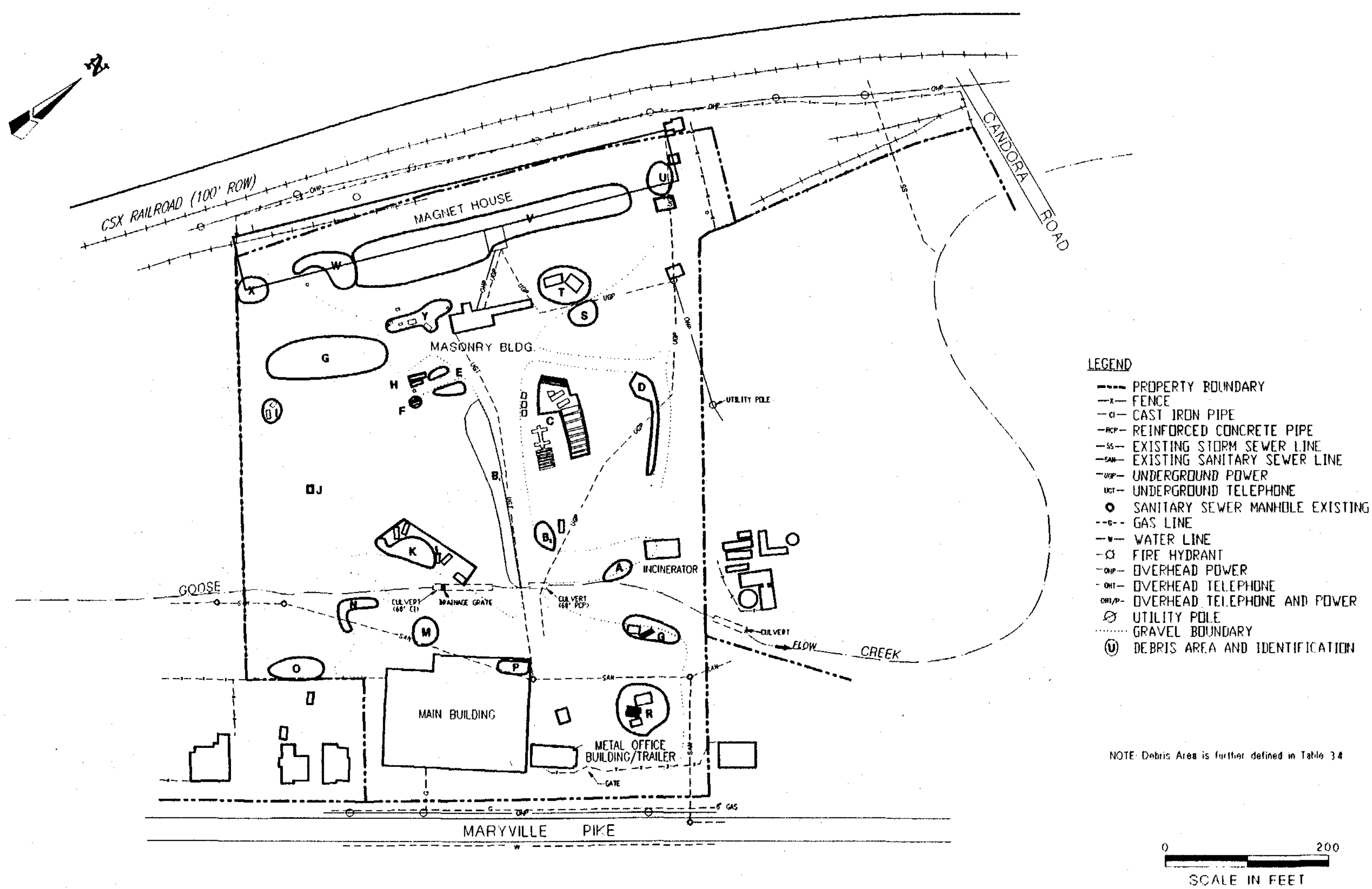
Table 3.4. (continued)

Area	Area volume	Concrete slabs	Spooled wire	Temporary building	Loose tires	Catalytic converters	Equipment (refrigerant compressors, fan units)[a]	Electric meters	Heavy gauge (iron/steel) metal bins, dumpsters, roll-offs	Heavy gauge (iron/steel) pipes, rods, rollers	Drums	Sheet metal	Tanks, cylinders	Lumber, pallets	Plastic	Fines (ash, scraped soil, any material < 6 in.)	Thin (wire-like) metal
	yd^3																
S	27.6	0	0	0	0	27.6	0	0	0	0	0	0	0	0	0	0	0
T	74.1	0	0	0	0	0	22.2	0	29.6	0	0	22.2	0	0	0	0	0
U	16.8	0	0	0	0	0	0	0	0	1.7	0	1.7	0	1.7	1.7	8	1.7
V	3,304.9	0	0	0	0	0	330.5	0	0	330.5	0	661.0	0	330.5	330.5	991	330
W	35.0	0	0	0	0	0	0	0	0	28.0	0	0	0	3.5	0	0	4
X	4.4	0.7	0	0	0	0	1.8	0	1.1	0.9	0	0	0	0	0	0	0
Y	67.2	0	0	0	0	0	10.1	0	23.5	10.1	0	16.8	0	6.7	0	0	0
Total	6,136.2	0.7	22.9	0.0[b]	5.0	27.6	587.1	31.3	404.4	780.0	98.7	1,024.8	23.5	686.3	412.1	1,363.3	668.6
%	100.0	0.01	0.4	0.0	0.1	0.5	9.6	0.5	6.6	12.7	1.6	16.7	0.4	11.2	6.7	22.2	10.9

[a]Potentially salvageable heavy equipment (welders/compressors, transfer trailers, fork lifts) is not included in estimation; items may require decontamination before release.
[b]Outbuildings are not included in debris estimation; items may require decontamination before release.

DWI = David Witherspoon, Incorporated
in. = inch
< = less than

% = percent
yd = yard



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	**Fig. 3.7**	**Debris locations** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13410.DWG	DRAWING DATE: OCTOBER 18, 1996 TG

3.1.6.4 SVOCs in debris

The TDSF PA showed that the waste sample exhibited detectable levels of anthracene, benzo(a)pyrene, and pyrene (TDSF 1990).

Contamination of the debris by PCBs was likely due to direct deposition of these compounds onto the scrap metal.

3.1.6.5 Radionuclides in debris

There were no radionuclides analyzed for debris.

3.2 SUMMARY OF CURRENT CONDITIONS

Current information indicates that surface soils are contaminated with a variety of metals, SVOCs, PCBs, radionuclides, and, potentially, dioxins/furans. The level of characterization for on-site surface soils is adequate. Characterization of sediment contamination shows that the contaminants in surface soil are comparable to those in sediments. Characterization also shows that site contamination could be transported to points downstream. Information regarding subsurface soil contamination is poorly understood. It is difficult to correlate contaminants observed in subsurface soil samples with contaminants from surface soils. Groundwater likewise is poorly characterized. Monitoring wells are not placed in the vicinity where most of the surface soil contaminants have been detected. Therefore, it is inconclusive whether there is a correlation between surface contaminants, subsurface, and groundwater conditions. Debris piles on site, particularly near the Magnet House, are a likely source for contamination by heavy metals, PCBs, and radionuclides. However, since the debris has not been characterized, the contribution that it makes to site contamination is not known. Surface water data are also sparse and poorly characterized.

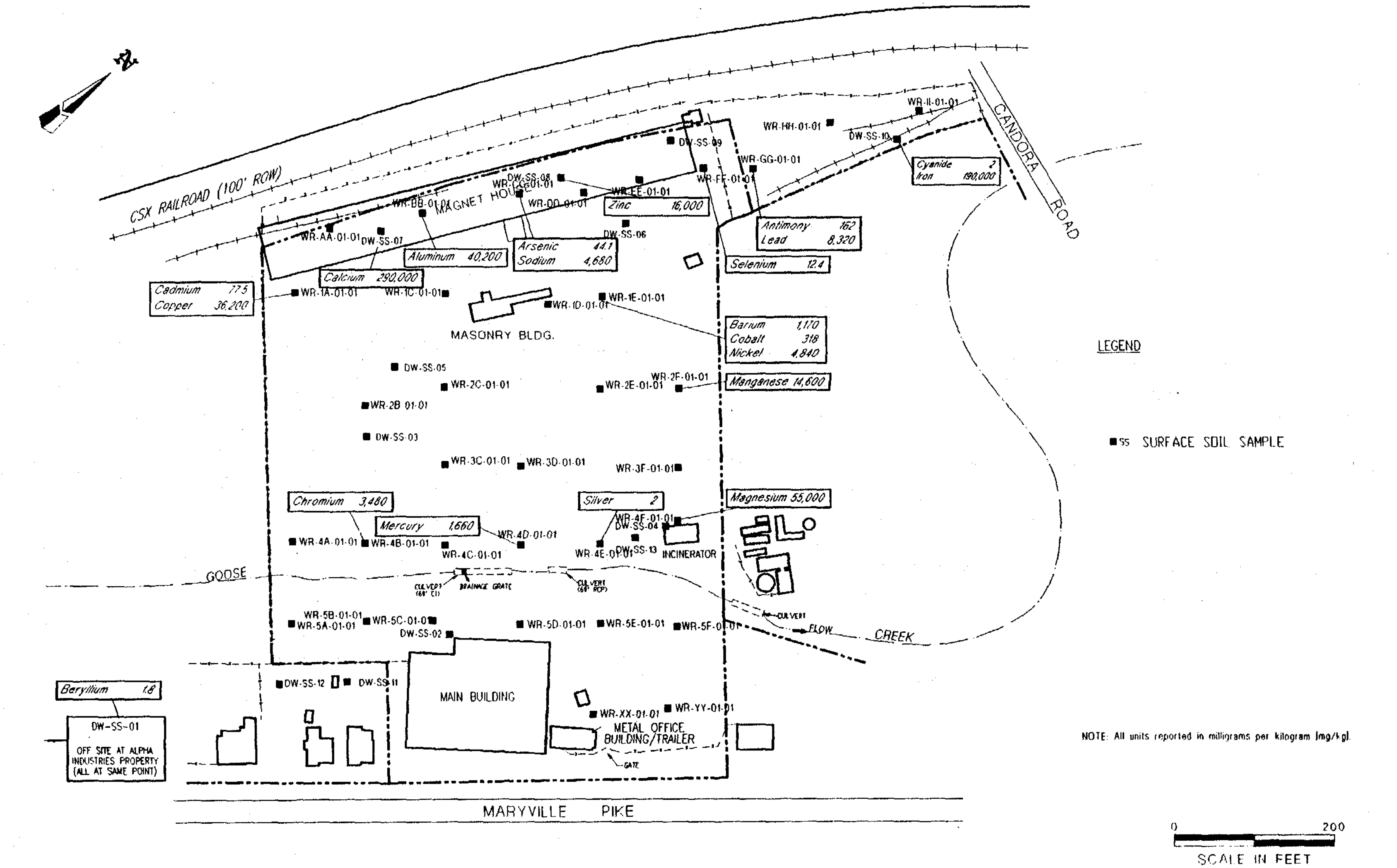
3.3 SUMMARY OF NATURE AND EXTENT OF CHEMICAL CONSTITUENTS

The degree of contamination at the DWI 901 Site may be related to the location of debris piles throughout the site. These debris piles are presumed to be a source of a suite of site contaminants. The presence of debris and poor housekeeping have created considerable surface soil contamination and, potentially, sediment contamination on site and downstream. The nature and extent of contamination of the remaining site media (groundwater and subsurface soil) are poorly understood and will require further study.

The levels of DWI 901 Site chemicals and compounds in surface soils are summarized in Figures 3.8–3.13. These figures show the maximum concentrations of compounds and elements that may be of concern because of their detrimental effect on the surrounding environment. The Candora Road Area, the Magnet House, and the Incinerator area should be examined closely with attention paid to several isolated areas associated with debris piles at the site. Figure 3.8 shows the areas where maximum metal detects occurred. No pattern is apparent. Figure 3.9 shows a strong correlation between the maximum detected PCBs and the Magnet House area. There is also a correlation between Goose Creek sediments and high PCB concentrations. Figure 3.10 shows a high correlation of VOCs with the Magnet House area. Maximum SVOC concentrations (Fig. 3.11) are in several areas of the site. The Candora Road Area, the Magnet House, and from several debris piles show high levels of SVOCs. In contrast, maximum levels of pesticides (Fig. 3.12) were found in off-site soil samples in a residential area south of the Main Building. The analysis of maximum radiological concentrations (Fig. 3.13) shows that the Candora Road Area and the Magnet House are primary areas of concern. Sediment from Goose Creek and a debris pile on the southern end of the site also exhibit high concentrations of radiological components. Data indicated that several media and areas within the DWI 901 Site exhibited high concentrations of several analytes. The media and areas included:

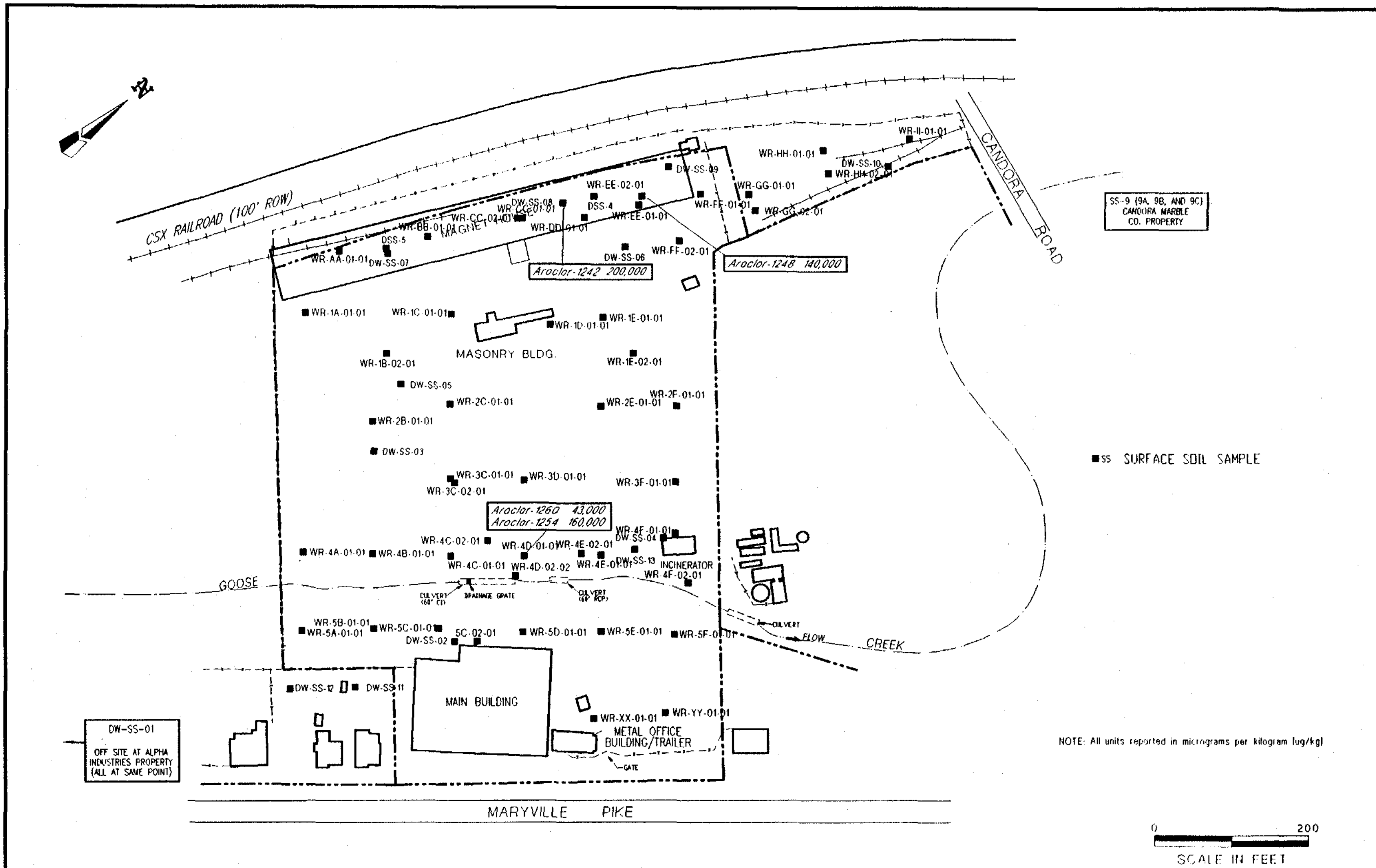
- the Candora Road Area,
- the Magnet House,
- Goose Creek sediments,
- the incinerator, and
- several debris piles.

Subsurface soil is the medium most contaminated by site operations and practices. This contamination is sitewide at varying levels and represents the greatest contamination source for other media. Contaminants can be transported from the soil surface by a number of transport modes. Contaminants can move gravimetrically from the surface into the soil substrate and potentially into groundwater. The surface soil can also erode and redistribute contamination in sediments to downslope and downstream locations. Potentially, impacted groundwater can recharge into the surface water, contaminating it as well. Additionally, erosion of the soil surface can lead to transport of contaminated particulate solids, redepositing them downwind. Another transport mechanism would be uptake by flora and direct or indirect uptake by fauna.



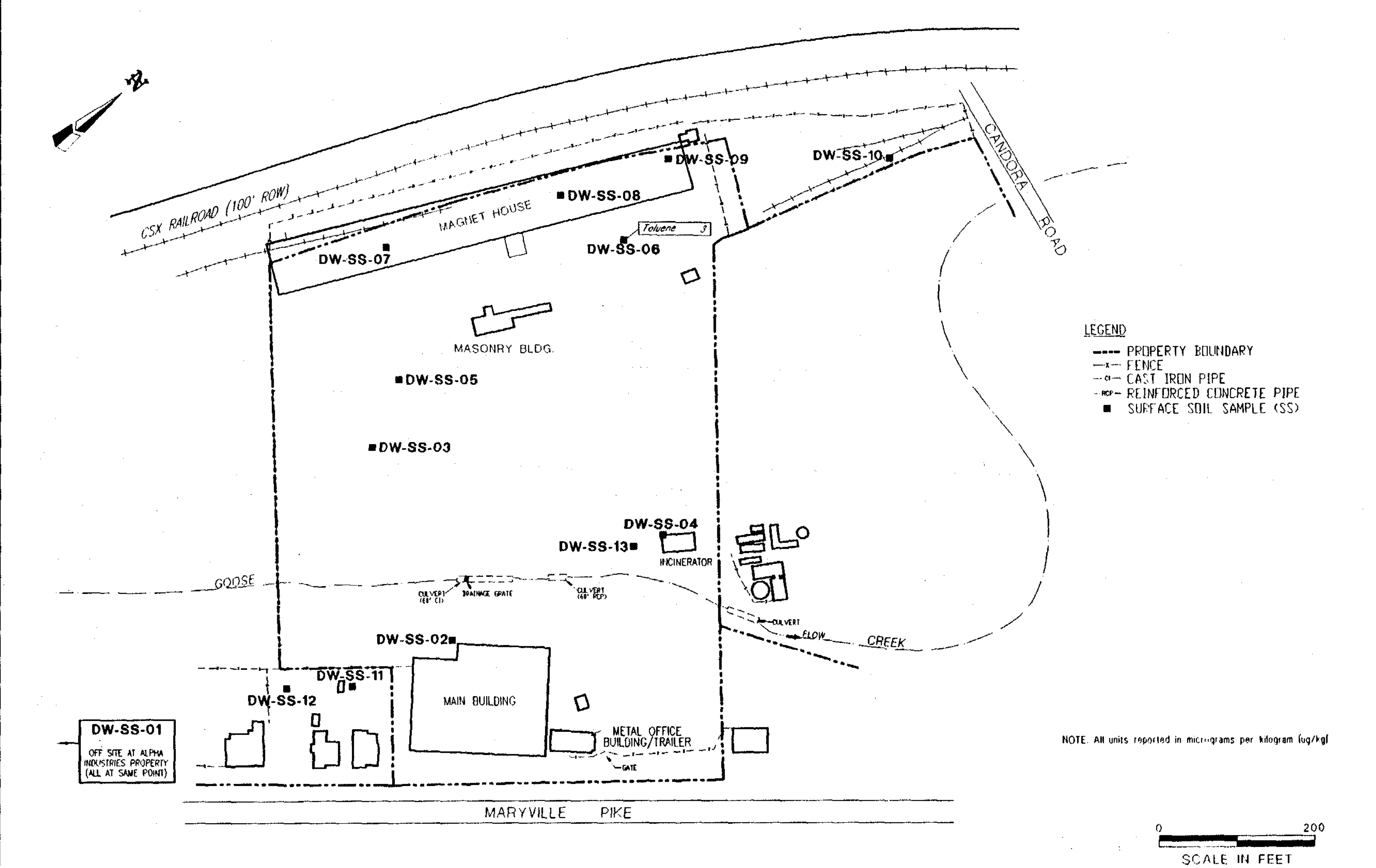
MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	**Fig. 3.8**	**Maximum metal hit locations in surface soil samples** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96 13083.DWG	DRAWING DATE: OCTOBER 18, 1996 TG



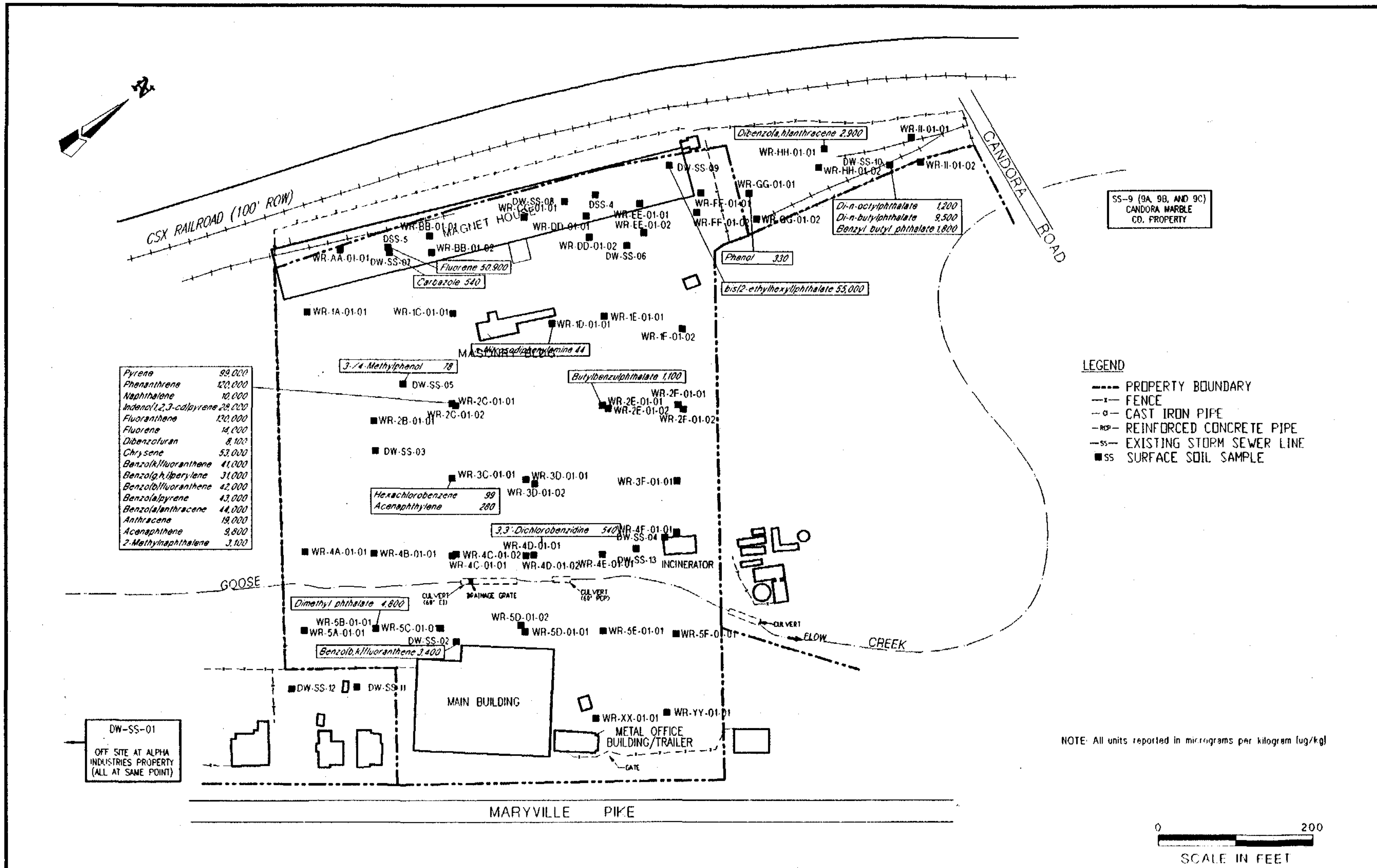
MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	Fig. 3.9	**Maximum PCB concentrations in surface soil samples** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13136.DWG	DRAWING DATE: OCTOBER 18, 1996 TG



MODIFIED FROM. Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	Fig. 3.10	Maximum volatile organic concentrations in surface soil samples DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13131DWG	DRAWING DATE OCTOBER 18, 1996 TG



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	Fig. 3.11	**Maximum semivolatile concentrations in surface soil samples** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13130.DWG

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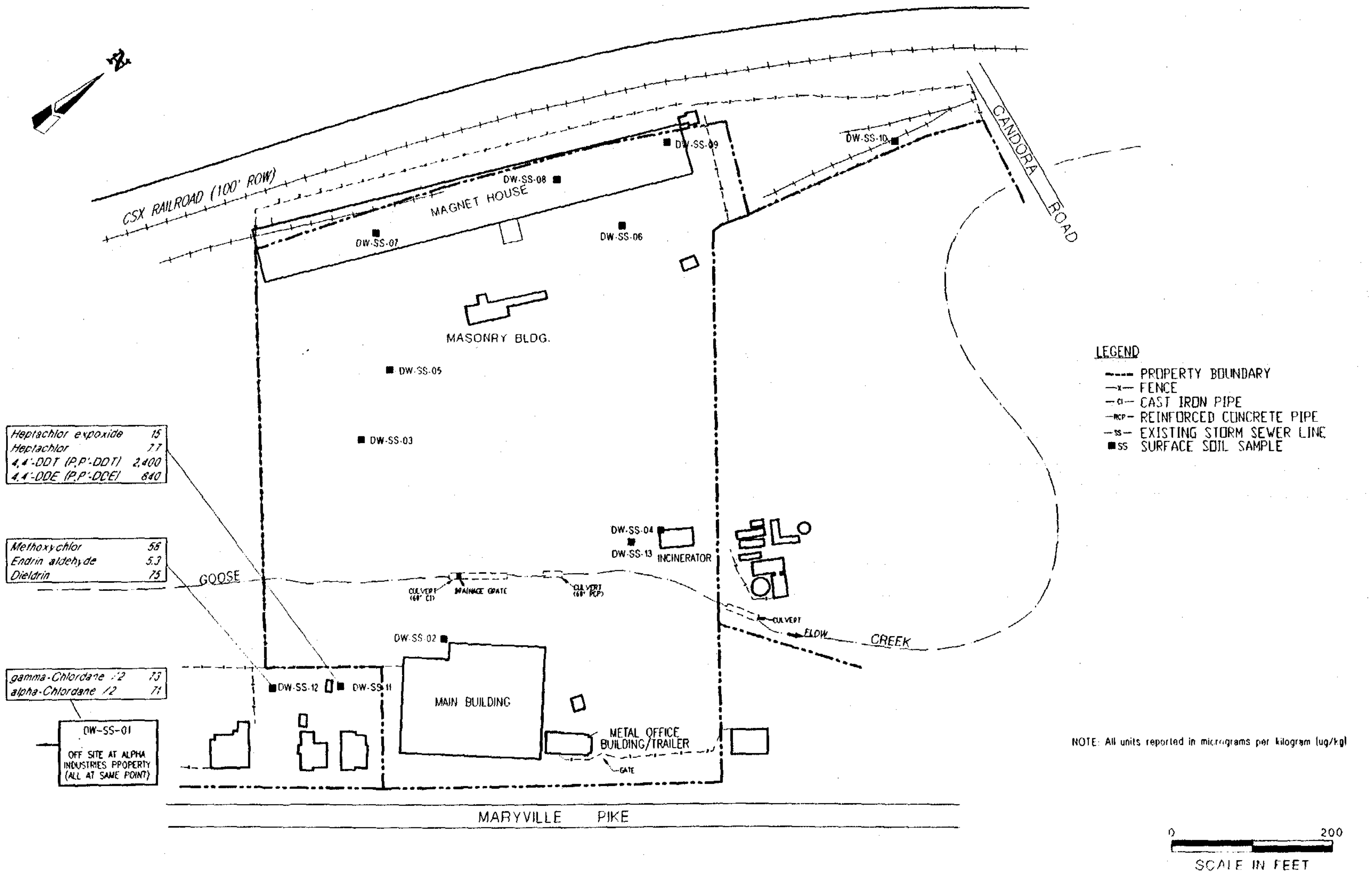

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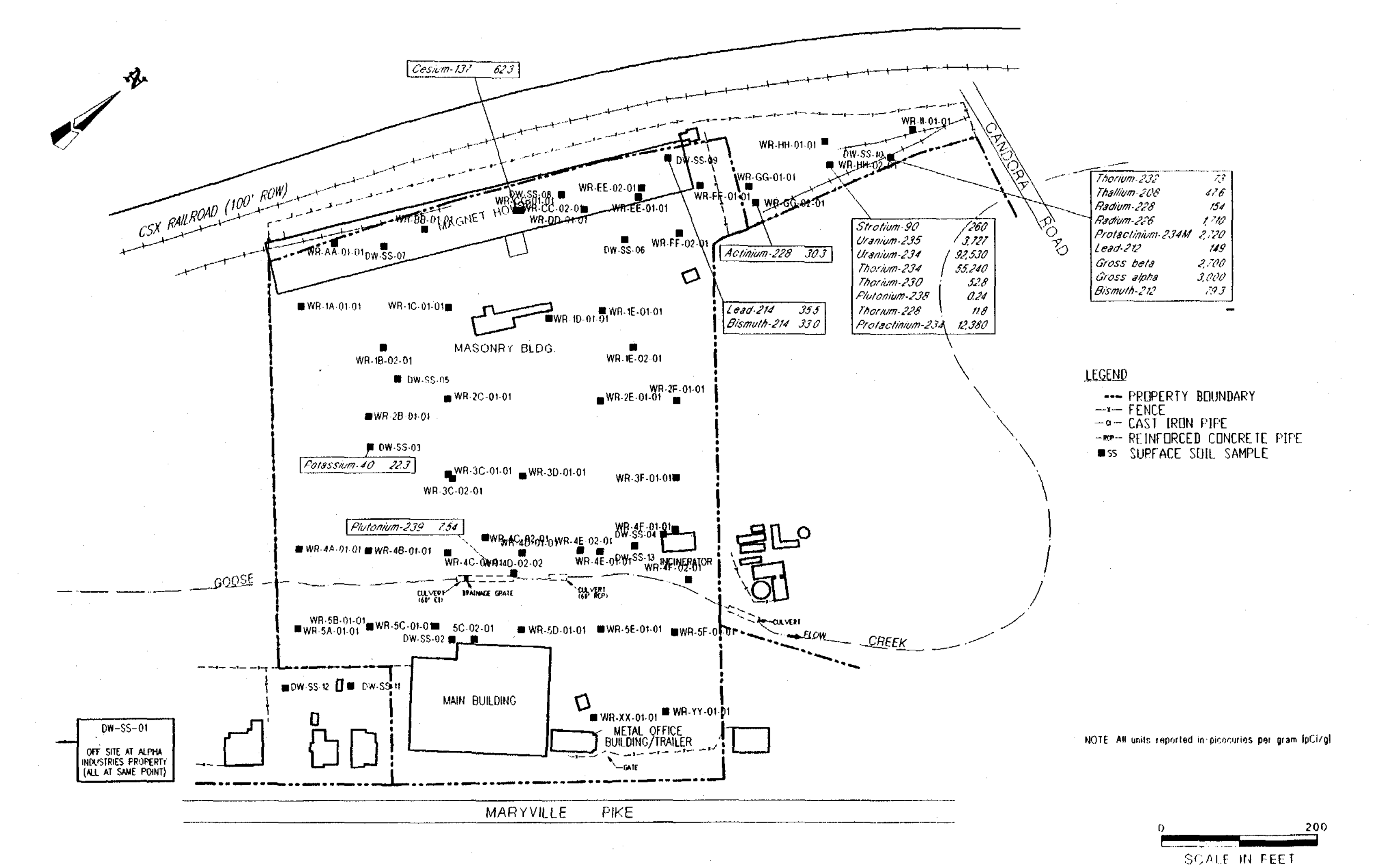
JE	**Fig. 3.12**	**Maximum pesticide concentrations in surface soil samples** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96 13132 DWG	DRAWING DATE OCTOBER 18, 1996 TG



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JE	Fig. 3.13	Maximum rad concentrations in surface soil samples DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35U830 0094-20 / RI/FS	DRAWING ID 96-13133.DWG	DRAWING DATE: OCTOBER 18, 1996 TG

4. PRELIMINARY BASELINE HUMAN HEALTH RISK ASSESSMENT

This preliminary baseline risk assessment evaluates the potential threat to human health and the environment assuming no further action is taken at the DWI 901 Site. The purpose of this assessment is to identify contaminants, quantify risks at the site using historical data from previous site investigations, and determine whether the site poses a risk to human health. Additionally, this assessment assists in identifying data gaps that currently exist. Land use scenarios considered for the site include current and future industrial and future residential land uses. Although the site is in an industrial setting, future residential land use is evaluated for informational purposes, provided that land use may change in the future. EPA methodologies used in performing this assessment are found in:

- Risk Assessment Guidance for Superfund (RAGS), Vol 1: Human Health Evaluation Manual, EPA;

- Part A: Baseline Risk Assessment (1989a);

- Part B: Development of Risk-Based Preliminary Remediation Goals (1991);

- Dermal Exposure Assessment: Principles and Applications, EPA, January (1992a); and

- Supplemental Guidance to RAGSs: Region 4 Bulletin, Human Health Risk Assessment, EPA, Region 4, Atlanta, GA, November 1995.

This evaluation was based on results obtained from previous characterization studies performed at the site. After identifying potential site-related contaminants, potential risks to human receptors were quantified. Potential impacts to human health are discussed qualitatively when risk estimates could not be calculated. The steps involved in the risk assessment include data evaluation, exposure assessment, toxicity assessment, risk characterization, and an uncertainty evaluation.

Results of the baseline risk assessment are used to determine whether or not action is warranted to protect human health and the environment.

4.1 DATA EVALUATION

This preliminary human health risk assessment is based on historical data. Data from the six investigations were reviewed for quality and extent of analyses. EPA guidance specifies that selection of chemicals of potential concern (COPCs) be based on data that "are of sufficient quality for use in the quantitative risk assessment" (EPA 1989a, 1992). For this reason, quality control (QC) criteria are established for analytical measures associated with sample analyses. When QC criteria exceedances are encountered, data qualifiers are assigned that indicate how the associated sample result is affected. Qualifiers associated with each data point are reviewed to assess data usability. Historical data were analyzed for use in the risk assessment. The screening process initially included a review of the historical data to assure compliance with data quality objectives. Some reports did not contain information pertaining to QA/QC requirements and, therefore, could not be used in the risk assessment. The most recent investigations (Halliburton 1995; WESTON 1994) contained the most comprehensive evaluation and, therefore, were used most extensively, but not exclusively for the preliminary risk assessment. Data from PRC (1993a and 1993b) and TDSF (1991) were used to support the Halliburton and WESTON data when available. Appendix C includes a list of the samples used in the risk assessments, including the investigators and analyses.

4.1.1 Organization and Sorting of Data by Medium and Location

The qualified, analytical data characterizing the DWI 901 Site were grouped according to medium and location. This grouping facilitates risk-based decision making for identified source areas and potential localized contamination. Media evaluated include surface soil, subsurface soil, sediment, and groundwater. Surface water data were not available for inclusion in the risk assessment. This represents a data gap, which will be addressed in the upcoming site characterization. Subsurface soil data were removed from initial consideration because direct human contact is unlikely and data were limited. Subsurface soil will be included when it is more fully characterized.

Surface soil data are grouped into two categories: the main DWI 901 Site and the Candora Road Area. This segregation was based on radiological walkover surveys, which indicated a higher level of radiological contamination in the Candora Road Area. Only surface soil [0–0.3 m (0–1 ft)] is considered available for direct contact (EPA 1995), so samples designated as deeper than 0.3 m (1 ft) were excluded from the preliminary risk assessment. Twenty-seven surface soil samples were evaluated at the main DWI 901 Site and 17 samples were evaluated in the Candora Road Area. Four samples collected off-site were used as representative off-site "background" samples.

Sediment data were collected at intervals along Goose Creek, upstream at the Edington Road bridge, on the DWI 901 Site, and downstream to Mary Vestal Park. Ten sediment samples were used for the risk assessment: two upstream, two on site, and six downstream. The two upstream samples were used as representative off-site samples.

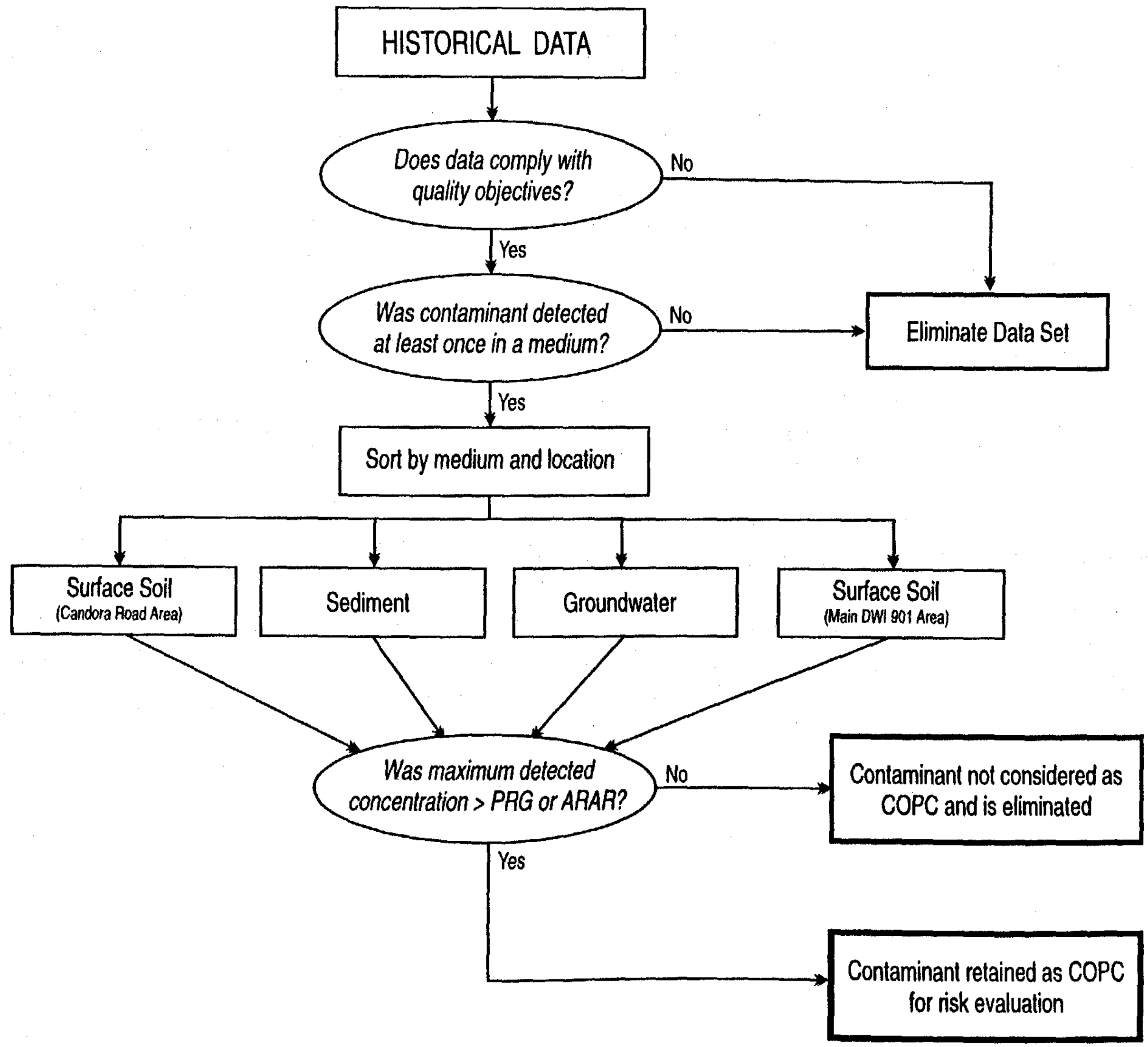
Groundwater data were available from only four monitoring wells. The Halliburton (1994) investigation sampled two wells and analyzed for a complete list of analytes. The PRC (1993b) investigation sampled two wells and analyzed for metals only. Two off-site wells were used as representative background, both sampled during the Halliburton (1994) investigation. Additional groundwater data will be available following the site characterization activities.

4.1.2 Identification of COPCs

The identification of COPCs follows a systematic screening process (Fig. 4.1) detailed in the EPA-Region IV supplemental guidance to Risk Assessment Guidance for Superfund (RAGS) (EPA 1995). The purpose of the screening is to reduce the number of chemicals addressed in the preliminary risk assessment by initially identifying the COPCs that are most likely to contribute to an unacceptable risk at the DWI 901 Site. The following sections describe the screening process used for the DWI 901 Site.

The maximum concentrations in soil, sediment, and groundwater were compared to risk-based PRGs obtained from *Preliminary Remediation Goals for Use at the U.S. Department of Energy Oak Ridge Operations Office* (Energy Systems 1995) (Appendix C). PRGs are chemical-specific contaminant concentrations for a medium based on land use combinations. They are calculated in accordance with RAGS Part B guidance (EPA 1991) to assess whether a particular compound presents a hazard. PRGs are contaminant concentrations in environmental media that would result in carcinogenic risk of 1×10^{-6} or a HI of 0.1 under the specified conditions of exposure. For this screening, health-protective, residential land use scenario default exposure PRGs were used.

A number of compounds reported as not detected could not be eliminated as COPCs because their associated detection limits exceeded PRGs. These compounds are identified in the screening tables presented in Appendix C. Since the actual concentrations are uncertain, these compounds are not included in the quantitative risk assessment. There are also a number of detected compounds for which no PRG is calculated. These compounds are also considered COPCs; however, they can only be evaluated qualitatively.



JE	Fig. 4.1	**Screening methodology for chemicals of potential concern** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96-12719.CDR-2	DRAWING DATE: OCTOBER 18, 1996 TG

Naturally occurring inorganics and radionuclides were also screened against background concentrations. Additionally, maximum concentrations were compared to ARARs. Those chemicals exceeding regulatory levels were retained for use in the quantitative risk assessment, and all others were eliminated.

COPCs were identified for each medium (surface soil, sediment, and groundwater) at the DWI 901 Site. Final lists of COPCs identified in surface soil, sediment, and groundwater for inclusion in this risk assessment are summarized in Appendix C. Surface soil COPCs for the DWI 901 Site included 11 metals, 6 dioxins furans, 4 PCBs, 6 radionuclides, and 5 SVOCs, while COPCs for the Candora Road Area included 11 metals, 6 dioxin/furans, 3 PCBs, 9 radionuclides, and 6 SVOCs. Sediment COPCs included six metals, two PCBs, and three SVOCs. Groundwater COPCs included nine metals and isotopic uranium.

4.1.3 Calculation of Representative Exposure Point Concentrations

Both mean (average) and reasonable maximum exposure (RME) concentrations were calculated for each data set associated with COPCs to assess the range of potential risks at the DWI 901 Site. RME concentrations are identified as the lesser of the 95 percent upper confidence level of the mean (UCL_{95}) or the maximum measured concentration.

During the calculation of representative exposure point concentrations, several potential problems with the existing data were identified that likely caused the values to exceed actual contamination concentrations at the DWI 901 Site. The most notable factors were the use of biased methodologies to collect surface soil samples and the use of very shallow sample intervals [as little as a 0–5-cm (0–2-in.) sample depth].

The first factor, biased sampling regimes, is likely to have the most pronounced effect on the radiological data, but also may affect the nonradiological data sets. Both of the most recent investigations from which the best data were derived used a variety of biasing mechanisms to bound the magnitude of the contamination concentrations at the DWI 901 Site. Halliburton took samples deliberately located within areas likely to exhibit contamination based on previous sampling efforts, surface drainage features, the presence of oily stains, and the presence of structures likely to be associated with handling and generating contamination. All of these techniques would have the potential for locating samples within areas exhibiting significantly higher concentrations of radiological and nonradiological contaminants than in the general site soils. WESTON used the results of their Phase I gross alpha/gross beta samples, along with surface surveying techniques, to deliberately collect their Phase II samples only within grids expected to have above-background levels of contamination, and then further biased the sample locations by placing these samples in locations exhibiting the highest radiological readings within those grids. Also, dioxin/furan samples were collected only within grids within which PCBs or dibenzofuran were detected, as well as in three additional suspected areas.

The second biasing factor, shallow sample intervals, has a more uncertain effect. Whenever contamination deposition is associated with surface spills, contaminant concentrations are generally expected to decrease with depth. Since, for the majority of the DWI 901 Site, it is theorized that surface deposition was the primary mechanism by which contamination was released into the environment, it is expected that the collection of samples over intervals of 0–7.5 cm (0–3 in.) would overestimate the actual concentrations averaged over the full surface soil depth of 0–0.3 cm (0–1 ft).

One example of the effect of the biased sampling approach can be illustrated by comparing predicted average and RME ^{226}Ra concentrations in the Candora Road Area, 630 and 1,710 pCi/g, respectively, to the range of measured exposure rates in that area, 20 to 210 μR/hour. Since the calculated average concentration should be representative of concentrations across the entire area, and since exposure rate measurements also are representative of general site conditions, these two measurements should be comparable. Experience with the Uranium Mill Tailings Remedial Action Program has shown a rough correlation of 2.5 μR/hour per pCi/g ^{226}Ra in surface soils. Using this rule of thumb, the expected range of ^{226}Ra in this area would be approximately 8–80 pCi/g. It can be inferred, therefore, that the use of the biased sample concentrations may have overestimated the ^{226}Ra concentrations by a factor of at least 8 and perhaps as high as 200.

Several methods were considered to compensate for these biasing mechanisms. For example, since WESTON did not sample grids expected to have background levels of radionuclides, a representative concentration equal to the average background concentrations (typically 1–2 pCi/g) could have been used for grids not sampled. Another option would have been to use the surface gamma exposure rates to estimate ^{226}Ra concentrations in place of using the soil sample results. However, any such techniques would introduce additional unquantifiable uncertainties into the risk assessment process and would tend to lower the resultant predicted risks. It was decided to use the values generated by the two most recent investigations without modification to remain conservative in the risk estimates and to avoid inappropriately excluding contaminants of concern. It should be recognized that the risks predicted by using mean and RME values derived from biased sampling approaches are themselves biased high and should be viewed as upper-bound estimates of actual site risks, it is possible that the concentrations and the risks are overestimated by several orders of magnitude. The effects of these uncertainties are discussed in Section 4.5 and in Appendix C.

4.2 EXPOSURE ASSESSMENT

The exposure assessment addresses the environmental fate and transport of COPCs 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. This section also estimates the concentrations of radiological and COPCs at points of human exposure, presents the conceptual site model, describes exposure scenarios, develops information on exposure pathways, and determines receptor intakes (doses). Appendix C provides the exposure assessment assumptions. RME and mean estimates are presented for radiation dose and chemical intakes within each scenario. Section 4.6 discusses the uncertainties of the exposure assessment.

Fate and Transport Mechanisms. Following release from sources, contaminants may migrate in environmental media by any of several transport mechanisms as shown in Figure 4.2. Qualitative evaluation of fate and transport helps to identify media currently receiving contaminants released from the DWI 901 Site and the Candora Road Area. 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, resulting in human exposure at the site. Plant uptake, bioaccumulation in animals ingesting plants, and subsequent human ingestion of contaminated vegetation and animals is not currently considered an important release mechanism to humans. However, it is considered important in the future because the residential scenarios are considered for the future scenario. Although surface water data are unavailable, surface water runoff is considered a significant transport mechanism.

Contaminant Concentrations. Contaminant concentrations were determined by sampling and radiation survey measurements. The data are summarized in Appendix C of the baseline risk assessment and presented as the RME and mean (average) concentrations for contaminants identified as COPCs. RME is defined as the UCL_{95} for exposure parameters and describes a

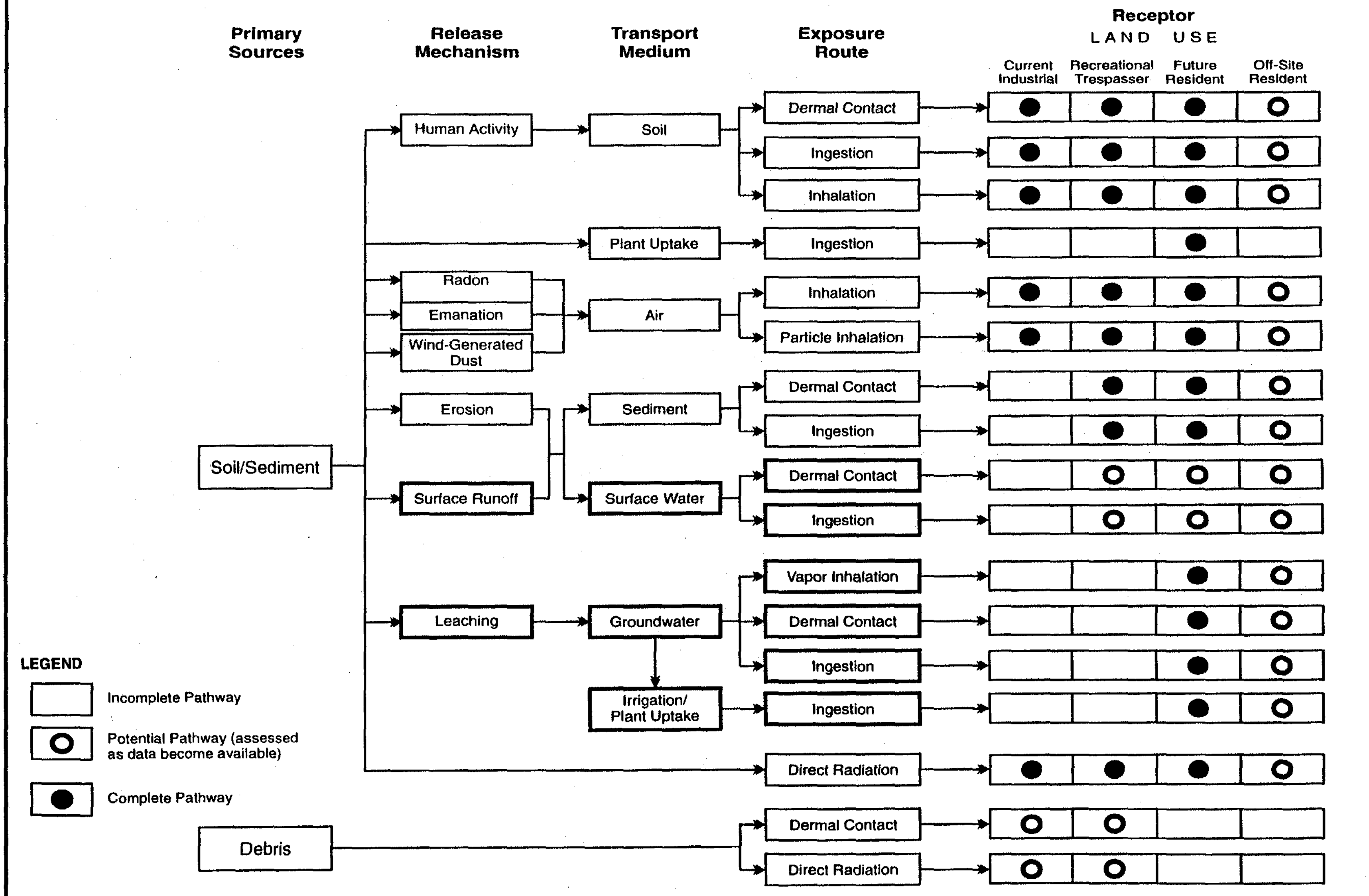


Fig. 4.2

Conceptual site model

DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-20 / RI/FS

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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 RA decisions. In identifying primary pathways of exposure at each location, current and plausible future land uses of the properties and surrounding areas were considered.

4.2.1 Characterization of Exposure Setting

The exposure setting for the DWI 901 Site is described briefly in terms of 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. Since contaminant concentrations in the Candora Road Area were significantly greater than those found in the remainder of the DWI 901 Site, separate analyses were conducted for both areas for each of the scenarios described below.

4.2.2 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 to a residential setting.

Table 4.1 summarizes both scenario descriptions.

4.2.2.1 Current use scenarios

Receptors considered at the site are employees who may work at the DWI 901 Site and in the Candora Road Area. Although no employees are currently on site, there are individuals who perform occasional work activities there. These employees are assumed to work at least 6 months each year outdoors. Employees are currently using the municipal water supply; therefore, the current use scenario does not include a drinking water exposure pathway for employees.

Receptors considered at the DWI 901 Site and the Candora Road Area consist of trespassers who spend time wandering on the site. This scenario assumes the trespasser, an adolescent, is not limited by boundaries at the site and roams in either the Candora Road Area or on the remainder of the DWI 901 Site. This scenario also assumes the trespasser wades in the creek. The assumption that the trespasser is an adolescent is conservative. The trespasser may also be an adult.

Table 4.1. Scenario/receptor descriptions, DWI 901 Site and Candora Road Area, Knoxville, Tennessee

Employee at DWI 901 Site/Candora Road Area
Current:
The RME and average exposed current employee are estimated to spend 8 hours/day on the site. Eight hours/day (RME) or 4 hours/day (mean) is spent outside maintaining or monitoring the property. The employee works 125 days/year and does not consume drinking water from the site.
Future:
The RME and average exposed 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. The future employee does not consume contaminated drinking water from the site.
Child and adolescent wading in Goose Creek
Future:
The RME and average exposed individuals are represented as a child and an adolescent wading in the creek on the DWI 901 Site. These receptors are 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.
Adolescent trespasser at the DWI 901 Site
Current and Future:
The average and RME exposed adolescent trespasser is assumed to wander on the DWI 901 Site and in the Candora Road Area. This scenario assumes the trespasser is not limited by site boundaries.
On-site resident
Future:
The RME and average exposed, future on-site resident is assumed to reside at the DWI 901 Site and in the Candora Road Area. The on-site resident consumes contaminated groundwater at the DWI 901 Site 350 days/year for 30 years. A child is also assumed to reside at the site 350 days/year for 6 years.

DWI = David Witherspoon, Inc.
RME = reasonable maximum exposure

4.2.2.2 Future use scenarios

Hypothetical future use scenarios are considered for employees, residents, and adolescent trespassers. The future employee scenario assumes that the DWI facility will remain a commercially operated industrial site. Future on-site receptors are assumed to be employees who spend the majority of their time working indoors. While indoors, employees are assumed to be exposed to radon 8 hours/day and spend 1 hour/day outdoors. As in the current scenario, these employees also use the existing municipal water supply and do not consume water drawn from on-site wells.

The residential land use scenario assumes that the DWI 901 Site has been abandoned and the area is available for residential use. This land use scenario assumes groundwater is used as the sole drinking water supply. Although no surface water data are available, this scenario evaluates recreational exposures to sediments along Goose Creek while on the DWI 901 Site. Current exposure-point concentrations will be used to assess future residential risk.

Trespassing at the site also cannot be discounted. Therefore, the trespasser scenario assumes an adolescent wanders on the DWI Site or in the Candora Road Area. This scenario assumes the trespasser is not limited by boundaries at the site and contacts sediments along Goose Creek.

4.2.3 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 (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.

4.2.4 Summary of Exposure Pathways Included in Quantitative Assessment

Figure 4.2 shows potential exposure pathways at the DWI 901 Site. Complete exposure pathways exist when a receptor could be exposed to a contaminated source. Although debris is abundant at the DWI 901 Site and may be a potential source of contamination, this exposure pathway was not included in the quantitative risk evaluation because it has not been characterized. Table 4.2 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 the DWI 901 Site because groundwater is not currently used at the site for drinking or other purposes. Groundwater usage by an on-site resident is considered in the future land use scenario for a conservative risk approach.

Table 4.2. Screening of potential exposure pathways for various media, DWI 901 Site, Knoxville, Tennessee

Potential exposure route	Potential receptors	Pathway included in assessment	Screening rationale
		Soil	
Direct radiation (radiological contaminants only)	Current employee	Yes	Radiological COPCs assessed
	Current trespasser	Yes	Radiological COPCs assessed
	Future resident	Yes	Radiological COPCs assessed
Dermal contact	Current employee	Yes	All COPCs assessed
	Current trespasser	Yes	All COPCs assessed
	Future resident	Yes	All COPCs assessed
Ingestion	Current employee	Yes	All COPCs assessed
	Current trespasser	Yes	All COPCs assessed
	Future resident	Yes	All COPCs assessed
		Air from soil	
Particulate inhalation	Current employee	Yes	All COPCs assessed
	Future employee	Yes	All COPCs assessed
	Future on-site resident	Yes	All COPCs assessed
	Future off-site resident	Yes	All COPCs assessed
	Trespasser	Yes	All COPCs assessed
Vapor inhalation	Current employee	No	No applicable COPCs
	Future employee	No	No applicable COPCs
	Future on-site resident	No	No applicable COPCs
	Future off-site resident	No	No applicable COPCs
	Trespasser	No	No applicable COPCs
Radon inhalation	Current employee	Yes	Radiological COPCs assessed
	Future employee	Yes	Radiological COPCs assessed
	Future on-site resident	Yes	Radiological COPCs assessed
	Future off-site resident	Yes	Radiological COPCs assessed
	Trespasser	Yes	Radiological COPCs assessed
		Sediment	
Direct radiation	Current employee	No	Recreational use not considered
	Future employee	No	Recreational use not considered
	Future on-site resident	Yes	Radiological COPCs assessed
	Future off-site resident	Yes	Radiological COPCs assessed
	Trespasser	Yes	Radiological COPCs assessed
Ingestion	Current trespasser	No	Recreational use not considered
	Future employee	No	Recreational use not considered
	Future on-site resident	Yes	All COPCs assessed
	Future off-site resident	Yes	All COPCs assessed
	Trespasser	Yes	All COPCs assessed
Vapor inhalation	Current employee	No	No applicable COPCs
	Future employee	No	No applicable COPCs
	Future on-site resident	No	No applicable COPCs
	Future off-site resident	No	No applicable COPCs
	Trespasser	No	No applicable COPCs

Table 4.2. (continued)

Potential exposure route	Potential receptors	Pathway included in assessment	Screening rationale
Dermal contact	Current employee	No	Recreational use not considered
	Future employee	No	Recreational use not considered
	Future on-site resident	Yes	All COPCs assessed
	Future off-site resident	Yes	All COPCs assessed
	Trespasser	Yes	All COPCs assessed
	Surface water		
Ingestion	Current employee	No	Data currently unavailable
	Future employee	No	Data currently unavailable
	Future on-site resident	No	Data currently unavailable
	Future off-site resident	No	Data currently unavailable
	Trespasser	No	Data currently unavailable
Dermal contact	Current employee	No	Data currently unavailable
	Future employee	No	Data currently unavailable
	Future on-site resident	No	Data currently unavailable
	Future off-site resident	No	Data currently unavailable
	Trespasser	No	Data currently unavailable
Vapor inhalation	Current employee	No	Data currently unavailable
	Future employee	No	Data currently unavailable
	Future on-site resident	No	Data currently unavailable
	Future off-site resident	No	Data currently unavailable
	Trespasser	No	Data currently unavailable
	Groundwater		
Ingestion	Current employee	No	No current groundwater usage
	Future employee	Yes	Radiological COPCs assessed
	Future on-site resident	Yes	All COPCs assessed
	Future off-site resident	Yes	All COPCs assessed
	Trespasser	No	No current groundwater usage
Dermal contact	Current employee	No	No current groundwater usage
	Future employee	Yes	Radiological COPCs assessed
	Future on-site resident	Yes	All COPCs assessed
	Future off-site resident	Yes	All COPCs assessed
	Trespasser	No	No current groundwater usage
Vapor inhalation	Current employee	No	No applicable COPCs
	Future employee	No	No applicable COPCs
	Future on-site resident	No	No applicable COPCs
	Future off-site resident	No	No applicable COPCs
	Trespasser	No	No applicable COPCs
	Food		
Ingestion	Future on-site resident	Yes	Mechanism for food contamination (radiological COPCs only)
	Future off-site resident	Yes	Mechanism for food contamination (radiological COPCs only)
	Debris		
Dermal contact	Trespasser	No	Debris contamination has not been quantified

COPC = chemical of potential concern

DWI = David Witherspoon, Inc.

4.2.5 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 COPC. 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 dermal contact and generates a calculated annual dose of radionuclides (mrem per year) and a daily chemical intake per unit body weight (milligrams/kilogram 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 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.

Additionally, the Integrated Exposure Uptake Biokinetic (IEUBK) model was used to evaluate blood lead levels in young children. The model is a quantitative method for estimating detrimental environmental lead levels due to the lack of toxicity values for lead. The model predicts blood lead levels in the most sensitive populations (6 months to 7 years) exposed to lead in air, dust, drinking water, soil and paint. The results can then be compared to an adverse effect level of 10 μg/dL.

4.2.6 Summary of Exposure Estimates

4.2.6.1 Summary of radiological exposure estimates

Maximally Exposed Individuals. Table 4.3 shows the total, annual, radiological, effective dose equivalent (EDE) estimates for the DWI 901 Site. Contributions from direct exposures to gamma radiation, soil ingestion, inhalation of particulates, and inhalation of radon and its daughters were calculated for workers in current and future scenarios. Again, because there is an existing municipal water system, the drinking water pathway was incomplete in the current and future employee scenarios. Appendix C shows incremental dose calculation methodology and associated components for the dose analysis for all pathways. For all scenarios, the maximum predicted doses are presented.

Total doses for the current worker exposed while working outdoors in the Candora Road Area were 5,056 mrem/year for the RME exposure and 4,090 mrem/year for the mean exposure.

Table 4.3. Total exposure dose summary, DWI 901 Site, Knoxville, Tennessee

Location	Receptor	Dose (mrem/year)	
		Mean	RME
Current use scenario			
Remainder of DWI 901 Site	Employee	23	34
Candora Road Area	Employee	4,090	5,056
Remainder of DWI 901 Site	Trespasser	17	773
Candora Road Area	Trespasser	0.12	5.3
Future use scenario			
Candora Road Area	Employee	7,827	37,330
Remainder of DWI 901 Site	Employee	43.8	152
Candora Road Area	Resident	Adult: 31,380 Child: 31,480	99,180
Remainder of DWI 901 Site	Resident	Adult: 176 Child: 176	463

DWI = David Witherspoon, Inc.
mrem = millirem
RME = reasonable maximum exposure

The largest component of the predicted dose, direct radiation, is based on modelled exposures to gamma-emitting radionuclides, most notably the ^{214}Bi daughter of ^{226}Ra. Based on measured exposure rates within this area, it is likely that the modelled doses are overestimates. However, since definitive exposure rate measurements are not available, the modelled doses are retained to provide conservative estimates.

Total doses for the current worker exposed while working outdoors on the remainder of the DWI 901 Site were 34 mrem/year for the RME exposure and 23 mrem/year for the mean exposure. The largest component of the current dose in this area was direct radiation, most notably the ^{214}Bi daughter of ^{226}Ra, and is also likely to overestimate actual exposures.

Doses for the trespasser scenario within the Candora Road Area were 773 mrem/year for the RME exposure, and 17 mrem/year for the mean exposure. As was the case for the employee scenarios, the largest component of the predicted dose was direct radiation, which was based on modelled exposures to gamma-emitting radionuclides, most notably ^{226}Ra. Based on measured exposure rates within this area, it is likely that these modelled doses are overestimates.

Doses for the trespasser scenario within the remainder of the DWI 901 Site were 5.3 mrem/year for the RME scenario and 0.12 mrem/year for the mean scenario.

Total doses for the future Candora Road Area worker were 37,330 mrem/year for the RME and 7,827 mrem/year for the mean. More than half of the total future dose (up to 77 percent) is from inhalation of radon and its daughters while working indoors. For this exposure scenario, it was assumed that a new slab-on-grade structure was constructed on top of the existing contaminated soil. Since existing structures likely were constructed before the soils became contaminated, and since the construction of new structures likely would relocate most or all of the contaminated surface soils, it is likely that these predicted doses are overestimates of actual doses that would be received.

Total doses for the future worker located within the remainder of the DWI 901 Site were 152 mrem/year for the RME and 44 mrem/year for the mean. Radon and radon daughter inhalation doses were the largest dose components. This calculation is likely to be an overestimate of actual doses that would be received.

Doses for future on-site residents within the Candora Road Area were 99,180 mrem/year in the RME scenario, and 31,380 and 31,480 mrem/year in the mean adult and child scenarios. The majority of this dose (73 percent) comes from inhalation of radon and its daughters.

Doses for future on-site residents within the remainder of the DWI 901 Site were 463 mrem/year in the RME scenario, and 176 mrem/year for the mean adult and child scenarios. The majority of this dose comes from inhalation of radon and its daughters.

4.2.6.2 Summary of chemical intake estimates

Chemical intakes through the exposure routes previously described were estimated for COPCs in soil. 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 milligram/kilogram 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. Chemical intake estimates for the DWI 901 Site are presented in Appendix C.

4.3 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 the impacts of toxicity.

4.3.1 Radiation Toxicity

The potential health effects associated with exposure to radionuclides at the DWI 901 Site are caused by ionizing alpha, beta, and gamma radiation. 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. Therefore, genetic effects are not the focus of this toxicity assessment, and radiological risks are evaluated only with respect to incremental cancer probabilities according to EPA guidance (EPA 1989). 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 because 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 DWI 901 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 the DWI 901 Site, where all exposures are longer term and relatively 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).

4.3.2 Methods of Evaluating Radiation Toxicity

A risk factor of 6×10^{-7}/mrem (EPA 1989; National Research Council 1990) can be 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 1989). It is a lifetime average value and believed to be representative of conditions defined for the exposure scenarios at the DWI 901 Site.

The Biological Effects of Ionizing Radiation (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 1989). 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 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 1989). 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 C presents radiological carcinogenic risk.

4.3.3 Chemical Toxicity

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.

Two COPCs (arsenic and chromium) are classified as known Class A human carcinogens. Appendix C summarizes toxicological properties of the COPCs, including carcinogenic and noncarcinogenic factors. The table briefly describes chemical routes of exposure, critical effects, and carcinogenicity of the chemicals.

4.3.3.1 Methods of evaluating chemical toxicity

Appendix C presents toxicity values used in the risk characterization of COCs. This table includes supporting toxicological information and 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., HIs) 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).

4.3.3.2 Chemicals for which EPA toxicity values are available

PAHs assume the oral and inhalation slope factors for benzo(a)pyrene and dioxin/furan assume the oral and inhalation slope factors for 2,3,7,8-TCDD. Inhalation slope factors are available for only 10 carcinogenic COC. Inhalation reference concentrations are available for three of the noncarcinogenic COPCs.

4.4 RISK CHARACTERIZATION

Risk characterization is the summation of information developed from the site characterization, exposure assessment, and toxicity assessment. Human receptors include employees, on-site residents, off-site residents, children wading in Goose Creek, and adolescent trespassers. Radiological risks and chemical risks are estimated separately. The overall human health risk and associated uncertainties from exposure to radiological and chemical contaminants are discussed.

For the radiological assessment, risk is defined as the excess 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, which is the goal EPA outlined in the National Contingency Plan (NCP).

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 is called a HQ. HQs for each COPC are then summed to obtain a HI for the specific pathway. A HI greater than one has been defined as the level of concern for potential, adverse, noncarcinogenic health effects (EPA 1989a).

4.4.1 Risk Characterization Methodology

The first step in 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 COPCs included in the quantitative exposure assessment was also evaluated. Toxicity values consistent with the assumed exposure for the DWI 901 Site were identified for use in the quantitative risk assessment.

4.4.2 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 DWI 901 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 EPA recommendations (EPA 1989), 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 EDEs resulting from a 1-year exposure, in mrem per year, for all exposure routes.

The risk is estimated as follows:

$$Risk = (Dose)\,(ED)\,(RF)$$

where

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

EPA cancer slope factors, as presented in the 1995 Health Effects Assessment Summary Tables tables (EPA 1993a), were used to assess radiological risk.

The radiological risks associated with exposures to contaminants at the DWI 901 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}/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.

4.4.3 Quantifying Chemical Risk and HI

4.4.3.1 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. The slope factor converts estimated daily intakes averaged over a lifetime of exposure directly to the incremental risk of an individual developing cancer. Cancer risk estimates can be compared to the EPA target risk range of 1×10^{-4} to 1×10^{-6}.

4.4.3.2 Hazard indexes

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

HQs for each chemical in each exposure pathway are summed to obtain the HI, which allows assessment of the overall potential for noncarcinogenic health effects (EPA 1989a). When the HI exceeds 1, there is a potential for adverse health effects to occur.

4.4.4 Risk Estimates for the DWI 901 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).

4.4.5 Radiological Risk Estimates

Table 4.4 presents current and future radiological risks for the DWI 901 Site and the Candora Road Area. Potential risks as a result of exposure to contaminants found at the sites were estimated for reasonable current uses and hypothetical future uses of the site properties.

Table 4.4. Summary of radiological risk, DWI 901 Site, Knoxville, Tennessee

Location	Receptor	Risk[a]	
		Mean	RME
Current use scenario			
Candora Road Area	Employee	4×10^{-3}	3×10^{-2}
DWI 901 Site	Employee	2×10^{-5}	2×10^{-4}
Candora Road Area	Trespasser	9×10^{-5}	4×10^{-3}
DWI 901 Site	Trespasser	7×10^{-7}	3×10^{-5}
Future use scenario, all pathways			
Candora Road Area	Employee	3×10^{-3}	2×10^{-2}
DWI 901 Site	Employee	1×10^{-4}	1×10^{-3}
Candora Road Area	Resident	Adult: 1×10^{-1} Child: 7×10^{-2}	1
DWI 901 Site	Resident	Adult: 6×10^{-4} Child: 4×10^{-4}	6×10^{-3}

[a]Numbers are rounded to one significant figure.

DWI = David Witherspoon, Inc.
RME = reasonable maximum exposure

4.4.5.1 Current use scenarios

Estimated RME and mean carcinogenic risks for occupational workers spending time both indoors and outdoors on the Candora Road Area portion of the DWI 901 Site were 3×10^{-2} and 4×10^{-3}, respectively. Estimated RME and mean carcinogenic risks for occupational workers spending time both indoors and outdoors on the remainder of the DWI 901 Site were 2×10^{-4} and 2×10^{-5}, respectively. Gamma irradiation contributes the largest percentage of the total radiological risk to the worker (Appendix C). As explained earlier, this is likely an overestimate of actual site risks under this scenario.

Estimated RME and mean carcinogenic risks for hypothetical trespassers on the Candora Road Area portion of the DWI 901 Site were 4×10^{-3} and 9×10^{-5}, respectively. Estimated RME and mean carcinogenic risks for hypothetical trespassers on the DWI 901 Site were 3×10^{-5} and 7×10^{-7}, respectively. Gamma irradiation contributes the largest percentage of the total radiological risk.

4.4.5.2 Hypothetical, future use scenarios

A hypothetical future employee in the Candora Road Area has estimated RME and mean risks of 2×10^{-2} and 3×10^{-3}, respectively. A hypothetical future employee on the remainder of the DWI 901 Site has estimated RME and mean risks of 1.0×10^{-3} and 1.0×10^{-4}, respectively. Gamma irradiation and radon/radon inhalation account for the majority of these risks.

For the hypothetical on-site resident in the Candora Road Area, the RME risk is 1 (i.e., above the linear range of the slope factors and thus interpreted as approaching a near certainty of cancer), and the mean is 1.0×10^{-1} and 7.0×10^{-2} for the adult and child receptors, respectively. For the hypothetical on-site resident on the remainder of the DWI 901 Site, the RME risk is 6.0×10^{-3}, and the mean risks are 6.0×10^{-4} and 4.0×10^{-4} for the adult and child receptors, respectively. Direct radiation and radion/radon daughter inhalation account for the majority of the risk.

4.4.6 Chemical Risk and HI Estimates

Table 4.5 presents risk and HI estimates associated with each exposure pathway for the DWI 901 Site. Risk or hazard is a function of exposure and toxicity. Therefore, chemical intake (exposure) estimates are converted to cancer risk and HIs 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, HIs, and chemical risk summary tables. 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 radiological risks.

4.4.6.1 Current use scenarios

Estimated total RME and mean carcinogenic risks to an industrial employee at the DWI 901 Site are 2×10^{-3} and 3×10^{-5}, respectively, and the total RME and mean HIs are 4 and 0.3, respectively. The total estimated RME and mean risks to an employee in the Candora Road Area is 6×10^{-4} and 9×10^{-6}, respectively. Additionally, the RME and mean HI are 33 and 4, respectively. Both RME risk estimates exceed the upper bound of the EPA target risk range, 1×10^{-4}. The mean HI at the Candora Road Area and the RME HIs at DWI 901 Site exceed the adverse effect level of 1.

Table 4.5. **Summary of chemical risks, DWI 901 Site, Knoxville, Tennessee**

Location	Receptor	Risk[a] Mean	Risk[a] RME	Hazard index Mean	Hazard index RME
Current use scenario					
Candora Road Area	Employee	9×10^{-6}	6×10^{-4}	4	33
DWI 901 Site	Employee	3×10^{-5}	2×10^{-3}	0.3	4
Candora Road Area	Trespasser	5×10^{-6}	3×10^{-4}	1	61
DWI 901 Site	Trespasser	3×10^{-6}	2×10^{-4}	0.3	4
Future use scenario, all pathways					
Candora Road Area	Employee	3×10^{-5}	2×10^{-3}	8	66
DWI 901 Site	Employee	2×10^{-5}	1×10^{-3}	4	9
Candora Road Area	Resident	Adult: 7×10^{-5} Child: 4×10^{-4}	4×10^{-3}	Adult: 23 Child: 166	166 1,359
DWI 901 Site	Resident	Adult: 1×10^{-4} Child: 3×10^{-4}	3×10^{-3}	Adult: 7 Child: 20	34 126

[a]Numbers are rounded to one significant figure.

DWI = David Witherspoon, Inc.
RME = reasonable maximum exposure

4.4.6.2 Future use scenarios

Total RME and mean carcinogenic risks to a future employee at the DWI 901 Site are estimated to be 1×10^{-3} and 2×10^{-5}, respectively, and the total RME and mean HI are 9 and 4, respectively. The total estimated RME and mean risk to an employee in the Candora Road Area are 2×10^{-3} and 3×10^{-5}, respectively. Additionally, the RME and mean HIs are 66 and 8, respectively. Appendix C presents the calculations and exposure pathway summary tables. Both RME risk estimates exceed the upper bound of the EPA target risk range, 1×10^{-4}. Additionally, RME and mean HI exceed the adverse effect level of 1. Risk to employees at both sites is driven by soil ingestion and dermal contact with soil. The cumulative mean risk estimates are within the EPA target range, suggesting that risks are acceptable for the exposures evaluated.

Total RME and mean carcinogenic risk estimates for an adult living on the DWI 901 Site are 3×10^{-3} and 1×10^{-4}, respectively, and the total RME and mean HI are 34 and 7, respectively. The total estimated RME risk to an adult resident at the Candora Road Area is 4×10^{-3}. In addition, the RME and mean HIs are 166 and 23, respectively. Appendix C presents these calculations. For this scenario, the primary exposure pathways contributing to these risk estimates are ingestion of groundwater, soil ingestion, and dermal contact with soil. While RME risk estimates exceed the upper bound of the EPA target risk range, 1×10^{-4}, mean estimates are less than the upper bound of the EPA target risk range. HIs estimated for both sites are greater than 1, suggesting that adverse health effects are likely to occur based on the exposures evaluated.

Total RME and mean carcinogenic risk estimates for a child living on the DWI 901 Site are 2×10^{-3} and 3×10^{-4}, respectively, and the total RME and mean HIs are 126 and 20. The total estimated RME and mean risk to a child resident in the Candora Road Area are 3×10^{-3} and 4×10^{-4}, respectively. In addition, the RME and mean HI are 1,359 and 166, respectively. Appendix C presents these calculations. For this scenario, the primary exposure pathways contributing to these risk estimates are ingestion of groundwater, soil ingestion, dermal contact with soil, and dermal contact with sediment. All exposure pathways except particulate inhalation contribute to the hazard estimates. RME and mean risk estimates exceed the upper bound of the EPA target risk range, 1×10^{-4}. Estimated HI for both sites are greater than 1, suggesting that adverse health effects are likely to occur based on the exposures evaluated.

Total RME and mean carcinogenic risks to an adolescent trespasser at the DWI 901 Site are estimated to be 2×10^{-4} and 3×10^{-6}, respectively, and the total RME and mean HI are 4 and 0.3, respectively. The total estimated RME and mean risk to an adolescent in the Candora Road Area are 3×10^{-4} and 5×10^{-6}, respectively. Additionally, the RME and mean HI are 61 and 1, respectively. Appendix C presents the calculations and exposure pathway summary tables. Both RME risk estimates exceed the upper bound of the EPA target risk range, 1×10^{-4} as well as the adverse effect level of 1. Risk to adolescents at both sites is driven by dermal contact with soil. Both mean risk estimates are less than the upper bound of the EPA target range, suggesting that adverse health effects are not likely to occur based on the exposures evaluated.

Blood lead levels in children were determined using RME and mean exposure point concentrations for lead in soil. Multiple simulations were performed using the IEUBK model. These simulations used the high-end exposure concentration (RME) in soil and household dust to a low-end exposure (mean) as the lead level in soil and zero as the lead level in household dust. All simulations, except the low-end exposure, resulted in blood lead levels exceeding 10 μg/dL in the majority of the age groups. The RME and mean concentrations at the DWI 901 Site were 1,067 and 2,722 mg/kg, respectively. RME and mean concentrations in the Candora Road Area were 1,978 and 8,320 mg/kg, respectively.

4.5 UNCERTAINTY IN THE ASSESSMENT PROCESS

Risks presented in the DWI 901 Site baseline risk assessment are single-point estimates of risk rather than probabilistic estimates. Therefore, it is important 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 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 COPCs,
- exposure assessment variables, and
- toxicity values.

A detailed discussion of each category is presented in Appendix C.

Since the exposure point concentrations were derived from data collected from uncertainty associated with biased sampling strategies, it is likely that actual exposures and risks are overestimated. However, given the magnitude of the exceedances of the EPA target risk range, these overestimates are not likely to impact the basic conclusions of the risk assessment. Even with refined exposure concentration source terms, it is anticipated that the outcome of the risk assessment would be an exceedance of the acceptable risk range.

4.6 SUMMARY OF HEALTH RISK CHARACTERIZATION

4.6.1 Radiological and Chemical Risks

At the DWI 901 Site, radiological risk from soil contaminants in the near surface of the site dominates the baseline risk assessment. In almost every current and future scenario, the EPA's target risk range is exceeded, indicating unacceptable current and future risk. Chemical RME risk to current and future receptors at the DWI 901 Site and in the Candora Road Area exceed the EPA target risk range and the HI of 1 for all exposure pathways evaluated.

This baseline risk assessment concludes that the on-site current and future, radiological RME risks to employees, residents, and trespassers in the Candora Road Area are always unacceptable, and only RME risks to trespassers are within the acceptable risk range for the remainder of the DWI 901 Site. The pathways contributing the majority of the risk are direct radiation and inhalation of radon and its daughters. Inhalation of airborne particulates and incidental ingestion of soil and sediment are minor contributes to risk.

5. PRELIMINARY ECOLOGICAL RISK ASSESSMENT

Since additional data will be collected during supplemental fieldwork activities, a preliminary ERA is being performed. This preliminary ERA involves screening available historic data. Screening helps narrow the scope of subsequent assessment activities by focusing on those aspects of the site that constitute credible potential risks. Chemicals of potential ecological concern (COPECs) can potentially be eliminated through the screening process. Screening can also identify situations that call for emergency responses and data gaps. Preliminary ERAs are only final assessments when they indicate that there are no potential hazards to ecological receptors. Additional lines of evidence (e.g., biological surveys and media toxicity tests) may be required to support or refute the results of the single chemical calculations and provide decision makers with more definitive information on which to base remedial decisions (Suter 1995).

5.1 ECOLOGICAL HAZARD IDENTIFICATION

The hazard identification phase of the preliminary ERA defines the scope of the assessment, the ecological resources at the site, endpoints of the assessment, and exposure pathways.

5.1.1 Scope

The scope of this site ecological risk assessment (SERA) includes benthic macroinvertebrates and terrestrial organisms that may be directly or indirectly exposed to chemicals associated with sources at the DWI 901 Site. Aquatic receptors (i.e., fish) could not be assessed in this preliminary ERA because representative surface water data were not available. Aquatic receptors will, however, be assessed following collection of surface water data during the proposed supplemental fieldwork activities. Terrestrial organisms are assessed for exposure within the boundary of the DWI 901 Site. The assessment of benthic macroinvertebrates is extended to include Goose Creek to the Mary Vestal Park.

Risks to local biota and habitats on the DWI 901 Site exposed to site contaminants can be identified and assessed, even though environmental and toxicological data are limited. Concentration data exist for metals, VOCs, SVOCs, radionuclides, dioxins, and PCBs in environmental media at the DWI 901 Site. No quantitative biological studies were conducted. Contaminants in soil at the site can be released via surface water runoff to Goose Creek, thereby exposing benthic macroinvertebrates directly by contact with and ingestion of sediment. Terrestrial organisms may be exposed to contaminants through the ingestion of soil or contaminated organisms. Terrestrial endpoint species include the meadow vole (herbivorous), white-footed mouse (omnivorous), and short-tailed shrew (vermivorous). Terrestrial plants may be exposed to contaminants present in the soil matrix. The relative risks to classes of organisms exposed to contaminants at the DWI 901 Site is estimated using ratios of the environmental concentrations of contaminants to the toxicity threshold concentrations obtained from published data.

Assessment of ecological risk from radionuclides is not evaluated in this SERA. In human health risk assessment, the primary concern from exposure to radionuclides is increased incidence of cancer at the individual level. In ERA, the concern is for population-level effects, except for T&E species. Because there is little evidence that cancer plays a significant role in wildlife populations (Sample et al. 1995), radionuclides are not considered.

5.1.2 Habitat Characterization

The DWI 901 Site consists of a 3.8-ha (9.5-acre) fenced lot that contains several buildings and scattered debris, including building materials, salvage metal, and large equipment. Approximately 50 percent of the site is covered by asphalt, gravel, and packed-down clay. Goose Creek runs north through the site and is partially covered (26 percent) by culverts. This evaluation considers on-site ecological effects and off-site effects from the surface water drainage, which ultimately flows to Fort Loudoun Lake.

5.1.2.1 Overview of DWI 901 Site habitat

The DWI 901 Site is in the Valley and Ridge Physiographic Province of the Southern Appalachians and is part of the Appalachian oak forest biome (Hammond 1964). Developments have converted the majority of the forests to habitats typical of mixed residential, commercial, and agricultural uses. The DWI 901 Site is in a mixed-use urban setting. Industrial, commercial, and residential properties bound the site. Wooded tracts connected by partially wooded areas in the DWI 901 Site vicinity are an excellent habitat for most wildlife species that tolerate some human interference or disturbances. Plants and animals live in or around these habitats. Aquatic habitats include drainageways, Goose Creek, and Fort Loudoun Lake. Wildlife species on the site are common to those adapted to suburban and semirural environments. Bird species could include sparrows, common crows, mourning doves, mockingbirds, and American robins. Mammalian species are likely to include white-footed mouse, meadow vole, short-tailed shrew, raccoon, cottontail rabbit, opossum, and eastern gray squirrel.

5.1.3 Assessment Endpoints

Assessment endpoints are formal expressions of the actual environmental values that are to be protected. At the DWI 901 Site, the assessment endpoints represent environmental characteristics which, if they were found to be significantly affected (resulting in a reduction in population abundance or production), would indicate the need for further evaluation and possible remediation. The specific endpoints for the DWI 901 Site SERA are discussed in the remainder of this section.

5.1.3.1 Aquatic endpoints

The benthic macroinvertebrate community is the assessment endpoint for aquatic exposures in Goose Creek. The fish community is the assessment endpoint for aquatic exposures in Goose Creek; however, this endpoint will not be addressed until data is collected during the supplemental fieldwork activities.

5.1.3.2 Terrestrial endpoint species

The small mammal and soil invertebrate communities are the mammalian terrestrial endpoints for this assessment. Specific terrestrial species include the meadow vole (herbivorous), white-footed mouse (omnivorous), and short-tailed shrew (vermivorous). The earthworm is the soil invertebrate endpoint species. Plant communities are also a terrestrial endpoint for exposure to soil contaminants.

Terrestrial carnivores were not included as an endpoint because most carnivores inhabit large ranges. These species are less likely to be clearly associated with a specific site such as the DWI 901 Site. In addition, wide-ranging species such as red-tailed hawks are less likely to be regularly associated with a specific contaminated site. Therefore, their level of exposure is likely to be smaller than the selected endpoint species.

5.1.3.3 T&E species

T&E species comprise an additional category of special receptors. The state is currently being consulted regarding any possible occurrences of T&E species on the DWI 901 Site. Critical habitats for federally listed species are administratively designated and protected. No critical or unique habitats have been designated on the DWI 901 Site.

5.1.3.4 Wetlands

Wetlands are considered a special receptor area. A review of the U.S. Department of Interior, National Wetlands Inventory Map of the Knoxville Quadrangle indicates that there are no identified wetlands on the DWI 901 Site. A site-specific survey is being conducted.

5.1.4 Site Conceptual Model

The site conceptual model graphically represents the relationships between contaminant sources, endpoint receptors, and potential endpoint receptors. It is not intended to show all of the possible sources, routes of transport, modes of exposure, or effects. Rather, it includes the site sources, receptors that are designated as assessment endpoint species or communities, and the major routes that result in exposure. The conceptual model is illustrated in Figure 5.1.

5.2 EXPOSURE ASSESSMENT

The exposure assessment describes the exposure routes and models used to calculate exposure.

5.2.1 Exposure Routes

5.2.1.1 Aquatic biota

The primary route of exposure for benthic macroinvertebrates is through ingestion of contaminated sediment.

5.2.1.2 Soil invertebrates

Exposure routes for earthworms include ingestion of and dermal contact with contaminated soil.

5.2.1.3 Terrestrial wildlife

Potential routes of exposure for terrestrial wildlife endpoint species include ingestion of food (either plant or animal) and surface water. Also, animals may ingest soil incidentally while burrowing, foraging, or purposefully to meet nutritional needs. The total exposure experienced by terrestrial wildlife is represented by the sum of the exposures from each individual source (e.g., food, water). Since surface water data are not available, total exposure from food and incidental soil ingestion were determined.

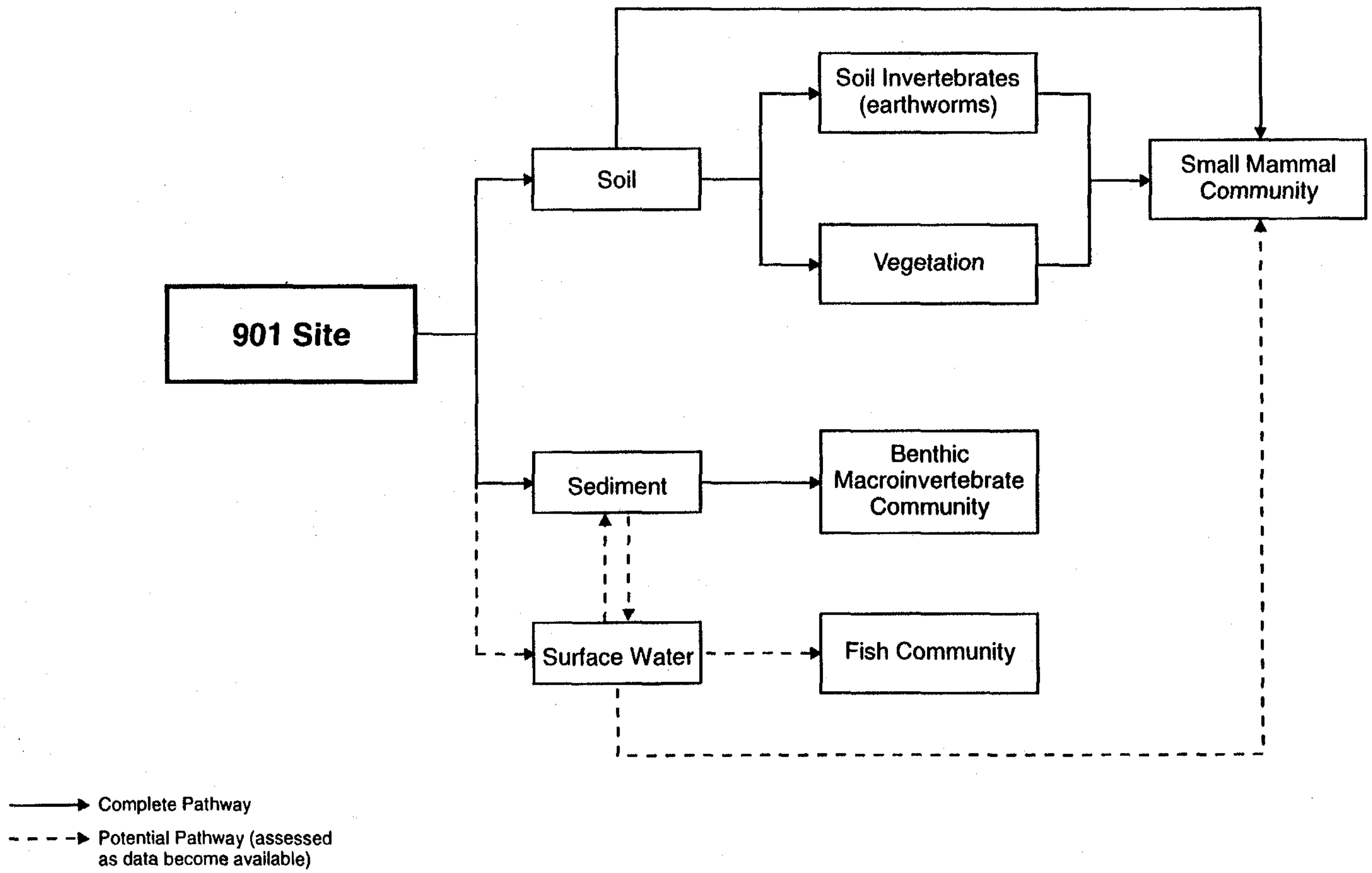

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Fig. 5.1

Ecological conceptual model

DOE - David Witherspoon Inc., 901 Site - Knoxville, Tennessee

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5.2.2 Exposure Models

5.2.2.1 Aquatic biota

Sediment concentrations are relatively constant and benthic macroinvertebrates are nearly immobile. Therefore, the RME for benthic macroinvertebrates is the maximum observed concentration in sediment. Quantitative models are not required for exposure of macroinvertebrates to sediments.

5.2.2.2 Soil invertebrates

Soil concentrations are relatively constant and invertebrates are nearly immobile. Therefore, the RME for earthworms is the maximum observed concentration in soil. Exceedence of ecotoxicological benchmarks at any location implies a potential risk to receptors.

5.2.2.3 Terrestrial wildlife

As terrestrial wildlife move through the environment, they may be exposed to contamination through three pathways: oral, dermal, or inhalation. Oral exposure occurs through the consumption of contaminated food, water, and soil. Dermal exposure occurs when contaminants are absorbed directly through the skin. Inhalation exposure occurs when volatile compounds or fine particulates are respired into the lungs. Dermal exposure and inhalation of contaminants are assumed to be negligible; therefore, only the oral exposure pathway is addressed in this assessment. The total oral exposure experienced by an individual may be estimated by the following generalized equation:

$$E_{total} \approx E_{food} + E_{water} + E_{soil}$$

where

E_{total} = total exposure from all pathways
E_{food} = exposure from food consumption
E_{water} = exposure from water consumption
E_{soil} = exposure from soil consumption

For exposure estimates to be useful in the assessment of risk to wildlife, they must be expressed in terms of a body weight-normalized daily dose or as milligrams of contaminant per kilogram of body weight per day. Exposure estimates expressed in this manner may then be compared to toxicological benchmarks for wildlife, such as those derived by Opresko et al. (1995). Estimation of the daily contaminant dose an individual may receive from a particular medium for a particular contaminant is calculated using the following equation:

$$E = (C \times IR)/BW$$

where

E	= exposure to contaminant (mg/kg/day)
C	= concentration contaminant in medium (mg/kg or mg/L)
IR	= ingestion rate (kg/individual/day)
BW	= body weight (kg)

Because contaminant concentrations in plant and animal wildlife foods are needed to fully estimate contaminant exposure, and only abiotic data are available, uptake factors that describe the relationship between contaminant concentrations in soil and that in biota are used. By multiplying the contaminant concentration in abiotic media by the appropriate uptake factor concentrations in biota can be estimated.

Exposure parameters used to estimate contaminant exposure to the wildlife endpoint species are provided in Table 5.1 (Opresko et al. 1995; EPA 1993).

Estimates of contaminant exposure experienced by wildlife using the DWI 901 Site were calculated using the UCL_{95} on the mean contaminant concentration observed in each medium. Because wildlife are mobile, use various portions of a site, and are exposed through multiple media, it is believed that the UCL_{95} best represents the spatial integration of contaminants to which wildlife will be exposed, unless it exceeds the maximum concentration. If that is the case, the maximum value is used as the RME. A discussion of assumptions and exposure estimates for each wildlife endpoint species follows.

Meadow Vole (*Microtus pennsylvanicus*). The diet of the meadow vole is predominantly vegetation. Contaminant concentration in plants was calculated using soil-plant uptake factors. Since its home-range is smaller than the size of the DWI 901 Site [3.8 ha (10 acres)], it is assumed that 100 percent of food, water, and soil was obtained from the site. Exposure estimates for meadow vole are listed in Table 5.1.

White-Footed Mouse (*Peromyscus leucopus*). The diet of the white-footed mouse consists of approximately 50 percent vegetative species and 50 percent arthropods (assumed to be uncontaminated). Contaminant concentration in plants were calculated using soil-plant uptake

Table 5.1. Wildlife exposure parameters, DWI 901 Site, Knoxville, Tennessee

Endpoint species	Body weight (kg)	Food consumption rate (kg/day)	Water consumption rate (L/day)	Soil consumption rate (kg/day)	Diet	Home range (ha)
Meadow vole	0.044	0.005	0.006	0.0001	100% vegetation	0.037–0.083
White-footed mouse	0.022	0.0034	0.0066	0.000068	50% vegetation	0.059
Short-tailed shrew	0.015	0.009	0.0033	0.00117	100% earthworms	0.39

DWI = David Witherspoon, Inc.
ha = hectare
kg = kilogram
L = liter
% = percent

factors. Since its home-range is smaller than the size of the DWI 901 Site [3.8 ha (10 acres)], it is assumed that 100 percent of food, water, and soil was obtained from the site. Exposure estimates for white-footed mouse are listed in Table 5.1.

Short-Tailed Shrew (*Blarina brevicauda*). The diet of the short-tailed shrew consists primarily of invertebrates. This assessment assumed 100 percent of the diet is earthworms and that 100 percent of these earthworms come from the DWI 901 Site. Contaminant concentrations in earthworms were calculated using soil-earthworm uptake factors. Exposure estimates for the short-tailed shrew are listed in Table 5.1.

5.3 EFFECTS ASSESSMENT

Effects assessment involves identifying known effects of contaminants on receptors using conventional toxicity data. These data will be used in the risk characterization section to evaluate risks to sediment biota, soil invertebrates, terrestrial wildlife, and terrestrial plants.

Conventional toxicity data consisting of published values for toxicity of contaminants to test species were used in the development of toxicological benchmarks. By comparing contaminant concentrations measured in media at the site to the benchmarks, the likelihood that contaminants pose a risk may be estimated. Contaminant concentrations or exposure doses are compared to benchmarks to compute the ecological HQ used in the risk characterization.

5.3.1 Toxicity Benchmarks for Sediment

EPA-Region IV sediment screening values were used as the screening benchmarks.

5.3.2 Toxicity Benchmarks for Soil

Screening benchmark concentrations for the toxicity of chemicals to earthworms were obtained from Will and Suter (1995).

5.3.3 Toxicity Benchmarks for Terrestrial Wildlife

Contaminant exposures were calculated for the three endpoint species and compared to the lowest observed adverse effect level (LOAEL) as outlined in Opresko et al. (1995).

5.3.4 Toxicity Benchmarks for Terrestrial Plants

Screening benchmark concentrations for phytotoxicity were obtained from Will and Suter (1995).

5.4 RISK CHARACTERIZATION

Risk characterization integrates the results of the exposure and effects assessments to estimate risks. Because only abiotic data were available for this preliminary ERA, the principle line of evidence is the single chemical toxicity data, which indicate the toxic effects of the concentrations measured in the site media.

5.4.1 Risk Characterization for Contaminant Screening

Risk characterization begins with a screening of contaminants to identify those that require more detailed assessment. Screening is done by comparing chemical concentrations measured in soil and sediment to ecotoxicological benchmarks to derive HQs using the following formula:

Hazard quotient = environmental concentration/toxicological benchmark

HQs greater than one suggest that the chemical is hazardous to the endpoint biota and therefore worthy of further assessment; HQs less than one suggest that the chemical is nonhazardous and need not be considered further.

5.4.1.1 Benthic macroinvertebrates

Sediment samples were collected from 10 Goose Creek locations. Not all samples were analyzed for a full suite of analytes. Two samples were located on site and six were located at intervals downstream from the site. The maximum concentration from each location was used for screening. Two additional samples collected upstream from the DWI 901 Site were averaged and used as representative background sediment samples for comparison. All maximum concentrations exceeded the representative background concentrations; therefore, no sediment analytes were screened out based on background. Results of the sediment screening are provided in Table 5.2. Seven metals (Cd, Cr, Cu, Pb, Hg, Ni, and Zn) exceeded the benchmark value (i.e., HQ > 1) and were greater than the representative background sample. Copper, Pb, Hg, and Zn exceeded the benchmark values by factors greater 10. Two pesticides, six SVOCs, and two PCBs also exceeded sediment benchmark values.

5.4.1.2 Soil invertebrates

The maximum concentrations of surface soil samples were screened against soil invertebrate benchmarks. For comparison purposes the concentrations of four off-site samples were averaged and used as the representative background sample. Definitive background samples will be collected during supplemental fieldwork activities. The results of the soil screening are provided in Table 5.3.

Seven out of 23 detected metal concentrations exceeded benchmark values. There were no benchmark values available for 14 of the detected metals. Benchmarks were not available for any of the other detected analytes.

5.4.1.3 Terrestrial plants

Maximum surface soil concentrations were screened against phytotoxicity benchmarks. Results of the terrestrial plant screening are provided in Table 5.4. Sixteen metal concentrations exceeded benchmark values. Mercury and chromium concentrations exceeded benchmark values by four orders of magnitude. PCBs were the only organic compounds that exceeded benchmarks, and none exceeded by more than a factor of 5.

5.4.1.4 Terrestrial wildlife

To evaluate the potential toxicity of contaminants to terrestrial wildlife, contaminant exposures were calculated for each surface soil contaminant that had a LOAEL benchmark and uptake factor. Surface water concentrations were not included in the exposure because these data were not available. RMEs were used as the representative contaminant concentration in soil. The sum of the soil and diet exposures were compared to LOAEL benchmarks (Opresko et al. 1995). The results of the contaminant exposures for each receptor are provided in Tables 5.5–5.7. Aluminum, Cd, Cu, Hg, and PCBs remained as COPECs for the white-footed mouse and meadow vole. Aluminum, Sb, As, Ba, Cd, Cr, Cu, Hg, Se, Zn, PCBs, benzo(a)pyrene, and bis(2-ethylhexyl)phthalate were retained as COPECs for the short-tailed shrew.

Table 5.2. Sediment contaminant screening for benthic macroinvertebrates, DWI 901 Site, Knoxville, Tennessee

Analyte	Detection frequency	Maximum detected	Benchmark	Background	Hazard quotient
Metals (mg/kg)					
Aluminum	9/9	13,000	NA	5,750	NA
Antimony	1/9	14	12	14	1
Arsenic	8/10	12.5	8	14	2
Barium	10/10	225	NA	35.8	NA
Beryllium	3/9	1.1	NA	ND	NA
Cadmium	6/10	6.2	1	ND	6
Calcium	9/9	217,000	NA	NA	NA
Chromium	10/10	86	33	15.75	3
Cobalt	9/9	18.2	NA	13	NA
Copper	10/10	830	28	14.7	30
Cyanide	2/9	0.56	NA	NA	NA
Iron	9/9	43,000	NA	19,550	NA
Lead	10/10	440	21	63.6	21
Magnesium	9/9	15,500	NA	NA	NA
Manganese	9/9	12,200	NA	730	NA
Mercury	7/10	7	0.1	0.33	70
Nickel	10/10	83	20.9	9.9	4
Potassium	3/9	1,100	NA	NA	NA
Sodium	2/9	75.6	NA	NA	NA
Vanadium	9/9	25.8	NA	18	NA
Zinc	10/10	1,900	68	102.5	28
Semivolatiles (μg/kg)					
(3-and/or 4-) methylphenol	1/5	1,700	NA	NA	NA
2-methylnaphthalene	3/5	84	330	NA	0.2
Benzo(a)anthracene	3/5	1,600	330	ND	5
Benzo(a)pyrene	5/9	1,700	330	676	5
Benzo(b)fluoranthene	5/5	4,600	NA	1,400	NA
Bis(2-ethylhexyl)phthalate	2/6	19,600	NA	ND	NA
Carbazole	1/5	420	NA	NA	NA
Chrysene	4/5	2,200	330	NA	7
Di-n-butylphthalate	1/9	52	NA	NA	NA
Fluoranthene	4/5	4,200	380	NA	11
Fluorene	1/5	120	330	NA	0.4
Naphthalene	2/5	170	330	NA	0.5
Phenanthrene	5/5	1,800	330	NA	6
Phenol	1/5	350	NA	NA	NA
Pyrene	5/5	2,700	330	NA	8

Table 5.2. (continued)

Analyte	Detection frequency	Maximum detected	Benchmark	Background	Hazard quotient
Volatiles ($\mu g/kg$)					
Acetone	4/9	49,000	NA	NA	NA
Ethylbenzene	1/9	470	NA	NA	NA
Xylenes	1/9	1,200	NA	NA	NA
PCBs ($\mu g/kg$)					
PCB-1254	5/6	4,000	33	ND	121
PCB-1260	5/6	2,700	33	ND	82
Pesticides ($\mu g/kg$)					
Chlordane	1/1	167	1.7	NA	98
Endrin	1/5	14	3.3	NA	4
Gamma-chlordane/2	1/5	6	NA	NA	NA
Dioxins/furans (ng/kg)					
1,2,3,4,6,7,8-HpCDD	2/2	260	NA	NA	NA
1,2,3,4,6,7,8-HpCDF	2/2	65	NA	NA	NA
1,2,3,4,7,8-HxCDF	2/2	17	NA	NA	NA
1,2,3,4,7,8,9-HpCDF	2/2	8.5	NA	NA	NA
1,2,3,6,7,8-HxCDF	2/2	8.2	NA	NA	NA
2,3,4,6,7,8-HxCDF	1/2	7.1	NA	NA	NA
2,3,4,7,8-PeCDF	2/2	7.8	NA	NA	NA
2,3,7,8-TCDF	2/2	11	NA	NA	NA
OCDD	2/2	2,800	NA	NA	NA
OCDF	2/2	220	NA	NA	NA

Source: Halliburton 1994; PRC RI 1993a

DWI = David Witherspoon, Inc.
kg = kilogram
μg = microgram
mg = milligram
NA = not available
ND = not detected
ng = nanogram
PCB = polychlorinated biphenyl

Table 5.3. Surface soil screening for soil invertebrates, DWI 901 Site, Knoxville, Tennessee

Analyte	Detection frequency	Maximum detection	Benchmark	Background	Hazard quotient
		Metals (mg/kg)			
Aluminum	31/31	34,900	NA	1,400	NA
Antimony	14/31	162	NA	ND	NA
Arsenic	31/31	30	60	12.7	0.5
Barium	31/31	986	NA	150.3	NA
Beryllium	9/31	1.5	NA	1.5	NA
Cadmium	30/31	45	20	2.1	2
Calcium	31/31	290,000	NA	NA	NA
Chromium	31/31	3,480	0.4	24.3	8,700
Cobalt	29/31	59	NA	15	NA
Copper	31/31	14,100	50	46.5	282
Cyanide	3/31	2	NA	NA	NA
Iron	31/31	190,000	NA	35,500	NA
Lead	31/31	8,320	500	166.7	17
Magnesium	31/31	55,000	NA	NA	NA
Manganese	31/31	14,600	NA	1,500	NA
Mercury	30/31	1,660	0.1	0.77	16,600
Nickel	31/31	3,160	200	22	16
Potassium	19/31	1,400	NA	NA	NA
Selenium	3/23	12.4	70	ND	0.2
Silver	2/31	3.8	NA	ND	NA
Sodium	5/31	1,650	NA	NA	NA
Vanadium	27/31	33	NA	32	NA
Zinc	31/31	16,000	200	315.4	80
		Semivolatiles (µg/kg)			
(3-and/or 4-) Methylphenol	1/10	510	NA	NA	NA
2-Methylnaph thalene	17/28	3,100	NA	NA	NA
3,3'-Dichloro benzidine	1/28	7,100	NA	NA	NA
Acenaphthene	14/28	9,800	NA	NA	NA
Acenaphthylene	4/27	280	NA	NA	NA
Anthracene	20/31	19,000	NA	NA	NA
Benzo(a)anthracene	19/31	44,000	NA	NA	NA
Benzo(a)pyrene	24/31	43,000	NA	NA	NA
Benzo(b)fluoranthene	29/31	42,000	NA	NA	NA
Benzo(ghi)perylene	18/31	31,000	NA	NA	NA
Benzo(k)fluoranthene	20/21	41,000	NA	NA	NA
Benzyl butyl phthalate	1/10	4,800	NA	NA	NA
Bis(2-ethylhexyl)phthalate	20/31	55,000	NA	NA	NA
Butylbenzylphthalate	4/17	1,100	NA	NA	NA
Carbazole	4/10	540	NA	NA	NA
Chrysene	29/31	53,000	NA	NA	NA
Di-n-butylphthalate	15/27	9,500	NA	NA	NA

Table 5.3. (continued)

Analyte	Detection frequency	Maximum detection	Benchmark	Background	Hazard quotient
Semivolatiles (μg/kg)					
Di-n-octylphthalate	2/27	1,200	NA	NA	NA
Dibenzo(a,h,)anthracene	15/31	2,900	NA	NA	NA
Dibenzofuran	13/27	8,100	NA	NA	NA
Dimethylphthalate	3/27	1,100	NA	NA	NA
Fluoranthene	30/31	130,000	NA	NA	NA
Flourene	12/28	14,000	NA	NA	NA
Hexachlorobenzene	1/27	3,500	NA	NA	NA
Indeno(1,2,3-cd)pyrene	19/31	28,000	NA	NA	NA
N-nitrosodiphenylamine	1/27	3,500	NA	NA	NA
Naphthalene	15/27	10,000	NA	NA	NA
Phenanthrene	29/31	120,000	NA	NA	NA
Phenol	2/27	330	NA	NA	NA
Pyrene	27/30	99,000	NA	NA	NA
PCBs (μg/kg)					
PCB-1242	1/31	200,000	NA	ND	NA
PCB-1248	3/31	140,000	NA	ND	NA
PCB-1254	29/31	160,000	NA	ND	NA
PCB-1260	26/31	43,000	NA	ND	NA
Dioxins/furans (ng/kg)					
1,2,3,4,6,7,8-HPCDD	6/6	2,600	NA	NA	NA
1,2,3,4,6,7,8-HPCDF	6/6	440	NA	NA	NA
1,2,3,4,7,8-HXCDF	6/6	88	NA	NA	NA
1,2,3,4,7,8,9-HPCDF	6/6	57	NA	NA	NA
1,2,3,6,7,8-HXCDD	4/6	91	NA	NA	NA
1,2,3,6,7,8-HXCDF	6/6	35	NA	NA	NA
1,2,3,7,8-PECDF	3/6	20	NA	NA	NA
1,2,3,7,8,9-HXCDD	2/6	34	NA	NA	NA
2,3,4,6,7,8-HXCDF	4/6	36	NA	NA	NA
2,3,4,7,8-PECDF	6/6	41	NA	NA	NA
2,3,7,8-TCDD	4/6	4.6	NA	NA	NA
2,3,7,8-TCDF	6/6	71	NA	NA	NA
OCDD	6/6	16,000	NA	NA	NA
OCDF	6/6	1,600	NA	NA	NA

Source: Halliburton 1994; Weston 1994.

DWI = David Witherspoon, Inc.
kg = kilogram
μg = microgram
mg = milligram
NA = not available
ND = not detected
ng = nanogram
PCB = polychlorinated biphenyl

Table 5.4. Surface soil contaminant screening for plant toxicity, DWI 901 Site, Knoxville, Tennessee

Analtye	Detection frequency	Maximum detection	Benchmark	Background	Hazard quotient
Metals (mg/kg)					
Aluminum	31/31	34,900	50	1,400	698
Antimony	14/31	162	5	ND	32
Arsenic	31/31	30	10	12.7	3
Barium	31/31	986	500	150.3	2
Beryllium	9/31	1.5	10	1.5	0.15
Cadmium	30/31	45	3	2.1	15
Calcium	31/31	290,000	NA	NA	NA
Chromium	31/31	3,480	1	24.3	3,480
Cobalt	29/31	59	20	15	3
Copper	31/31	14,100	100	46.5	141
Cyanide	3/31	2	NA	NA	NA
Iron	31/31	190,000	NA	35,500	NA
Lead	31/31	8,320	50	166.7	166
Magnesium	31/31	55,000	NA	NA	NA
Manganese	31/31	14,600	500	1,500	29
Mercury	30/31	1,660	0.3	0.77	5,533
Nickel	31/31	3,160	30	22	105
Potassium	19/31	1,400	NA	NA	NA
Selenium	3/23	12.4	1	ND	12
Silver	2/31	3.8	2	ND	2
Sodium	5/31	1,650	NA	NA	NA
Vanadium	27/31	33	2	32	17
Zinc	31/31	16,000	50	315.4	320
Semivolatiles ($\mu g/kg$)					
(3-and/or 4-) Methylphenol	1/10	510	NA	NA	NA
2-Methylnaphthalene	17/28	3,100	NA	NA	NA
3,3'-Dichlorobenzidine	1/28	7,100	NA	NA	NA
Acenaphthene	14/28	9,800	20,000	NA	0.5
Acenaphthylene	4/27	280	NA	NA	NA
Anthracene	20/31	19,000	NA	NA	NA
Benzo(a)anthracene	19/31	44,000	NA	NA	NA
Benzo(a)pyrene	24/31	43,000	NA	NA	NA
Benzo(b)fluoranthene	29/31	42,000	NA	NA	NA
Benzo(ghi)perylene	18/31	31,000	NA	NA	NA
Benzo(k)fluoranthene	20/21	41,000	NA	NA	NA
Benzyl butyl phthalate	1/10	4,800	NA	NA	NA
Bis(2-ethylhexyl) phthalate	20/31	55,000	NA	NA	NA
Butylbenzylphthalate	4/17	1,100	NA	NA	NA
Carbazole	4/10	540	NA	NA	NA
Chrysene	29/31	53,000	NA	NA	NA

Table 5.4. (continued)

Analtye	Detection frequency	Maximum detection	Benchmark	Background	Hazard quotient
		Semivolatiles (μg/kg)			
Di-n-butylphthalate	15/27	9,500	200,000	NA	0.05
Di-n-octylphthalate	2/27	1,200	NA	NA	NA
Dibenzo(a,h,)anthracene	15/31	2,900	NA	NA	NA
Dibenzofuran	13/27	8,100	100,000	NA	0.1
Dimethylphthalate	3/27	1,100	NA	NA	NA
Fluoranthene	30/31	130,000	NA	NA	NA
Flourene	12/28	14,000	NA	NA	NA
Hexachlorobenzene	1/27	3,500	NA	NA	NA
Indeno(1,2,3-cd)pyrene	19/31	28,000	NA	NA	NA
N-nitrosodiphenylamine	1/27	3,500	NA	NA	NA
Naphthalene	15/27	10,000	NA	NA	NA
Phenanthrene	29/31	120,000	NA	NA	NA
Phenol	2/27	330	70,000	NA	0.005
Pyrene	27/30	99,000	NA	NA	NA
		PCBs (μg/kg)			
PCB-1242	1/31	200,000	40,000	ND	5
PCB-1248	3/31	140,000	40,000	ND	4
PCB-1254	29/31	160,000	40,000	ND	4
PCB-1260	26/31	43,000	40,000	ND	1
		Dioxins/furans (ng/kg)			
1,2,3,4,6,7,8-HPCDD	6/6	2,600	NA	NA	NA
1,2,3,4,6,7,8-HPCDF	6/6	440	NA	NA	NA
1,2,3,4,7,8-HXCDF	6/6	88	NA	NA	NA
1,2,3,4,7,8,9-HPCDF	6/6	57	NA	NA	NA
1,2,3,6,7,8-HXCDD	4/6	91	NA	NA	NA
1,2,3,6,7,8-HXCDF	6/6	35	NA	NA	NA
1,2,3,7,8-PECDF	3/6	20	NA	NA	NA
1,2,3,7,8,9-HXCDD	2/6	34	NA	NA	NA
2,3,4,6,7,8-HXCDF	4/6	36	NA	NA	NA
2,3,4,7,8-PECDF	6/6	41	NA	NA	NA
2,3,7,8-TCDD	4/6	4.6	NA	NA	NA
2,3,7,8-TCDF	6/6	71	NA	NA	NA
OCDD	6/6	16,000	NA	NA	NA
OCDF	6/6	1,600	NA	NA	NA

Source: Halliburton 1994; Weston 1994

DWI = David Witherspoon, Inc.
kg = kilogram
μg = microgram
mg = milligram

NA = not available
ND = not detectable
ng = nanogram
PCB = polychlorinated biphenyl

Table 5.5. Quantitative evaluation of potential exposure through ingestion by white-footed mice, DWI 901 Site, Knoxville, Tennessee

Analyte	Soil (mg/kg)	Uptake factor[a]	Plant (mg/kg)	Exposure dose (mg/kg/day)	LOAEL	HQ
Aluminum	13,352	0.004	53.41	45.4	21.4	2
Antimony	43.1	0.04	1.72	0.27	1.38	0.2
Arsenic	15	0.004	0.06	0.05	1.4	0.04
Barium	545.5	0.15	81.83	8.01	49.3	0.2
Cadmium	40.7	0.645	26.25	2.15	0.03	72
Chromium	259.3	0.041	10.63	1.62	32.7	0.05
Copper	8,028.2	0.04	3,211.28	273	53.3	5
Lead	2,893	0.045	130.19	19	199	0.10
Manganese	3157.9	0.25	789.48	70.8	708	0.10
Mercury	608.9	0.143	87.07	8.61	0.4	22
Nickel	575.2	0.06	34.51	4.44	199	0.02
Selenium	1.8	0.033	0.06	0.01	0.84	0.01
Vanadium	18.2	NA	NA	0.06	4.7	0.01
Zinc	11,483	0.37	4,249.9	363.9	797	0.5
PCB-1254	71,713	0.0127	910.8	292	0.59	495
PCB-1260	32,267	0.0029	93.6	107	0.59	181
Benzo(a)pyrene	2,745	0.0115	31.6	11	11.1	1
Bis(2-ethylhexyl) phthalate	9,389	0.0001	0.94	29	203	0.1

[a]Soil to plant uptake factors from Sample et al. 1995.

DWI = David Witherspoon, Inc.
HQ = hazard quotient (exposure dose/LOAEL)
kg = kilogram
LOAEL = lowest observed adverse effect level
mg = milligram
PCB = polychlorinated biphenyl

5.4.2 Chemicals of Ecological Concern

For this preliminary ERA, all COPECs were retained as COECs. Table 5.8 provides a summary of the COECs. Chemicals with HQs greater than 10 would be more likely to produce adverse effects to the biota. A qualitative discussion of the COECs for each medium is given.

5.4.2.1 Soil

COECs in soil primarily include metals and PCBs. Metal concentrations exceeded benchmarks for the earthworm, mouse, vole, and shrew. Concentrations of Cr, Cu, Hg, and Zn on the DWI 901 Site pose the most risk to earthworms. Concentrations of chromium and mercury pose the most risk to terrestrial plants. Concentrations of cadmium in the soil pose the highest risk to the mouse, vole, and shrew. PCB benchmarks were not available for the

Table 5.6. Quantitative evaluation of potential exposure through ingestion by meadow vole, DWI 901 Site, Knoxville, Tennessee

Analyte	Soil (mg/kg)	Uptake factor[a]	Plant (mg/kg)	Exposure dose (mg/kg/day)	LOAEL	HQ
Aluminum	13,352	0.004	53.41	36.4	17	2
Antimony	43.1	0.04	1.72	0.29	1.1	0.3
Arsenic	15	0.004	0.06	0.04	1.11	0.04
Barium	545.5	0.15	81.83	10.5	39.3	0.3
Cadmium	40.7	0.645	26.25	3.08	0.02	154
Chromium	259.3	0.041	10.63	1.8	26	0.07
Copper	8,028.2	0.4	3,211.28	383.2	42.4	9
Lead	2,893	0.045	130.19	21.4	159	0.1
Manganese	3,157.9	0.25	789.48	96.9	563	0.2
Mercury	608.9	0.143	87.07	11.3	0.32	35
Nickel	575.2	0.06	34.51	5.23	159	0.03
Selenium	1.8	0.033	0.06	0.01	0.67	0.02
Vanadium	18.2	NA	NA	0.04	3.8	0.01
Zinc	11,483	0.37	4,249.9	509	634	0.8
PCB-1254	71,713	0.0127	910.8	266.5	0.47	567
PCB-1260	32,267	0.0029	93.6	84	0.47	179
Benzo(a)pyrene	2,745	0.0115	31.6	9.8	8.8	1
Bis(2-ethylhexyl) phthalate	9,389	0.0001	0.94	21.4	161	0.1

[a]Soil to plant uptake factors from Sample et al. 1995.

DWI = David Witherspoon, Inc.
HQ = hazard quotient (exposure dose/LOAEL)
kg = kilogram
LOAEL = lowest observed adverse effects level
mg = milligram
PCB = polychlorinated biphenyl

earthworm and therefore could not be assessed. PCBs pose the most risk to the shrew because of high soil to earthworm uptake factors. The shrew is also at risk from Al, Cu, Hg, Zn, and benzo(a)pyrene in the soil.

5.4.2.2 Sediment

Sediment represents the most direct pathway for off-site risk to ecological receptors. To evaluate the extent of contamination downstream from the DWI 901 Site, the concentration at each sampling location was compared to its respective benchmark. The maximum metal concentrations for Cu, Pb, Hg, and Zn were detected in on-site samples. Based on HQs, these metals present the highest risk to benthic macroinvertebrates. Concentrations decreased downstream to below benchmark values or below upstream concentrations. The PCB contamination followed a similar pattern; however, all detected concentrations of PCB-1254 and PCB-1260 exceeded the sediment screening value. The maximum detected concentrations for PCBs were in sample DW-SD-02, which is located directly in front of the culvert on the DWI

Table 5.7. **Quantitative evaluation of potential exposure through ingestion by shrew, DWI 901 Site, Knoxville, Tennessee**

Analyte	Soil (mg/kg)	Uptake factor[a]	Earthworm (mg/kg)	Exposure dose (mg/kg/day)	LOAEL	HQ
Aluminum	13,352	0.032	427.3	1,298	24.3	53
Antimony	43.1	NA	NA	3.4	1.57	2
Arsenic	15	0.632	9.5	6.9	1.57	4
Barium	545.5	0.078	42.6	68.1	56	1
Cadmium	40.7	4.812	195.8	120.7	0.03	4,023
Chromium	259.3	0.289	74.9	65.2	37.2	2
Copper	8,028.2	NA	NA	626.2	60.5	10
Lead	2,893	NA	NA	225.6	226	1
Manganese	3,157.9	NA	NA	246.3	803	0.3
Mercury	608.9	5.767	3,511.5	2,154	0.45	4,787
Nickel	575.2	NA	NA	44.9	226	0.2
Selenium	1.8	7.416	13.4	8.2	0.96	8
Vanadium	18.2	NA	NA	1.4	5.4	0.3
Zinc	11,483	5.59	64,190	39,410	905	44
PCB-1254	71,713	7.107	510,000	311,000	0.66	472,000
PCB-1260	32,267	7.107	229,000	140,110	0.66	212,000
Benzo(a)pyrene	2,745	NA	NA	214	12.6	17
Bis(2-ethylhexyl) phthalate	9,389	NA	NA	732.3	230	3

[a]Soil to earthworm uptake factor from Sample et al. 1995.

DWI = David Witherspoon, Inc.
HQ = hazard quotient (exposure dose/LOAEL)
kg = kilogram
LOAEL = lowest observed adverse effect level
mg = milligram
NA = not available
PCB = polychlorinated biphenyl

901 Site. These on-site concentrations were an order of magnitude higher than any other detection. The concentrations of SVOCs that exceeded sediment screening values were located downstream from the DWI 901 Site near Mary Vestal Park at the confluence of Goose Creek and an unnamed tributary. The pesticides chlordane and endrin also exceeded benchmarks only at off-site locations.

5.4.3 Uncertainties in the ERA

The structure of the biotic community (i.e., the distribution and abundance of organisms) comprising the ecological receptors at the DWI 901 Site was not quantified for the preliminary ERA. The lack of quantitative data introduces uncertainties concerning whether, and to what extent, the risk characterization based on proxy organisms underestimates or overestimates the risk to the remainder of the ecological community.

Table 5.8. Chemicals of ecological concern, DWI 901 Site, Knoxville, Tennessee

Soil invertebrates	Vegetation	Small mammals	Benthic macroinvertebrate community
Cadmium	**Aluminum**	**Aluminum**	Cadmium
Chromium	**Antimony**	Antimony	Chromium
Copper	Arsenic	Arsenic	**Copper**
Lead	Barium	Barium	**Lead**
Mercury	**Cadmium**	**Cadmium**	**Mercury**
Nickel	**Chromium**	Chromium	Nickel
Zinc	Cobalt	**Copper**	**Zinc**
	Copper	**Mercury**	**Chlordane**
	Lead	Selenium	Endrin
	Manganese	**Zinc**	Benzo(a)anthracene
	Mercury	**PCBs**	Benzo(a)pyrene
	Nickel	**Benzo(a)pyrene**	Chrysene
	Selenium	Bis(2-ethylhexyl)phthalate	**Fluoranthene**
	Silver		Phenanthrene
	Vanadium		Pyrene
	Zinc		**PCB-1254**
	PCBs		**PCB-1260**

Bold = hazard quotient > 10

DWI = David Witherspoon, Inc.
> = greater than

PCB = polychlorinated biphenyl

Benchmark values were not available for many of the detected contaminants. Therefore, these contaminants cannot be quantitatively evaluated.

There is a large degree of uncertainty when using soil to vegetation and earthworm uptake factors to model contaminant concentrations in vegetation and earthworms. Uptake factors of inorganics vary with the physical characteristics of soil and the species and age of plants and earthworms. Using uptake factors assumes that the uptake rate is best estimated by taking the average of all observed values. Therefore, the predicted contaminant concentrations in vegetation and earthworms may be overestimated or underestimated, thus overestimating or underestimating contaminant exposure for each endpoint species.

It is assumed that the contaminant concentrations reported in soil, modeled vegetation, and earthworms are as bioavailable as the chemical in the material ingested by the test organisms. Therefore, exposure estimates based on the contaminant concentrations in media are highly conservative and likely overestimate the actual contaminant exposure experienced.

Toxicity of metals varies depending on the valence state or form (organic or inorganic) of the metal. For example, Cr^{+6} and methyl mercury are more toxic than Cr^{+3} and inorganic mercury, respectively. The available data on the contaminant concentrations in media do not indicate which species or form of contaminant was observed. Benchmarks used for comparison represented the more toxic species/form of the metals. If the less toxic species/form of the metal was present at the DWI 901 Site, potential toxicity at the site may be overestimated.

While ecological receptors at the DWI 901 Site are exposed to multiple contaminants concurrently, published ecotoxicological values consider effects experienced by exposures to single contaminants. Because some contaminants to which ecological receptors are exposed can interact antagonistically, single contaminant studies may overestimate their potential at the DWI 901 Site. Similarly, for those contaminants that interact synergistically, single contaminant studies may underestimate their toxic potential at the DWI 901 Site.

5.5 SUMMARY

This preliminary ERA was conducted to define and evaluate the potential for adverse effects on the environment from exposure to chemicals at the DWI 901 Site. Without biotic data (i.e., the distribution and abundance of organisms) and toxicity tests, the actual risk to ecological receptors at the DWI 901 Site is unknown. However, based on single chemical data, there is a likely potential for adverse effects to the ecological receptors associated with the DWI 901 Site if conditions remain unchanged. The primary contaminants include metals (Al, Sb, Cd, Cr, Cu, Pb, Hg, Mn, Ni, Se, V, and Zn) and PCBs in the soils and sediment.

6. BASIS FOR FEASIBILITY STUDY

Existing site information and the subsequent preliminary risk assessment show that risk associated with the DWI 901 Site is unacceptable. Therefore, CERCLA requires that an FS be conducted. The FS develops several remedial alternatives then evaluates and compares them. This chapter provides the groundwork for the FS by defining the specific objectives for RA at the site. First, target remediation levels for each contaminant for each media are determined. Next, debris, soil, and sediment areas with contamination above the remedial goals and volumes are provided. Finally, overall RAOs for the site are developed. Background groundwater data do not confirm the presence or absence of COPCs. Further groundwater sampling will determine (1) whether the DWI 901 Site is the source of groundwater contamination and (2) whether groundwater remediation is necessary. No surface water data are available. Further surface water sampling will determine the need for surface water remediation.

6.1 TARGET REMEDIATION LEVELS

Several factors contribute to the determination of the target remediation levels, including background concentrations, regulatory levels, and risk levels.

Risk-based cleanup levels were presented in Chapter 3 in the form of PRGs. In that chapter, chemical concentrations were compared to regulatory levels and PRGs. Following the baseline risk assessment, site-specific remedial goal options (RGOs) were calculated for each contaminant. An RGO is the concentration that, for a particular receptor and its associated site-specific exposure assumptions, would result in a carcinogenic risk of 1×10^{-6} or a HI of 0.1. Therefore, an RGO exists for each COPC, receptor, and medium. RGOs are similar to PRGs except that they are site-specific.

Table 6.1 provides the approximate percent risk contribution of major risk contributors in soil and sediment. Total risk for each receptor is summarized in the last column. Major contributors are defined as those contaminants causing total risk to be greater than 10^{-4} or the HI to be greater than 1.0.

Figures 6.1–6.8 show contaminant contours for the major risk contributors in soil. Table 6.1 shows that PCBs are the major carcinogenic risk contributors in the main area of the site and that the major noncarcinogenic contributors are Aroclor-1254, mercury, and ^{238}U. The major radiological contributors are ^{226}Ra, ^{238}U, and ^{137}Cs. Except for Aroclor-1242 and ^{137}Cs,

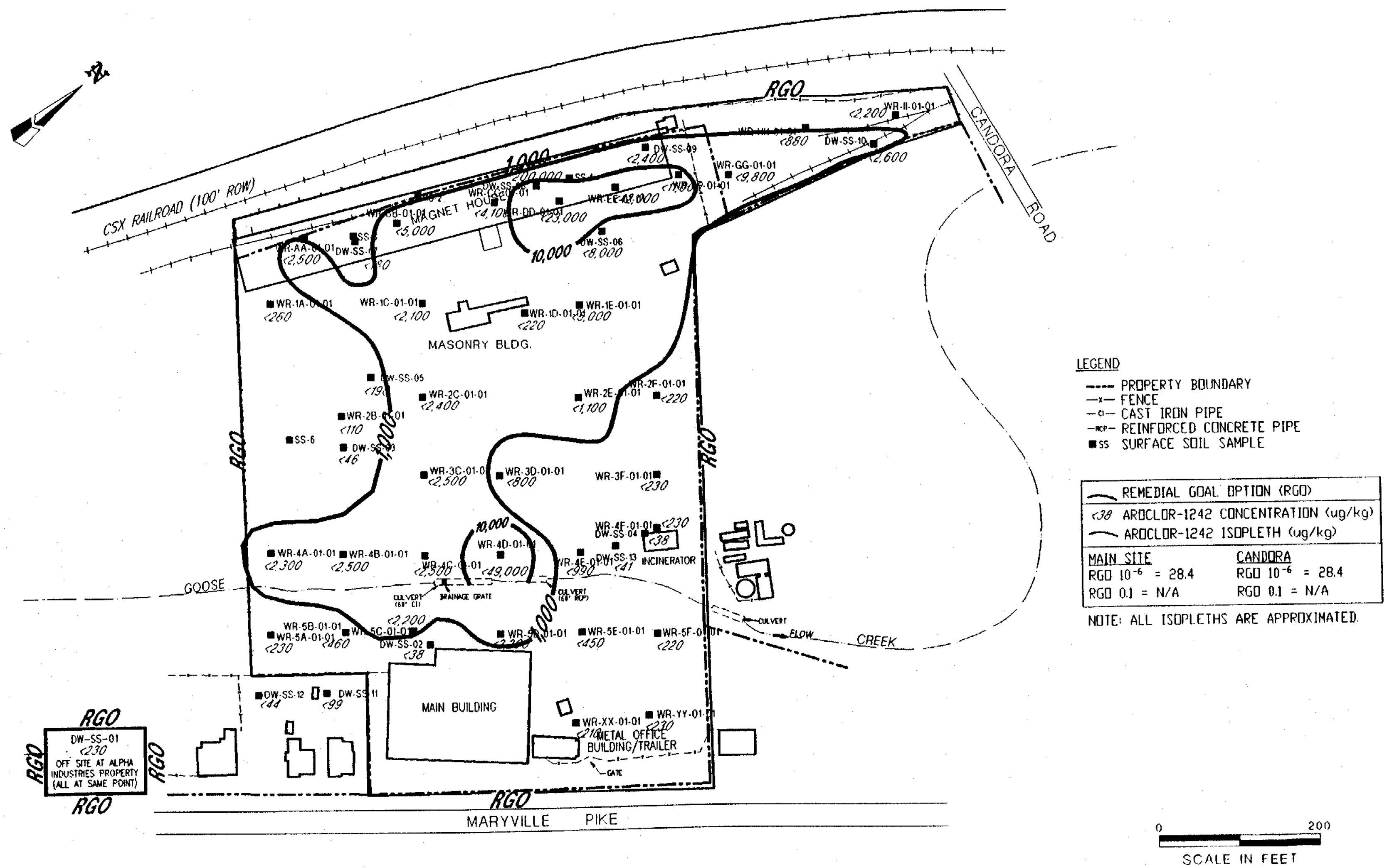
Table 6.1. Major risk contributors and percentage contribution, DWI 901 Site, Knoxville, Tennessee

Media	Risk type	Aroclor-1242	Aroclor-1248	Aroclor-1254	Aroclor-1260	Mercury	Benzo(a)pyrene	^{226}Ra	^{238}U	^{137}Cs	Risk[a]
Soil—DWI 901 Site	Carcinogenic chemical	29	28	23	16						4.32E-03
	Noncarcinogenic chemical			63		23			4		69
	Radiological							73	12	11	5.6E-03
Soil—Candora Road Area	Carcinogenic chemical		63	20	13						7.94E-03
	Noncarcinogenic chemical			13		3			81		1,359
	Radiological							91	7		1.26
Sediment	Carcinogenic chemical			43	29		9				5.37E-04
	Noncarcinogenic chemical			62							25

[a]Risk number presented is the highest risk or hazard index of all receptors assessed.

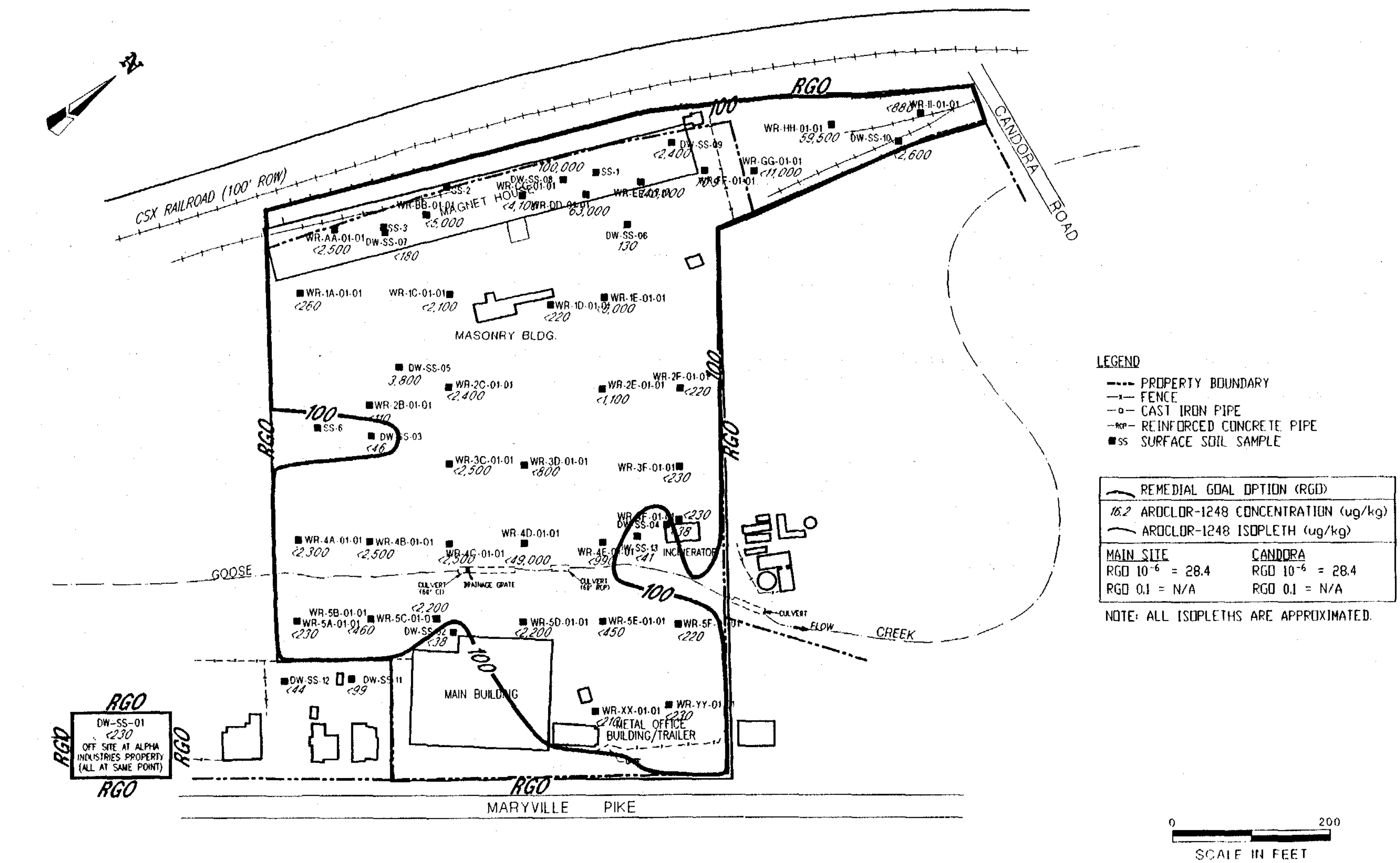
Cs = cesium
DWI = David Witherspoon, Inc.

Ra = radium
U = uranium



MODIFIED FROM. Jesse Walker, RLS, PE, Survey, July 29, 1992.

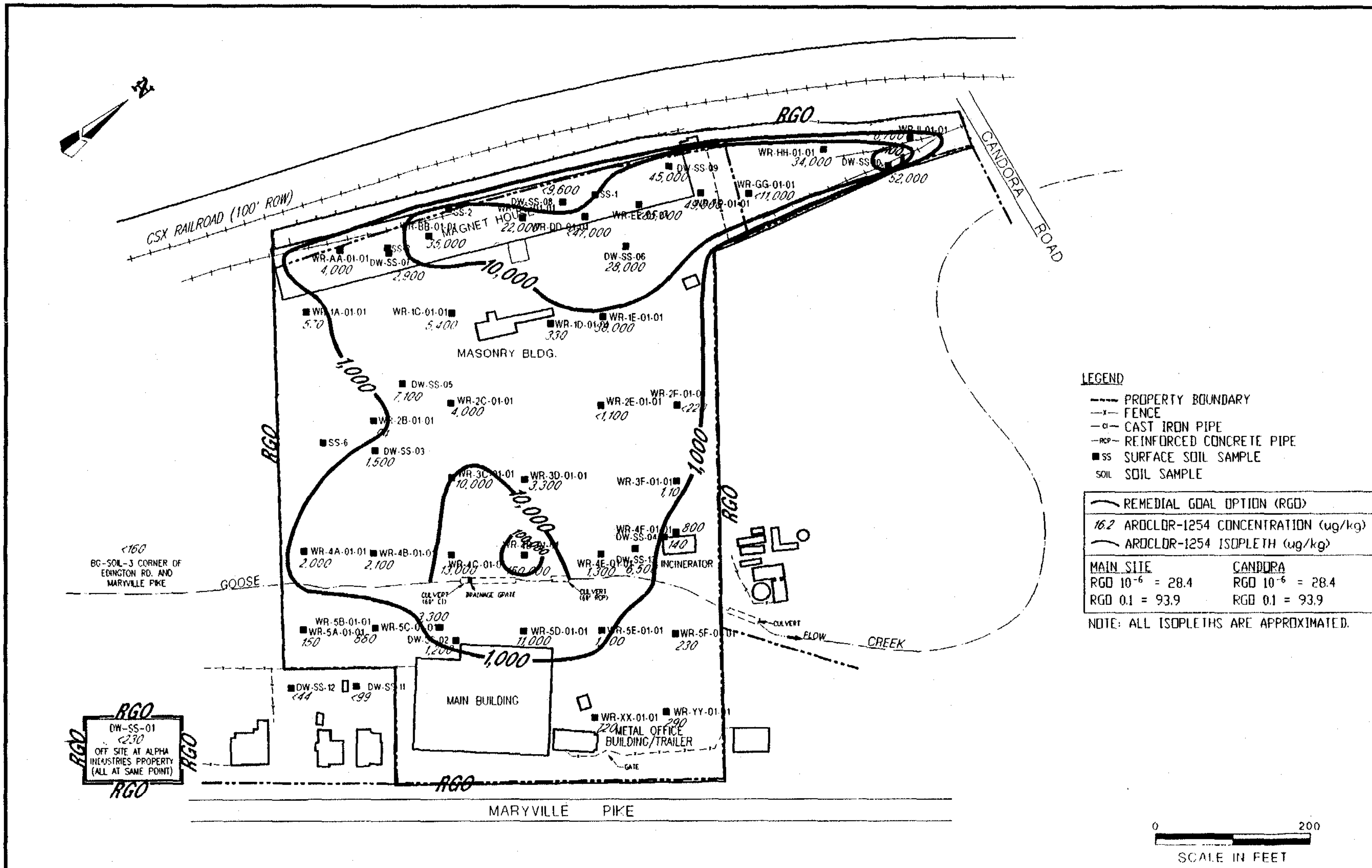
JE **Fig. 6.1**	**Horizontal distribution of Aroclor-1242 in surface soil** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96-13300DWG	DRAWING DATE OCTOBER 18, 1996 TG



MODIFIED FROM. Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	**Fig. 6.2**	**Horizontal distribution of Aroclor-1248 in surface soil** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13155.DWG

DRAWING DATE: OCTOBER 18, 1996 TG



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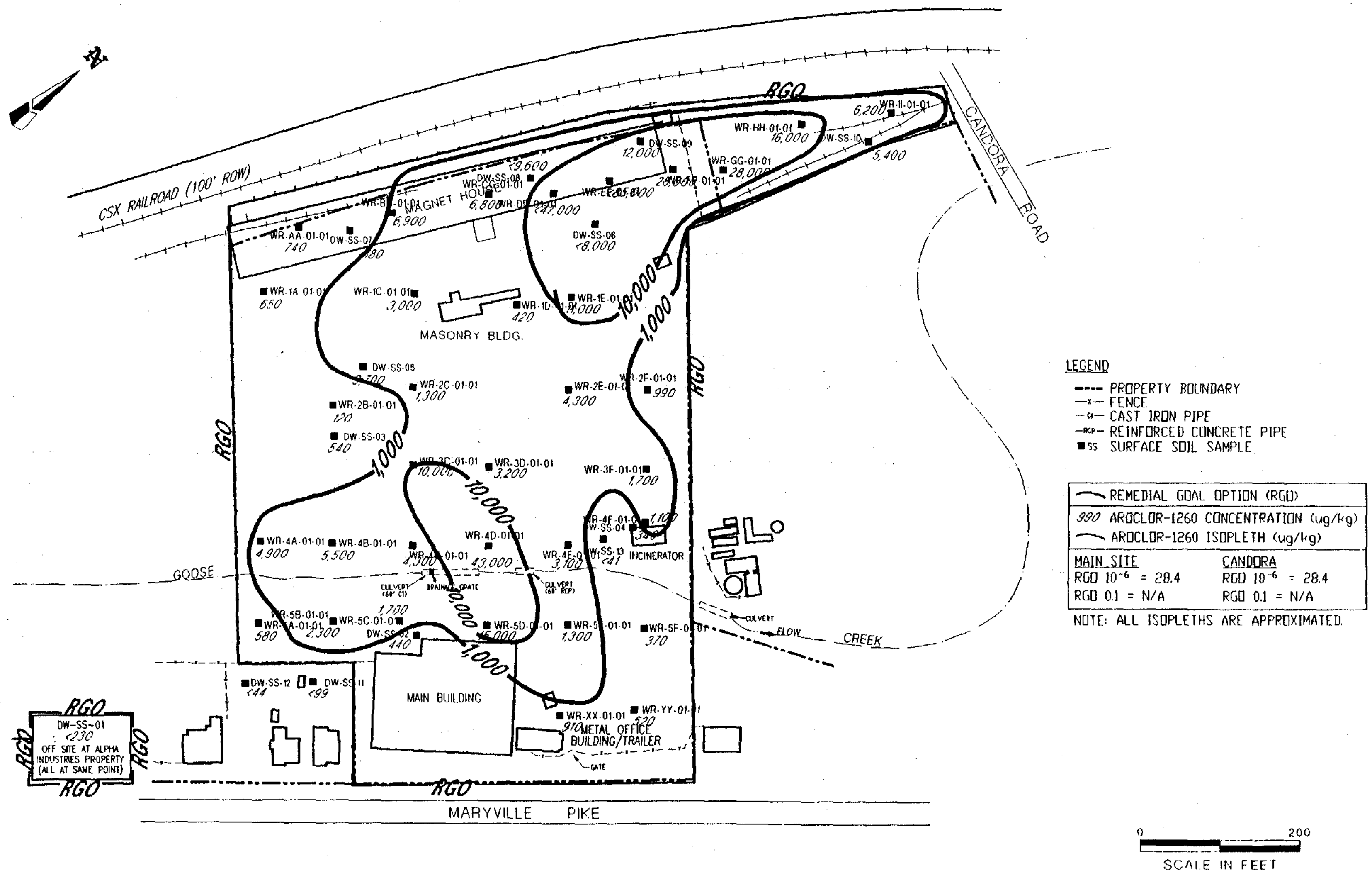
JE	Fig. 6.3	Horizontal distribution of Aroclor-1254 in surface soil DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96-13156.DWG	DRAWING DATE: OCTOBER 18, 1996 TG



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

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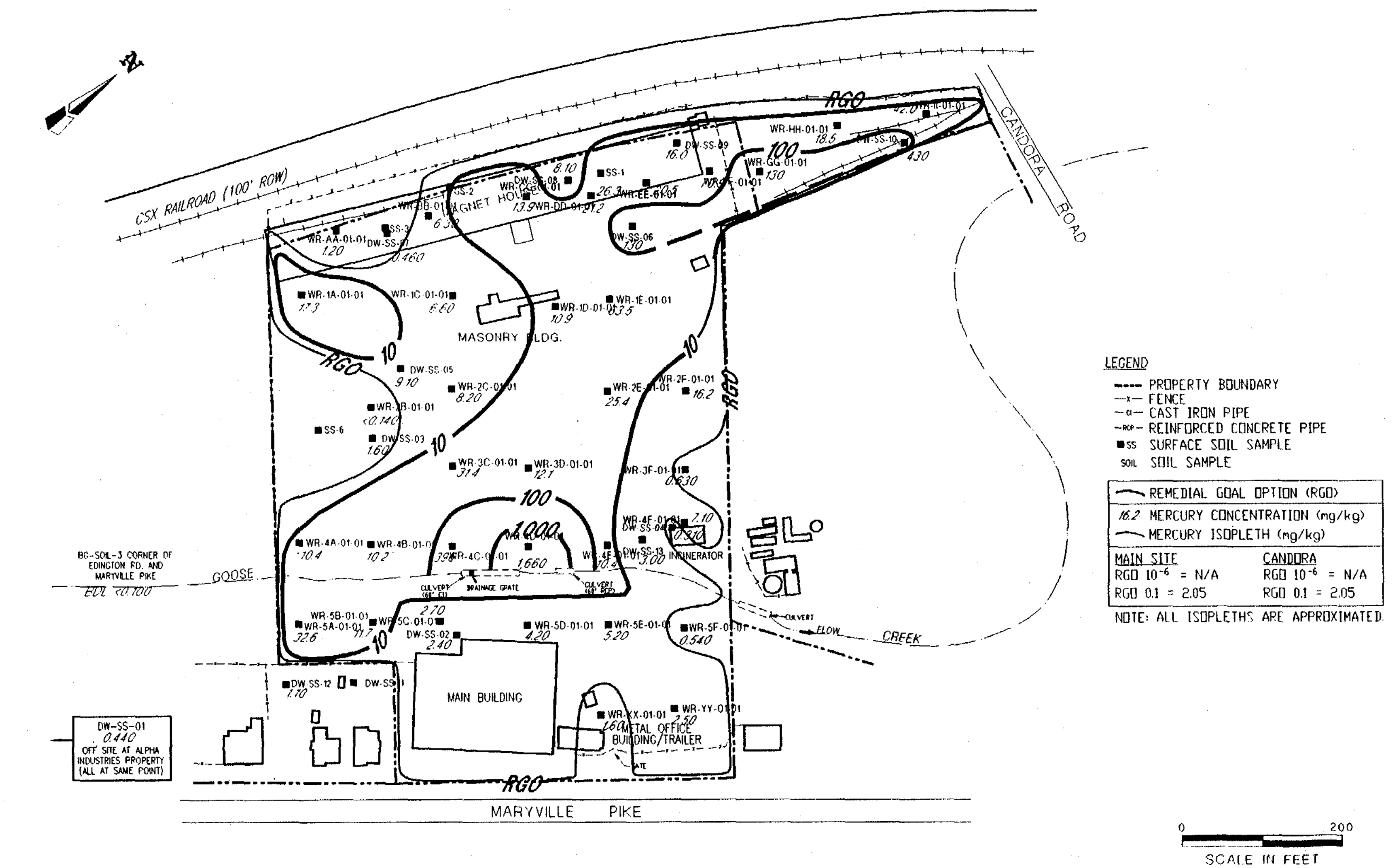
Fig. 6.4 Horizontal distribution of Aroclor-1260 in surface soil

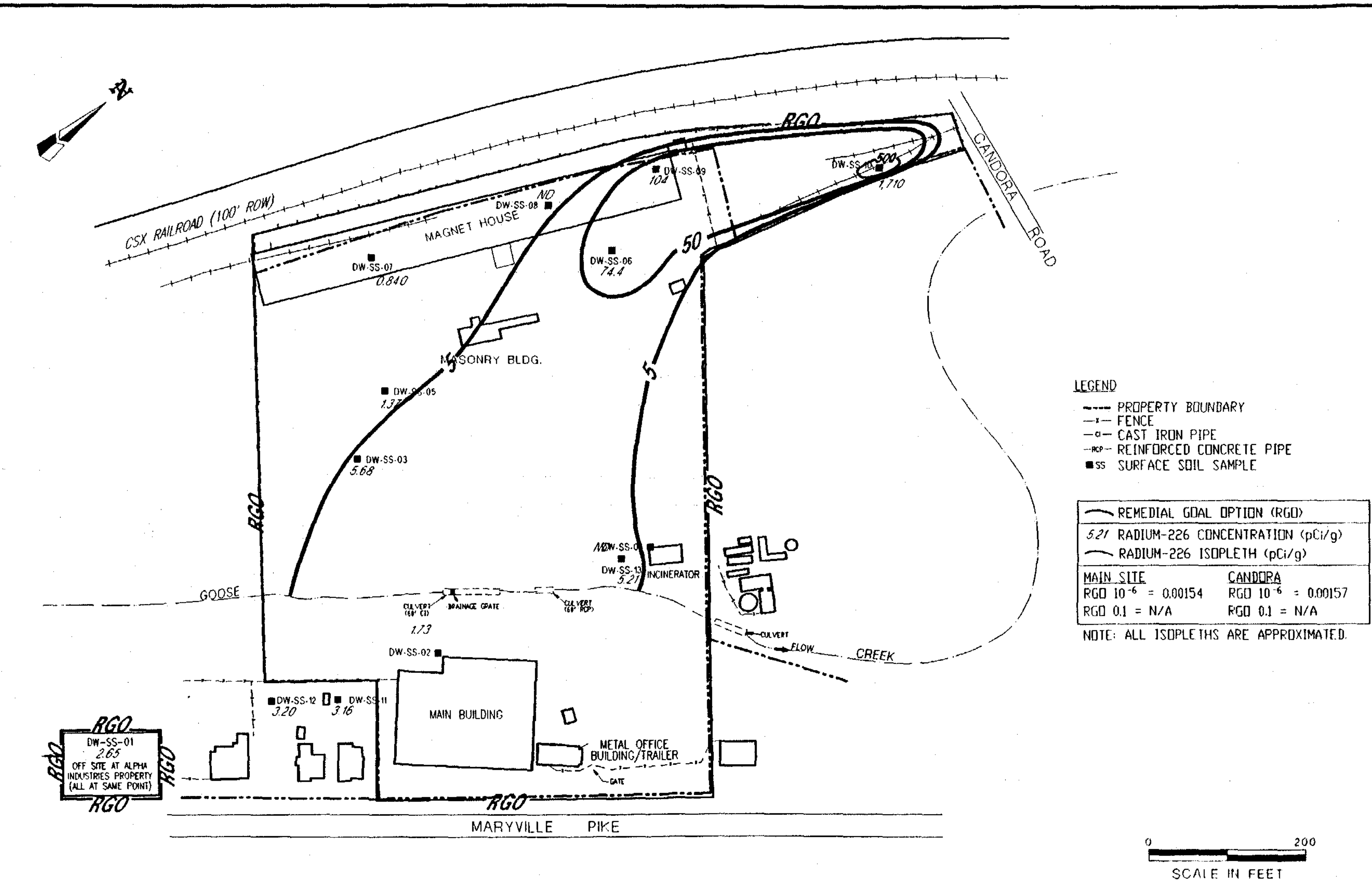
DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96-13157 DWG	DRAWING DATE OCTOBER 18, 1995 TG



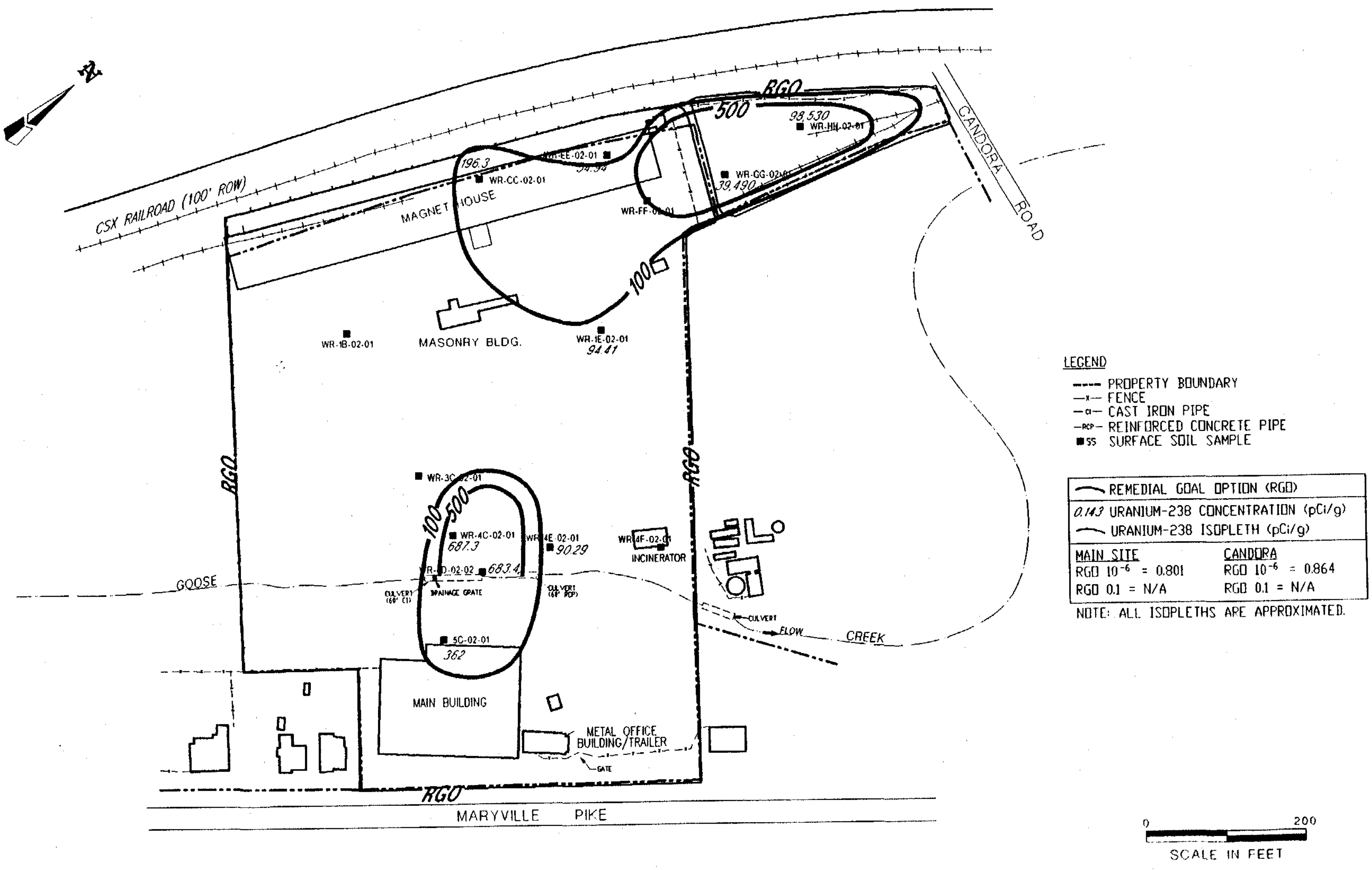
MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE Fig. 6.5	**Horizontal distribution of mercury in surface soil** *DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee*	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96-13154DWG	DRAWING DATE OCTOBER 18, 1996 TG



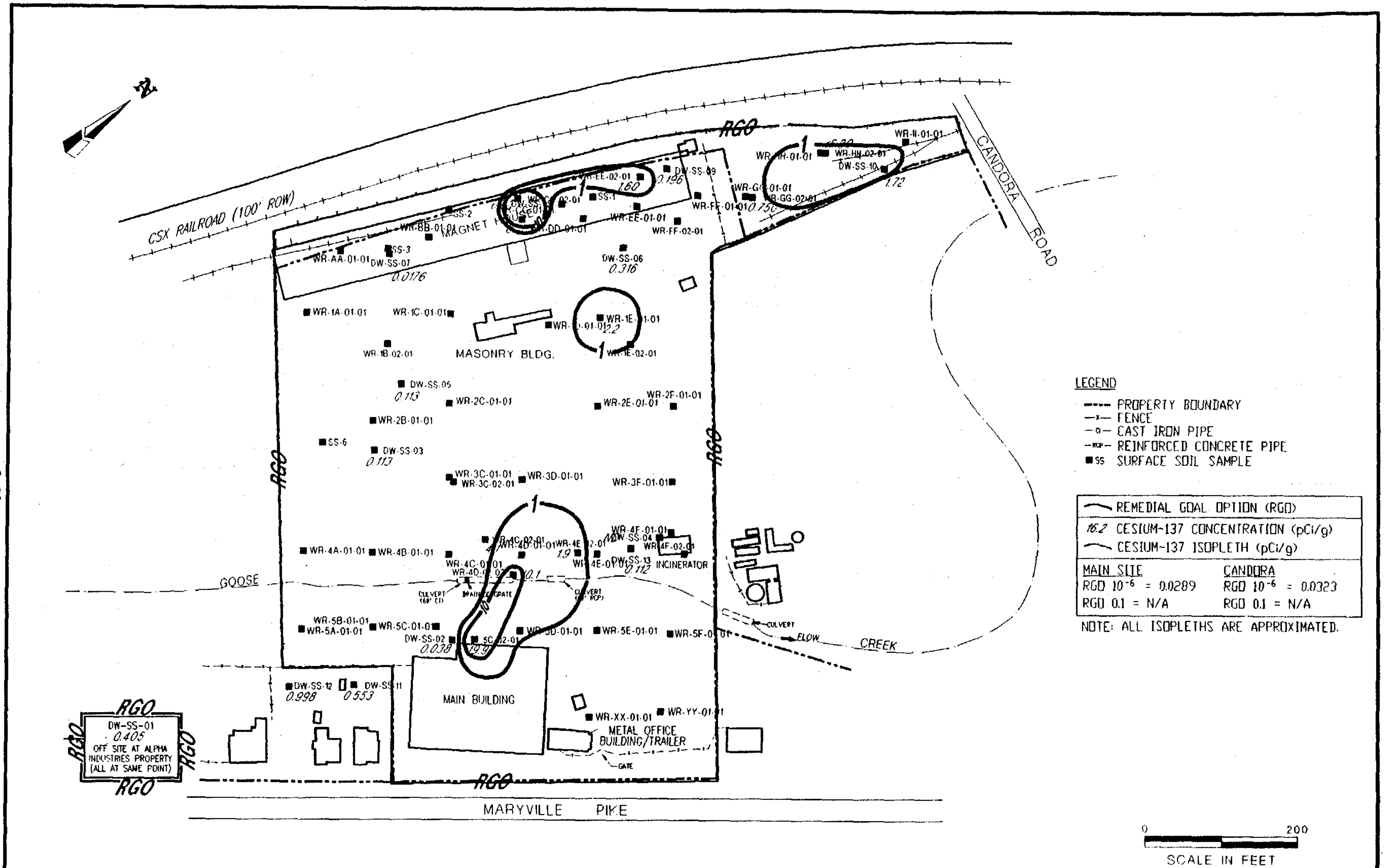
MODIFIED FROM. Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE **Fig. 6.6**	**Horizontal distribution of radium-226 in surface soil** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0034-20 / RI/FS	DRAWING ID: 96-13159 DWG	DRAWING DATE: OCTOBER 18, 1996 TG



MODIFIED FROM. Jesse Walker, RLS, PE, Survey, July 29, 1992

JE	Fig. 6.7	**Horizontal distribution of uranium-238 in surface soil** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13164.DWG	DRAWING DATE OCTOBER 18, 1996 TG



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JE® **Fig. 6.8**	**Horizontal distribution of cesium-137 in surface soil** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094 20 / RI/FS	DRAWING ID 96-13158.DWG	DRAWING DATE: OCTOBER 18, 1996 TG

the same chemicals are also the major risk contributors in soil in the Candora Road Area. Figures 6.1–6.8 show that these contaminants are found throughout the entire site. Remediation of these contaminants would encompass remediation of all the COPCs to acceptable levels.

Figure 6.9 shows the contour for all sediment COPCs above remediation levels. The extent of groundwater and surface water contamination is not determined because of data limitations.

6.2 AREAS AND VOLUMES OF CONTAMINATED MEDIA

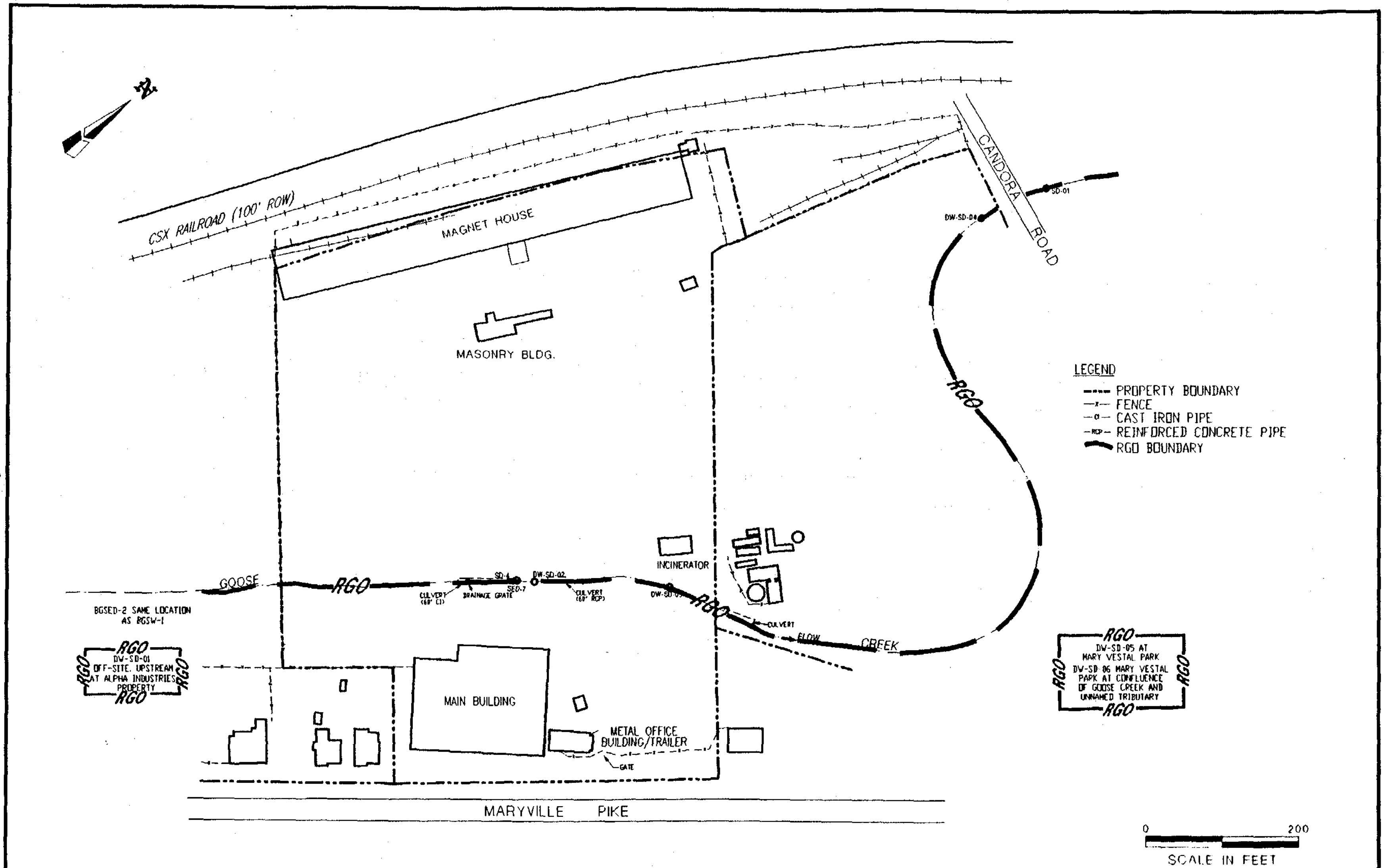
The assumed area and volume of contaminated surface debris, surface soil, and sediment are provided below. Additional media, including groundwater and surface water, will be added following analysis of planned sampling activities (see Appendix B).

6.2.1 Debris

The estimated volume of debris at the surface of the DWI 901 Site is 4,700 m^3 (6,100 yd^3). A visual characterization of the debris is described in Section 3.1.6 and in Table 3.4. The majority of the debris is categorized as follows (with estimated percent in parentheses):

- fines [ash, scraped soil, any material < 15 cm (6 in.) in all dimensions] (22 percent);
- sheet metal (17 percent);
- heavy gauge (iron/steel) pipes, rods, and rollers (13 percent);
- lumber and pallets (11 percent);
- thin (wire-like) metal (11 percent);
- equipment (refrigerant compressors and fan units) (10 percent);
- heavy gauge (iron/steel) metal bins, dumpsters, and roll-offs (7 percent);
- plastic (7 percent); and
- drums (2 percent).

Other miscellaneous debris includes electric meters, catalytic concretes, tanks and cylinders, spooled wire, loose tires, concrete slabs, and vegetation. Note that buildings or associated building debris are not included in this estimate. Approximately 50 percent of the site is vegetated or available for vegetation (i.e., not paved or covered by debris).



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE	Fig. 6.9	**Furthest distribution of sediment COCs** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID 96-13306.DWG	DRAWING DATE: OCTOBER 18, 1996 TG

6.2.2 Soil

Figures 6.1–6.8 show that the major contributors to soil risk are prevalent over the entire site. Therefore, the area of surface soil requiring remediation is assumed to be the entire site, 40,000 m^2 (10 acres). Based on the surface soil assumptions used in the risk assessment, contamination is assumed to extend 0.3 m (12 in.) deep. The resultant volume of soil requiring remediation is 12,000 m^3 (16,000 yd^3).

Subsurface soil data are not currently available. Therefore, no subsurface soil volumes are calculated or used in the development of alternatives. This shortcoming will be addressed during planned field sampling (see Appendix B).

6.2.3 Sediment

Figure 6.9 shows that the major contributors to sediment risk are prevalent over the entire on-site length of the stream. Assuming the extent of stream sediment is 180 m (589 ft) long, 1 m (3 ft) wide and 0.3 m (12 in.) deep, the areal extent of sediment is 180 m^2 (1,800 ft^2) and the volume of sediment requiring remediation is 54 m^3 (65 yd^3).

6.3 RA OBJECTIVES

This section presents the RAOs for the DWI 901 Site. RAOs are media-specific goals for the protection of human health and the environment. RAOs outlined in this section are as specific as possible while allowing flexibility in the development of remedial alternatives. They are based on human health risk assessment summaries for different receptors and comparisons of maximum concentrations detected in different media to corresponding regulatory levels. All contamination posing risk to ecological receptors is addressed when considering risk to human health. The RAOs for the DWI 901 Site include:

- Debris—To reduce contaminant contribution to environmental media through the removal or isolation of debris from the DWI 901 Site.

- Soil—To prevent current and future unacceptable risk ($> 1 \times 10^{-4}$ excess cancer risk or a HI of 1) to humans from exposure to contaminated soil. In particular, prevent ingestion of, direct contact with, direct radiation from, and particulate inhalation of contaminants in soil. Prevent ingestion of plants, meat, and milk contaminated as a result of uptake of radionuclides. Prevent contaminant migration to surface water in excess of human health and ecological RGOs and federal and state ambient water quality criteria. Prevent contaminant migration to groundwater in excess of human health RGOs and maximum contaminant levels.

- Sediment—To prevent current and future unacceptable risk ($> 1 \times 10^{-4}$ excess cancer risk or a HI of 1) to humans from exposure to contaminated sediment. In particular, prevent ingestion of and direct contact with contaminants in sediment. Prevent contaminant migration to surface water in excess of human health and ecological RGOs and federal and state ambient water quality criteria.

- Surface water—To develop RAOs for surface water following analysis of planned surface water sampling.

- Groundwater—To develop RAOs for groundwater following analysis of planned groundwater sampling.

This approach is consistent with EPA guidance (EPA 1988a) and recognizes that protection of human health and the environment can be achieved by reducing or limiting human exposure through institutional controls and by reducing contaminant levels. For example, risk associated with ingestion of contaminated soil can be reduced either by (1) restricting access to the contamination or (2) removing the contaminated soil. The importance of protecting human health and the environment through preserving or restoring environmental media (i.e., reducing contaminant levels) is recognized and serves as the main objective where technically feasible.

7. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Technologies applicable to the remediation of the DWI 901 Site are identified and screened in this chapter. The method used to identify technologies begins with development of general response actions that address the RAOs. General response actions are then subdivided into remedial technology types. Remedial technology types are further refined into process options, which provide a focused approach for treatment of a specific medium of interest. After technologies are identified, screening is performed to select the most appropriate technologies for alternative development. This screening is performed by a two-step process. First, options that are not applicable because of site conditions or contaminants are removed from consideration. After the initial screening, a more detailed screening is performed by evaluating each remaining technology on the basis of effectiveness, implementability, and cost. From the detailed screening, representative process options are selected, which are used in alternative development.

Section 7.1 presents the general response actions. Section 7.2 presents the remedial technology types and process options. Appendix D discusses and evaluates the technologies retained for alternative development. Section 7.3 provides a summary and rationale for representative process options chosen for each remedial technology type.

7.1 GENERAL RESPONSE ACTIONS

General response actions are broad categories of technologies that, alone or in combination, satisfy the RAOs listed in Chapter 6 and still apply to the remediation of a hazardous waste site.

General response actions applicable to this site include no action, monitoring, institutional controls, source containment, source removal, disposal, ex situ treatment, and in situ treatment. To better meet the RAOs, general response actions can be combined to address site conditions. For example, monitoring and institutional controls are often combined with source containment to provide overall protection to human health and the environment without removing or treating the source of contamination. NCP (40 CFR 300) mandates inclusion of the no action category. This category serves as a baseline against which other alternatives are compared.

7.2 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

Each general response action for the COPCs can be achieved using one or more remedial technology types. Some remedial technology types within the general response action of source containment include capping and subsurface vertical barriers. Examples of remedial technology types with the general response action ex situ treatment include physicochemical treatment and biological treatment. Remedial technology types are further refined by process options. Examples of process options within capping include single-layer caps and multilayer caps. Examples of physicochemical treatment process options include soil venting and groundwater carbon adsorption. Main resources for identification of technology types and process options include:

- EPA (U.S. Environmental Protection Agency). 1994. *Superfund Innovative Technology Evaluation Program*, EPA/540/R-94/526.
- EPA. 1990. *Handbook on In Situ Treatment of Hazardous-Waste Contaminated Soils*, EPA/540/2-90/002. Office of Research and Development.
- EPA. 1988. *Technology Screening Guide for Treatment of CERCLA Soils and Sludges*, EPA/5480/2088/004.
- EPA. 1985. *Remedial Action at Waste Disposal Sites: Handbook*, revised, EPA/625/6-85/00.
- Koerner, R. M. 1990 *Designing with Geosynthetics*. Prentice Hall.
- White, M. K., and J. L. Bryant. 1995. *ReOpt™ V 2.1 User Documentation*, PNL-7840, Rev. 1. Pacific Northwest Laboratory.

Figure 7.1 identifies the general response actions, technology types, and process options for the remediation of the DWI 901 Site. Figure 7.1 also identifies the applicable media for each process option and provides a brief description of the technology.

As specified in the RI/FS guidance, two steps are used to select the most appropriate technology types and process options to undergo detailed analysis. First, each process option is evaluated for its technical applicability at the site by comparing the capabilities of the process options with the site characteristics, contaminant properties, and associated contaminant

General Response Action	Remedial Technology Type	Process Option	Soil	GW	SW	Sediment	Debris	Description	Discussion
No Action	None	Natural Attenuation	P	P	P	P	P	No treatment is performed and media is allowed to degrade by natural means such as dispersion, *diffusion, adsorption*, or *biodegradation*.	
Monitoring	Sampling	Soil/Sludge Samples	S	X	X	S	X	Collect and analyze soil for contaminants.	
		Surface Water Samples	X	X	S	X	X	Collect and analyze surface water for contaminants.	
		Monitoring Wells	X	S	X	X	X	Collect and analyze groundwater for contaminants.	
		Vegetative Sampling	S	X	S	S	X	Collect and analyze vegetation for contaminants.	
		Air Sampling	S	X	X	S	S	Monitor air quality.	
		Wipe Sampling	X	X	X	X	S	*Wipe debris surfaces with cloth swatches to* sample for contamination.	
Institutional Controls	Permit Programs	Land Use Restrictions	P	P	P	P	P	Restrictions placed in the zoning plan to restrict land use or development.	
	Land Acquisition	Land Purchase Eminent Domain	P	P	P	P	P	Purchase or condemnation of potentially contaminated land.	
	Access Restrictions	Fencing and Warning Signs	P	P	P	P	P	Erection of physical barriers to prevent access to contaminated media.	
		Deed Restrictions	P	P	P	P	P	Restrictions and notifications attached to the deed of the impacted property.	

Representative Process Options — Screened Out — P - Primary Process Option — S - Secondary Process Option — X - Not Applicable

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Fig. 7.1

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Process option technology screening

DOE - David Witherspoon Inc, 901 Site - Oak Ridge, Tennessee

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General Response Action	Remedial Technology Type	Process Option	Soil	GW	SW	Sediment	Debris	Description	Discussion
Source Containment	Capping	Single Layer Cap	P	X	X	P	P	Compacted clay and soil covering for a contaminated area.	
		Multilayer Cap	P	X	X	P	P	Compacted clay, synthetic geomembranes, and soil covering for a contaminated area.	
	Vertical Barriers	Slurry Walls	X	P	X	X	X	Trench surrounding areas of contamination filled with soil/betonite or cement/betonite mixtures.	
		Diaphragm Wall	X	P	X	X	X	Concrete panels placed in trenches to form a barrier.	
		Polyethylene Sheeting	X	P	X	X	X	A trench filled with a slurry mixture and a geomembrane liner.	
		Grout Curtain	X	P	X	X	X	Pressure injection of cement, clay, bentonite, alkali, silicate, or organic polymer grout in a regular pattern of drilled holes	
		Rock Grouting	X	P	X	X	X	Pressure injection of cement, clay, bentonite, alkali, silicate, or organic polymer grout into the ground to seal voids in rocks.	
		Sheet Pile Wall	X	P	X	X	X	Directional drilling from the site perimeter followed by grout injection to form a horizontal or curved barrier under the waste.	
	Subsurface Horizontal Barriers	Grout Injection	X	P	X	X	X	Directional drilling from the site perimeter followed by grout injection to form a horizontal or curved barrier under the waste	
		Block Displacement	X	P	X	X	X	A perimeter barrier is constructed of slurry or cement and grout is injected into a pattern of notched holes through the site until displacement of the earthen block is accomplished.	Not effective in fractured rock
	Surface Water Controls	Collection Ditches/Culverts	S	S	S	X	X	Ditches used to divert surface water from the site or collect surface water runoff from the site.	
		Grading	S	S	S	X	X	Reshaping site topography to decrease ponding and erosion at the site from surface water run on or runoff.	
		Terraces/Benches	S	X	S	X	X	Embankments constructed along contours of long or steep slopes to intercept or divert flow.	The slope of the site is not steep

Media: Soil, GW, SW, Sediment, Debris

Representative Process Options

Screened Out

P - Primary Process Option S - Secondary Process Option X - Not Applicable

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Fig. 7.1

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Process option technology screening

DOE - David Witherspoon Inc, 901 Site - Oak Ridge, Tennessee

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General Response Action	Remedial Technology Type	Process Option	Soil	GW	SW	Sediment	Debris	Description	Discussion
Source Containment *continued...*	Surface Water Controls *continued...*	Sedimentation Basins	X	X	S	X	X	Earthen dams constructed to impede surface water runoff and allow solids to settle to the bottom of the basin.	
		Berms/Levees	X	X	S	X	X	Embankments that protect low lying areas during flood events.	
		Channels/Waterways (screened out)	X	X	X	X	X	Wide, shallow, excavated ditches used to intercept surface water runoff.	Not intended for small water bodies
		Soil/Sediment Stabilization	S	X	X	S	X	Installation of rip-rap, cement, or another binder to stabilize the soil in an area.	
		Silt Curtains	S	X	X	S	X	Installation of fencing and haybales to prevent sediment loading to surroundng waters.	
	Dust Controls	Revegetation	S	X	X	X	X	Planting vegetation at the site to minimize transfer of contaminants by airborne emissions during dry conditions	
		Temporary Capping	S	X	X	X	S	Utilization of clay, soil, asphalt, or cement to control airborne emissions.	
		Vapor-Suppressing Foam	S	X	X	X	X	Application of a foam over a contaminated area to prevent escape of potentially harmful vapors.	
		Wetting	S	X	X	X	X	Spray application of water or other dust suppressant liquids on the soil at a site.	
Source Removal	Excavation	Solids Excavation	P	X	X	P	P	Removal of soil, sediment, and debris by a variety of mechanized and manual methods that are contingent upon the site topography and conditions.	
	Separation	Manual Sorting	X	X	X	X	S	Removal of debris from the soil media by hand separation.	
		Magnetic Sorting	X	X	X	X	S	Removal of metallic debris from the soil media by using a magnet.	

Representative Process Options

Screened Out

P - Primary Process Option S - Secondary Process Option X - Not Applicable

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Fig. 7.1

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Process option technology screening

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General Response Action	Remedial Technology Type	Process Option	Soil	GW	SW	Sediment	Debris	Description	Discussion
Source Removal *continued...*	Separation *continued...*	Mechanical Sizing (Shredding)	S	X	X	S	S	The utilization of screens to remove large pieces of debris and provide a more homogenous soil mix for treatment operations.	
		Screening	S	X	X	S	S	The utilization of screens to remove large pieces of debris and provide a more homogenous soil mix for treatment operations.	
	Extraction	Extraction Wells	X	P	X	X	X	Series of wells used to remove contaminated groundwater.	
		Vacuum Extraction	X	P	X	X	X	Wells with a vacuum applied that assists in the collection of groundwater from low permeability soils.	
		Pumping from Trench or Excavation	X	P	P	X	X	Trenches or excavated areas used to collect groundwater for removal.	
Disposal	Decontaminated Material	Leave Treated Material On-Site	S	S	S	S	S	The soil and sediment from treatment operations are placed back on site and used as backfill to level site.	
		Sanitary/ Industrial Landfill	S	X	X	S	S	Transportation to and disposal of treated and uncontaminated media in a commercial non-hazardous waste landfill either sanitary or industrial depending upon the characteristics of the media.	
		Salvage	X	X	X	X	S	Shipment of materials that can be recycled to a salvage yard for recycling.	
		Injection Wells	X	S	X	X	X	The introduction of treated or uncontaminated groundwater back into a shallow aquifer.	
		Discharge to Surface Water	X	S	S	X	X	Introduction of treated or uncontaminated water into a surface water body near the site.	
		Discharge to a Public Owned Treatment Works	X	S	S	X	X	Introduction of treated or uncontaminated water into a sanitary sewer line for transport to a water treatment plant.	

Media: Soil, GW, SW, Sediment, Debris

Representative Process Options — Screened Out — P - Primary Process Option — S - Secondary Process Option — X - Not Applicable

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Fig. 7.1

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Process option technology screening

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General Response Action	Remedial Technology Type	Process Option	Soil	GW	SW	Sediment	Debris	Description	Discussion
Disposal *continued...*	Contaminated Material	Disposal at Envirocare of Utah	P	X	X	P	P	Transportation to and disposal of treated media at Envirocare	
		Oak Ridge CERCLA Waste Management Facility	P	X	X	P	P	Transportation to and disposal of untreated media at the CWMF.	
		Discharge to Off-Site Water Treatment Facility	X	P	P	X	X	Shipping liquid waste streams to a facility for treatment.	
		Storage Pending Final Disposal	S	S	S	S	S	Disposition of treated or untreated media at a storage facility until final disposal is achieved.	
Ex Situ Treatment	Physicochemical Treatment	Chemical Dechlorination	P	P	P	P	X	Removal of chlorine from the organic contaminants in a waste media by the introduction of chemicals to dehalogenate the	
		Solvent Extraction	P	P	P	P	X	Usage of solvents both organic and inorganic to remove contaminants from a contaminated waste stream. *Supercritical solvent extraction uses*	
		Soil Washing	P	X	X	P	X	Mixing contaminated soils with water or surfactants followed by a rinse to remove contaminants from the soil.	
		Soil Venting	P	X	X	X	X	Staging of excavated soil into piles and using direct, induced, or natural air flow through the soil piles to remove volatile compounds.	VOCs are not COCs
		Solidification/ Stabilization	P	X	X	P	P	Uses binders like cement, flyash, clays, silicates, or thermoplastics to immobilize contaminated materials into a solidified mass.	
		Macro Encapsulation	P	X	X	P	P	Placement of waste materials into a container or overpack to decrease mobility of a contaminant.	
		Sedimentation	X	P	P	X	X	The use of gravity to remove suspended particulates from a liquid waste stream due to density differences	

Representative Process Options — Screened Out (Soil Venting) — P - Primary Process Option — S - Secondary Process Option — X - Not Applicable

Fig. 7.1 Page 5 of 8

Process option technology screening

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General Response Action	Remedial Technology Type	Process Option	Soil	GW	SW	Sediment	Debris	Description	Discussion
Ex Situ Treatment continued...	Physicochemical Treatment continued...	Manual Scraping/ Brushing	X	X	X	X	P	Intimate contact of a contaminated liquid with a The removal of soil from debris by manual methods such as scraping, brushing, or wiping,	
		High Pressure Washing	X	X	X	X	P	The removal of soil from debris by using a high pressure water stream to dislodge dirt from the debris.	
		Debris Washing System	X	X	X	X	P	The removal of soil from debris by using an automated system that washes, and rinses the debris to remove the contaminated soil and also treats and recycles the wash and rinse water..	
		Air Stripping	X	P	P	X	X	Intimate contact of a contaminated liquid with a large volume of air in a tray or packed column to facilitate transfer of volatile compounds from the	VOCs are not COCs
		Activated Carbon Adsorption	X	P	P	X	X	Requires intimate contact between a liquid waste stream and activated carbon to promote transfer of the contaminant from the liquid to the activated sites on the carbon.	
		Membrane Separation	X	P	P	X	X	The implementation of polymer based membranes which are selective to the size of molecules that are allowed to flow through the membrane, thereby	
		Filtration	X	P	P	X	X	Suspended solids are removed by a porous media that allows the fluid to pass through and retains the solids. Can be gravity or pressure driven and uses a variety of media, such as sand and coal.	
		Distillation	X	P	P	X	X	Separates contaminants based upon different volatilities with the more volatile being vaporized and condensed.	
		Electrokinetics	P	P	P	P	X	The application of direct current to remove contaminants through mass transfer operations such as diffusion and ion migration.	
		Neutralization	X	S	S	X	X	Addition of acids/bases to raise or lower the pH of a media.	
		Chemical Oxidation	X	P	P	X	X	Oxidation of contaminants in water to CO2 and H20 by using such oxidants as ozone, peroxide, chlorine, potassium permanganate, and/or UV light.	
		Chemical Precipitation	X	P	P	X	X	The addition of chemicals to a liquid stream that causes the contaminants to form insoluble compounds that will fall out of suspension in the	

Representative Process Options

Screened Out

P - Primary Process Option S - Secondary Process Option X - Not Applicable

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Fig. 7.1

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Process option technology screening

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General Response Action	Remedial Technology Type	Process Option	Soil	GW	SW	Sediment	Debris	Description	Discussion
Ex Situ Treatment *continued...*	Thermal Treatment	Incineration	P	P	P	P	P	Combustion in a rotary kiln incinerator.	
		Steam Stripping	P	P	P	P	X	Passage of steam through contaminated soil to drive off volatile compounds, requires off-gas treatment.	VOCs are not COCs
		Low-Temperature Thermal Desorption	P	X	X	P	X	Heating of soils to volatilize contaminants, requires collection and treatment of off-gas.	
		Vitrification	P	X	X	P	X	Heating of a contaminated media with glass formers to high temperatures where the mix becomes a molten glass upon cooling.	
		Fuel Source	P	X	X	X	P	Using contaminated media as a fuel source to operate thermal processes.	Insufficient BTU content
	Biological Treatment	Slurry-Phase Biodegradation	P	P	P	P	X	Biodegradation of soils and sludges mixed with water in a soil/water *slurry reactor using either* naturally-occurring microorganisms or bioaugmentation with specialized inocula.	
		Constructed Wetlands	P	P	P	P	X	Utilizes soil and sediment as wetlands substrate where microbial activity in the root mass will degrade volatile and semivolatile organic compounds in sol and water	
		Aerobic Land Treatment	P	X	X	P	X	Biodegradation in engineered, prepared bed with naturally-occurring microorganisms.	
		Aerated Lagoons	X	P	P	X	X	Biodegradation in an open lagoon equipped with mechanical aeration.	
		Stabilization Pond	X	P	P	X	X	Biodegradation in a combined aerobic/ anaerobic process with no mechanical aeration.	

Representative Process Options — Screened Out (Steam Stripping, Fuel Source)

P - Primary Process Option S - Secondary Process Option X - Not Applicable

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Fig. 7.1

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Process option technology screening

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General Response Action	Remedial Technology Type	Process Option	Media: Soil	GW	SW	Sediment	Debris	Description	Discussion
Ex Situ Treatment *continued...*	Biological Treatment *continued...*	Sequencing Batch Reactor	X	P	P	X	X	Activated sludge treatment in a timed batch process. Typically operation alternates between two or more reactors.	
		Aerobic Fixed-Film Treatment	X	P	P	X	X	Biodegradation using rotational biological contactors, trickling filters, or an aerobic fluidized bed reactor.	
		Anaerobic Fixed-Film Treatment	X	P	P	X	X	Biodegradation in fixed-bed reactor or an anaerobic fluidized-bed reactor.	
In Situ Treatment	Physicochemical Treatment	Soil Vapor Extraction	P	X	X	X	X	Pressure gradient applied to a soil to enhance volatilization of organic compounds, requires offgas collection and treatment.	VOCs are not COCs
		Soil Flushing	P	X	X	X	X	Use of extraction/reinjection system to flush soil with a solvent to mobilize the contaminants and remove them from the media.	
		Stabilization/Solidification	P	X	X	P	P	Binding contaminants into a solidified matrix by using an auger with a spray attachment to drill holes at the site and mix grout with the soil.	
		Chemical Oxidation	X	P	X	X	X	Using a system of injection wells or trenches to deliver oxidants to a contaminated media to oxidize the contaminants.	
		Electrical Separation	P	P	P	P	X	Use of direct current to remove contaminants from the soil by mass transfer mechanisms.	Subsurface inorganic debris will result in malfunction of electrodes
	Thermal Treatment	In Situ Vitrification	P	X	X	P	P	Using electrodes inserted into a soil to melt the soil into a glass form that is stable and retains inorganic contaminants, while organic contaminants are destroyed by the high temperatures.	
		Steam Stripping	P	P	X	P	X	Injection of steam into soils to remove the volatile contaminants from the media, requires an offgas collection and treatment system.	VOCs are not COCs
	Biological Treatment	In Situ Biodegradation	P	P	P	P	X	Degradation of organics by adding nutrients, oxidants, and microbes to the soil or media at the site, can be either aerobic or anaerobic.	

Representative Process Options — Screened Out

P - Primary Process Option — S - Secondary Process Option — X - Not Applicable

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Fig. 7.1

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Process option technology screening

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concentrations. Process options that are not technically applicable are eliminated from further consideration. In some cases, no process option for a given technology is considered technically applicable at the site, thus the entire technology type is eliminated. Process options or technology groups that do not pass this first screening step are not carried forward, as indicated by a cross-hatched box in the figure. For process options screened out, a brief explanation is provided.

If a process option has the potential of satisfying one or more RAOs by itself, it is considered a primary process option and is designated "P" for the applicable medium. Process options used only to support a primary process option are referred to as secondary process options and are designated "S."

In the second screening step, the retained process options are evaluated for effectiveness, implementability, and cost (see Appendix D). This evaluation is used to select representative process options for each technology type, as indicated by double boxes in Figure 7.1. Representative process options are carried forward for development into sitewide remedial alternatives in Chapter 8. Remedial alternatives combine representative process options from appropriate technology groups in a manner that protects human health and the environment. 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 cases, two or more process options for a single technology type may be carried forward for alternative development.

7.3 SUMMARY OF REPRESENTATIVE PROCESS OPTIONS

Sections 7.3.1–7.3.8 discuss the representative process options remaining after reviewing and screening the technology types and process options listed in Figure 7.1. The results of the representative process option discussion are condensed in Table 7.1.

7.3.1 No Action

The no action general response action is retained because no effort or expense is required for its implementation. Natural attenuation of contamination, which may result from this action, is not likely and would not effectively prevent exposures of current or future off-site receptors to contaminants.

7.3.2 Monitoring

Monitoring is a secondary process option that alone would not achieve any of the RAOs. Media monitoring techniques are commonly applied at hazardous waste sites and generally do not significantly alter the effectiveness or implementability of most RA alternatives. Long-term monitoring programs may have substantial costs associated with them. Monitoring programs are

Table 7.1. Summary of representative process options, DWI 901 Site, Knoxville, Tennessee

General response action	Remedial technology type	Representative process option
No action	None	Natural attenuation
Monitoring	Sampling	Sample all media
Institutional controls	Permit programs Land acquisition Access restrictions	Land use restrictions Fencing and warning signs Deed restrictions
Source containment	Capping	Multilayer capping
	Surface water controls	Collection ditches/culverts Grading Sedimentation basin Soil/sediment stabilization Silt curtains
	Dust controls	Revegetation and wetting
Source removal	Excavation	Solids excavation
	Separation	Manual sorting Magnetic sorting Mechanical sizing (shredding) Screening
	Extraction	Extraction wells
Disposal	Decontaminated material	Leave on site Salvage Injection wells Discharge to surface water Discharge to POTW
	Contaminated material	Disposal at Envirocare of Utah Contaminated material Discharge to water treatment facility
Ex situ treatment	Physicochemical treatment	Solvent extraction Solidification/stabilization Manual scraping/brushing High-pressure washing Debris washing system Chemical oxidation Chemical precipitation
	Thermal treatment	Incineration Low-temperature thermal desorption Vitrification

DWI = David Witherspoon, Inc.
POTW = publicly owned treatment work

developed for each alternative and discussed in subsequent sections. Soil, surface water, groundwater, vegetation, air, and debris sampling are selected as representative process options to verify the effectiveness of the RA used at the site. Verification sampling will also be required to satisfy regulatory requirements for effectiveness of excavation and site closure.

7.3.3 Institutional Controls

Institutional controls are effective and inexpensive means of limiting exposure to contaminated media. Land use restrictions, fencing, warning signs, and deed restrictions are selected as representative process options to maintain institutional control at the site.

7.3.4 Source Containment

The source containment general response action is divided into capping, vertical barriers, subsurface-horizontal barriers, surface water controls, and dust controls.

Among the capping, vertical barrier, and subsurface horizontal barrier technology types, the multilayer cap is the only representative process option. Multilayer capping is more suitable for the DWI 901 Site than any of the options available within the vertical and horizontal barrier technology types because of its known effectiveness at reducing infiltration to the contaminant zone, ease of implementability, and relative low cost.

Implementability and cost differences among all the process options within the surface water controls technology type are relatively indistinguishable. The collection/diversion ditch, grading, sedimentation basin, soil/sediment stabilization, and silt curtains are selected as representative process options for surface water control. These options are carried forward because of their ability to collect and contain surface water runoff effectively. All of the process options are secondary process options and will be used in conjunction with other remedial technology types and will be used, as appropriate, in the development of detailed alternatives.

The use of dust controls, such as vegetation, caps, foams, water, and other chemical sprays to suppress dust during on-site construction activities will be necessary. Revegetation and wetting are selected as representative process options for the dust control technology. All the dust control process options are considered secondary and will be used in conjunction with other remedial technology types, as appropriate, in the development of detailed alternatives.

7.3.5 Source Removal

The source removal general response action is divided into excavation, separation, and extraction.

The primary means of source removal will be solids excavation/backfilling. Removal of soil, debris, and sediment from the site is a prerequisite for ex situ treatment and disposal, hence solids excavation with backfilling is a representative process option for source removal.

Soil and debris at the DWI 901 Site will require sorting during excavation activities so that they are treated and disposed of appropriately. Manual and magnetic sorting, mechanical sizing, and screening are representative process options for the separation technology type. These activities are secondary process options and will be employed throughout detailed alternative development.

Within the extraction technology type, extraction wells are chosen to represent groundwater removal technologies. Extraction wells are more suitable for the DWI 901 Site than vacuum extraction and pumping from a trench because of their proven effectiveness and low cost for collecting groundwater.

7.3.6 Disposal

The disposal general response action is divided into the disposal of contaminated and decontaminated materials remedial technology types.

Within the disposal of decontaminated materials technology type, on-site disposal, salvage, injection wells, publicly owned treatment work (POTW) discharge, and discharge to surface water are retained as representative process options. All of these are secondary process options that may be implemented after a treatment technology. On-site disposal options are retained because shipping costs for large volumes of soil would be avoided. The salvage option is selected for debris because of the requirement of debris removal for treatment operations. Injection wells or discharge to a POTW is retained for treated water disposal because of the proximity of an aquifer or local sanitary sewer to the site.

Within the disposal of contaminated materials technology type, disposal at Envirocare of Utah, the proposed Environmental Management Waste Management Facility (EMWMF), and discharge to an off-site water treatment facility are selected as representative process options.

Storage pending final disposal is retained as a secondary option to allow flexibility in the detailed development of alternatives. Long-term storage and disposal and an industrial landfill are retained as representative process options.

7.3.7 Ex Situ Treatment

The ex situ treatment general response action is divided into the physicochemical, thermal, and biological remedial technology types.

Within the physicochemical remedial technology type, several techniques are selected as representative process options. Solvent extraction is retained for PCB removal from soils and other media. Solidification/stabilization is also selected as a representative process option to immobilize inorganic contaminants in soil. Manual cleaning, high-pressure washing, and a debris-washing system using water and surfactants are selected for decontamination of the large metallic debris at the site. Chemical oxidation is selected for organic treatment. Also, chemical precipitation is selected to remove inorganics from aqueous wastes.

Process options selected to represent thermal treatment are incineration, low-temperature thermal desorption (LTTD), and vitrification. Both incineration and vitrification are effective in the destruction of PCB molecules and are implementable. LTTD is effective for the separation of PCBs and mercury from a waste stream and destruction of other organics.

No process options using biological treatment are retained for alternative development, because of the difficulty in removing PCBs, the concern regarding heavy metal toxicity to the biological organisms, the extensive time period required for treatment, and the space requirements for a treatment system.

7.3.8 In Situ Treatment

The in situ treatment general response action is divided into the physicochemical, thermal, and biological remedial technology types.

Within the physicochemical remedial technology type, no in situ treatment technologies were chosen because of the unknown nature of the subsurface soil. The difficulty in control and the availability of in situ treatment systems for groundwater eliminate all physicochemical techniques as process options.

No in situ thermal treatment technologies are retained for alternative development. The suspected presence of buried waste would inhibit thermal treatment techniques.

Within the in situ biological technology type, no treatment options are retained as representative process options because of the uncertainty in large-scale application of biological techniques under uncontrolled conditions.

8. DEVELOPMENT OF ALTERNATIVES

This chapter develops alternatives for RA at the DWI 901 Site. Section 8.1 presents media-specific alternatives and Section 8.2 presents sitewide alternatives. The media specific alternatives are assembled from the representative process options selected in Chapter 7 and address each medium independently, without consideration of other media. By focusing on one medium at a time, the technologies can be evaluated thoroughly. Sitewide alternatives address all media types, focus on the interrelationships among the various media, and present comprehensive approaches for RA.

8.1 DEVELOPMENT OF MEDIA-SPECIFIC ALTERNATIVES

Media-specific alternatives address the different media types that may require treatment at the DWI 901 Site. These media include soil, debris, and sediment. Surface water and groundwater will be addressed after planned sampling activities, if remediation is necessary. The complexity of the site and the different media types warrant the development of media-specific alternatives. Media-specific alternatives are developed from representative process options that address corrective action for each media type. The alternatives are evaluated on the basis of effectiveness, implementability, and cost. This evaluation is presented in Table 8.1. Media-specific alternatives are removed from further consideration for sitewide alternatives if (1) they do not compare favorably with other media-specific alternatives or (2) they are adequately represented by other retained media-specific alternatives.

8.2 DESCRIPTION OF SITEWIDE ALTERNATIVES

This section presents four sitewide alternatives for the DWI 901 Site. Media-specific alternatives from Section 8.1 are combined to develop the comprehensive actions needed for development of the sitewide alternatives. Table 8.2 shows the combination of media specific alternatives used to develop the sitewide alternatives. Only one technology is presented for each medium, though during remedial design, other media-specific technologies may be substituted for those represented in the sitewide alternatives. Surface water and groundwater remediation components will be added to the alternatives, if necessary, following analysis of planned sampling activities (see Appendix B). The proposed action for each sitewide alternative is listed in Table 8.2.

The sitewide alternative descriptions provide conceptual-level design criteria in sufficient detail to ensure that the RAs can be implemented and to analyze and compare the alternatives

Table 8.1. Media-specific alternative development and evaluation, DWI 901 Site, Knoxville, Tennessee

Media	Alternative	Retained for SWA	Effectiveness	Implementability	Cost
Debris	(1) No action	Yes	Natural attenuation may not be effective because permanent toxicity reduction cannot be achieved for certain contaminants	No implementation required	None
	(2) Multilayer cap	Yes	A multilayer cap would effectively reduce exposure to the contaminated debris and would be moderately effective at reducing the transport of contamination via erosion and infiltration. It would not achieve permanent contaminant reduction	Readily implementable	Low
	(3) Disposal at proposed EMWMF	Yes	Landfill controls would effectively reduce exposure to and transport of contaminants in debris; however, permanent reduction of contamination would not occur	Readily implementable if available	Low
	(4) Clean and salvage or dispose	Yes	Debris-washing technologies have been demonstrated in the SITE program as a viable treatment option for contaminated debris	Readily implementable	Moderate
Soil	(1) No action	Yes	Natural attenuation may not be effective because permanent toxicity reduction cannot be achieved for certain contaminants	No implementation required	None
	(2) Multilayer cap	Yes	A multilayer cap would effectively reduce exposure but would not achieve permanent contaminant reduction	Readily implementable	Low
	(3) Disposal at proposed EMWMF	Yes	Landfill controls would effectively reduce exposure to and transport of contaminants in the debris; however, permanent reduction of contamination would not occur	Readily implementable if available	Low
	(4a) Incineration	No	Organic contaminants would be destroyed by incineration. The resulting ash may contain increased levels of heavy metals	Difficult to implement	High

Table 8.1. (continued)

Media	Alternative	Retained for SWA	Effectiveness	Implementability	Cost
	(4b) LTTD	Yes	LTTD is capable of removing PCBs and mercury, but the soil would still require hazardous waste disposal	Readily implementable, mobile treatment units available	Moderately high
	(4c) Solvent extraction	No	Solvent extraction is capable of achieving PCB removal, but the soil would still require hazardous waste disposal	Difficult to implement on clayey soils	Moderately high
	(4d) Vitrification	Yes	Vitrification would destroy organic contaminants, bind heavy metals, and disperse radioactivity throughout the melt to distribute the overall activity evenly	Moderately implementable, mobile treatment units available	Very high
Sediment	(1) No action	Yes	Natural attenuation may not be effective because permanent toxicity reduction cannot be achieved for certain contaminants	No implementation required	None
	(2) Source containment	No	Sediment stabilization with riprap would not reduce the concentration of the contaminants but would reduce the mobility of contaminants	Readily implementable	Low
	(3) Consolidate with soil	Yes	This alternative would remove contaminants from the stream bed and prevent future contact with on-site and downstream ecological or human receptors	Readily implementable	Moderate

DWI = David Witherspoon, Inc.
EMWMF = Environmental Management Waste Management Facility
LTTD = low-temperature thermal desorption
PCB = polychlorinated biphenyl
SITE = Superfund Innovative Technology Evaluation
SWA = sitewide alternative

Table 8.2. Sitewide alternatives, DWI 901 Site, Knoxville, Tennessee

Media	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Debris	No action	Treat with a debris-washing technology for subsequent salvage or sanitary disposal to the extent practical; incorporate remainder with soils	Incorporate with soils to the extent practical or treat with a debris-washing technology for subsequent salvage or sanitary disposal	Incorporate with soils to the extent practical; treat with a debris-washing technology for subsequent salvage or sanitary disposal
Soil	No action	Multilayer cap and monitoring	Excavation, treatment (LTTD), and disposal at proposed EMWMF	Excavation, ex situ vitrification, and disposal
Sediment	No action	Consolidate and cap with soil	Consolidate; treat and dispose with soil	Consolidate; treat and dispose with soil
Surface water	No action	TBD	TBD	TBD
Groundwater	N7o action	TBD	TBD	TBD

DWI = David Witherspoon, Inc.
EMWMF = Environmental Management Waste Management Facility
LTTD = low-temperature thermal desorption
TBD = to be determined

with respect to CERCLA criteria listed in Chapter 9. Appendix G, "Cost Estimate Documentation," provides additional details and assumptions to develop cost estimates for each alternative and presents detailed schedule information for remedial design and RA. Specifications regarding material quantities, construction techniques, locations of facilities, and other similar items may be revised during preparation of the ROD or the remedial design.

Each alternative description includes a discussion of (1) base RAs, which address probable site conditions and expected remediation results; (2) process modifications (if any) that could be developed during remedial design or RA; and (3) contingency actions (if any) to address reasonable deviations from the probable conditions and remediation results assumed. During remedial design, implementation, and during the life of the engineering controls, monitoring actions would be implemented to determine if any deviations from the probable conditions occur. Results of this monitoring would indicate whether contingency actions or process modifications would be required to address the deviations.

Reasonable deviations from the assumed site conditions, policy, or technology performance (if any) that may require the use of new or additional process options are identified for each alternative. If such deviations occur, contingency actions are discussed. Early identification of potential deviations and development of appropriate contingency actions (1) allow preparation of a ROD that can be readily implemented based on probable conditions and (2) allow development and approval of monitoring and contingency plans to avoid the need for additional document preparation and approval, if identified deviations occur.

8.2.1 Alternative 1—No Action

For the no action alternative, no treatment, removal, disposal, monitoring, or controls will be implemented. The soil, debris, and sediment will be left in place at the DWI 901 Site. Risks will remain for all of the media addressed by this FS. There is no cost associated with the implementation this alternative. This alternative is required by NCP and NEPA as a baseline for comparison with other alternatives.

8.2.2 Alternative 2—Multilayer Cap and Monitoring

Following is a list of media and associated remedial activities for Alternative 2.

- Debris—Treat with debris-washing technology for subsequent salvage or sanitary disposal to the extent practical and cap remaining debris along with soils.

- Soil—Multilayer cap, monitoring, and institutional controls.

- Sediment—Consolidate with soil and cap.
- Surface water—To be determined (TBD).
- Groundwater—TBD.

Alternative 2 includes installing an approximately 0.6 ha (1.5-acre) multilayer cap to contain and isolate contaminated soil, debris, and sediment. This alternative is designed for a future industrial land use scenario. Implementation is estimated to take 36 months, not including monitoring. Appendix G contains schedule assumptions addressing remedial design and RA for each of the alternatives. A flowsheet describing Alternative 2 is presented as Figure 8.1.

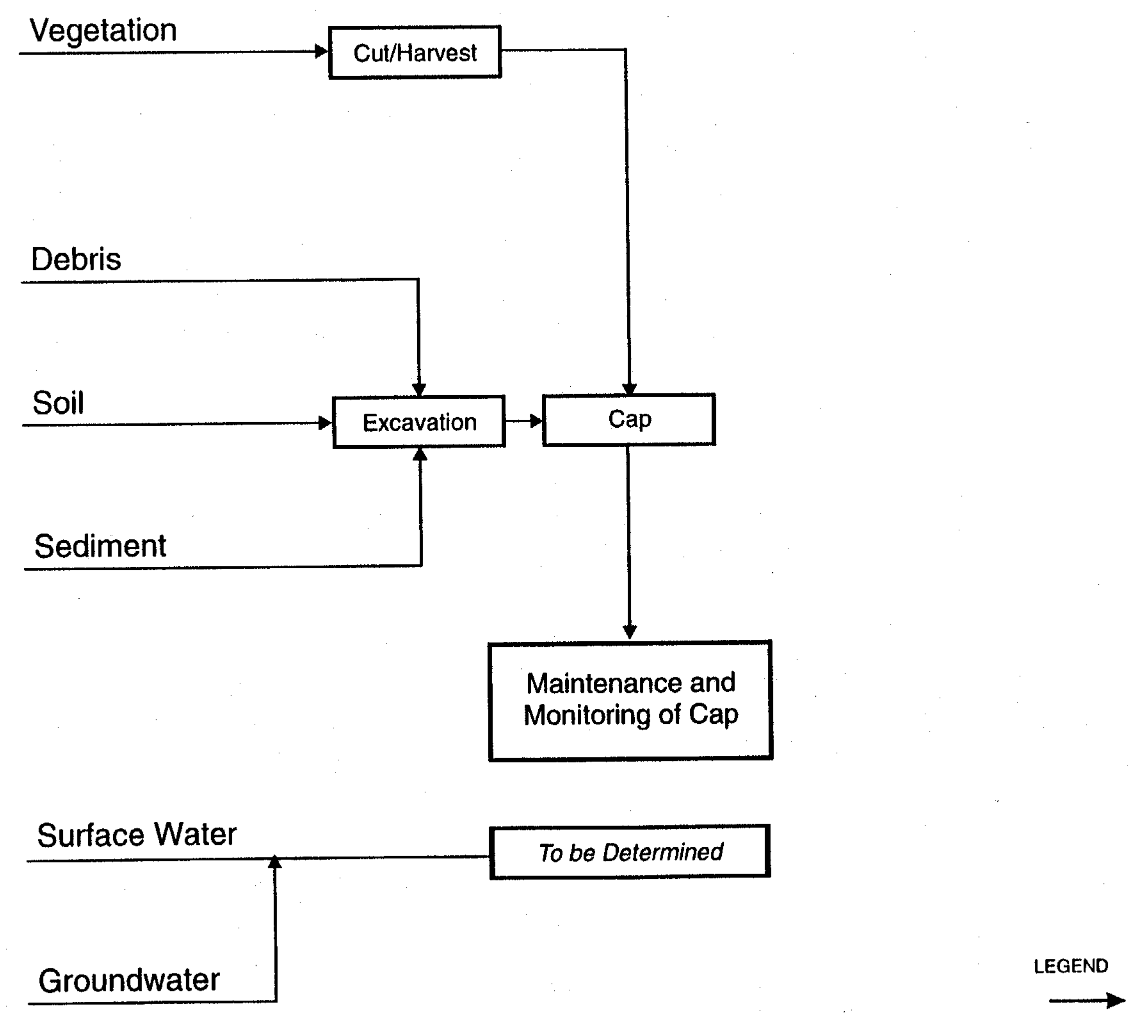
8.2.2.1 Base actions for Alternative 2

Initial Actions and Site Preparation. Initial actions will include completion of agreements for access to private property required to implement remediation. The type and number of agreements will depend on the extent of the remediation activities.

Mobilization activities include installation of a construction office trailer, equipment yard, personnel decontamination facility, and equipment decontamination facility. A debris decontamination facility staging area will be constructed to facilitate sampling, decontamination, staging, compaction, and loading of debris that could be salvaged. Underground utilities and overhead power lines at the site will be relocated, if necessary. Institutional controls such as fencing and warning signs will be installed to restrict unauthorized access to the site. Temporary surface water controls will be implemented to divert run-on away from the site during RA. Monitors for detection of airborne particulate will be installed, as needed. Adverse effects to surface waters, the floodplain, and any wetlands present will be minimized.

Removal of Surface Debris. Surface debris will be removed from the site and salvaged to allow action for other environmental media. Debris that cannot be salvaged will be left on site for incorporation with capping materials. Each salvageable debris item will be screened for radioactivity and then visually inspected for the presence of any other contaminants. Inspection will include looking for adhered soil or hydrocarbons. Contaminated salvageable debris will be staged for subsequent cleaning and decontamination.

Debris Treatment. Debris treatment will remove surface contamination from buried debris, surface debris, and building materials. Removal of surface contamination from the debris will yield materials suitable for recycling or disposal in a landfill. A debris treatment facility will be constructed and will include an area for material staging, sampling, conditioning, decontamination, packaging, and storage of uncontaminated and decontaminated material. Two



JE	Fig. 8.1	Process flow diagram for Alternative 2 - multi-layer cap and monitoring DOE - David Witherspoon Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-13569.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

decontamination methods will be used, a manual and an automated method. The manual decontamination method will be used for large debris and materials unsuitable for the automated method. At least one vendor currently offers an automated system that can accommodate debris up to 1.3 m (4 ft) in any dimension.

The manual decontamination method will use hand labor and various physical cleaning techniques such as washing, scraping, brushing, wiping, spraying, or sandblasting to remove surface contamination from the debris. The manual decontamination area may include an impervious pad, a protective enclosure, a liquid collection sump, liquid storage tanks, and a pressure washer for spray cleaning.

The automated decontamination method will use an automated spray and soak vessel. Small debris will be loaded into a basket and placed in the vessel; large debris will be loaded directly into the vessel. After loading, the vessel will be sealed and the debris will be soaked and sprayed with a cleaning fluid. The fluid will be collected, treated, and recycled in the system. After decontamination, the debris will be dried and characterized. Decontaminated recyclable debris may be shipped to salvage facilities. Nonrecyclable material will require landfilling.

Removal of Standing Vegetation. Standing vegetation is assumed to be contaminated. It includes trees and brush covering approximately 50 percent of the site. These materials will be harvested and consolidated with the contaminated soil. Capping the vegetation will be less costly than carefully harvesting the vegetation and removing it from the site in an uncontaminated state. Clearing activities will occur before, during, and after removal of surface debris, depending on the accessibility of these materials. Trees will be cut into manageable pieces to facilitate handling for transportation to the Oak Ridge Y-12 Plant Sanitary Landfill. Brush will be cut and chipped to minimize volume and settling under the cap. After cutting and chipping, vegetation will be staged for later incorporation into the soils.

Sediment Removal. Sediment will be removed from the stream channel and included in the RA for site soils. Downstream sediment will be transported to the DWI 901 Site, if site contaminants are present. On-site sediment will be excavated and incorporated into site soils during site excavation activities. Sediment control devices will be installed adjacent to the stream to prevent soil erosion into the stream. Other silt control devices, such as silt curtains or sedimentation basins, can be installed along the stream to minimize release of sediment during clearing and excavation activities. Sediment will be loaded into lined trucks and staged for capping. After sediment removal, the cleared area will be graded and seeded, and the sedimentation structures will be removed. Sediment captured by the sedimentation structures will be included with the site soils for RA. Depending on the stability of the stream bed after the removal operation, riprap or another suitable material can be used to prevent stream bed erosion.

Soil Consolidation and Cap Construction. A multilayer cap will be installed to isolate contaminated materials at the DWI 901 Site. Soils, sediment, and vegetation will be incorporated and graded to a relatively smooth and level condition following debris removal. A water spray will be used during excavation activities involving contaminated materials to control fugitive dust. The finished grade required for proper cap performance will be determined during remedial design. Additional soil or fill material will be added, as needed, to achieve the required surface geometry. A multilayer cap will then be installed over the area indicated in Figure 8.2 to isolate the contaminants and cause surface water to drain away from the site. The cap will consist of layers of clay and/or synthetic liner. Permeable layers and drains can be installed between the clay/liner layers to capture and remove any water that might penetrate the cap. The uppermost surface of the cap will consist of 0.3–0.7 m (1–2 ft) of topsoil, which will be seeded for erosion control. The top of the cap will be crowned to cause precipitation to flow away from the cap. Drainage features will be constructed to prevent run-on from the surrounding area and to control runoff from the capped area. Figure 8.3 presents a cross section of the cap.

Maintenance and Monitoring. The cap will require maintenance and monitoring (M&M) for at least 30 years, although the cap will be designed to last longer than 30 years. Maintenance will consist of restricting access to the cap, as necessary, to prevent damage and mowing and repair of any erosion or settling of the cap or drainage structures.

Residuals Management. This alternative will produce decontamination water, personal protective equipment (PPE), and uncontaminated surface debris. Decontamination water will be temporarily stored at the site, characterized according to applicable waste acceptance criteria (WAC), and transported to an Oak Ridge Reservation (ORR) wastewater treatment facility for treatment. PPE will be packaged on site and transported to an appropriate ORR facility using process knowledge and radiological screening for characterization. Uncontaminated surface debris includes materials such as lumber, packaging materials, and miscellaneous garbage. These materials will be stored in roll-off containers and transported to an ORR industrial landfill for disposal.

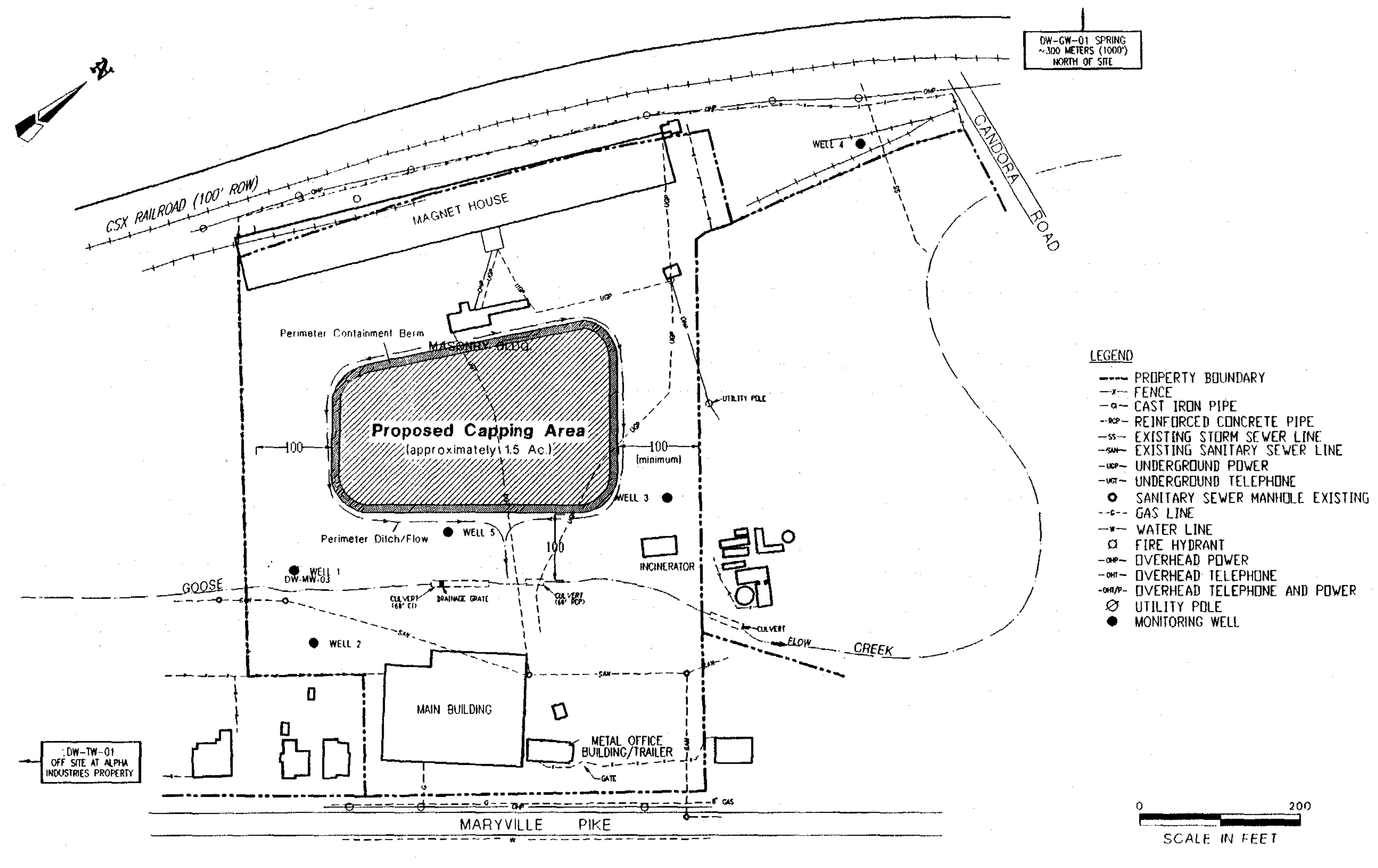
8.2.3 Alternative 3—Minimal Treatment and Disposal

Alternative 3 includes the following media and remedial activities.

- Debris—Treat with a debris-washing technology for salvage or sanitary disposal to the extent practical and incorporate the remainder with soils.

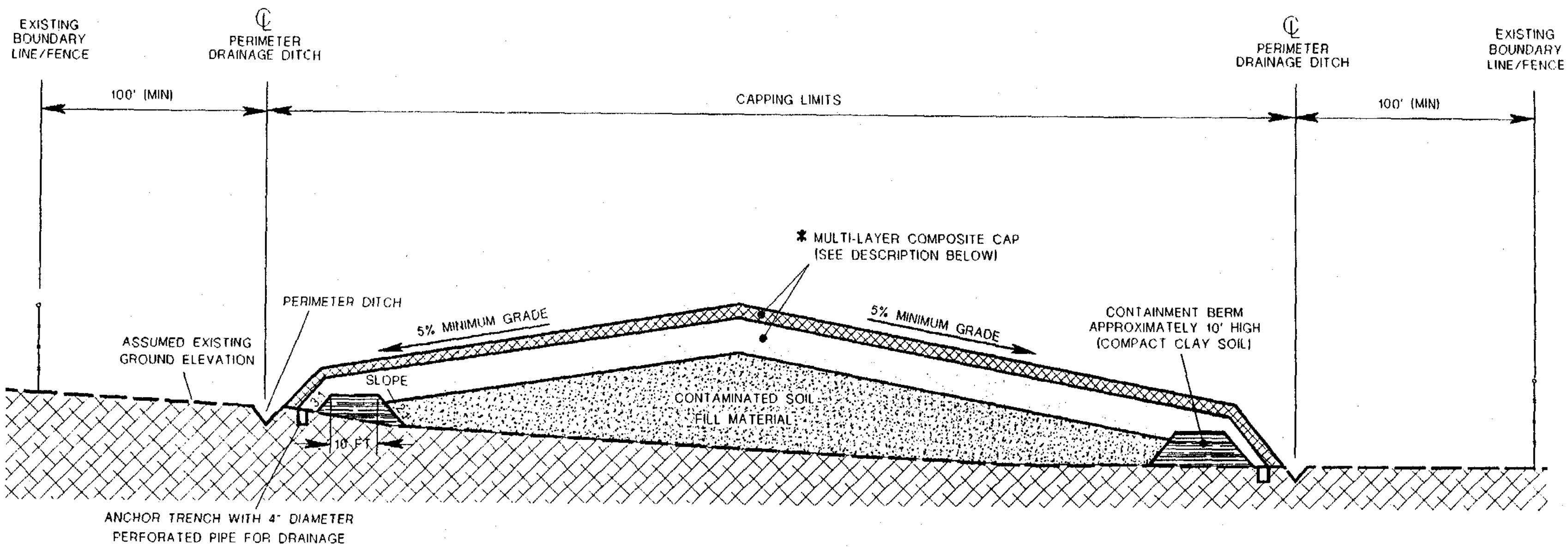
- Soil—Treat using LTTD and dispose of at the proposed EMWMF.

- Sediment—Consolidate with soil, treat, and dispose.



MODIFIED FROM: Jesse Walker, RLS, PE, Survey, July 29, 1992.

JE® Fig. 8.2	**Proposed capping area** DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094.20 / RI/FS	DRAWING ID 96-13413.DWG	DRAWING DATE: OCTOBER 18, 1996 TG



NOT TO SCALE

FROM TOP TO BOTTOM

* MULTI-LAYER COMPOSITE CAP:
1) 6" top soil
2) 1'-6" soil cover
3) 6oz. geotextile (heat bonded to drainage layer)
4) 5mm. geonet (drainage layer)
5) 6oz. geotextile (heat bonded to drainage layer)
6) 40 mil Very Low Density Polyethylene Liner (VLDPE) (synthetic geomembrane liner)
7) 2' thick clay soil cap (compacted)

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Fig. 8.3

Cross-sectional view of cap

DOE - David Witherspoon, Inc., 901 Site - Knoxville, Tennessee

DOCUMENT ID: 35H830 0094-20 / RI/FS	DRAWING ID: 96-13121DWG	DRAWING DATE: OCTOBER 18, 1996 TG

- Surface water—TBD.

- Groundwater—TBD.

Alternative 3 includes the excavation and disposal of all contaminated soil, debris, and sediment. These contaminated materials will be characterized, treated, packaged, and transported to the proposed EMWMF located on the DOE ORR. It is assumed that the proposed EMWMF will be permitted to accept Toxic Substances Control Act of 1976 (TSCA), Resource Conservation and Recovery Act of 1976 (RCRA), and low-level waste (LLW), so all of the DWI 901 Site materials could be dispositioned after treatment. The present risk at the DWI 901 Site will be eliminated because the materials creating risk will be removed. Additional surface water and groundwater contamination will cease upon removal of the contaminated materials. Surface water and groundwater actions will be determined after further sampling. This alternative is designed for a future residential land use scenario. Implementation of this alternative is estimated to take 41 months, not including monitoring. A flowsheet describing Alternative 3 can be found in Figure 8.4.

8.2.3.1 Base actions for Alternative 3

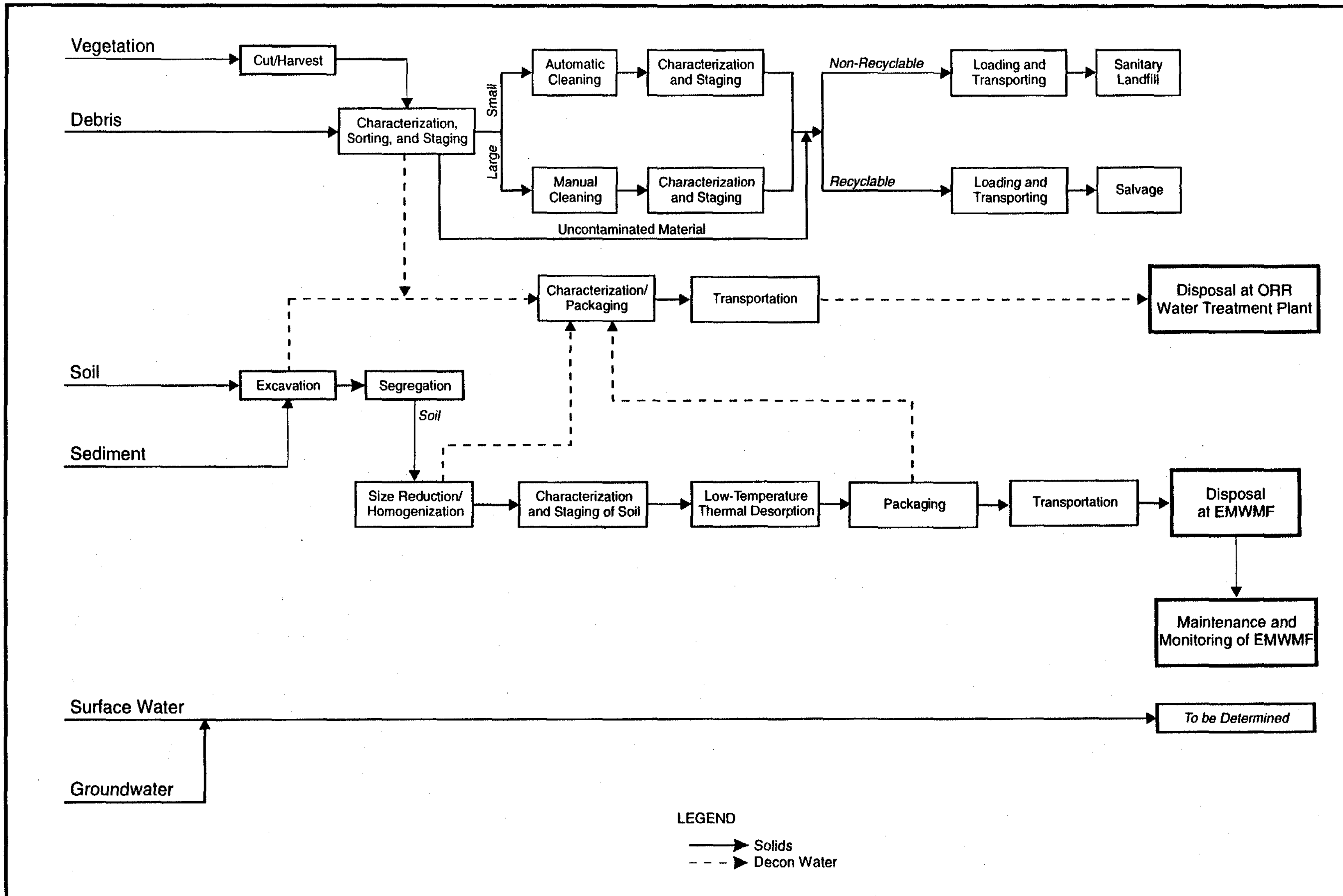
Initial Actions and Site Preparation. These activities are the same as Alternative 2 plus the following. A sorting, treating, packaging, and loading area will be prepared to facilitate the transportation of contaminated materials to the proposed EMWMF.

Removal of Surface Debris. Surface debris will be removed, screened for radioactive and inspected for visual contamination, decontaminated, and salvaged, if practical, or consolidated with soil for disposal as described for Alternative 2.

Removal of Standing Vegetation. This would involve the same activities as Alternative 2 except vegetation will be disposed of with the contaminated soil.

Sediment Removal. On-site and off-site sediment will be excavated and consolidated with soils for treatment and disposal, and the streambed will be stabilized as described for Alternative 2.

Excavation and Disposal of Soil and Debris. The contaminated soils will be excavated and the contaminated soil and debris staged, treated, packaged, and transported to the proposed EMWMF. A water spray will be used to control fugitive dust emissions during excavation and processing. Material processing will include contaminant screening, sorting, and size reduction.



JE	Fig. 8.4	Process flow diagram for Alternative 3 - minimal treatment and disposal DOE - David Witherspoon Inc., 901 Site - Knoxville, Tennessee	DOCUMENT ID: 35H830 0094-30 / RI/FS	DRAWING ID: 96-13415.CDR	DRAWING DATE: OCTOBER 18, 1996 TG

Any uncontaminated materials found during screening will be sorted and staged separately from the contaminated material for reclamation at a salvage facility. Size reduction techniques will include cutting, compaction, or shredding.

Soil Treatment. Soil, sediment, and, to the extent practical, debris will be treated in a mobile LTTD unit. Inorganic and radiological contamination in the waste will not be affected. Organic contaminants, however, will be transferred from the waste to a gaseous phase. Mercury in the waste may also be volatilized. LTTD works by heating the soil until volatilization occurs. An inert gas carrier transports the vaporized compounds to a vapor treatment system. Organic compounds will then be destroyed in an onboard afterburner. The resulting solid waste stream will be characterized and sent to an appropriate disposal facility.

After processing, contaminated materials will be characterized, treated, and packaged according to the WAC for the proposed EMWMF. Contaminated materials will be transported to the proposed EMWMF and off-loaded by the RA contractor. Contaminated materials will be managed at the proposed EMWMF according to applicable permits. After removal of contaminated materials from the DWI 901 Site, clean fill material and topsoil will be backfilled, graded, and seeded to restore and stabilize the site.

Residuals Management. Management and disposal of decontamination water, PPE, and uncontaminated surface debris will be the same as described as Alternative 2.

8.2.3.2 Monitoring and contingency actions for Alternative 3

This section discusses the monitoring requirements for identifying deviations from the probable site conditions and expected technology performance. Contingency actions to address deviations detected by monitoring are also discussed.

Contaminated Standing Vegetation. Standing vegetation will be sampled for COCs and characterized before RA begins. If the vegetation is contaminated, cannot be harvested safely, or comes in contact with contaminated site soils, it will be shredded, characterized, packaged, and transported to the ORR disposal facility along with other DWI 901 Site wastes.

EMWMF Not Implemented. Existing permitted facilities and disposal would be selected.

8.2.4 Alternative 4—Extensive Treatment and Disposal

Alternative 4 includes the following media and remediation activities.

- Debris—Treat with a debris-washing technology for salvage or sanitary disposal to the extent practical and incorporate the remainder with soil.

- Soil—Excavation, ex situ vitrification to destroy organics and immobilize metals and radionuclides, and off-site disposal as sanitary waste.
- Sediment—Consolidate and treat with soil.
- Surface water—TBD.
- Groundwater—TBD.

Alternative 4 includes the excavation and treatment of soil, debris, and sediment. The volume of debris to be vitrified cannot exceed 30 percent of the soil/sediment volume; therefore, the remaining debris may require treatment before salvage or disposal, if contamination is found. Manual and automated cleaning processes will remove surface contamination from the debris. Decontaminated debris will be transported to a metal salvage facility for recycling or a sanitary landfill for disposal, depending on the material. The glassified product from the vitrification process will be tested for waste acceptance and sent to a sanitary landfill for disposal.

Surface water and groundwater actions will be determined after further sampling. This alternative is designed for a future residential land use scenario. Implementation of this alternative is estimated to take 36 months. A flowsheet describing the methodology used in Alternative 4 can be found in Figure 8.5.

8.2.4.1 Base action for Alternative 4

Initial Actions and Site Preparation. These actions involve the same activities as Alternative 2, plus site preparation for debris treatment, including electric power, water, gravel area, and concrete pads.

Removal of Surface Debris. Surface debris will be removed and a portion salvaged as described in Alternative 2. Remaining debris will be either incorporated into the on-site debris treatment or consolidated with the soil for vitrification.

Removal of Standing Vegetation. Vegetation will be harvested from the site in an uncontaminated condition. Trees and brush will be cut down in a manner to prevent contact with contaminated site soils, cut into manageable pieces to facilitate handling and transportation, and hauled off site for disposal in a sanitary landfill.

Soil/Sediment Removal. Sediment will be removed and consolidated with soil as described in Alternative 2. Additional excavation may be required to remove hot spots or areas of excessive contamination.

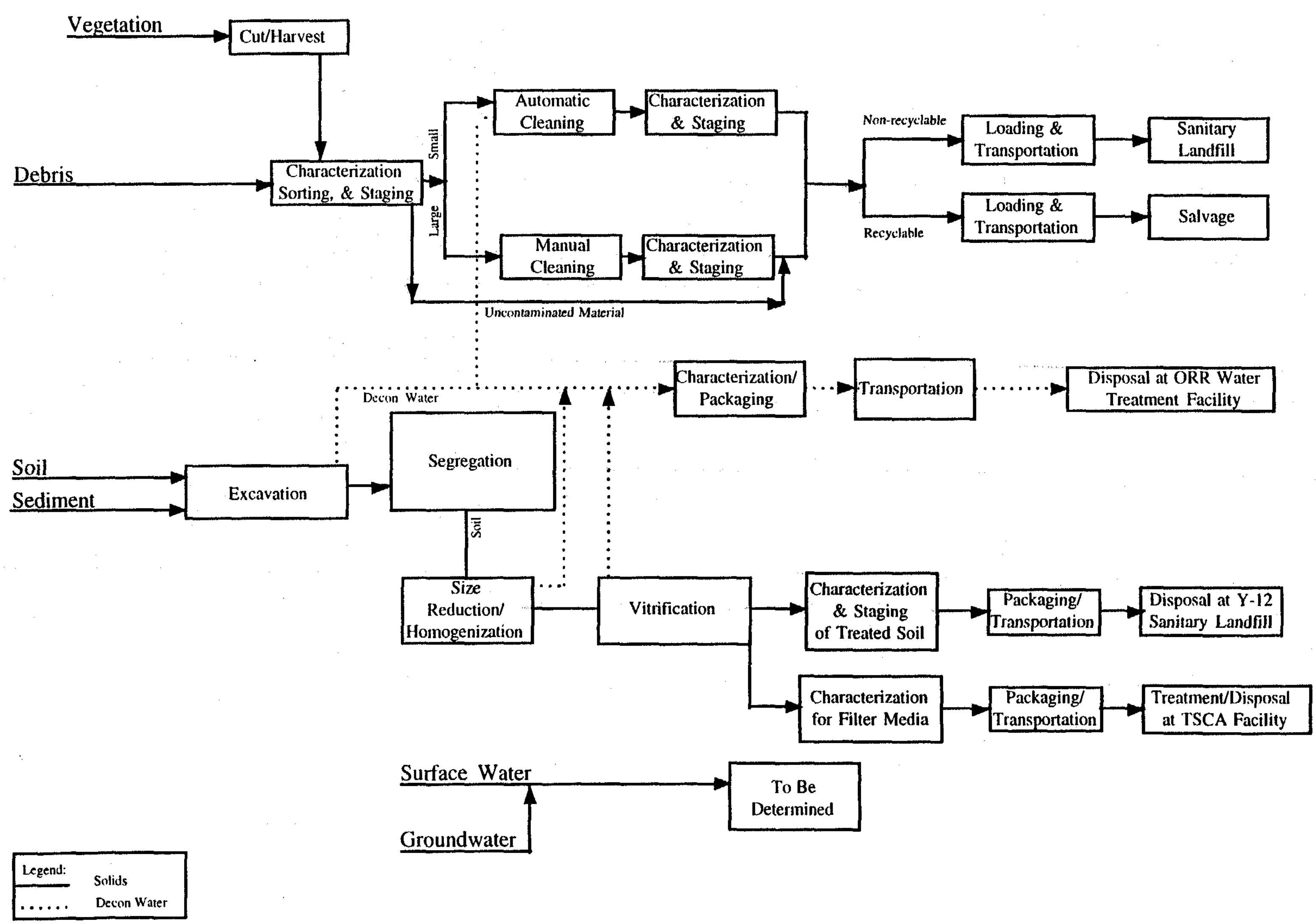


Fig. 8.5	**Process flow diagram for Alternative 4 - treatment for all contaminants and disposal at a sanitary facility** DOE - David Witherspoon Inc. 901 Site- Oak Ridge, Tennessee	DOCUMENT ID: 35H830 0094-60 / FS	DRAWING ID: 96-13254.PPT-C	DRAWING DATE: OCTOBER 18, 1996 TG

Preparation of Soil and Debris for Treatment. After some of the surface debris and all of the vegetation are removed from the site, sediment will be staged with the excavated soil for treatment.

During the staging of excavated soil, verification sampling will be performed periodically during soil removal to determine if cleanup levels have been achieved and to guide further excavation activities.

Any buried debris encountered will be characterized to determine if excavation and treatment are warranted. If contaminated, buried debris will be excavated, sorted, and treated in the same fashion as other debris. If uncontaminated, it will be left in place.

Soil Treatment. Ex situ vitrification will be used to treat the soil, sediment, and unsalvaged debris by immobilizing contaminants in stable, structurally sound matrix. Before treatment, waste materials staged for drying will be shredded to create a homogeneous mixture.

The soil mixture will be placed in the rotating combustion and melting system and current will be applied to destroy organic contaminants and solidify inorganic contaminants. Once the soil is heated to a molten state, resultant glass pellets will be cooled to ambient soil temperatures. Organic contaminants will be pyrolyzed and reduced to simple gases. Off-gas emissions will be captured using a series of filters and scrubbers to reduce contaminant discharge to the atmosphere. Although most of the filter waste can be incorporated into the vitrification product, some contaminated waste from the off-gas system will require disposal in a sanitary landfill. Inorganic and radioactive contaminants will be incorporated into the glass matrix, resulting in a material similar to volcanic obsidian. Gases and particulates will be contained by the treatment vessel and treated in an off-gas system. Characterization of the waste will be required before disposal. The vitrification process is expected to destroy organic contaminants, stabilize metals, and disperse radionuclides throughout the glass matrix so that average contaminant concentrations will not exceed levels acceptable for disposal in a facility such as the Y-12 Plant industrial landfill.

Site Reclamation. After removal of the contaminated materials from the site, clean fill material and topsoil will be backfilled, graded, and seeded to restore the site.

Disposition of Residuals. Residuals will be handled in the same manner as described in Alternative 2.

8.2.4.2 Process modifications for Alternative 4

Before and during implementation of the RAs, engineering support studies and monitoring of the site conditions will be performed to optimize specifics of the treatment technology (e.g., operating parameters, waste preparation, etc.). Following is a discussion of process modifications for Alternative 4 that can be implemented to address any observed differences from the probable conditions.

Disposal at a Hazardous Waste Landfill. The resulting vitrified waste may require disposal at a low-level or mixed waste facility. This modification will depend on whether the radiological activity is above the 35 pCi/g waste acceptance criterion for the Y-12 Plant industrial landfill. Treatability studies will be required to verify implementability of this alternative.

Vitrification Not Effective. If vitrification cannot be used to treat the waste, other process options can be used. Solvent extraction will remove organic contaminants, mainly PCBs. The subsequent treated product will require disposal in a mixed waste facility such as Envirocare of Utah.

Solidification/stabilization can be used to immobilize contaminants in the soil and sediment. Some experts caution against the use of solidification/stabilization for organic contaminants, because in some cases, organics have reduced the hardness of the solidified matrix. In other cases, organics have been encapsulated in the matrix and have displayed acceptable levels of contaminant leaching.

Alternative solidification/stabilization technologies such as a ceramic-brick making using soils with a high clay content are available. Contaminated soil or sediment would be mixed with material favorable for formation of ceramic material. The material will be heated to temperatures similar to LTTD, thereby volatilizing contaminants to be captured in an off-gas treatment system. The ceramic bricks will be allowed to harden before waste characterization. The ceramic bricks will probably bind the inorganic contaminants, but they may only provide minimal shielding for radiological constituents. Therefore, a LLW disposal facility would be the most likely destination for the DWI 901 Site wastes.

Alternate methods for organic removal before solidification/stabilization are available. Treatments such as incineration, LTTD, and solvent extraction are effective proven technologies for removal of organics. Incineration offers greater volume reduction than LTTD and solvent extraction. LTTD and solvent extraction are separation techniques which use physical properties of the contaminants for removal from the excavated media.

9. DETAILED ANALYSIS OF ALTERNATIVES

The assembled and screened RA alternatives presented in Chapter 8 represent a distinct range of management strategies for the contaminants at the DWI 901 Site. Each alternative addresses protection of human health and the environment. Chapter 9 presents a detailed analysis of alternatives and a comparative analysis of alternatives that remain after screening.

The detailed analysis of the alternatives builds upon previous evaluations developed in the screening phase. Section 9.1 describes the evaluation criteria and the approach used in the detailed analysis. Section 9.2 presents an evaluation of each alternative with respect to each criterion. Section 9.3 presents a comparison of the strengths and weaknesses of the alternatives regarding each evaluation criterion.

9.1 CRITERIA FOR ANALYSIS

The specific evaluation criteria used in conducting the detailed analysis are described in this section. These criteria were taken from *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a).

Evaluations of individual alternatives are provided in Sections 9.2.1–9.2.5. Appendix F contains a detailed description of the ARARs referenced in the "Compliance with ARARs" discussions of this chapter. Appendix G contains the Automated Estimating System Summary Reports that support the capital costs and operating and maintenance costs presented in this analysis.

The detailed analysis considers the following types of evaluation criteria:

Threshold Criteria. Developed alternatives (except the no action alternative) must meet the threshold criteria of overall protection of human health and the environment and compliance with ARARs.

Balancing Criteria. The effectiveness of an alternative in meeting these criteria is evaluated in sufficient detail to present to decision makers the significant aspects of each alternative and any uncertainties associated with the evaluation. These criteria include:

- long-term effectiveness and permanence;
- reduction of toxicity, mobility, and volume through treatment;

- short-term effectiveness;
- implementability; and
- cost.

Modifying Criteria. State acceptance and community acceptance, the modifying criteria, will be addressed following public and regulatory review of this document. Though these criteria are listed in the guidance document, they are not evaluated.

The seven evaluation criteria (excluding the modifying criteria) addressed in the detailed analysis are discussed in the following subsections.

9.1.1 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 RAOs established in Section 6.1. 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 evaluating 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 remediation itself.

9.1.2 Compliance with ARARs

This criterion addresses compliance with promulgated, location-, chemical-, and action-specific federal and state environmental requirements. ARARs are presented in full in Appendix F as well as being discussed in the text of this chapter. If an alternative cannot meet a requirement, a determination can be made that a waiver should be granted, and a basis for justifying the waiver would be presented as described under CERCLA and the Tennessee Superfund Program Rules (TDEC 1200-1-13) for an on-site action. Waivers may not be granted for off-site actions. ARARs include two types of requirements, those that apply and those that are relevant and appropriate. In certain cases, standards may not exist that address the proposed action or the contaminants of concern. In such cases, nonpromulgated advisories, criteria, or guidance developed by EPA, other federal agencies, or states can be to-be-considered (TBC) guidance.

Other requirements that do not fall within EPA-established criteria for ARARs include DOE Orders. Atomic Energy Act requirements for management of DOE's waste are incorporated into DOE Orders developed under DOE's Atomic Energy Act authority. EPA's *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 that are not addressed by existing ARARs, they should be considered when necessary to develop a protective remedy." DOE Orders provide standards which can be TBC guidance.

9.1.3 Long-Term Effectiveness and Permanence

This criterion addresses the ability of an alternative to meet the RAOs (see Sect. 6.1.4) regarding expected site conditions after remedial efforts are complete. The criterion also addresses the adequacy and reliability of in-place controls (e.g., containment), expected conditions regarding RAs, and reasonable deviations and their potential impact on long-term effectiveness and permanence. The effects of the alternative on sensitive ecological resources and each alternative's cumulative effects are also discussed.

9.1.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

This criterion considers the following:

- treatment processes used (if any) 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.

9.1.5 Short-Term Effectiveness

This criterion considers the following:

- community protection during RAs,
- worker protection during RAs,
- short-term environmental effects of RAs,
- estimated time until RAOs are achieved,
- potential for sudden failure to occur,
- direct or indirect socioeconomic impact, and
- short-term cumulative effects.

9.1.6 Implementability

This criterion considers the technical and administrative feasibility and the availability of services and materials by addressing:

- ability to construct and operate a given technology;
- reliability of the technology;
- ease of undertaking additional RA, if necessary;
- ability to monitor effectiveness of RAs;
- ability to obtain regulatory approvals;
- activities needed to coordinate with other offices and agencies;
- availability of necessary permitted facilities (e.g., disposal facilities);
- availability of necessary equipment, technologies, and specialists; and
- effect of reasonable deviations on implementability.

9.1.7 Cost

Cost estimates are included for each remedial alternative. The estimates are based on feasibility level scoping and are intended to aid in making project evaluations and comparisons among alternatives. The estimates have an expected accuracy of +50 percent to -30 percent for the scope of action described in Chapter 8 for each alternative.

The estimates have been divided into capital cost and M&M costs. All estimates have been escalated using approved DOE escalation rates and a schedule for the various activities based on similar project experience. Escalation rates used are 2.8 percent for fiscal year (FY) 1996, 2.8 percent for FY 1997, 2.7 percent for FY 1998, 2.9 percent for FY 1999, 3.0 percent for FY 2000, 3.1 percent for FY 2001, 3.2 percent for 2002 and no escalation added for FY 2003 and beyond.

Contingency has been included in each estimate and is based on the degree of difficulty of the RA, the technology status, and the uncertainty level of the action scope.

Capital costs are defined as those expenditures required to initiate and install an alternative. These are short-term costs and are exclusive of costs required to maintain the action throughout the project lifetime. Capital costs consist of direct and indirect costs. Direct costs include construction costs (material, labor, and equipment to install an action), service equipment, process and new process buildings, utilities, and waste disposal costs. Indirect costs include Titles I and II engineering, Title III inspection, project integration, project administration and management, and project contingencies.

M&M costs are long-term costs associated with ongoing remediation at a site. These costs occur after construction and installation are completed, The costs include labor, materials, utilities, and services required to monitor, operate, and maintain the facilities for up to 30 years.

The estimated present worth of each remedial alternative was determined on a discount rate of 7 percent and a base maintenance/monitoring period of 30 years according to EPA guidance.

Summary cost estimates, proposed project schedules, and the major assumptions used to develop the cost estimate for each remedial alternative are presented in Appendix G.

9.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES

This section provides a detailed analysis of the four sitewide alternatives developed in Chapter 8. Instead of reiterating a description of each alternative, only the bulletized form of the alternative is provided here. Each alternative is evaluated with respect to each of the criteria and subcriteria previously discussed.

9.2.1 Alternative 1—No Action

Consideration of the no action alternative is required by the NCP and NEPA. This alternative serves as a baseline for comparison with other alternatives. In this study, Alternative 1, the no action alternative, makes no provisions for containment, removal, treatment, or disposal of wastes.

9.2.1.1 Overall protection of human health and the environment

Alternative 1 would provide no measures to control exposure beyond that which may occur through natural attenuation or radioactive decay. Therefore, this alternative will not protect human health and the environment for the current or future scenario.

9.2.1.2 Compliance with ARARs

There are no ARARs under CERCLA for the no action alternative; however, the no action alternative does not meet the RAOs of this project or statutory requirements under the Tennessee Hazardous Waste Management Act (*Tennessee Code Annotated* 201 et seq.) for protection of human health and the environment.

9.2.1.3 Long-term effectiveness and permanence

Under the no action alternative, contaminants in the soil could continue to migrate off-site, and the potential for groundwater contamination could increase. The baseline risk assessment shows that risk due to contaminants in the soil and sediment at the DWI 901 Site is unacceptable for current and future users of the site for both industrial and residential scenarios. Risk due to groundwater may also be unacceptable. The soil and sediment also pose a risk to ecological receptors. None of the RAOs would be achieved under the no action alternative.

Sensitive Resources. The no action alternative would not adversely affect any endangered or threatened animal or plant species because none have been identified at the DWI 901 Site. There are also no designated critical or unique habitats on the site. The streamsides of Goose Creek may be identified as a riparian wetland when the pending wetlands survey is completed. The no action alternative would not disturb any potential wetlands. The 100-year floodplain would also remain undisturbed. However, contamination would likely continue to adversely affect the flora and fauna which come in contact with it.

Cumulative Effects. The no action alternative has the highest, long-term, cumulative risk to human health and the environment of any alternative. These risks are presented as part of the human health and ERAs, (see Chapts. 4 and 5). The potential for adverse effects to the environment as a result of implementing the no action alternative could increase over time as the likelihood of continued contaminant migration into the surrounding area increases.

9.2.1.4 Reduction of toxicity, mobility, and volume through treatment

No treatment, removal, disposal, monitoring, or control actions will be implemented under Alternative 1. The soil, debris, and sediment will be left in place. No reduction of toxicity, mobility, or volume of the soil, sediment, or debris will be achieved with the no action alternative.

9.2.1.5 Short-term effectiveness

Community and Worker Protection. There will be no uncontrolled exposure risks to workers, the community, or the environment resulting from remediation activities, transportation, or disposal since no such actions will take place.

Environmental Effects. No effects on ambient noise levels, ecological habitats, or historic resources are anticipated.

Potential for Sudden Failure. Since no actions will be taken, no potential for sudden failure exists. Sudden releases of contamination that could increase the likelihood of exposure are also unlikely. Increased human use of the site is a major scenario that could increase exposure.

Time to Meet RAOs. Natural attenuation will not reduce contaminant levels sufficiently to meet RAOs for centuries.

Socioeconomic Effects. The no action alternative is the baseline condition and will have little new influence on the socioeconomics of the area. The proximity of a contaminated site may slow the appreciation of nearby land values, particularly with respect to privately owned residential properties. Selection of the no action alternative will not provide any new jobs.

Cumulative Effects. Short-term cumulative effects will be limited to continued contaminant entry into the ecological food chain and continued risk to human health.

9.2.1.6 Implementability

Since no actions will be taken, this alternative is readily implementable.

9.2.1.7 Cost

No cost will be incurred to implement this alternative.

9.2.2 Alternative 2—Multilayer Cap and Monitoring

Alternative 2 includes the following media and RAs.

- Debris—Treat with debris-washing technology for subsequent salvage or sanitary disposal to the extent practical and cap remaining debris along with soils.
- Soil—Multilayer cap, monitoring, and institutional controls.
- Sediment—Consolidate with soil and cap.
- Surface water—TBD.
- Groundwater—TBD.

9.2.2.1 Overall protection of human health and the environment

Alternative 2 will protect current and future employees from risks and hazards associated with direct contact and ingestion of soil. The employees will also be protected from direct radiation. The cap will minimize the potential for contaminant migration into Goose Creek, thereby protecting residents and trespassers from risks associated with direct contact and ingestion of surface water and sediment on site and downstream.

A maintained cap could reduce the area available for wildlife habitats, but the positive effects of reducing the potential for exposure to contaminated soil outweigh the slight reduction in habitat area. Minimizing future contaminant migration into Goose Creek will also aid the health of future aquatic receptors.

Monitoring of the cap will ensure continued effectiveness of the cap in protecting the previously mentioned receptors.

Implementation of best management practices while constructing the cap will adequately mitigate any adverse effects to the community, remediation workers, and the environment during RAs.

9.2.2.2 Compliance with ARARs

Alternative 2 will leave waste in place within the operable unit (OU), therefore precluding residential use. Industrial land use is in agreement with existing zoning. Monitoring, some institutional controls, and CERCLA reviews are required when waste is left in place. The cover design will require perpetual monitoring. RCRA land disposal restrictions (LDRs) will not be triggered by this alternative because the contaminated soils and sediments will remain within the OU and will not be treated. ARARs for this, and other alternatives, are presented in Appendix F.

Surface water quality has not yet been established, but it may be presumed that any surface water contamination will be addressed by an action alternative which removes or contains the contaminant sources (e.g., soil, sediment, and debris). In this case, water quality criteria for the stream (Goose Creek) will be met. Since the contaminated media will remain on the OU, surface water quality may be affected by contaminant migration through the groundwater. This alternative may not meet all of the regulatory criteria for groundwater quality and segregation of wastes from groundwater. It is unlikely that a justifiable basis for a waiver from these requirements could be made if they were needed. However, further data are needed, particularly with respect to water quality, to evaluate this alternative's ability to comply with ARARs.

Location-specific ARARs are triggered by actions in a 100-year floodplain or in a wetlands. The requirements for consideration and protection of these resources can be met by this alternative.

9.2.2.3 Long-term effectiveness and permanence

Ability to Meet RAOs. Alternative 2 will meet the RAOs developed in Section 6.3. Direct contact with and incidental ingestion of soil and sediment will be minimized by isolation of the waste beneath the cap. Direct contact with potentially contaminated surface water will also be minimized by isolating contaminant sources (i.e., soil, sediment, and debris) with the cap. Although potential groundwater contamination will remain, its use as a drinking water source will be prohibited.

Sensitive Resources. Alternative 2 will not adversely affect any endangered or threatened animal or plant species because none have been identified at the site. Excavation of sediment in Goose Creek will disturb any riparian wetlands in the creek channel and the 100-year floodplain. All disturbances will be mitigated and restored. A wetlands assessment will be conducted concurrent with sampling activities if any wetlands are identified during the wetlands survey.

Cumulative Effects. The on-site cap could result in an incremental loss of ecological habitat; however, this will likely not result in an overall reduction of terrestrial wildlife. Allowing contamination to remain below ground could contribute incrementally to long-term cumulative risk for human health and the environment in the DWI 901 Site area if contaminants were to migrate off site. However, stabilizing the contamination and protecting the community from contaminant migration would contribute positively to the environment in the area. The acceptability of this risk is being determined throughout the CERCLA process and will be based on input from regulators and the public.

9.2.2.4 Reduction of toxicity, mobility, and volume through treatment

Alternative 2 will significantly reduce contaminant transfer by reducing the amount of water that infiltrates the contaminated media. However, no reduction of toxicity, mobility, or volume through treatment will be achieved by implementing of Alternative 2.

9.2.2.5 Short-term effectiveness

Community Protection. The community will be protected from contaminant exposure during remedial activities through the implementation of temporary institutional controls such as fencing, warning signs, and dust suppression to prevent airborne migration of contaminants off-site.

There will be a minor increase in traffic for 7 months during excavation and cap construction. Traffic on public roads will consist of trucks and equipment such as bulldozers and privately owned vehicles. No new paved roads will be constructed. Existing access roads on the site will be improved, if necessary. No risk to the public from transportation of contaminated media will occur because no contaminated material will be transported off site.

Worker Protection. Appropriate mitigative measures will be applied during RAs to meet worker health and public health exposure requirements. By planning the construction activities and staging in accordance with Occupational Safety and Health Administration (OSHA) requirements and DOE Orders (e.g. regarding PPE for remediation workers), risks from contaminant exposures and accidents will be controlled.

Environmental Effects. Short-term environmental effects associated with this alternative will include soil disturbances in areas adjacent to the site and disturbance of any riparian wetlands along Goose Creek. Construction activities will disturb the habitats of individual nesting birds, amphibians, and burrowing mammals. These effects will be mitigated to the maximum extent possible through best management practices (e.g., erosion control, temporary stream diversion, and stream bed stabilization). The adverse effects will be offset by long-term benefits derived from reduced contaminant levels at the site.

Time to Meet RAOs. RAOs will be achieved in 36 months after initial site mobilization.

Potential for Sudden Failure. During excavation, subsurface debris of unknown composition could be unearthed. The characterization of the material will be required before handling and final disposition.

Socioeconomic Effects. The socioeconomic effects of implementing this alternative will be minimal. A skilled work force will perform the necessary activities needed to implement remediation under this alternative. Land use will remain restricted to industrial use. The area is currently mixed industrial/residential use. The public will be consulted as to whether this alternative will significantly affect surrounding property values.

Cumulative Effects. Incremental contributions to cumulative effects include increased traffic, noise, and dust levels during implementation of this alternative. They are similar to other construction activities and are unlikely to be significant.

9.2.2.6 Implementability

Ability to Construct and Operate. Consolidation and capping activities will be readily implementable using conventional equipment and construction techniques. Surface water and groundwater remediation will be evaluated after planned sampling activities end.

Reliability of the Technology. Capping is a reliable technology and no substantial obstacles for implementation are anticipated.

Ease of Undertaking Additional Remediation. Additional RAs, such as groundwater or surface water treatment can be easily performed without interfering with the cap. However, to maintain cap integrity, wells must not be installed within the capped area. If for some unforeseen reason the cap is deemed unacceptable, contaminated materials under the cap could be excavated for treatment and/or off-site disposal. Consolidation activities performed before capping will make waste retrieval easier, if necessary, because the waste will be in one area.

Ability to Monitor Effectiveness. Monitoring the effectiveness of the cap can be easily performed through groundwater monitoring, surface water sampling, and visual inspection of cap integrity.

Ability to Obtain Regulatory Approvals. As a state Superfund site, no permits will be required for on-site RAs as long as the substantive requirements of applicable regulations are followed. The ability to perform the actions described by this alternative will be based on negotiations with regulators and acceptance by the public.

Coordination with Other Agencies. U.S. Army Corps of Engineers (COE) will be consulted with respect to any actions taken in jurisdictional wetlands or the floodplain.

Availability of Permitted Facilities. Until a need for surface water or groundwater treatment is determined, no permitted facilities will be used for this alternative.

Availability of Equipment, Technologies, and Specialists. The land needed for consolidation and capping is physically available, but is privately owned. Negotiations between PRPs will be required to resolve ownership, liability, and financial responsibility issues. All other required equipment, technologies, and specialists are readily available.

Effect of Reasonable Deviations. If groundwater or surface water treatment is required, the overall alternative cost will increase. If a larger volume of contaminated material is identified during RA, the height or aerial extent of the cap can be enlarged to accommodate the increase of waste volume.

9.2.2.7 Cost

The total project present worth cost of Alternative 2 is approximately $4,845,000. Table 9.1 provides a detailed breakdown of the escalated project costs. More detailed information is provided in Appendix G.

Table 9.1. Cost estimate for Alternative 2 (multilayer cap and monitoring), DWI 901 Site, Knoxville, Tennessee

Project cost item		Cost ($ thousands)[a]
Capital cost		
Direct cost:		
Temporary facilities/mobilization		317
Site preparation		264
Cap construction		2,195
Decontamination/demobilization		19
Secondary waste disposal		189
	Direct cost total (rounded)	2,984
Indirect cost:		
Project management		612
Remedial design work plan		53
Remedial design report		356
Remedial action work plan		62
Remedial action integration		1,041
	Indirect cost total (rounded)	2,124
	Total capital cost	5,108
M&M cost		
Site maintenance		50
	Total M&M cost	50
Contingency—35%		1,805
	Total project escalated cost	6,963
	Total project present worth[b]	4,845

[a]Escalated.
[b]Present value cost based on a 30-year present value, 7 percent discount rate.

Note: Costs presented in table are rounded.

$ = dollar
DWI = David Witherspoon, Inc.
M&M = monitoring and maintenance
% = percent

Direct Capital Cost. The estimated escalated direct capital cost is $2,984,000. Direct capital cost includes temporary facilities, mobilization, site preparation, and cap construction.

Indirect Capital Cost. The estimated escalated indirect capital cost is $2,124,000. Indirect capital cost includes project management, remedial design work plan, RA design report, RA work plan, and RA integration.

Maintenance and Monitoring. The estimated escalated cost for M&M is $50,000. M&M cost includes site maintenance.

Contingency. Total escalated cost allowed for contingency is $1,805,000.

9.2.3 Alternative 3—Minimal Treatment and Disposal

Alternative 3 includes the following media and remedial activities.

- Debris—Treat with a debris-washing technology for salvage or sanitary disposal to the extent practical and incorporate the remainder with soil.
- Soil—Treat using LTTD and dispose of at the proposed EMWMF.
- Sediment—Consolidate with soil and dispose.
- Surface water—TBD.
- Groundwater—TBD.

9.2.3.1 Overall protection of human health and the environment

Physical removal of contaminated debris, soil, and sediment from the site will protect all current and future human receptors (industrial and residential) from risks and hazards associated with direct contact and ingestion of soil and sediment. Risk associated with direct radiation will also be eliminated. Protection from risks associated with the surface water and groundwater will be determined after future sampling.

Use of best management practices while implementing the alternative will adequately mitigate any adverse short-term effects to the community, remediation workers, and the environment during RAs.

9.2.3.2 Compliance with ARARs

Although contaminated debris, soils, and sediments will be removed from the site under Alternative 3, there is a potential that groundwater will still require monitoring and reviews in accordance with CERCLA requirements. Alternative 3 complies with water quality ARARs provided that groundwater quality standards can be met. Treatment of soils and sediments with LTTD would meet LDRs for organic contaminants and mercury. If inorganic constituents are present at levels that characterize the waste as RCRA-hazardous, additional treatment to meet LDRs would be required to meet ARARs. Soil and sediments with PCB contamination at concentrations between 50 and 499 ppm can be disposed of at a permitted land disposal facility (such as the proposed EMWMF) provided the facility meets TSCA requirements for a chemical landfill. This alternative also assumes that disposal requirements for LLW will be met based on design and operation of the receiving facility.

Surface water, groundwater, and location-specific ARARs are the same as for Alternative 2.

9.2.3.3 Long-term effectiveness and permanence

Ability to Meet RAOs. Alternative 3 has the same ability to met ARARs as Alternative 2 except all exposure pathways will be cut off by removal of contaminated soil, sediment, and debris instead of by capping. Both industrial and residential receptors will be protected.

Sensitive Resources. Same as Alternative 2.

Cumulative Effects. Removal of all contaminated debris, soil, and sediment will reduce or eliminate any adverse cumulative effect on the site. The action also would have an incremental positive effect by reducing the total amount of potential contaminant sources in the immediate vicinity and in Goose Creek and the associated watershed.

9.2.3.4 Reduction of toxicity, mobility, and volume through treatment

Treatment by LTTD will reduce the toxicity of organic contaminants and mercury in the soil and sediments. Toxicity, mobility, and volume of the radionuclides and other inorganic contaminants in these media will be reduced.

9.2.3.5 Short-term effectiveness

Community Protection. Engineered and institutional controls of this alternative will protect the community during solid waste removal and treatment. Dust emission control and monitoring will be implemented during excavation and packaging activities, so the effect to the community will be negligible. Air emission will be monitored during vitrification of the wastes before shipping to the disposal area.

Worker Protection. Risk to workers will be controlled to regulatory limits, and the as low as reasonably achievable (ALARA) program and control measures will be implementated due to exposure during removal, treatment, handling of contaminated materials, transportation, and final handling of materials at the receiving facilities. Through the use of engineered controls and a worker health and safety plan in compliance with 29 CFR 1910.120(b)(4), these exposures will be kept to ALARA levels and will comply with federal and state regulations and DOE Orders. It is assumed that modified Level C PPE will provide adequate protection in the contaminated area. There will be an increased risk to transportation workers and the community from moving the waste off site. Compliance with U.S. Department of Transportation requirements will be maintained to protect transportation workers and the public.

Risk of exposure during vitrification activities will be controlled because the operation will be monitored and controlled from a process control room located a safe distance from the vitrification process. The cumulative controlled risk to workers will likely be less than estimated in the baseline risk assessment because of a lower exposure duration and the strict application of radiological protection methods and controls. Appropriate mitigative measures will be applied during remedial activities; planning of the construction activities; and staging in accordance with ALARA principles, industry and OSHA codes and requirements, and DOE Orders. The existing contaminant concentrations are sufficiently low so that additional precautions over standard construction techniques and conventional radiological protection are not warranted.

Environmental Effects. Same as Alternative 2.

Time to Meet RAOs. RAOs will be achieved 41 months after initial site mobilization.

Potential for Sudden Failure. Same as Alternative 2.

Socioeconomic Effects. The socioeconomic effects of Alternative 3 will be the same as Alternative 2 except this alternative allows for industrial and residential land use, potentially with restricted groundwater usage. Nearby land use and values may be slightly enhanced as a result.

Cumulative Effects. Same as Alternative 2.

9.2.3.6 Implementability

Ability to Construct and Operate. The excavation, characterization, packaging, and disposal of contaminated materials will be readily implementable using conventional equipment and techniques. The ability to treat and dispose of contaminated materials in the proposed EMWMF is unknown because this facility and its associated WAC are only in the proposed stage. Surface water and groundwater remediation will be evaluated after planned sampling activities end.

Reliability of the Technology. Waste removal and transportation activities are well established and can be performed without substantial problems. However, the WAC for the proposed EMWMF have not been established, so it cannot be determined if delays in waste acceptance or disposal will occur.

Ease of Undertaking Additional Remediation. Groundwater and surface water treatment can be added without difficulty, but with additional cost after the wastes are removed from the site. Additional RAs in the form of waste treatment before disposal or excavation of additional material could be implemented.

Ability to Monitor Effectiveness. The effectiveness of this alternative can be easily determined through groundwater monitoring, surface water sampling, and verification soil sampling. These sampling activities will confirm risk reduction at the DWI 901 Site.

Ability to Obtain Regulatory Approvals. The ability to obtain regulatory approval is the same as Alternative 2 except regulatory acceptance of this alternative will depend on the proposed EMWMF. The proposed EMWMF will be constructed and permitted to receive wastes such as those at the DWI 901 Site, so regulatory issues should be limited to meeting on-site and transportation ARARs and LDRs.

Coordination with Other Agencies. Same as Alternative 2.

Availability of Permitted Facilities. The proposed EMWMF is currently in the planning stages. It is not known when this facility will be available; however, it is likely that a conceptual design will exist and possible approval for final engineering and construction will occur before the issuance of the DWI 901 Site ROD. No other permitted facilities will be required.

Availability of Equipment, Technologies, and Specialists. All required equipment, technologies, and specialists are readily available.

Effect of Reasonable Deviations. Deviations will have the same effect on Alternative 3 as Alternative 2 except that a larger volume of contaminated material will increase the activities associated with disposal. Additionally, if the proposed EMWMF is not constructed, this alternative will be substantially affected. As a contingency, a waste management facility for the exclusive disposal of DWI 901 Site wastes could be constructed on ORR. However, the feasibility of implementing this contingency action is extremely uncertain.

9.2.3.7 Cost

The total project present worth cost of Alternative 3 is approximately $13,587,000. No costs for the construction and operation of EMWMF are included. Table 9.2 provides a detailed breakdown of the escalated project costs. More detailed information is provided in Appendix G.

Direct Capital Cost. The estimated escalated cost direct capital cost is $11,489,000. Direct capital cost includes temporary facilities, mobilization, general conditions, site preparation, cap construction, decontamination/demobilization, and secondary waste disposal.

Indirect Capital Cost. The estimated escalated indirect capital cost is $3,494,000. Indirect capital cost includes project management, RA design work plan, RA design report, RA work plan, and RA integration.

Maintenance and Monitoring. The estimated escalated cost for M&M is $5,000. M&M cost includes site maintenance.

Contingency. Total escalated cost allowed for contingency is $5,247,000.

9.2.4 Alternative 4—Extensive Treatment and Disposal

Alternative 4 includes the following media and remedial activities.

- Debris—Treat with a debris-washing technology for salvage or sanitary disposal to the extent practical and incorporate the remainder with soil.
- Soil—Excavation, ex situ vitrification to destroy organics and immobilize metals and radionuclides, and off-site disposal as sanitary waste.
- Sediment—Consolidate and treat with soil.
- Surface water—TBD.
- Groundwater—TBD.

Table 9.2. Cost estimate for Alternative 3 (minimal treatment and disposal), DWI 901 Site, Knoxville, Tennessee

Project cost item	Cost ($ thousands)[a]
Capital cost	
Direct cost:	
Temporary facilities/mobilization	288
Site preparation	262
Excavation/segregation	939
Treatment	8,183
Packaging/loading/transportation	1,033
WAC required actions	470
Decontamination/demobilization	39
Secondary waste disposal	275
Direct cost total (rounded)	11,489
Indirect cost:	
Project management	547
Remedial design work plan	53
Remedial design report	556
Remedial action work plan	62
Remedial action integration	2,276
Indirect cost total (rounded)	3,494
Total capital cost	14,983
M&M cost	
Site maintenance	5
Total M&M cost	5
Contingency—35%	5,247
Total project escalated cost	20,235
Total project present worth[b]	13,987

[a]Escalated.
[b]Present value cost based on a 30-year present value, 7 percent discount rate.

Note: Costs presented in table are rounded.

$ = dollar
DWI = David Witherspoon, Inc.
M&M = monitoring and maintenance
% = percent
WAC = waste acceptance criteria

9.2.4.1 Overall protection of human health and the environment

Physical removal of contaminated debris, soil, and sediment from the site will protect all current and future human receptors from risks and hazards associated with direct contact and ingestion of soil and sediment. Risk associated with direct radiation will also be eliminated. Protection from risks associated with surface water and groundwater will be determined after future sampling.

As with all of the alternatives, the use of best management practices (i.e., PPE, fugitive dust control, and personnel monitoring) while implementing this alternative will adequately mitigate any adverse short-term effects to the community, remediation workers, and the environment.

9.2.4.2 Compliance with ARARs

Although contaminated source material, soils, and sediments will be removed from the site under Alternative 4, there is a potential that groundwater could still require monitoring and reviews in accordance with CERCLA requirements. Alternative 4 assumes residential or industrial land use. Alternative 4 complies with water quality ARARs provided that groundwater quality standards can be met within the negotiated restoration period. LDRs and PCB disposal requirements can be met by this alternative. This alternative also assumes that disposal requirements for LLW will be met in order to place the waste in a sanitary landfill. Treatment variances from RCRA from prescribed methods of treatment may be required because of the mix of contaminants and use of unspecified treatment methods for specific types of media. Such variances are commonly granted in situations where environmental media have been contaminated by uncontrolled releases. Location-specific ARARs will be triggered by the presence of a 100-year floodplain and any riparian wetlands at the site. The requirements for consideration and protection of these resources can be met by this alternative.

9.2.4.3 Long-term effectiveness and permanence

Alternative 4 will meet RAOs developed in Section 6.1.4. As with Alternative 3, the direct contact with and incidental ingestion of contaminated soil and sediment will be permanently eliminated by removal of the material from the site. Contaminant migration into Goose Creek will no longer occur, thereby protecting residents and trespassers from potential risks associated with direct contact and ingestion of surface water. As long as institutional controls on groundwater use are enforced, this risk pathway will be controlled. Risk posed by ingestion and contact of contaminants in the groundwater is expected to be reduced through natural attenuation. The time frame for natural attenuation of the groundwater will be addressed following the next phase of site sampling.

Risk posed by organic and inorganic constituents in the soil and sediment will be eliminated after treatment.

Sensitive Resources. Same as Alternative 3.

Cumulative Effects. Same as Alternative 3.

9.2.4.4 Reduction of toxicity, mobility, and volume through treatment

Alternative 4 includes the excavation and treatment of soil, sediment, and debris. Ex situ vitrification will be used to glassify soil and debris contaminated with organics, metals, and radionuclides. The radiological characteristics of the waste will remain, but the glassy matrix produced from vitrification provides some shielding. Inorganic constituents will be less leachable as a result of the glassy matrix formed during vitrification. Organic constituents will be destroyed during the vitrification process as a result of the high temperatures needed to achieve molten conditions. The volume of the waste form produced from vitrification will be reduced by a factor of 25–50 percent from the initial volume.

Process modifications for treatment of all contaminants in the soil and sediment include stabilization/solidification which will reduce soil and sediment contaminant mobility but will increase volume.

Manual and automated cleaning processes will remove surface contamination from the debris. The residual solvent will require treatment to reduce toxicity, mobility, and volume.

9.2.4.5 Short-term effectiveness

Community Protection. Same as Alternative 3.

Worker Protection. Same as Alternative 3.

Environmental Effects. Short-term effects associated with this alternative include soil disturbances in areas adjacent to the site and disturbance of any riparian wetlands along Goose Creek. Remediation activities will disturb the habitats of individual nesting birds, amphibians, and burrowing mammals. Mitigation measures will be taken to the maximum extent practicable (e.g., erosion control, temporary stream diversion, and streambank stabilization). Dust emissions will be monitored and treated to control short-term environmental impacts from excavation, treatment, and packaging of contaminated material.

Time to Meet RAOs. Construction, treatment, and disposal activities under this alternative will be completed within 50 months after site mobilization.

Potential for Sudden Failure. During excavation, subsurface debris of unknown composition could be unearthed. The characterization of the material will be required before handling and final disposition. The vitrification process may require multiple tests involving various additives to form a more stable matrix. Any physical or chemical change in the contaminated media may require increased tests to discover the correct mixture of additives needed to achieve a stable, nonleachable waste matrix.

Socioeconomic Effects. Same as Alternative 3.

Cumulative Effects. Same as Alternative 2.

9.2.4.6 Implementability

Ability to Construct and Operate. The excavation, characterization, and staging of contaminated materials will be readily implementable using conventional equipment and techniques. The harvesting of potentially uncontaminated vegetation will be more difficult, but will eliminate the costs associated with treatment and disposal as contaminated material. Debris decontamination equipment is available in both manual and automated forms. Equipment and materials necessary to perform vitrification operations are available. Transportation and disposal of the treated soil as LLW is feasible.

Reliability of the Technology. Waste removal and transportation activities are well established and can be performed without substantial problems. Both automated and manual debris decontamination will be labor intensive, but feasible. Some debris types such as paper, cloth, wood, and tree stumps may be difficult to treat. Additional cleaning and characterization time will be required for these materials. Vitrification is an established technology for the treatment of organics and inorganics. The variability of material types, textures, and the inclusion of debris in the soil will make vitrification more difficult. The variabilities in materials will necessitate more adjustments to process operations, which will result in a moderate increase in schedule and cost. Transportation and disposal of treated soil as LLW is feasible.

Ease of Undertaking Additional Remediation. Groundwater and surface water treatment, if needed, can be performed without difficulty after the wastes are removed from the site. Additional remediation, if any, can be easily implemented.

Ability to Monitor Effectiveness. The effectiveness of this alternative can be easily determined through sampling. These sampling activities will determine whether risk has been reduced at the DWI 901 Site. Monitoring the effectiveness of debris decontamination and soil treatment will be performed by conventional sampling techniques and statistical analysis. Sampling will be relatively simple, though the certainty of complete treatment throughout the media will be based on mathematical probability, particularly with regard to the technique used to demonstrate the leachability or mobility of contaminants after vitrification. Regulators and the disposal facility managers will need to agree that the sampling techniques used were acceptable.

Ability to Obtain Regulatory Approvals. As a state Superfund site, no permits will be required for on-site RAs as long as the substantive requirements of applicable regulations are followed. The ability to perform the actions described by this alternative will be based on negotiations with regulators and acceptance by the public. Transportation and disposal activities will require strict adherence to characterization, packaging, and transportation regulations, as well as the WAC of the disposal facility.

Coordination with Other Agencies. COE will be consulted with respect to actions being taken in the floodplain or in a wetland.

Availability of Permitted Facilities. Self-contained, permitted treatment units for vitrification are commercially available. Permitted treatment facilities exist at the ORR to treat sanitary and special waste. Licensed waste haulers are also available in East Tennessee to transport the waste.

Availability of Equipment, Technologies, and Specialists. The equipment, technologies, and specialists required for this alternative are available. However, the number of vendors having vitrification and automated debris decontamination equipment and experience is limited.

Effect of Reasonable Deviations. If ORR water treatment facilities will not, or cannot treat contaminated water resulting from this alternative, moderate additional cost will be incurred to ship the liquid waste to another off-site facility for treatment and disposal. If groundwater or surface water treatment is required, there will be a moderate increase to the overall alternative cost. If nearby properties are not available for staging, treating, and packaging waste, RA will take slightly longer and cost substantially more. If off-site contamination is extensive rather than isolated to the principle threat areas, the scope of RA will increase proportionally to the increase in contaminant volume. In the unlikely event that off-site contamination is extensive, there will be a moderate increase in time and cost. If debris has more than surface contamination, debris decontamination will become substantially more difficult. To decontaminate such debris, additional wash cycles or more labor intensive cleaning actions will be required. If buried debris is not similar to surface debris, such that the same cleaning processes could be used, substantial delays and cost increases will result. Since the buried debris will not be fully characterized until after RA begins, a search for a new decontamination technique will be required during RA. This would necessitate either costly fast-track procurement, testing, and process set-up, or substantial project delays.

9.2.4.7 Cost

The total project present worth cost of Alternative 4 is approximately $22,553,000. Table 9.3 provides a detailed breakdown of the escalated project costs. More detailed information is provided in Appendix G.

Direct Capital Cost. The estimated escalated direct capital cost is $19,130,000. Direct capital cost includes temporary facilities, mobilization, general conditions, site preparation, excavation, segregation, treatment, transportation, WAC actions, monitoring well installation, decontamination/demobilization, and secondary waste disposal.

Indirect Capital Cost. The estimated escalated indirect capital cost is $5,652,000. Indirect capital cost includes project management, RA design work plan, RA design report, RA work plan, and RA integration.

Maintenance and Monitoring. The estimated escalated cost for M&M is $5,000. M&M cost includes site maintenance.

Contingency. Total escalated cost allowed for contingency is $8,676,000.

9.3 COMPARATIVE ANALYSIS

The comparative analysis of remedial alternatives summarizes the information presented in the detailed analysis of alternatives and contrasts the various aspects of the alternatives. A discussion of each of the criterion and a comparison of alternatives follows. Any conclusions concerning the most appropriate alternative for the site will be presented in subsequent documents. Table 9.4 presents a condensed comparison of the alternatives.

9.3.1 Overall Protection of Human Health and the Environment

Alternative 1 provides no protection of human health or the environment. Alternatives 2, 3, and 4 will achieve overall protection of human health and the environment. Alternatives 2, 3, and 4 will protect current and future employees and trespassers. Alternatives 3 and 4 will also protect potential future residents. Use of best management practices and compliance with governing regulations during construction activities will provide adequate short-term protection for all receptors for all alternatives. Alternative 2 provides the least amount of long-term protection because all waste, though capped, will remain on site. The long-term effectiveness provided by Alternatives 3 and 4 will be assured because of the active controls used at the disposal facilities.

Table 9.3. Cost estimate for Alternative 4 (extensive treatment and disposal), DWI 901 Site, Knoxville, Tennessee

Project cost item		Cost ($ thousands)[a]
Capital cost		
Direct cost:		
Temporary facilities/mobilization		371
Site preparation		352
Excavation/segregation		927
Treatment		12,323
Packaging/loading/transporting		1,568
WAC required actions/disposal		3,078
Decontamination/demobilization		27
Secondary waste disposal		484
	Direct cost total (rounded)	19,130
Indirect cost:		
Project management		1,015
Remedial design work plan		53
Remedial design report		858
Remedial action work plan		81
Remedial action integration		3,645
	Indirect cost total (rounded)	5,652
	Total capital cost	24,782
M&M cost		
Site maintenance		5
	Total M&M cost	5
Contingency—35%		8,787
	Total project escalated cost	33,463
	Total project present worth[b]	22,553

[a]Escalated.
[b]Present value cost based on a 30-year present value, 7 percent discount rate.

Note: Costs presented in table are rounded.

$ = dollar
DWI = David Witherspoon, Inc.
M&M = monitoring and maintenance
% = percent
WAC = waste acceptance criteria

Table 9.4. Comparison of remedial alternatives, DWI 901 Site, Knoxville, Tennessee

Evaluation criteria	Alternative			
	1 No action	2 Multilayer cap and monitoring	3 Minimal treatment and disposal	4 Extensive treatment and disposal
Overall protection	None	Protection of employees and trespassers achieved. Future on-site residents not protected	Achieves protectiveness of all receptors	Achieves protectiveness of all receptors
Compliance with ARARs	None	Complies with all ARARs[a]	Complies with all ARARs[a]	Complies with all ARARs[a]
Long-term effectiveness and permanence	No long-term effectiveness achieved	Long-term effectiveness achieved while institution control maintained	Long-term effectiveness achieved	Long-term effectiveness achieved
Reduction of toxicity, mobility, and volume through treatment	No reduction achieved since no treatment employed	No reduction achieved since no treatment employed	Toxicity of organics reduced through LTTD	Mobility of metals and radionuclide contamination, total waste volume, and toxicity of organics reduced through vitrification
Short-term effectiveness	No short-term effectiveness achieved. RAOs never achieved	Short-term effectiveness achieved with the use of BMPs and compliance with governing regulations. RAOs achieved in 36 months	Short-term effectiveness achieved with the use of BMPs and compliance with governing regulations. RAOs achieved in 41 months	Short-term effectiveness achieved with the use of BMPs and compliance with governing regulations. RAOs achieved in 50 months
Implementability	Readily implementable	Readily implementable	Readily implementable if EMWMF is developed	Implementable but complex
Present worth cost ($ millions)	0	7	20	33

[a]Assuming that surface water and groundwater ARARs can be met once data are available to demonstrate this.

ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
$ = dollar
DWI = David Witherspoon, Inc.
EMWMF = Environmental Management Waste Management Facility
LTTD = low-temperature thermal desorption
RAO = remedial action objective

9.3.2 Compliance with ARARs

It is not possible to fully address ARARs compliance for groundwater and surface water until more data are available after the planned sampling event. Alternative 2 could have difficulty in meeting the ARARs for these media based on the likelihood of contamination through continued contact with contaminant sources. This can be better evaluated after data gaps have been filled. Until then, Alternative 2 would only be selected if ARARs could be met. Alternatives 3 and 4 will probably be able to comply with water quality standards based on an assumption of no further contact with contaminant sources and an attenuation of current contamination through time. Alternatives 3 and 4 are expected to comply with RCRA LDR requirements. In the case of Alternative 3, ARARs would only be met if inorganics do not exceed RCRA-characteristic thresholds. Alternative 3 will be potentially acceptable for soils and sediments with PCB contamination at concentrations of up to 499 ppm. All alternatives will meet location-specific ARARs.

Based on these considerations, Alternative 2 is likely to meet ARARs. Alternatives 3 and 4 are currently expected to meet all ARARs, provided that limitations on residential land use and restrictions on groundwater use are acceptable.

9.3.3 Long-Term Effectiveness and Permanence

Alternative 1 provides no long-term protection of human health or the environment. Alternative 2 provides the least amount of long-term protection because all waste, though capped, would remain on site. Alternatives 3 and 4 provide long-term effectiveness at the DWI 901 Site because all waste will be removed from the site, treated, and disposed.

All three alternatives would contribute positively to human health and the environment by reducing contaminant migration off site to surrounding areas. This would represent an incremental decrease in total contaminant releases, which have the potential to enter Goose Creek via surface water runoff and shallow groundwater infiltration. While contamination from the DWI 901 Site contributes a negligible amount of the total pollution in Fort Loudoun Lake and the overall region, any permanent reduction of contaminant sources is beneficial.

9.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This criterion addresses the statutory preference for RA alternatives that permanently reduce the toxicity, mobility, or volume of contaminated media through treatment. If treatment operations are not a component of an alternative, the preference is not satisfied.

Alternatives 1 and 2 do not incorporate treatment actions into base RAs for the site, therefore, they do not satisfy the preference for reduction of toxicity, mobility or volume. Alternative 3 reduces the toxicity of the organic contaminants through LTTD. Mobility and volume of waste are not reduced, nor are the inorganic and radionuclide contaminants. Mercury levels may, however, be reduced by LTTD. Alternative 4 reduces the toxicity of organics and the mobility of metals and radionuclides through vitrification. Therefore, Alternative 4 best meets this criterion.

9.3.5 Short-Term Effectiveness

This criterion refers to the estimated time until RAOs are achieved and the effects to human health and the environment during implementation of RAs.

Alternative 1 does not involve any action; therefore, there will be no increase in short-term risks and no short-term environmental effects.

9.3.5.1 Community and worker protection

Alternatives 2, 3, and 4 protect the community and workers during remediation activities through the use of engineered and institutional controls. Short-term risks to the community (not including transportation) and to nonremediation workers will be regulated to acceptable limits. The risk to the community along the transportation route will be slightly higher for Alternatives 3 and 4 because of the potential for accidents during off-site rail and truck transportation of the waste. Alternative 2 provides the least risk to the community and remediation workers because this alternative does not require off-site transportation of contaminated material.

The risk to workers is expected to be within acceptable limits. By planning the activities for Alternatives 2, 3, and 4 in accordance with ALARA principles, industry and OSHA codes and requirements, and DOE Orders, worker risks from contaminant exposure will be maintained to acceptable levels.

9.3.5.2 Environmental effects

The potential short-term effects include increased noise and traffic levels associated with construction for Alternatives 2, 3, and 4. Environmental effects will be noticeable without proper site reclamation. All of these alternatives involve excavation of the site, resulting in the potential for permanent off-site damage to surrounding habitat.

9.3.5.3 Time to meet RAOs

Alternatives 2, 3, and 4 can be implemented in roughly the same amount of time. Alternative 2 is estimated to take 36 months until RAOs are achieved, and Alternative 3 is estimated to take 41 months. Alternative 4 would take 50 months to achieve RAOs.

9.3.5.4 Potential for sudden failure

Alternatives 2, 3, and 4 involve excavation, during which, subsurface debris of unknown composition could be unearthed. Because Alternatives 3 and 4 require more excavation, failure is more likely to occur.

9.3.5.5 Cumulative effects

Dust and sediment control measures will help curtail any cumulative effects of soil erosion during excavation activities. Incremental contributions for Alternatives 2, 3, and 4 include traffic, noise, and dust levels during construction activities.

9.3.5.6 Socioeconomic effects

Because any of the actions will likely be performed by an existing work force, there will be minimal variations in socioeconomic impact among the alternatives during remediation.

9.3.6 Implementability

9.3.6.1 Ability to construct and operate

All of the alternatives can be constructed and operated. Alternative 4 would be moderately more difficult to construct and operate because of the vitrification treatment equipment used by this alternative.

9.3.6.2 Reliability of the technology

Implementation of Alternatives 1 and 2 will not likely result in any substantial delays or problems because the technologies used are reliable. Alternatives 3 and 4 are at a higher risk of causing delays and operational problems because of the complexity of the technologies used and the complexity of the wastes to be treated. Thorough engineering support studies performed before RA could enhance the reliability of Alternatives 3 and 4.

9.3.6.3 Ease of undertaking additional remediation

All of the alternatives can be easily modified to include surface water and/or groundwater treatment. For Alternative 2, excavating additional material during remediation will not be difficult. Adding additional material underneath an already-constructed cap, however, will be difficult. For Alternative 3, additional treatment of LTTD-treated waste will be readily implementable. The vitrified waste resulting from Alternative 4 could not be further treated.

9.3.6.4 Ability to monitor effectiveness

The effectiveness of all alternatives can be readily monitored using common environmental monitoring methods.

9.3.6.5 Ability to obtain regulatory approvals

Alternatives 3 and 4 involve off-site transportation of hazardous waste. Waste will have to meet WAC at the disposal facilities. Alternatives 1 and 2 will not require permits.

9.3.6.6 Coordination with other agencies

Coordination with regulators from the state of Tennessee will be required of all alternatives. Alternative 2 will require additional coordination within DOE and possibly interaction with the city of Knoxville concerning institutional controls at a privately owned site.

9.3.6.7 Availability of permitted facilities

Water treatment facilities and waste haulers are available for all alternatives. The required waste disposal facilities exist for Alternative 4. The land needed for Alternative 2 is available. The proposed EMWMF needed for Alternative 3 is currently in the planning stages. Envirocare is an existing permitted facility.

9.3.6.8 Availability of equipment, technologies, and specialists

The equipment, technologies, and specialists needed for each alternative are available. Several LTTD vendors are available for Alternative 3. Several vitrification vendors are also available for Alternative 4.

9.3.6.9 Effect of reasonable deviations

All alternatives will be negatively affected if the following reasonable deviations occur: the ORR water treatment facilities will not, or cannot treat contaminated wastestream water and a greater volume of contaminated material is realized during RA. Alternative 3 will be greatly affected if the proposed EMWMF does not come into existence. Alternative 4 will be substantially affected if debris has more than surface contamination or if buried debris is not similar to surface debris.

9.3.7 Cost

A cost comparison of direct, indirect, and M&M costs for the alternatives is provided in Table 9.5. Of the action alternatives, Alternative 2 has the highest M&M cost but the lowest total project present worth, Alternative 3 costs substantially less than Alternative 4, partially because no project cost is associated with disposal of the treated waste at the proposed EMWMF. Alternative 4 is the most expensive remedial alternative.

Table 9.5. Comparison of remedial alternative cost components, DWI 901 Site, Knoxville, Tennessee

Comparatives	Alternative 1 No Action ($ thousands)	Alternative 2 Multilayer Cap and Monitoring ($ thousands)	Alternative 3 Minimal Treatment and Disposal ($ thousands)	Alternative 4 Extensive Treatment and Disposal ($ thousands)
Direct cost	0	2,984	11,489	19,130
Indirect cost	0	2,124	3,494	5,652
Monitoring/maintenance	0	50	5	5
Contingency[a]	0	1,805	5,247	8,676
Total project[b]	0	6,963	20,235	33,463
Present value[c]	0	4,845	13,987	22,553

[a]Total contingency is inclusive of direct, indirect, and all O&M associated contingencies.
[b]Total cost includes all capital cost, direct and indirect, with operations and maintenance and associated reports for the 30-year term of comparison in each alternative.
[c]Present value is based on present worth analysis and is calculated using the National Standards and Technology Building Life-cycle Cost 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" vs. "internal" costs. (R. Lyon OMB 1-5-1995, OMB Sect. 8C.3, "Cost Effectiveness").

Note: See detailed cost submitted as a separate document for line-item cost descriptions.

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 Society for Testing and Materials
BLCC = Building Life-Cycle Cost
$ = dollar
DWI = David Witherspoon, Inc.
EPA = U.S. Environmental Protection Agency
FEMP = Federal Energy Management Program
O&M = operating and maintenance
OMB = Office of Management and Budget
% = percent

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