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Remedial Investigation Report on the Melton Valley Watershed at Oak Ridge National Laboratory, Oak Ridge, Tennessee

Volume 1. Evaluation, Interpretation, and Data Summary

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PREFACE

This *Remedial Investigation Report on the Melton Valley Watershed at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (DOE/OR/01-1546/V1&D2, /V2&D2, and /V3&D2), was prepared in accordance with requirements under the Comprehensive Environmental Response, Compensation, and Liability Act for reporting results of site characterization for public review. This work was performed under Work Breakdown Structure 1.4.12.6.1.02.45.08.30 (Activity Data Sheet 3302, "RI Report"). This document provides the Environmental Restoration Program with a watershed-wide compilation and interpretation of data from previous studies conducted in the area. It includes information on risk assessments that have evaluated long-term impacts to human health and the environment. Information provided in this document forms the basis for the development of the Feasibility Study.

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ACRONYMS AND ABBREVIATIONS

1,1-DCA	1,1-dichloroethane
1,1-DCE	1,2-dichloroethylene
1,2-DCE	1,2-dichloroethylene
ACL	alternate concentration limit
AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ARAP	Aquatic Resource Alteration Permit
ARAR	applicable or relevant and appropriate requirement
ARE	Aircraft Reactor Experiment
AWQC	ambient water quality criteria
BMAP	Biological Monitoring and Abatement Program
BMP	Best Management Practice
CA	cost analysis
CERCLA	Comprehensive Environmental Restoration, Compensation, and Liability Act of 1980
CFR	*Code of Federal Regulations*
CLP	Contract Laboratory Program
COC	chemical of concern
COEC	chemical of ecological concern
COPEC	chemical of potential ecological concern
CV	chronic value
D&D	decontamination and decommissioning
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
DQO	data quality objective
EDE	effective dose equivalent
EE	engineering evaluation
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ERMA	Environmental Restoration Monitoring and Assessment
EWB	Emergency Waste Basin
FFA	Federal Facilities Agreement
FR	*Federal Register*
FS	feasibility study
GA	groundwater area
GV	groundwater volume
HFIR	High Flux Isotope Reactor
HI	hazard index
HQ	hazard quotient
HRE	Homogeneous Reactor Experiment
HRT	Homogeneous Reactor Test
ILLW	intermediate-level liquid waste
LLLW	liquid low-level waste
LLW	low-level radioactive waste
LOAEL	lowest observed adverse effect level

MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MSL	mean sea level
MSRE	Molten Salt Reactor Experiment
MV	Melton Valley
NEPA	National Environmental Policy Act
NHF	New Hydrofracture Facility
NHPA	National Historical Preservation Act
NOAEL	no observed adverse effect level
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
OECD	Office of Environmental Compliance and Documentation
OHF	Old Hydrofracture Facility
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PRG	preliminary remediation goal
PVC	polyvinyl chloride
PWSB	Process Waste Sludge Basin
QC	quality control
RA	remedial action
RCRA	Resource Conservation and Recovery Act of 1976
RI	remedial investigation
SCS	seep collection system
SDWA	Safe Drinking Water Act
SSA	soil/sediment area
SSV	soil/sediment volume
SWMU	solid waste management unit
SWSA	solid waste storage area
T&E	threatened and endangered
TBC	to be considered
TCA	Tennessee Code Annotated
TCE	trichloroethylene
TDEC	Tennessee Department of Environment and Conservation
TPP	Transuranium Processing Plant
TRE	trivalent rare earth
TRU	transuranic
TURF	Transuranium Research Facility
UIC	Underground Injection Control
USC	United States Code
USDW	underground source of drinking water
USRADS	Ultrasonic Ranging and Data System
VOC	volatile organic compound

WAG	Waste Area Grouping
WOC	White Oak Creek
WOCE	White Oak Creek Embayment
WOD	White Oak Dam
WOL	White Oak Lake

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ACRONYMS AND ABBREVIATIONS

COEC	contaminants of ecological concern
COPECs	contaminants of potential ecological concern
CVs	Chronic Values
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
HI	hazard index
HQ	hazard quotient
LCV	lowest chronic value
LOAELs	lowest observed adverse effects levels
LTV	lowest test value
MV	Melton Valley
MVW	Melton Valley watershed
NAWQC	National Ambient Water Quality Criteria
NOAELs	no observed adverse effects levels
NPDES	National Pollutant Discharge Elimination System
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
OU	operable unit
PCB	polychlorinated biphenyl
RI	Remedial Investigation
SAV	secondary acute value
SCV	secondary chronic value
SWMUs	solid waste management units
T&E	threatened and endangered
UCL	upper confidence limit
WAGs	waste area groupings
WOCW	White Oak Creek watershed
WOCE	White Oak Creek Embayment
WOC	White Oak Creek

EXECUTIVE SUMMARY

The Melton Valley watershed presents a multifaceted management and decision-making challenge because of the very heterogeneous conditions that exist with respect to contaminant type, disposal unit age, mode of disposal, release mechanism, and potential risk-producing pathways. The investigation presented here has assembled relevant site data in the geographic context with the intent of enabling program managers and decision-makers to understand site conditions and evaluate the necessity, relative priority, and scope of potential remedial actions.

Approach

The remedial investigation (RI) has been prepared using a watershed approach. At the watershed scale the analysis is built by compiling the systematic analyses performed for each subbasin in the watershed. The analysis presented includes:

- description of contaminated sites, waste types and inventories, including estimates of radioactive decay inventory reductions;
- formulation of hydrologic conceptual models addressing interactions of contaminant source units with water;
- identification of contaminant release mechanism and pathway control options;
- identification of locations, quantities, and characteristics of secondary contaminated media throughout the watershed;
- ranking of contaminant releases from the subbasin and from areas within the subbasin when possible;
- assessment of human health and ecological risk conditions in each subbasin; and
- identification of applicable or relevant and appropriate requirement (ARAR) exceedances in each subbasin.

The industrial and recreational exposure scenarios are used to provide a risk assessment reference context to evaluate levels of contamination in surface water, groundwater, soil, and sediment within each subbasin of the Melton Valley watershed. All available analytical results for the media of interest that could be qualified for use in the risk assessment were screened to determine carcinogenic risk values and noncarcinogenic hazard indexes and to identify the chemicals of concern (COCs) for each evaluated media in each subbasin.

Physical Setting

In the humid climate of the Oak Ridge Reservation, rainfall rapidly percolates through surface soils and can infiltrate shallow waste disposal units forming leachate, which seeps laterally to nearby streams. During wet season storms, shallow lateral water seepage combined with rising water tables can cause rapid rises of water levels in contaminated areas, causing pulses of contaminant discharge to the local surface water system. Groundwater occurs and moves through fractures in soil and bedrock. The groundwater table in most of the Melton Valley area is a subdued replica of the land surface and seepage occurs quickly from hillslopes to adjacent streams. Contaminant concentrations are frequently higher near the water table than in deeper wells. Active contaminated groundwater seepage depths beneath most sites in Melton Valley are within about 100 to 150 ft of the land surface.

Contaminated Sites Summary

The Melton Valley watershed contains numerous contaminated sites including:

- legacy waste disposal sites containing buried mixed radiological waste and chemical waste from Oak Ridge National Laboratory and numerous off-site waste generators, some of which are of classified nature;
- two inactive experimental nuclear reactors;
- inactive, backfilled and asphalt-capped liquid waste Seepage Pits and Trenches;
- several inactive wastewater impoundments;
- abandoned underground liquid waste transfer pipelines and associated historic leak or spill sites;
- secondary contaminated soil adjacent to contaminant sources;
- contaminated floodplain soil and sediment; and
- deep-injected radiological waste/grout mixture associated with two formerly used hydrofracture waste disposal wells.

Measures to prevent water contacting contaminant sources or contaminated media have been applied to only a small fraction of the contaminated sites. Much of the contaminant source material is intermittently wetted during the winter and spring seasons. In some areas contaminant sources are perennially inundated.

Results

In overview, there are three separate factors of the Melton Valley watershed that comprise the major problems identified in this RI – current contaminant releases to surface water, the presence of high activity and long half-life radiological wastes, and widespread distribution of radiological contamination in secondary media.

These three factors are interrelated in the watershed but constitute separate individual problems from the standpoint of site and risk management. The importance of these factors varies in the decision-making process and varies spatially throughout the Melton Valley watershed.

Subbasins in the Melton Valley watershed have been ranked based on several criteria including contribution of the area to current ^{3}H and ^{90}Sr releases from the watershed, estimated radiological waste inventory, secondary contaminated media volumes, and recreational and ecological risk.

- The importance of contaminant sources can be ranked using ^{3}H and ^{90}Sr releases to surface water from the source areas within the subbasins. The most important sources of current radionuclide releases to surface water are associated with Solid Waste Storage Areas (SWSAs) 4 and 5 and the Homogeneous Reactor Experiment (HRE) area.

- Ranking according to estimated current radionuclide inventory in the subbasin provides a somewhat different perspective because not all waste inventory is directly associated with the current releases. Other than the deep-injected hydrofracture waste, the highest inventory of disposed radioactive waste lies in the West Seep subbasin. This inventory is associated with the combination of high activity waste disposed in auger holes in SWSA 6 and residual waste contained in the inactive Seepage Pits 2, 3, and 4.

- In general ranking according to the human health risk assessment for potential recreational risk and the ecological risk assessment highlight subbasins other than those which are identified for inventory and current ^{90}Sr and ^{3}H release. Potential exposure of humans and wildlife to contaminated surface soils and sediment account for this difference. The areas where the risk assessments identified on the most significant soil and sediment problems were in the Intermediate Pond subbasin, the East Seep subbasin, the Lower White Oak Creek (WOC) subbasin upstream of White Oak Lake, SWSA 5 drainages, and the sediment and contaminated soil areas associated with the High Flux Isotope Reactor (HFIR) Ponds. Radiological contaminants dominated in the risk assessments; however, nonradiological contaminants contribute somewhat to risk in several areas.

- Contaminant concentration and affected acreage of contaminated surface soil are critical parameters in assessing potential risk because surface contamination is accessible to expose humans and biota. Secondary contaminated soil that is not exposed at the land surface is a problem with respect to feeding contaminated groundwater seepage and may pose a future release risk.

Several general conclusions may be drawn from the assessments performed throughout the Melton Valley watershed. These conclusions focus on the conditions that are fundamental to scoping remedial actions that can meet remedial action goals and are key points for decision-makers in selecting a realistically achievable endpoint for the site.

1. *Thirteen of 35 subbasins in the Melton Valley watershed contribute approximately 71% of the ^{90}Sr and 97% of the ^{3}H currently released to surface water.*

Releases of contaminants to surface water, though diminished by several significant control actions taken between 1994 and 1996, continue to produce concentrations of ^{90}Sr and ^{3}H that exceed maximum contaminant levels (MCLs) and recreational risk scenario action levels (1E-04) at the watershed exit point and in the main stems of streams in the Melton Valley watershed. Portions of some tributaries are also affected.

The distribution of estimated current ^{90}Sr releases following Comprehensive Environmental Response, Compensation, and Liability Act of 1980 actions to reduce releases shows that SWSA 4 Main, SWSA 5 Seep C, HRE, Seep B East, SWSA 4 East, and SWSA 5 WOC subbasins are the six most important sources of continuing release in the Melton Valley area. SWSA 5 Drainage D-2, West Seep Tributary, and W6MS3 are significant but of less importance for ^{90}Sr releases measured at the watershed exit point. Remedial actions recently completed in the SWSA 4 Main subbasin are expected to further reduce ^{90}Sr releases.

Tritium releases have not been affected significantly by the remedial actions taken to reduce ^{90}Sr releases because locations treated were not major ^{3}H sources and because the treatment methods selected have no effect on ^{3}H. The SWSA 5 Seep B subbasin is the major source area for watershed releases of ^{3}H (56.3%), followed by SWSA 4 Main (13.9%), SWSA 5 Seep A, SWSA 5 Drainage D-2, SWSA 5 Seep B East, and W6MS3.

2. *The current trends for ^{3}H and ^{90}Sr releases suggest that ^{3}H may become a localized problem in tributaries within about 20 years while ^{90}Sr presents a persistent release problem.*

Projection of the current release trend for ^{3}H, incorporating the radioactive decay process, suggests that if no additional ^{3}H releases occur, ^{3}H contributions from Melton Valley sources may produce concentrations at the WOC watershed exit point less than the proposed MCL within about 20 years. Tritium concentrations could still exceed the proposed MCL in Melton Branch and in some tributaries and seeps. A similar projection for ^{90}Sr shows the benefits of seep collection and treatment projects completed in 1994 and 1996 and show timespans of 10 to 70 years to reach ^{90}Sr contributions to streams producing concentrations less than the proposed MCL at the watershed exit point. The actual time span will depend upon the aggressiveness and effectiveness of remedial actions.

3. *Perennial inundation of buried waste appears to be the principal cause of current contaminant releases.*

Five of the six most important contaminant releasing subbasins in Melton Valley have a large percentage of their contaminant inventory in perennially inundated trenches. The highest ranked subbasins where source inundation is the predominant release mechanism include SWSA 4 Main, SWSA 5 Seep B East and West, SWSA 4 East, and HRE. Contaminant sources in SWSA 5 Seep C, which is also a major contaminant release area, are known to be seasonally inundated. Seasonal inundation and direct infiltration affect most other contaminated sites to some extent.

In the Melton Valley watershed, most contaminants derived from near-surface contaminant sources follow shallow, fracture-controlled seepage pathways, which discharge to the local streams. Tritium is detected in some deep (100 to 400 ft) wells beneath tritium disposal areas at concentrations much lower than those detected in the shallow groundwater zone; however, other contaminants are attenuated in soil or bedrock at shallower depths. Volatile organic compounds (VOCs) are detected in groundwater in some wells beneath and adjacent to several waste disposal areas including SWSAs 4, 5, and 6. Concentrations are typically less than about 100 μg/L, although concentrations as high as about 3 mg/L have been detected near solvent auger hole groups at SWSA 5. The local "hot spot" distribution of VOCs suggests that sources of these contaminants are localized and that the migration is controlled by the fracture-dominated groundwater flow patterns.

4. *Radiological contaminants dominate in risk assessments; however, other contaminants are present in surface water, groundwater, and soil at concentrations above ambient water quality criteria (AWQC), action levels for hazard indexes for human health or ecological risk.*

Contaminants in the Melton Valley watershed surface water that exceed the AWQC for protection of human health include arsenic – detected in less than half the surface water samples from many subbasins downgradient of contaminated sites; mercury – detected near the HFIR area and in the West Seep Tributary; polychlorinated biphenyls (PCBs) – detected in the Lower WOC and WOC subbasins; thallium – detected near HFIR, HRE, SWSA 5, and in WOC/White Oak Lake (WOL).

Contaminants in the Melton Valley watershed surface water that exceed the AWQC for protection of aquatic life include Cd, Se, and Ni. While the AWQC were exceeded in several subbasins for Cd, Se, and Ni, the more detailed, subbasin-specific analyses suggest that these analytes may not always be a concern. PCBs were detected above the AWQC for protection of aquatic wildlife in unfiltered WOC floodplain surface water samples.

Volatile organic contaminants in the Melton Valley watershed in groundwater that exceed MCLs include carbon tetrachloride, 1,1-dichloroethylene, tetrachloroethylene, trichloroethylene, and vinyl chloride. These contaminants were detected primarily at SWSAs 4, 5, and 6. Arsenic and thallium were detected in groundwater in several areas.

Nonradiological contaminants detected in soil and sediment and potentially significant in the human health recreational risk assessment or in the ecological risk assessment include: mercury – detected in the contaminated soil of the Intermediate Pond, WOC, Lower WOC, and SWSA 5 Trib 1; and PCBs – detected in the floodplain soils of the Intermediate Pond, WOC, Lower WOC, and HRE subbasins. Chromium was detected at high concentrations in soils and sediments in the HF-2 subbasin and in Lower WOC and WOL, however, the ecological risk assumption was that the chromium was Cr^{+6} rather than the more probable Cr^{+3}. Aluminum and manganese were present in high concentrations in some soil samples; however, these two elements are naturally abundant and the risk estimate assumptions are very conservative with respect to potential adverse effects on plants and soil invertebrates.

5. *Contaminated surface soils are a significant problem in the Melton Valley watershed as shown by both the human health recreational risk assessment and the ecological risk assessment.*

Radiological contamination present at the ground surface in soil or sediment exceeds recreational risk levels for gamma radiation exposure in contaminant source area hot spots, in secondary contaminated areas along seepage discharge routes, and in broad floodplain areas. Cesium-137 is the most common radionuclide present in the areas of surface contamination, although ^{60}Co is detected along with ^{137}Cs in some areas. These contaminants bind strongly to soil and sediment particles, and they move along with soil and sediment by erosion. In subbasins containing main stem streams in Lower WOC, Middle WOC, and Melton Branch, much of the mapped wetland area contains contaminated soil and sediment. In areas designated wetlands, the ARAR for wetland protection applies to any proposed remediation activities.

6. *Long half-life radionuclides pose a future risk for several areas.*

Although short half-life (<30 years) fission products such as ^{3}H, ^{60}Co, ^{90}Sr, and ^{137}Cs will decay to levels below concern in most disposal areas within about 100 to 300 years, the presence of long half-life (>100 years) radionuclides in some of the contaminated sites in Melton Valley poses a future on-site risk. Before the mid-1960s, long half-life wastes, including uranium, thorium, and transuranic isotopes, were disposed in shallow land burial trenches. These wastes were usually placed in special containers such as concrete casks or had concrete poured over the waste after emplacement in a trench. Locations of such wastes in SWSA 4 are poorly known because of loss of disposal records for SWSA 4 and a portion of SWSA 5. Remaining disposal records for SWSA 5 suggest that casks containing high activity levels of alpha emitting waste were disposed in six known shallow land burial trenches in SWSA 5 South including areas in SWSA 5 Seep B West, Drainage D-2, Seep C, and SWSA 5 WOC subbasins. Isotopic inventories for other shallow land burial trenches in SWSA 5 and in SWSA 6 suggest that undesignated but presumably small quantities of transuranic isotopes are widely distributed throughout the buried waste. The greatest concern lies with the larger curie inventory in the high alpha activity special disposals. A management strategy for these wastes must be included in long-term site remediation and management planning.

7. *Hydrofracture wastes and wells are a long-term site management challenge.*

The deeply injected wastes associated with the hydrofracture waste disposal process and the deep wells associated with these wastes present a potential long-term site management requirement. The grouted waste and associated highly contaminated fluids have permeated fractures in the shale bedrock to distances in excess of 1000 ft horizontally from the two injection wells. While the bedrock permeability is very low at depths of 800 to 1000 ft below ground where the grout was injected, and fluid migration rates are slow in the deep briney zone, elevated pressure is evident in some wells penetrating the grout injection interval. This pressure, combined with the high salinity of the deep groundwater, is capable of causing contaminant migration upward into shallow groundwater or to the ground surface through deteriorated deep wells.

This RI identifies the three principal factors of greatest importance to management and remediation of the Melton Valley watershed to be:

- Presence of sources of contamination that cause current releases to surface water,

- Presence of high radiological activity and long half-life radioactive contaminants that pose a potential risk of future release or exposure, and

- Presence of secondary contaminated media—principally contaminated soil and sediment—that provide potential current and future human health and ecological risk.

These factors represent three related, but distinct, aspects of the conditions in Melton Valley that comprise the current and future problems of the area. This RI develops information pertinent to each factor and for each, presents a ranking of subbasins within the Melton Valley watershed.

1. INTRODUCTION

1.1 OBJECTIVES

The purpose of this Remedial Investigation (RI) Report is to present an analysis of the Melton Valley watershed, which will enable the U.S. Department of Energy (DOE) to pursue a series of cost-effective remedial actions resulting in site cleanup and stabilization. In this RI existing levels of contamination and radiological exposure are compared to levels acceptable for future industrial and potential recreational use levels at the site. This comparison provides a perspective for the magnitude of remedial actions required to achieve a site condition compatible with relaxed access restrictions over existing conditions. Ecological risk will be assessed to evaluate measures required for ecological receptor protection. The RI approaches the Melton Valley area from the perspective of surface water subbasins that fit together like jigsaw puzzle pieces, each piece containing critical information that contributes to the analysis of the whole site. For each subbasin, this report will provide site-specific analyses of the physical setting for the relevant Federal Facility Agreement (FFA) Appendix C (DOE, EPA, and TDEC 1992) sites including:

- identification of contaminant source areas;
- creation of subbasin conceptual models describing the contaminant transport pathways for each FFA Appendix C site;
- identification of release mechanisms;
- analysis of contaminant source interactions with groundwater;
- identification of secondary contaminated media associated with the source and seepage pathways;
- assessment of potential human health and ecological risks from exposure to contaminants detected in the environment of the Melton Valley watershed;
- ranking of each source area within the subwatershed, and each subwatershed at the watershed scale based on the estimated contaminant inventory, current release condition, and estimated potential for future release; and
- outlining the conditions that remedial technologies must address to stop present and future contaminant releases, prevent the spread of contamination, and achieve the goal of limiting environmental contamination to be consistent with a potential recreational use of the site.

The RI spans the scale of local, site-specific contaminant source analyses as well as broad area assessment of the importance of remedial action at each FFA Appendix C site to obtain the overall programmatic goal of remediation of contaminated sites at Oak Ridge National Laboratory (ORNL). The breadth of scale considered in this document will allow a logical sequencing of remedial actions to reach the remedial objectives as quickly and cost effectively as possible. This RI will provide the watershed conceptual models and detailed site data to allow the feasibility study (FS) to focus on the most effective site-specific remedial technologies.

This RI considers industrial and recreational use of the site as the risk assessment reference or benchmark in determining areas that warrant remedial action based on water quality and soil contaminant levels. Residential scenario risk estimates for the site are included in the Human Health and Ecological Risk Assessment Appendixes to this report for reference. Ranking or prioritization will consider the severity of exceedance of the industrial and recreational criteria, ecological risk, and the contribution of individual areas to the total watershed criteria exceedances.

1.2 PROBLEM STATEMENT

The Melton Valley watershed encompasses 1062 acres. Approximately 160 acres of the area lie within designated FFA Appendix C sites or contain secondary contamination. Historic waste management practices within the area have led to the presence of tens of acres of buried solid radioactive and hazardous mixed waste in shallow trenches and auger holes with minimal hydrologic control, several large liquid radioactive waste seepage basins closed by backfilling and asphalt capping, numerous pipeline leaks and spills of liquid radioactive waste, tens of acres of contaminated sediment and soil on the WOC floodplain and in the bed of White Oak Lake (WOL) and WOC Embayment (WOCE), and deep injected (800 to 1000 ft below ground surface) radioactive waste mixed with cement grout associated with two formerly operational hydrofracture sites.

Current direct radiation exposure levels in many parts of the Melton Valley watershed exceed the risk-based recreational exposure threshold because of contaminated soil, sediment, or vegetation. Releases of contamination (principally radiological) from these areas cause current exceedances of surface water and sediment quality as measured against a goal of recreational use of the site and create ecological risk.

Most areas of contaminated soils and sediment in the Melton Valley watershed are the result of historic releases and are in a condition of ongoing radioactive decay with some migration in the hydrologic system and cycling in the local biological systems. The predominant contaminant transport mechanism in the Melton Valley watershed is release by contact of infiltrating precipitation (rainwater) into and through shallow buried waste with subsequent leachate seepage through the shallow groundwater system to adjacent streams. Groundwater seepage from contaminant sources to receiving surface water bodies causes secondary contamination of soil along the seepage pathway and at the point of emergence at seeps and springs.

The problem posed at the Melton Valley watershed scale is the presence of a large inventory of radioactive waste combined with other hazardous waste constituents in numerous locations, which is allowed to release contaminants into the environment at concentrations exceeding legal or risk-based exposure criteria. As stated in Sect. 1.1, the objective of this RI is to analyze data, identify the predominant contaminant release mechanisms, and outline a sequence of potential actions for the Melton Valley watershed to enable the FS to efficiently scope remedial projects, which will bring the area into compliance with potential recreational use criteria.

1.3 SCOPE

This RI addresses contaminated media and FFA sites within Melton Valley at ORNL except active facilities, nuclear reactors, and the cesium plots in the 0800 area along the Clinch River [Waste Area Grouping (WAG) 13]. DOE plans to address the decommissioning and demolition of reactors under a separate Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) action and the WAG 13 area is being remediated under its own CERCLA action.

1.4 REGULATORY INITIATIVE

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

DOE, the U.S. Environmental Protection Agency (EPA), and TDEC negotiated an FFA (DOE, EPA, and TDEC 1992) in response to the NPL listing of ORR. The FFA was developed to integrate CERCLA, RCRA, and the National Environmental Policy Act (NEPA) and provide a legal framework for remediation activities on ORR. A common goal of those parties to the FFA was to ensure that past releases from process and waste management operations at ORR were thoroughly investigated and that appropriate remedial action was taken to protect human health and the environment. The general purposes of the FFA are as follows:

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

It is understood that DOE will comply with the requirements of NEPA as specified in 10 CFR 1021. DOE's Secretary Policy Statement on NEPA was signed on June 13, 1994. This 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.

1.5 REPORT ORGANIZATION

This RI Report is organized to present the Melton Valley watershed analysis on a basin-by-basin scale. The rationale for this organization is consistent with the management and remediation of the numerous contaminant source areas in a sequence of actions that balance near-term improvements in surface water quality with longer term cleanup of areas to the desired endpoint. Section 2 of the report presents a brief description of the existing site conditions, presents the conceptual model of physical processes active in the watershed, identifies applicable or relevant and appropriate requirements (ARARs), defines receptors and exposure scenarios used in the human health and ecological risk assessments, and identifies data sources used to support the RI. Section 3 presents and interprets physical site data for all FFA Appendix C sites contained in the watershed area in a basin-by-basin organization and identifies the major uncertainties that will affect site remediation decisions. The information in Sect. 3 describes contaminant sources, ranks their releases according to importance in the basin, identifies release and transport mechanisms and pathways, identifies secondary contaminated media, presents the risk assessment for various sources, and identifies points of intervention in the contaminant release and transport system that may be useful in the FS for site stabilization. Section 4 presents the summary and conclusions of the watershed analysis. Section 5 lists references. Appendix A includes source description tables.

2. SITE DESCRIPTION, CONCEPTUAL MODEL, AND DATA SOURCES

2.1 SITE DESCRIPTION

The following sections describe the site location and define the waste units within the watershed. After defining the waste units, a conceptual model is developed for the identified remedial groupings (e.g., buried waste, tanks, leak/spill sites). The conceptual model encompasses the primary contaminant release mechanisms, pathways, and potential receptors by defining the site hydrology and hydrogeology. This section also includes identification of ARARs for this site.

2.1.1 Site Location

The Melton Valley watershed occupies the southeastern portion of the ORNL DOE ORR site. ORNL covers approximately 3560 acres and is located 10 miles southwest of downtown Oak Ridge, Tennessee, as shown in Fig. 2.1. The area surrounding the ORR is predominantly rural with the exception of Oak Ridge, which has a population of 27,310 (1990 census). The site lies southeast of Haw Ridge in Melton Valley, a prominent northeast-southwest-trending valley typical of land forms in the Valley and Ridge Physiographic Province. The two major drainages at this site are WOC and Melton Branch. ORNL's remediation sites were originally organized into WAGs based on drainage area and similar waste characteristics, but this report will focus more on the subwatersheds that make up this drainage basin as shown on Fig. 2.2. Subbasin boundaries were established to incorporate surface water and groundwater basins that contribute flow and dissolved and suspended contaminant loadings at surface water measurement points. Defining the downstream ends of subbasins at measurement locations enables relating contaminant releases to the upstream contributing area. This subbasin structure varies from the boundary patterns that result from using purely hydrologic criteria for basin delineation. Areas south of Melton Branch Road have not been included in the Melton Valley watershed because no contaminant sources are known to lie in the area. Similarly, the headwater portion of Melton Branch is excluded from the RI because no FFA Appendix C sites are located in the area. Section 2.1.2 will discuss the waste units within these watersheds with minimal reference to the WAGs.

2.1.2 Description of Waste Units in Watershed

ORNL is one of the three principal facilities built in 1943 as part of the World War II Manhattan Project with a mission to produce and chemically separate the first gram quantities of plutonium to support the national effort to produce the first atomic bomb. ORNL's current mission is to conduct applied research and engineering development in support of DOE programs in nuclear fusion and fission, energy conservation, fossil fuels, and other energy technologies and to perform basic scientific research in selected areas of the physical, life, and environmental sciences. These 50 years of production, operation, and research activities have produced a legacy of diverse contaminated inactive facilities, research areas, and waste disposal areas that are potential candidates for remedial action. From 1955 to 1963, ORNL's solid waste storage areas (SWSAs) were designated by the Atomic Energy Commission as the Southern Regional Burial Ground. About one million cubic feet of solid waste from various off-site installations were buried in SWSAs 4 and 5. During this period, ORNL served as a major disposal site for wastes from such facilities as Argonne

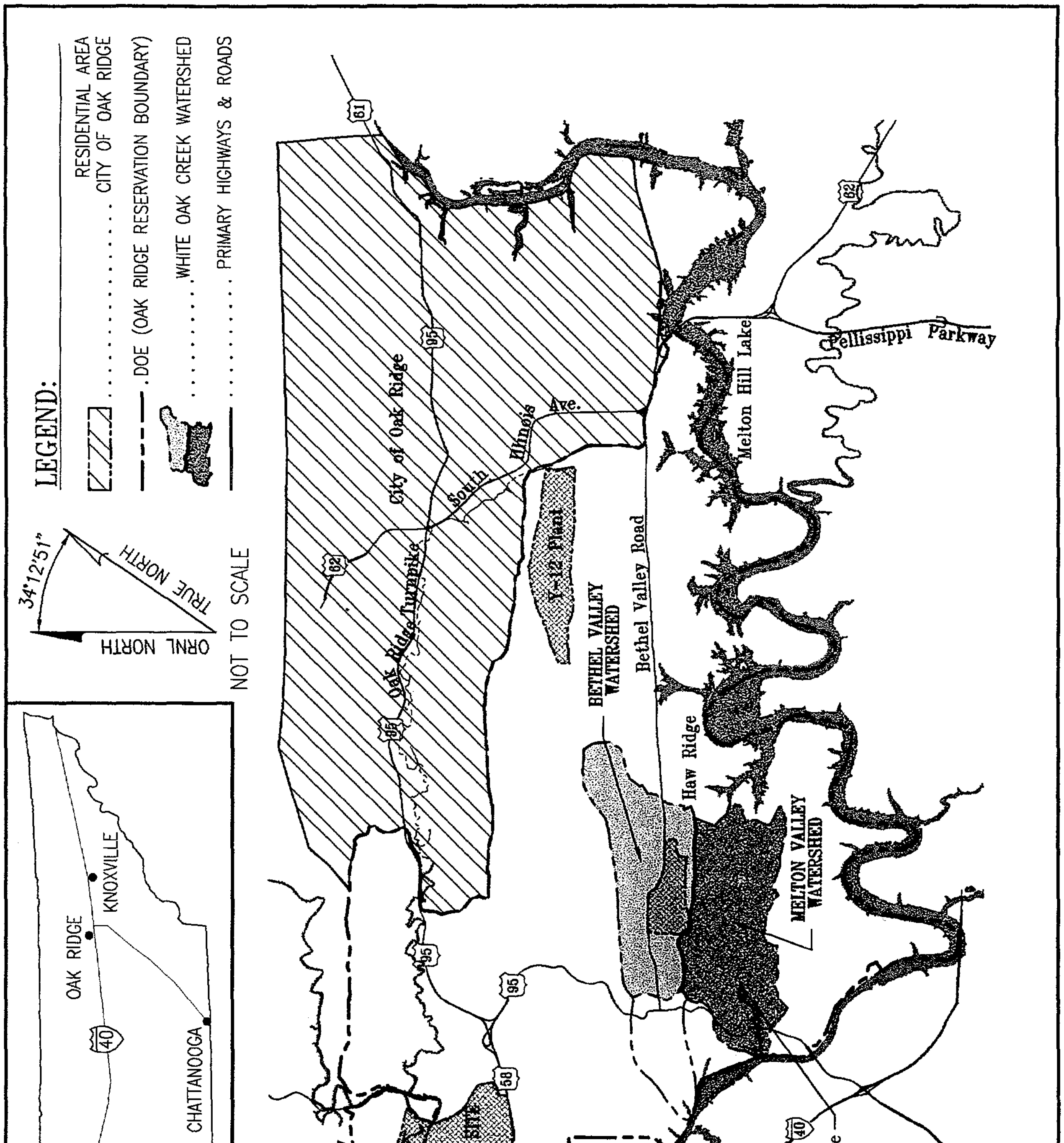


Fig. 2.1. Location of Melton Valley watershed.

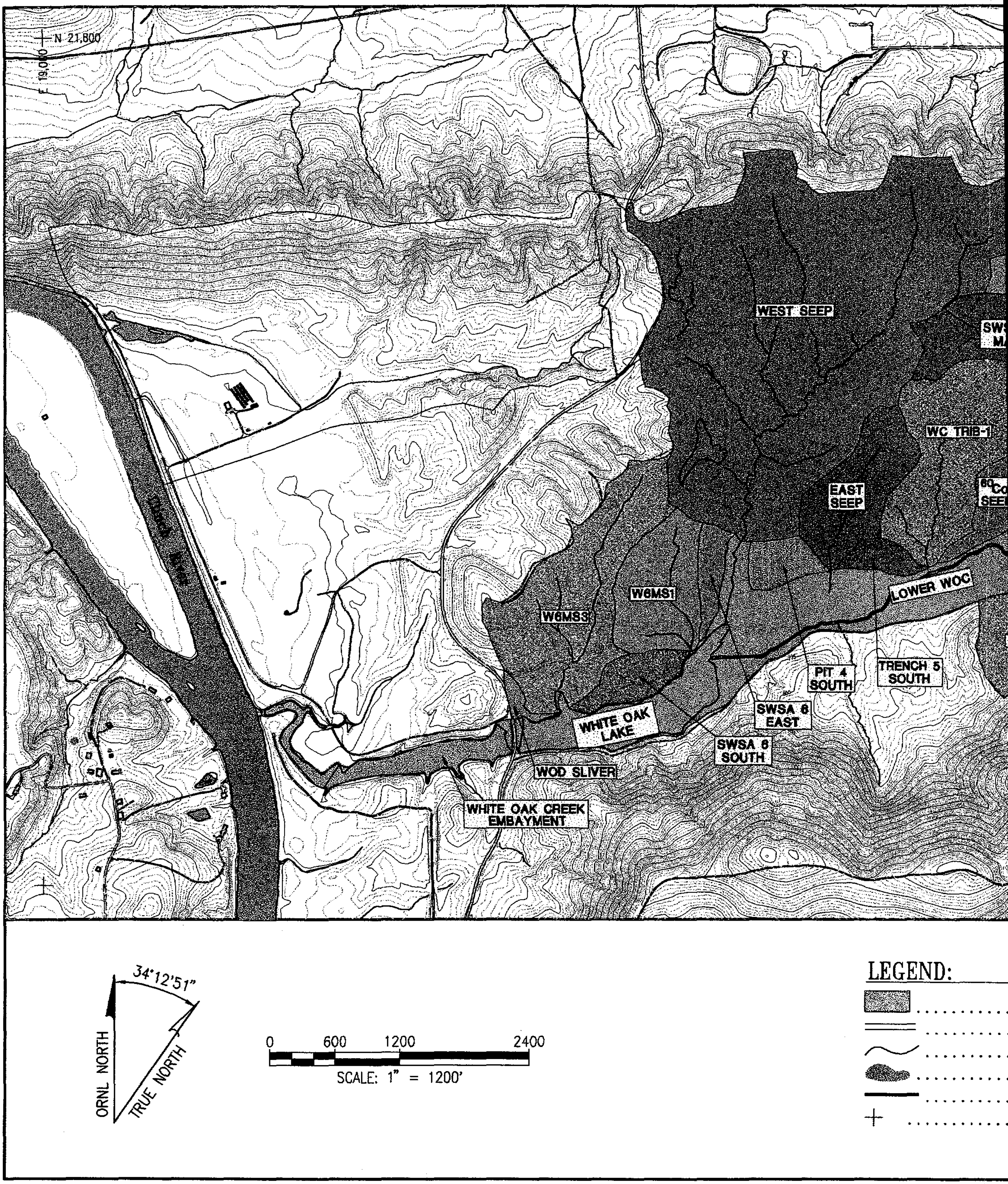
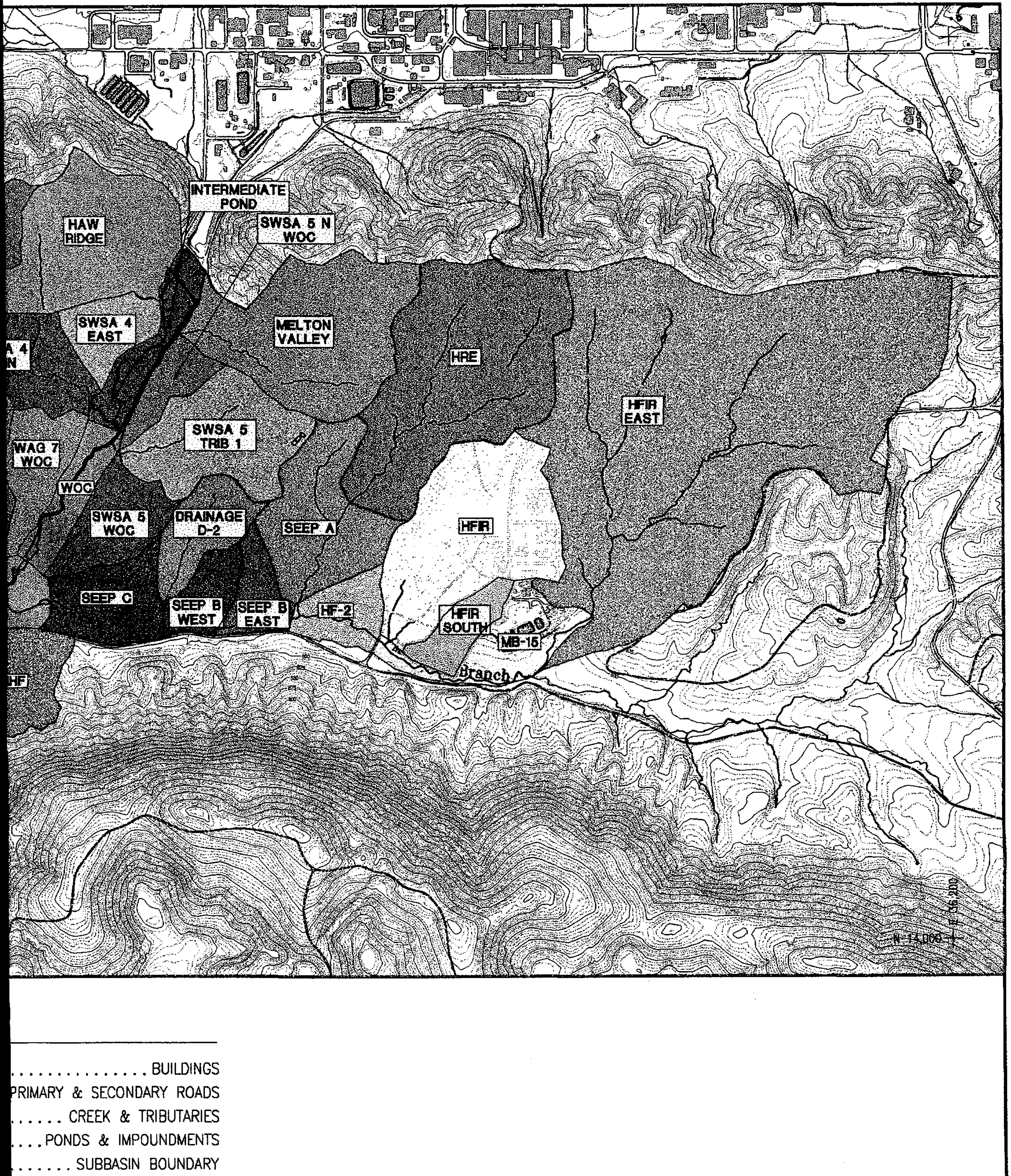


Fig. 2.2. Subbasin structure of the M



. . . . BUILDINGS
PRIMARY & SECONDARY ROADS
. . . . . . CREEK & TRIBUTARIES
. . . . PONDS & IMPOUNDMENTS
. . . . SUBBASIN BOUNDARY
. . . . .ORNL GRID

ton Valley watershed.

National Laboratory, Knolls Atomic Power Laboratory, Mound Laboratories, Battelle Memorial Institute, General Electric Company in Evendale, Ohio, and about 50 other off-site installations. Among the other off-site sources were Atomic Energy Commission installations, small contractors, research institutions, and numerous private and public isotope users.

Areas in Melton Valley that have been identified in Appendix C of the FFA for further evaluation are listed in Table 2.1 and are shown on Fig. 2.3. In the FFA the sites are grouped as Operable Units (OUs), Characterization Areas, Remedial Site Evaluation Areas, and Removal Site Evaluation Areas. These categories imply CERCLA status for each site. Sites can also be categorized, or grouped, according to their physical characteristics, as follows:

- buried waste,
- landfills,
- tanks,
- impoundments,
- seepage pits and trenches,
- hydrofracture wells and associated grout sheets,
- buried liquid waste transfer pipelines,
- leak/spill sites,
- surface structures, and
- contaminated soil and sediment.

The specific location of each of the FFA Appendix C sites will be discussed in more detail in Sect. 3.

Buried Waste. Shallow land burial was used routinely for disposal of solid low-level radioactive waste (LLW) between the facility startup in 1943 and 1986 when improved disposal technology was implemented. The principal waste burial sites at ORNL are SWSAs 4, 5, and 6 (Fig. 2.3). Early burial procedures involved the use of unlined trenches and auger holes covered by either soil from the trench excavation or by a combination of concrete caps and soil. The concrete caps were used when disposing of high activity wastes (>200 mrem/h at the container surface) or transuranic (TRU) wastes primarily in auger holes and, to a lesser extent, in some trenches. However, in 1970 TRU waste was segregated and stored in a retrievable manner in SWSA 5 North. Burial of LLW in unlined trenches and auger holes ceased in 1986 when ORNL began placing solid LLW in concrete-lined silos below grade in SWSA 6. Since 1988, this waste has been placed in concrete boxes and placed on aboveground concrete storage pads, which were covered with a multilayered cap before final closure (Energy Systems 1992).

Landfills. Bulky solid waste, which was not considered LLW, was disposed on-site in landfills. Landfills usually contain construction debris and used equipment that were placed in a large excavation. These excavations were then backfilled with the excavated material.

Tanks. During the early years of ORNL operation, liquid low-level waste (LLLW) produced by ORNL was concentrated and stored in underground storage tanks primarily in Bethel Valley. There are 9 inactive tanks [5 at Old Hydrofracture Facility (OHF), 1 at New Hydrofracture Facility (NHF), 2 at Homogeneous Reactor Experiment (HRE), and 1 at Molten Salt Reactor Experiment (MSRE)] and 16 tanks that are currently in service in Melton Valley as defined in Appendix F of the FFA. These tanks are constructed of stainless steel with only a few constructed of carbon steel

Table 2.1. FFA Appendix C sites

Unit/area description	Site number	Operation dates	Comment	Unit type[a]
White Oak Creek and Tributaries (0853)			Floodplain soils and creek sediments	DA
White Oak Lake and Embayment (7846)			Floodplain soils and creek sediments	DA
Low-Level Waste Line North of Lagoon Road (7800)	4.1	1954–1961		L/S
SWSA 4 (7800)	4.3	1951–1973	EE/CA for seeps in progress	BW
Pilot Pits 1,2 (7811)	4.2	1955–present		BW
Old Landfill (NE edge of SWSA 5)	5.14	Unknown	Received solid waste	LF
Drainage 3 Next to WAG 5		NA		DA
Drainage 1,2 in WAG 5		NA		DA
Inactive OHF Waste Storage Tank T-1	5.5A	1963–1980	EE/CA in progress	Tank
Inactive OHF Waste Storage Tank T-2	5.5B	1963–1980	EE/CA in progress	Tank
Inactive OHF Waste Storage Tank T-3	5.5C	1963–1980	EE/CA in progress	Tank
Inactive OHF Waste Storage Tank T-4	5.5D	1963–1980	EE/CA in progress	Tank
Inactive OHF Waste Storage Tank T-9	5.5E	1963–1980	EE/CA in progress	Tank
LLLW Line from Valve Box to OHF	5.5F			L/S
LLLW Lines and Leak Site–OHF		1964, 1968		L/S
LLLW Lines and Leak Site–Building 7852		1977		L/S
OHF Pond (7852A)	5.2	1964–1980, 1984–1985		IMP
PWSB Pipeline from PWSB to Process Waste Treatment Plant		1976–1981		L/S
Process Waste Sludge Basin (7835)	5.6	1976–1981		IMP
SWSA South 5 (7802)	5.7	1959–1973	Sites 5.071–5.079 on Fig. 2.3	BW
TRU Direct Burial Trenches (SWSA 5 North)[b]	5.10I	1970–1981		
OHF Site Surface Facilities (7852)	5.3	1964–1980		SS
SWSA 6 (7822)	6.1	1969–present	Sites 6.01a–6.01u on Fig. 2.3	BW
Explosives Detonation Trench (7822A)	6.3	?–1987	Treatment of shock-sensitive waste chemicals	BW
Emergency Waste Basin (7821)		1961–present		IMP

Table 2.1 (continued)

Unit/area description	Site number	Operation dates	Comment	Unit type[a]
SWSA 6 TVA Easement		NA	Deer reportedly congregate in this area and it is suspected that deer scat is responsible for elevated gamma readings.	SC
Homogeneous Reactor Experiment (HRE) Fuel Wells (7809)	7.2	1964–?	Received sulfuric acid solutions	BW
LLLW Lines and Leak Sites – Gauging Station NW of Bldg. 7852	7.4A	1970		L/S
LLLW Lines and Leak Sites – Pit 6 SE (Leak Site 1)	7.4B	1973		L/S
LLLW Lines and Leak Sites – End of Trench 7 Access Rd. (Leak Site 2)	7.4C	1966		L/S
LLLW Line and Leak Sites – Decon. Facility (7819) to Pit 1 (7805)	7.4D	1960–1970	Includes 19 contaminated trees; found in 1994; lines transfered acidic waste	L/S
LLLW Line and Leak Site Between Pit 3 (7807) and Trench 6 (7810)	7.4E	1961		L/S
LLLW Line Leak Site – Leak at Valve Pit North of Trench 7 (7818)	7.4F	1963–1983		L/S
Pit 1 (7805)	7.5	1951–1981	Received lab waste, acidic waste	SP/ST
Pit 2 (7806)	7.6A	1952–1962	Received lab waste, primarily RAD contamination	SP/ST
Pit 3 (7807)	7.6B	1955–1961	Received lab waste, primarily RAD contamination	SP/ST
Pit 4 (7808)	7.6C	1956–1976	Received lab waste, primarily RAD contamination	SP/ST
Trench 5 (7809)	7.7	1960–1966	Received lab waste, primarily RAD contamination	SP/ST
Trench 6 (7810)	7.8	1961	Received lab waste, primarily RAD contamination	SP/ST
Trench 7 (7818)	7.9	1962–1966	Received lab waste, primarily RAD contamination	SP/ST
Shielded Transfer Tank (ST1) (by 7819 Shed)	7.10A	1960–1970	Was part of 7.10	Tank
Shielded Transfer Tank (ST2) (by 7819 Shed)	7.10B	1958–1971	Was part of 7.10	Tank
Shielded Transfer Tank (ST3) (by 7819 Shed)	7.10C	1958–1971	D&D; was part of 7.10	Tank
Shielded Transfer Tank (ST4) (by 7819 Shed)	7.10D	1958–1971	D&D; was part of 7.10	Tank
Shielded Transfer Tank (ST5) (by 7818 Shed)	7.10E	1958–1971	D&D; was part of 7.10	Tank
Hydrofracture Experimental Site 1, Soil Contamination (HF-S1A)		1959		HF

Table 2.1 (continued)

Unit/area description	Site number	Operation dates	Comment	Unit type[a]
Septic Tank – Building 7819		1964–early 1970s		SS
HFIR/TRU Waste Collection Basin (7905)	8.1A	1965–present	Emergency storage basin only; received lab drain wastewaters, etc.	IMP
HFIR/TRU Waste Collection Basin (7906)	8.1B	1965–present	Emergency storage basin only; received acids	IMP
HFIR/TRU Waste Collection Basin (7907)	8.1C	1965–present	Emergency storage basin only; filled and drained intermittently	IMP
HFIR/TRU Waste Collection Basin (7908)	8.1D	1965–present	Emergency storage basin only; filled and drained intermittently	IMP
LLLW Lines and Leak Sites – Lagoon Road and Melton Valley Drive	8.3A	1954–present	Leak occurred in April–June 1960	L/S
LLLW Lines and Leak Sites – Melton Valley Dr. and SWSA 5 Access Rd.	8.3B	1954–present	Leaks occurred in July 1970	L/S
LLLW Lines and Leak Sites – 7500 Area	8.3C	1954–present	Leaks occurred in July 1969	L/S
LLLW Lines and Leak Sites – West of Melton Valley Pumping Station	8.3D	1954–present	Leaks occurred on January 15, 1971	L/S
LLLW Lines and Leak Sites – Bldg. 7920 and MV Pumping Station Area	8.3E	1954–present	Leaks occurred July 1980	L/S
LLLW Lines and Leak Sites – 7920 Ditch Line	8.3F	1954–present	Leaks occurred January 31, 1972	L/S
LLLW Lines and Leak Sites – The Melton Valley Transfer Line	8.3G	1954–1973	New line installed in 1973	L/S
Contractor Spoils Area – Melton Valley, W-SW of 7900	8.13	1962–?		LF
HFIR Cooling Tower Surface Impoundment	8.14	Unknown	Shutdown; chromium/cobalt-contaminated wastewaters	IMP
Inactive LLLW Collection Tank 7503A	8.20	1965–1969	Empty	Tank
MSRE Cooling Tower 7513	8A.1B	1965–1969	D&D; residual waste	SS
ARE Contaminated Tool Storage		1954–1957		SS
Abandoned Sanitary Waste Pipeline and Septic Tank N of 7917				Tank
Hydrofracture Experiment Site 2 Soil Contamination (HF-S2A)		1960		HF

Table 2.1 (continued)

Unit/area description	Site number	Operation dates	Comment	Unit type[a]
MSRE Storage Well				MW
Aircraft Reactor Experiment Surface Impoundment		1952	Constructed in 1952; no record exists that the pond was ever used	IMP
Homogeneous Reactor Experiment (HRE) Pond (7556)	9.1	1958–1961		IMP
LLLW Collection and Storage Tank 7560	9.2A	1957–1961	Permit-by-rule, empty	Tank
LLLW Collection and Storage Tank 7562	9.2B	1957–1986	Permit-by-rule	Tank
Trash Area East of HRE Parking Lot	9.4	Unknown	Construction spoils area	LF
HRE Waste Evaporator 7502	9.5	1958–1961	D&D	SS
HRE Waste Evaporator Loading Pit (7558)	9.6	1951–1961	D&D	SS
HRE Cooling Tower 7554	9A.1A	1958–1961	D&D; residual waste	SS
Charcoal Absorber Valve Pit 7559		1958–1961		SS
HRE Charcoal Absorber Pit 7557		1958–1961		SS
Soil at HRE Decontamination Pad/Shed (7561)		1954–present		SS
HRE Decon Pad/Shed (7561)			D&D	
HRE Waste Valve Pit		1958–1961		SS
OHF Grout Sheets (7852) and Injection Well (HF-3)	10.3A	1963–1980	CWA disposal	HF
New HF Grout Sheets and Injection Well (HF-4)	10.4A	1974–1985	CWA disposal	HF
Hydrofracture Experimental Site 1 (HF-S1)	10.1	1959		HF
Hydrofracture Experimental Site 2 (HF-S2)	10.2	1960		HF
Tc-99 and Np-237 Contaminated Soil Lysimeters		June 1984		
Cs-137 Bagged Leaves Study		~1961	NFI approved October 1994	

[a] BW = Buried waste
DA = Drainage area
HF = Hydrofracture wells
IMP = Impoundments
LF = Landfills
L/S = Leak/spill site
MW = Monitoring Well
SC = Surface Contamination
SP/ST = Seepage pit and trenches
SS = Surface structures
Tank = Tanks

[b] Not on the FFA.

Source: FFA, Appendix C (DOE, EPA, and TDEC 1997).

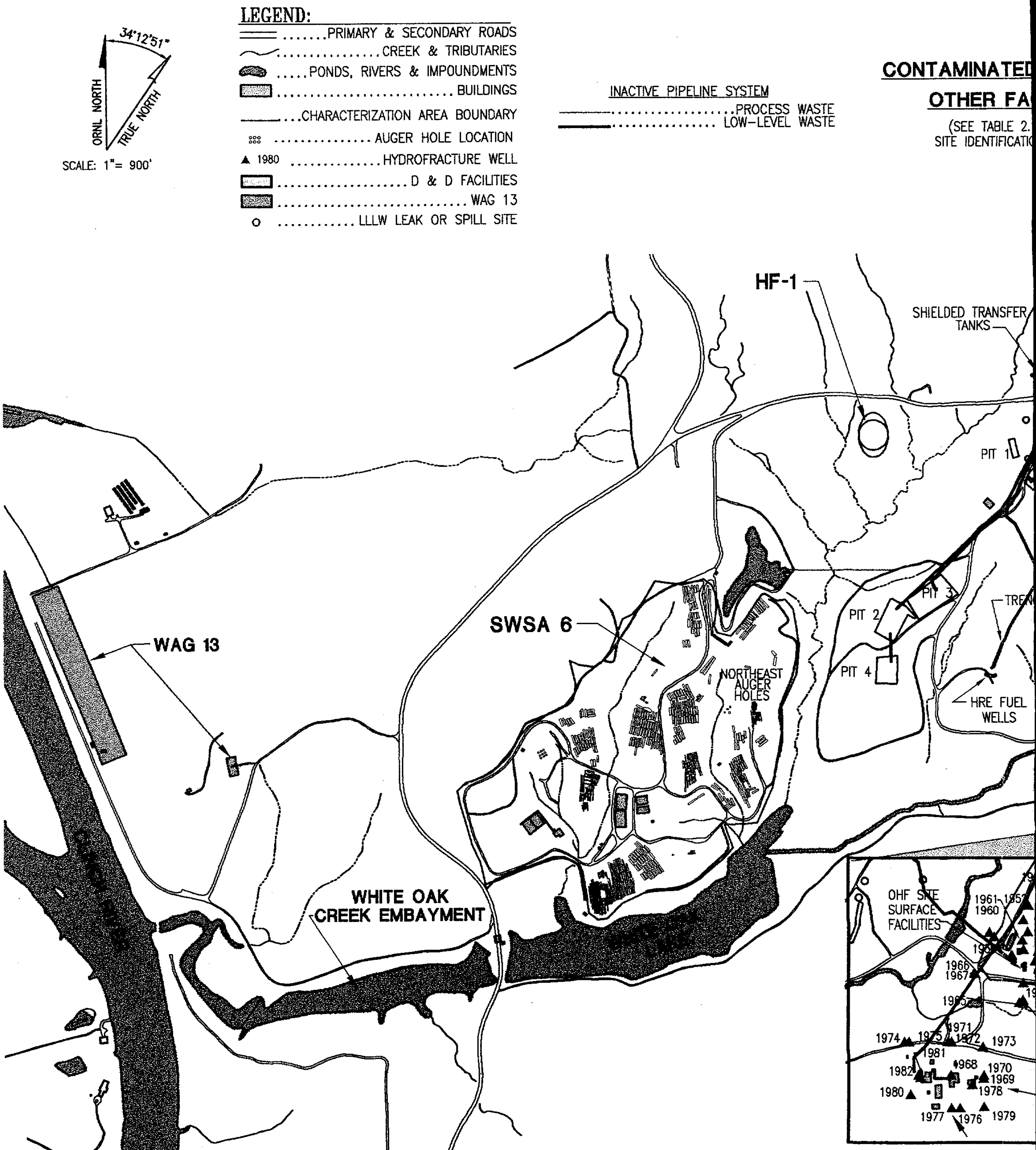


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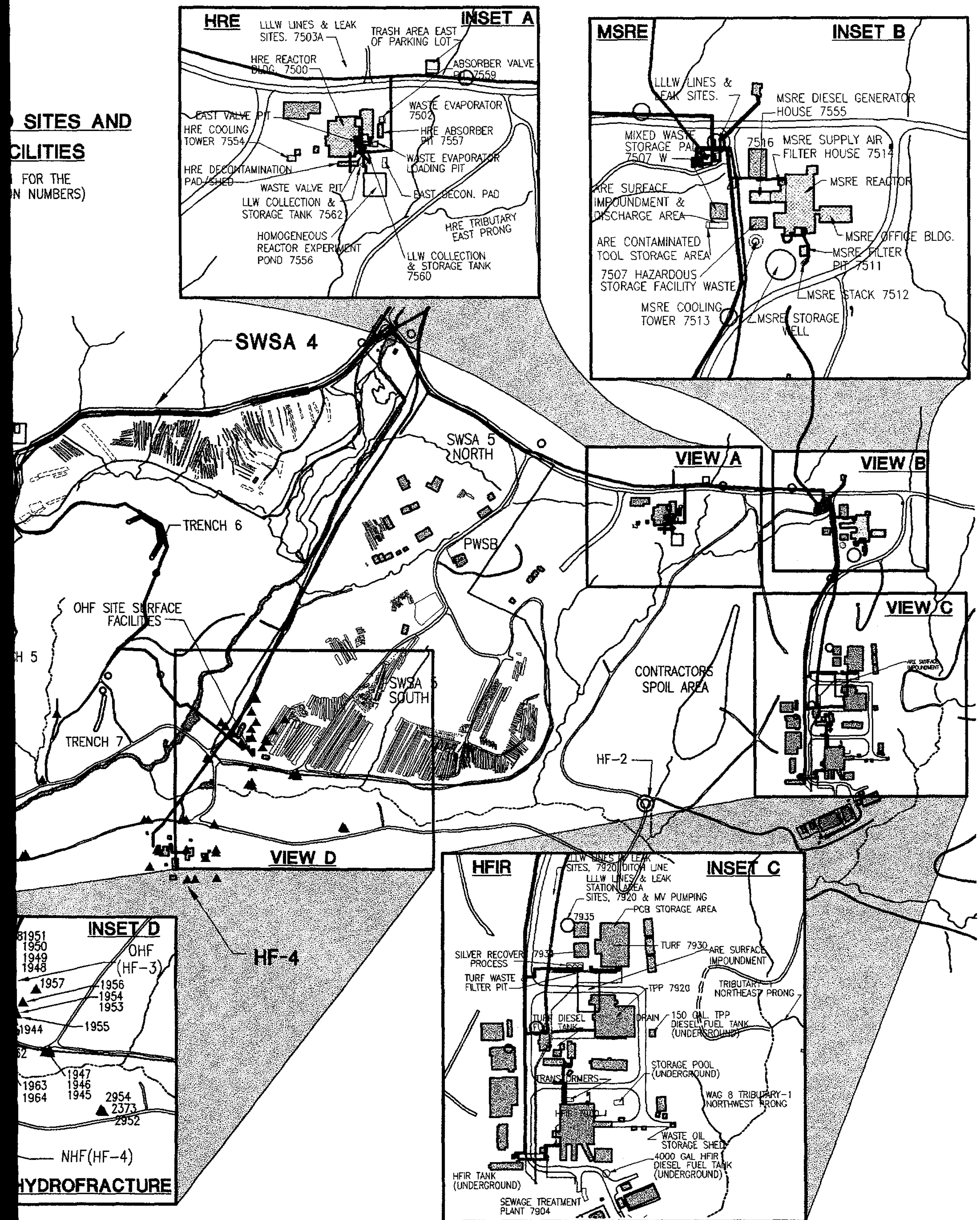
Fig. 2.3. Contaminated sites and other fac



ities in the Melton Valley watershed.

(tanks T-1, T-2, and T-9) with rubber liners (tanks T-3 and T-4). Over the years, tank systems were abandoned as their integrity was breached or as programs were terminated. Some of these tanks were abandoned in place with liquid waste and sludge left in them. Some of these tanks also have no existing cathodic protection or secondary containment. Locations of tanks in the Melton Valley watershed are shown on Fig. 2.3.

Impoundments. In 1943, settling basins (or impoundments) were constructed in the main plant area (Bethel Valley) for pretreatment/settling of LLLW before discharge to WOC. A treatment plant was then constructed to increase the volume of waste that could be treated and discharged. Impoundments were constructed in Melton Valley to store wastewater and provide additional settling and storage capacity for diversion of LLLW to avoid an off-site release due to a failure in the system. Impoundments in the Melton Valley watershed include High Flux Isotope Reactor (HFIR) Ponds, OHF Pond, Process Waste Sludge Basin (PWSB), and the Emergency Waste Basin (EWB). These impoundments were constructed in the natural clays with no liner with the exception of the PWSB that has a polyvinyl chloride (PVC) liner.

Seepage Pits and Trenches. In the early 1950s, chemically treated LLLW began to be disposed in large seepage pits and trenches excavated into relatively low permeability, strata of the Conasauga Group in Melton Valley. As intended, the LLLW seeped into the surrounding soil that was primarily clay. This clay soil acted as a sorption agent for some radionuclides contained within the waste. Seven seepage pits and trenches were used from 1951 to 1966, until the hydrofracture method of liquid waste disposal became operable.

Hydrofracture Wells. Four hydrofracture well injection sites (two experimental and two previously operational) were used to pump LLLW grout slurry into a fracture in the underground geologic formation (>600 ft below ground surface) produced by pumping water into a slot cut in the injection well casing. The grout slurry was pumped into the formation and allowed to harden. Using this technique, the radionuclides were retained in the grout and were thought not to be subject to groundwater transport although the possibility of excess liquid (filtrate) from incomplete grout set has long been known. Use of the hydrofracture process for waste disposal was terminated in 1984. In 1986, a well in the vicinity of the grout sheet showed the presence of radionuclides at the approximate depth of the grout sheets.

Buried Pipelines. The LLLW system is complex, requiring buried pipelines to transport the aqueous radioactive waste solution from the generator facilities to storage tanks, and historically for disposal in seepage pits/trenches or hydrofracture injection. These buried pipelines are constructed of various materials, including steel, black iron, and stainless steel. These pipelines were triple rinsed and abandoned after they were no longer needed. However, poor configuration control exists on these pipelines because of the lack of as-built drawings. Consequently, it is unknown what and where residual waste may remain in them.

Leak/Spill Sites. Leak and spill sites have resulted from ruptures in pipelines or spills from handling LLLW. Most of these sites are associated with abandoned pipelines but some are associated with spills that occurred during the LLLW handling operations (i.e., hydrofracture operations).

Surface Structures. Surface structures were required to support waste handling and operations. Theses facilities consist of support building and grout storage/mixing equipment for hydrofracture operations, decontamination facility, MSRE support facilities, and HRE support facilities.

The environment (including soil, sediment, groundwater, and surface water) surrounding these waste units has been impacted by release of contaminants and will be discussed in Sect. 3.

Contaminated Soil and Sediment. Radiological contamination of surface soil occurs in many areas of the Melton Valley watershed. Causes of surface soil contamination include:

- material spills on the ground surface,
- contaminated biological material including leaves and animal droppings,
- pipeline leaks that caused surface contamination,
- surface breakouts of contaminated seepage during operation of the Seepage Pits and Trenches,
- surface breakouts of contaminated seepage and groundwater originating as leachate in primary contaminant source areas such as waste burial trenches, and
- contaminated sediment deposited in the floodplains of WOC and tributaries.

Figure 2.4 shows the distribution of contaminated surface soils throughout the Melton Valley watershed based on detection of elevated gamma exposure measurements made at the site. Surface-contaminated areas range in size from small "hot spots" for material spills, to areas less than 1 acre for most pipeline leak sites, to areas as large as 10 acres for the contaminated sediment area on the WOC floodplain upstream of WOL. Contaminated soil hot spots are identifiable on the radiological walkover data shown in Fig. 2.4. These hot spots are isolated locations where surface radiological contamination occurs.

Gamma radiation exposure levels are shown as color-coded contours in areas of high density Ultrasonic Ranging and Data System (USRADS) walkover data and as colored areas where spot measurements or lower density walkover data were used. The maximum acceptable gamma exposure level for the recreational scenario is approximately 50 μR/h. The future unrestricted industrial exposure scenario uses a maximum gamma exposure threshold of 15 μR/h. These exposure rates represent an incremental risk of 1×10^{-4} above background. Data sources for the RI include the radiological walkover datasets from the WAG 2 RI and the WAG 5 RI as wells as results of several other conventional walkover surveys performed in SWSA 6, the Seepage Pits and Trenches, and along Lagoon Road and Melton Valley Drive.

2.2 WATERSHED CONCEPTUAL MODEL

Water movement is the primary cause of contaminant transport associated with the historic LLW disposal sites and the floodplain soils and sediments at ORNL. The watershed conceptual model identifies the main water and contaminant flow paths and provides at least a semiquantitative estimate of the magnitude of flow and contaminants associated with those flow paths. The quantitative description of contaminant flow paths is important because most contamination moves in shallow pathways, although fractures and potential groundwater flow paths are evident at all depths. It makes sense to focus clean-up activities on pathways known to carry or suspected of carrying most of the contamination.

This section provides a brief summary of hydrologic concepts that are common to the transport of both surface water and groundwater contaminants. At ORNL, surface water and groundwater are tightly coupled. A large fraction of runoff measured at the main surface water weirs consists of water that has moved through the subsurface. In addition, groundwater seeps and springs provide groundwater samples that are representative of the most mobile portion of groundwater. In contrast,

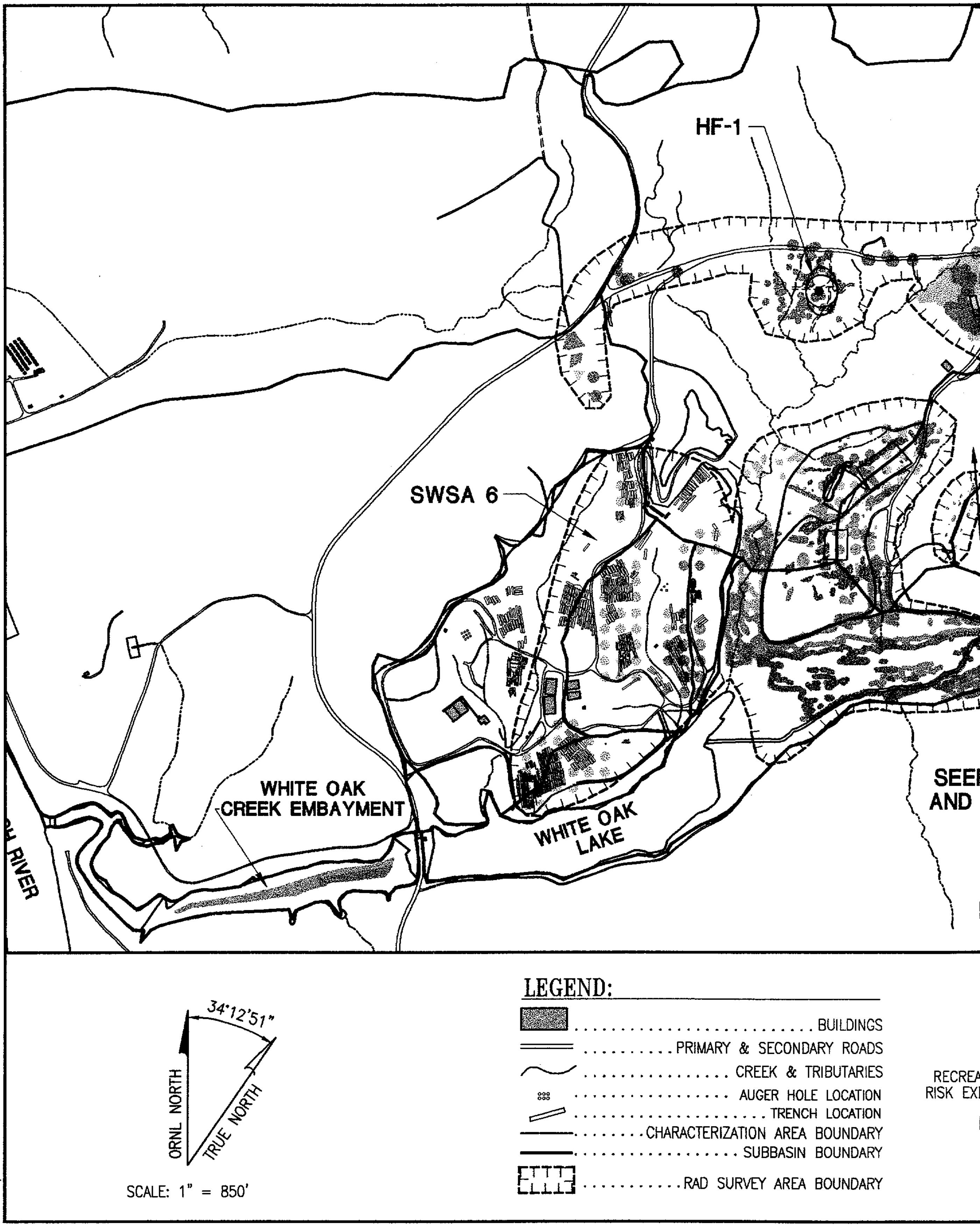
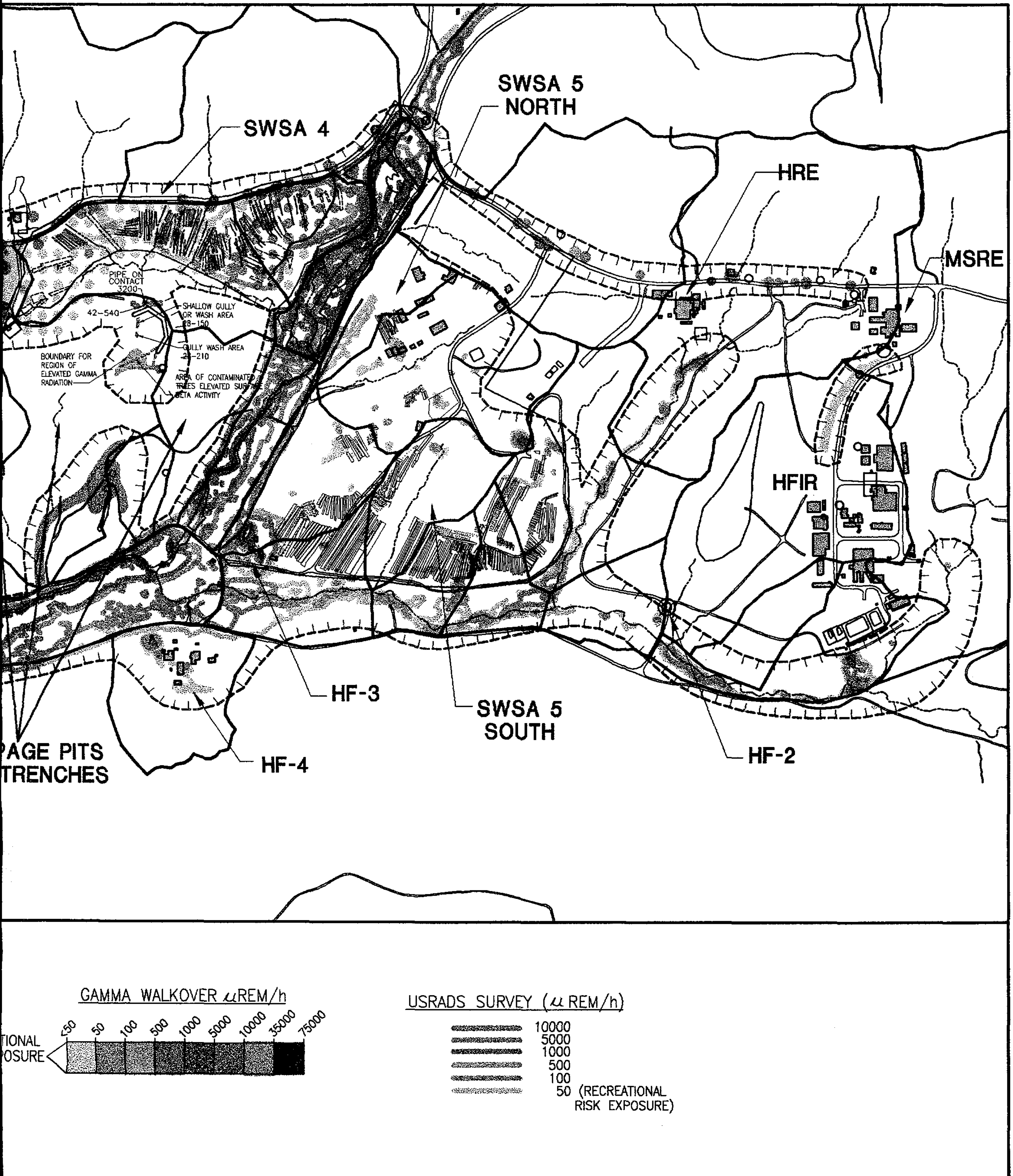


Fig. 2.4. Distribution of contaminated surface



soil in the Melton Valley watershed.

most groundwater monitoring wells have a low probability of intersecting the fractures or macropores that compose the most active groundwater flow paths; therefore, seep sampling is critically important to understanding and quantifying the quality of both groundwater and surface water.

The surface water and groundwater systems transport mostly soluble contaminants, in particular, ^{90}Sr and ^{3}H. The surface water system also transports sediments and soils with particle-reactive contaminants, especially ^{137}Cs. These particle-reactive contaminants were mostly discharged directly to the stream as a result of historical activities at ORNL (Clapp et al. 1996). They have accumulated in the floodplains of WOC and the sediments of WOL. The last part of this section addresses the mechanisms that transport particle-reactive contaminants in the watershed. The gamma radiation associated with ^{137}Cs poses the largest on-site risk for soils and sediments; however, the many other particle-reactive contaminants (e.g., TRU radionuclides and heavy metals) tend to complicate the analysis of risk.

2.2.1 Site Geology and Hydrogeology

2.2.1.1 Geology

The Melton Valley watershed is underlain by bedrock of the Rome Formation and the Conasauga Group. Geologic formations that outcrop within the area include:

- the Rome Formation along the crest of Haw Ridge,
- the Pumpkin Valley Shale on the southeastern slope of Haw Ridge,
- the Rutledge Limestone and the Rogersville Shale in the northwestern valley floor,
- the Maryville Limestone beneath the mid-valley knobs,
- the Nolichucky Shale beneath the valley floor, and
- the Maynardville Limestone along the northern slope of Copper Ridge.

Figure 2.5 is a surficial geologic map of the Melton Valley area showing the outcrop pattern of the local formations and the Copper Creek Thrust Fault that underlies the area. As shown on Fig. 2.5, most of the buried waste in SWSAs 5 and 6 lies in the Maryville Limestone outcrop belt. Lesser amounts of waste lie in the Nolichucky Shale. SWSA 4 waste lies in the Upper Pumpkin Valley Shale and Rutledge Limestone outcrop belts.

At a large scale, bedrock generally dips to the southeast with steeper dips near the Copper Creek Thrust Fault on and beneath Haw Ridge and flatter dips beneath the axis of the valley (Fig. 2.6). At a local scale, the bedrock has innumerable small scale folds, faults, and fractures that play a major role in groundwater flow and contaminant migration pathways. Most of the bedrock in the Melton Valley area (excluding the Maynardville Limestone) consists of thin beds (<1 ft) of shale, siltstone, or limey siltstone that are fractured and folded. The individual bedding planes become fractures upon weathering and form pathways for water movement. Fractures that cut across individual beds (bed-normal fractures) were formed during deformation of the rock mass and these fractures form a three-dimensional rectangular network within beds. Bedding plane fractures and bed-normal fractures combined provide a fracture system that promotes stratabound groundwater flow and contaminant transport. Fractures or fracture zones that cut across large thicknesses of bedrock are less abundant than either the bedding plane fractures or the bed-normal fractures; these features occur at a scale that is difficult to identify and map because of the regolith cover that obscures the bedrock surface over most of the area. Cross cutting fractures and fracture zones can

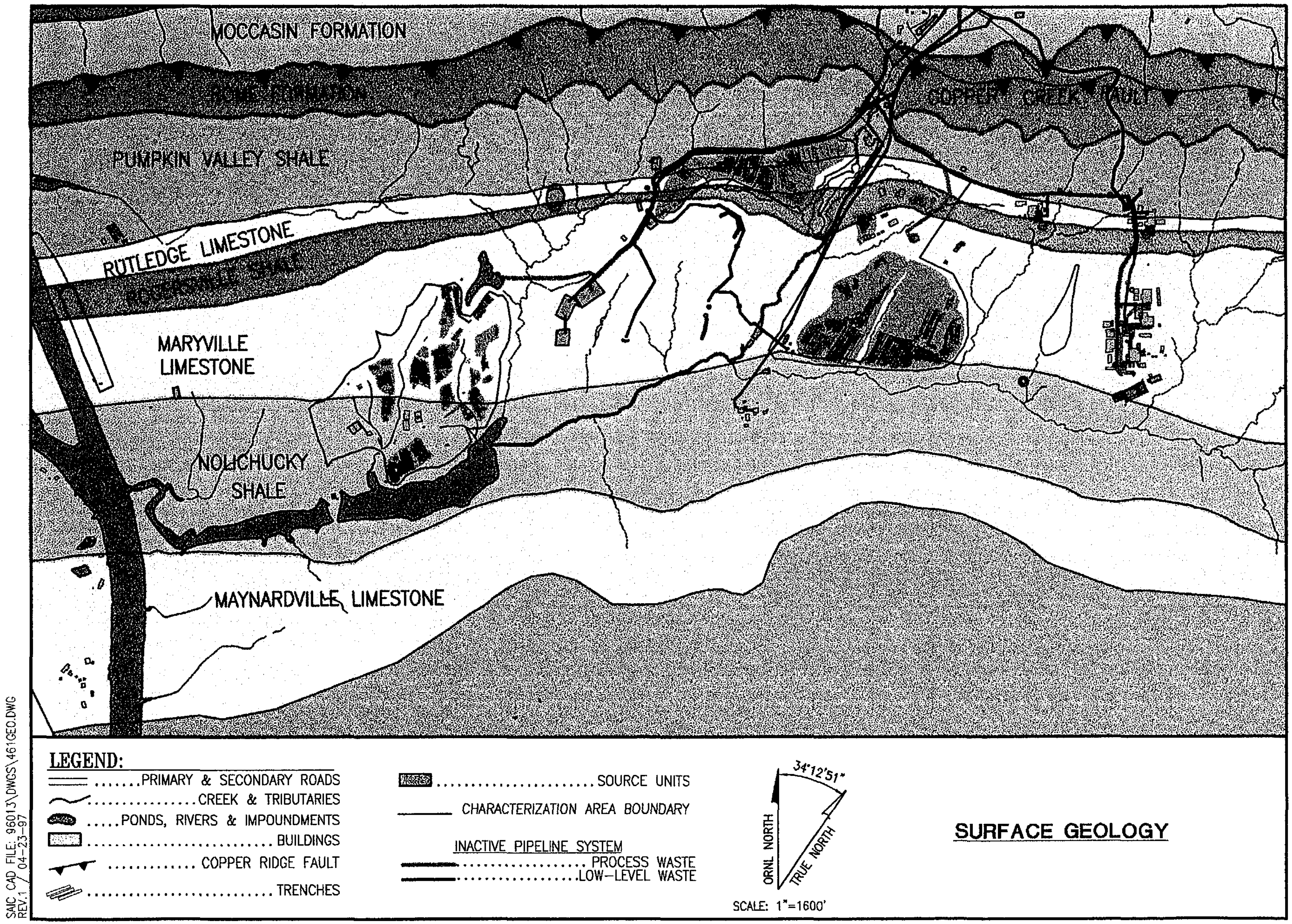


Fig. 2.5. Surface geology of the Melton Valley watershed.

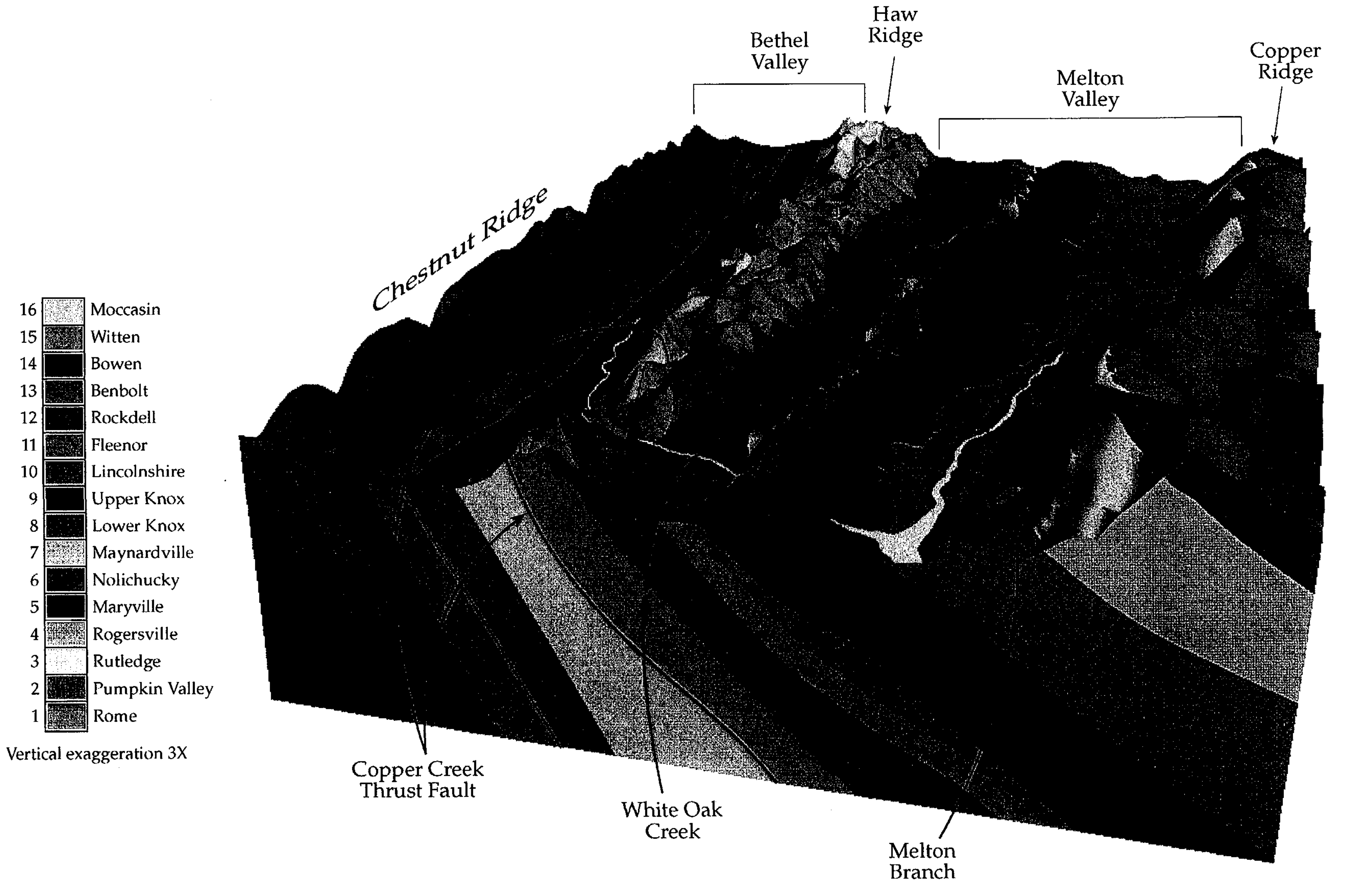


Fig. 2.6. Geologic block model of the Melton Valley watershed.

provide pathways for groundwater to move across the regional geologic structure or grain of the area. The presence of such features is of concern when considering movement of contaminants at depth such as the deep injected hydrofracture wastes.

Bedrock is covered with a mantle of residual soil formed by the weathering of bedrock in place. These soils tend to have a saprolitic structure (retain visible parent bedrock characteristics such as fractures and bedding planes) and differ from the parent rock material in color, have a higher porosity than parent rock, and are generally more permeable than unweathered bedrock. The residual soils tend to be thin to absent where erosion has removed them near streams and thicker in upland areas and where bedrock contains higher calcium carbonate content such as on the knobs underlain by the Maryville Limestone. Soils overlying the Conasauga Group formations are predominantly silty clays or clayey silts. Relict fractures in the soils form pathways for rapid movement of water from the surface downward to the water table when surficial soils become saturated during heavy precipitation events. These fractures also form pathways in excavation walls for rapid lateral groundwater inflows and outflows above the water table when excavations bathtub or hold perched water. Groundwater flows through these features at or below the water table in the direction of the hydraulic gradient along the fracture path.

2.2.1.2 Hydrogeology

Solomon et al. (1992) developed a generalized conceptual hydrologic framework for the entire ORR including the Melton Valley watershed. The geologic units of the ORR were assigned to two broad hydrologic groups: (1) the Knox aquifer—formed by the Knox Group and the Maynardville Limestone—which is dominated by solution conduits and which stores and transmits relatively large volumes of water and (2) the ORR aquitards—made up of all other geologic units of the ORR—in which flow is controlled by fractures, and which may store fairly large volumes, but transmit only limited amounts of groundwater. Water balance estimates are discussed in Sect. 2.2.2, Surface Water Conceptual Model. The Melton Valley watershed is underlain by both geologic units as shown in Fig. 2.7.

In vertical cross sections, both the Knox aquifer and the ORR aquitards are divided into four zones described as follows and shown conceptually in Fig. 2.8.

The **storm flow zone** is a thin region at the surface in which transient, precipitation-generated flow accounts for a large portion of the water moving through the subsurface. This zone is a major pathway for transporting contaminants from the subsurface to the surface. The **vadose zone** is a mostly unsaturated zone above the water table. The **groundwater zone**, which is continuously saturated, is the region where most of the remaining subsurface flow occurs. Zones where permeability is low and groundwater movement is extremely slow are called aquicludes.

In most of the Melton Valley watershed, the water table lies at or somewhat above the bedrock/soil weathering interface. Figure 2.9 shows the average water table and generalized groundwater flow direction in the Melton Valley watershed. Recharge to the water table can occur both as porous medium flow through the soil and as flow through relict bedding planes and fractures in the soil connecting the surficial soil to the water table. Below the water table the spatial density, aperture, orientation, and connectivity of fractures control the transmissivity and actual flow paths of groundwater. The predominant groundwater flow and contaminant migration direction in the shallow groundwater system is parallel to local geologic strike because of the abundance of open bedding plane and bed-normal fractures. Small-scale (tens of meters) folds and fracture sets control

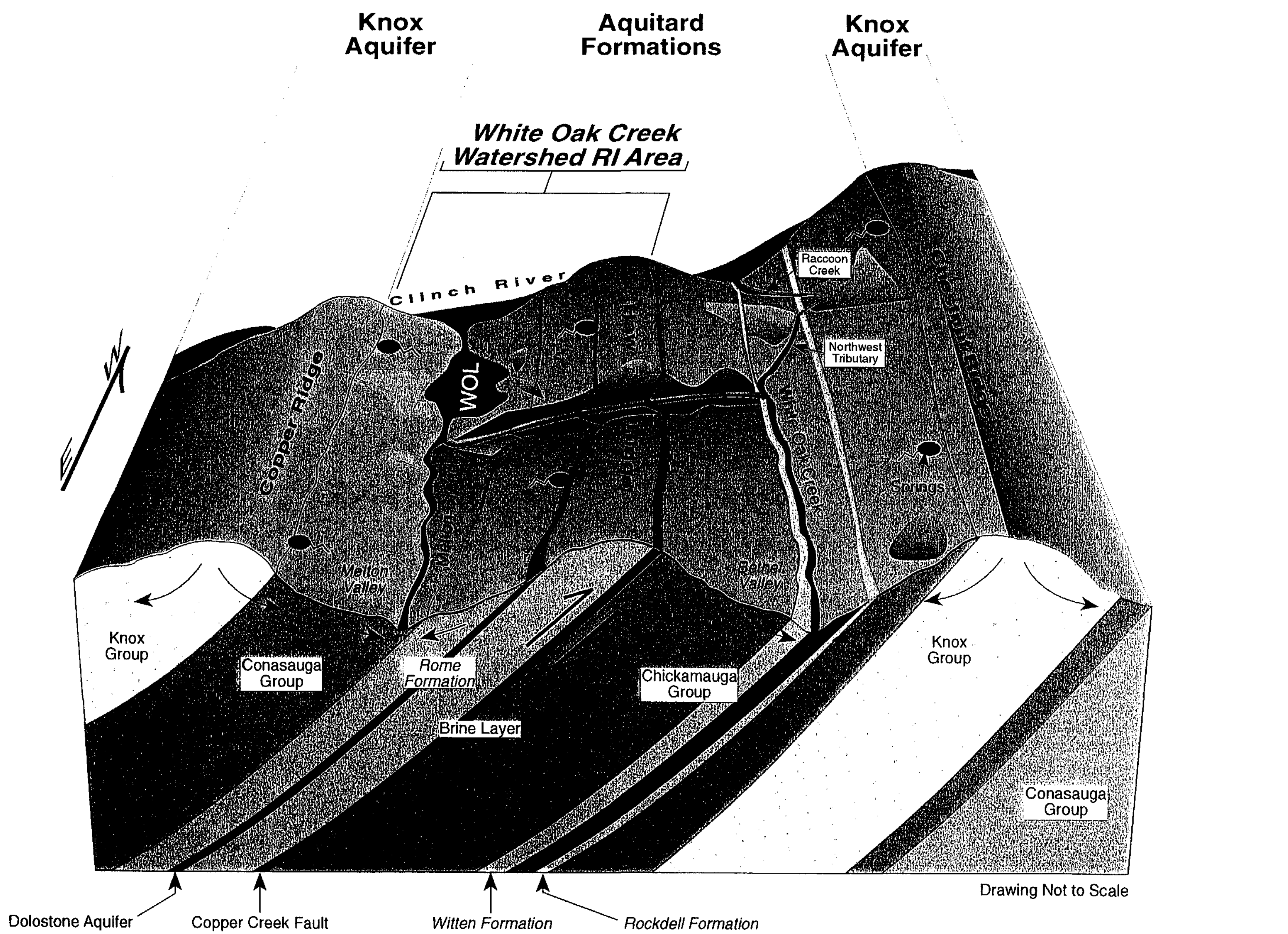


Fig. 2.7. Distribution of hydrogeologic units in the Melton Valley watershed.

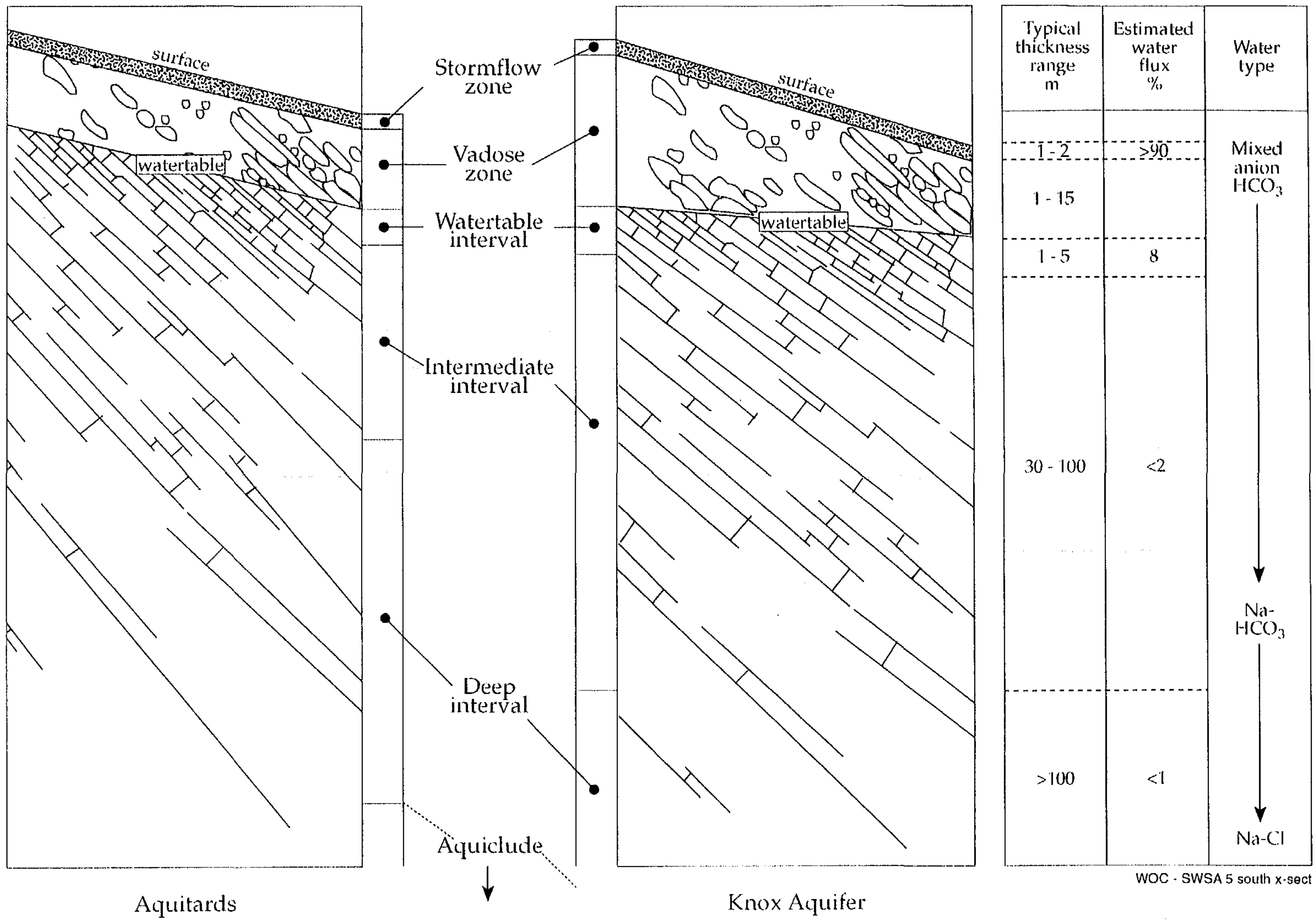


Fig. 2.8. Near surface hydrogeologic zones.

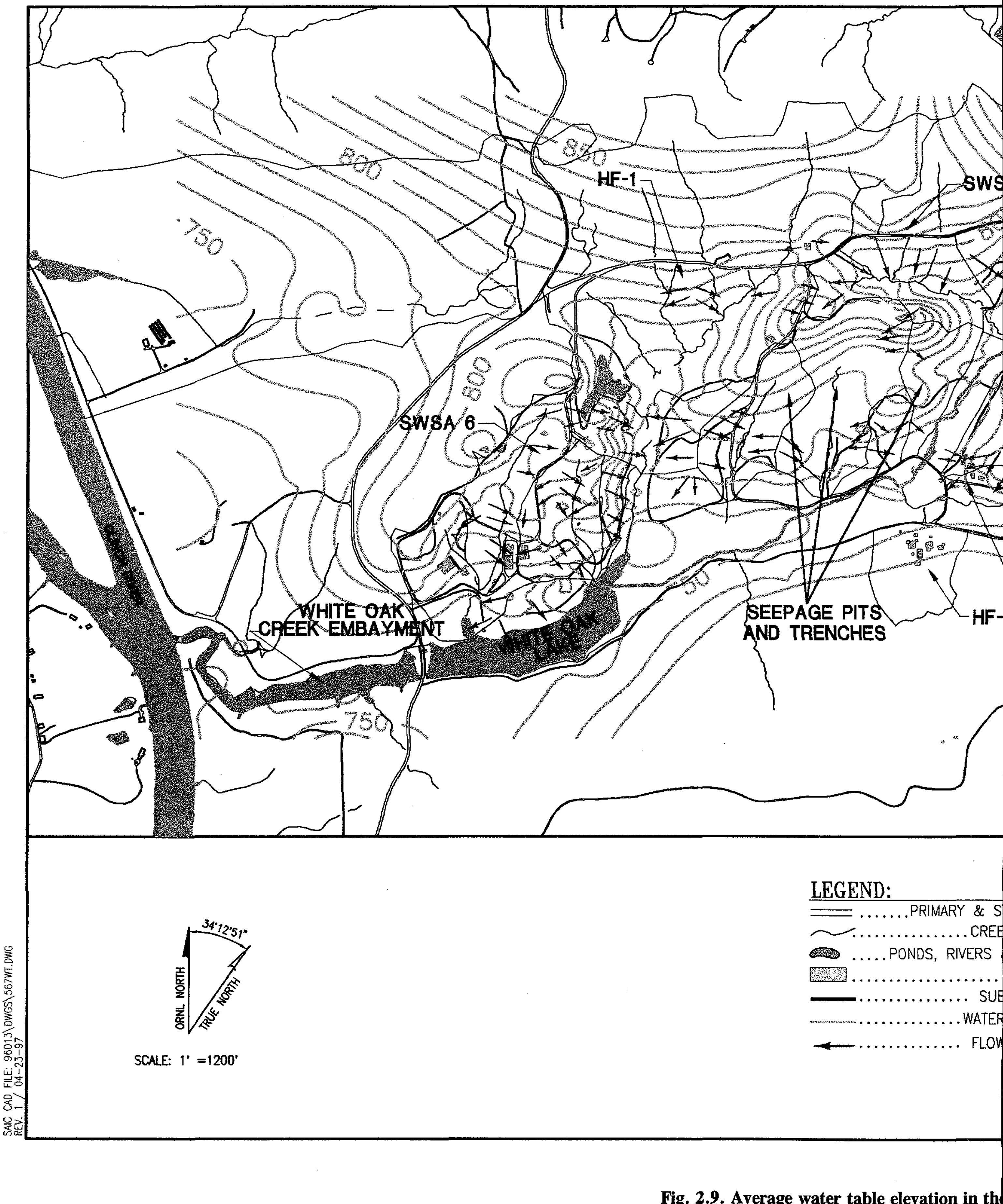
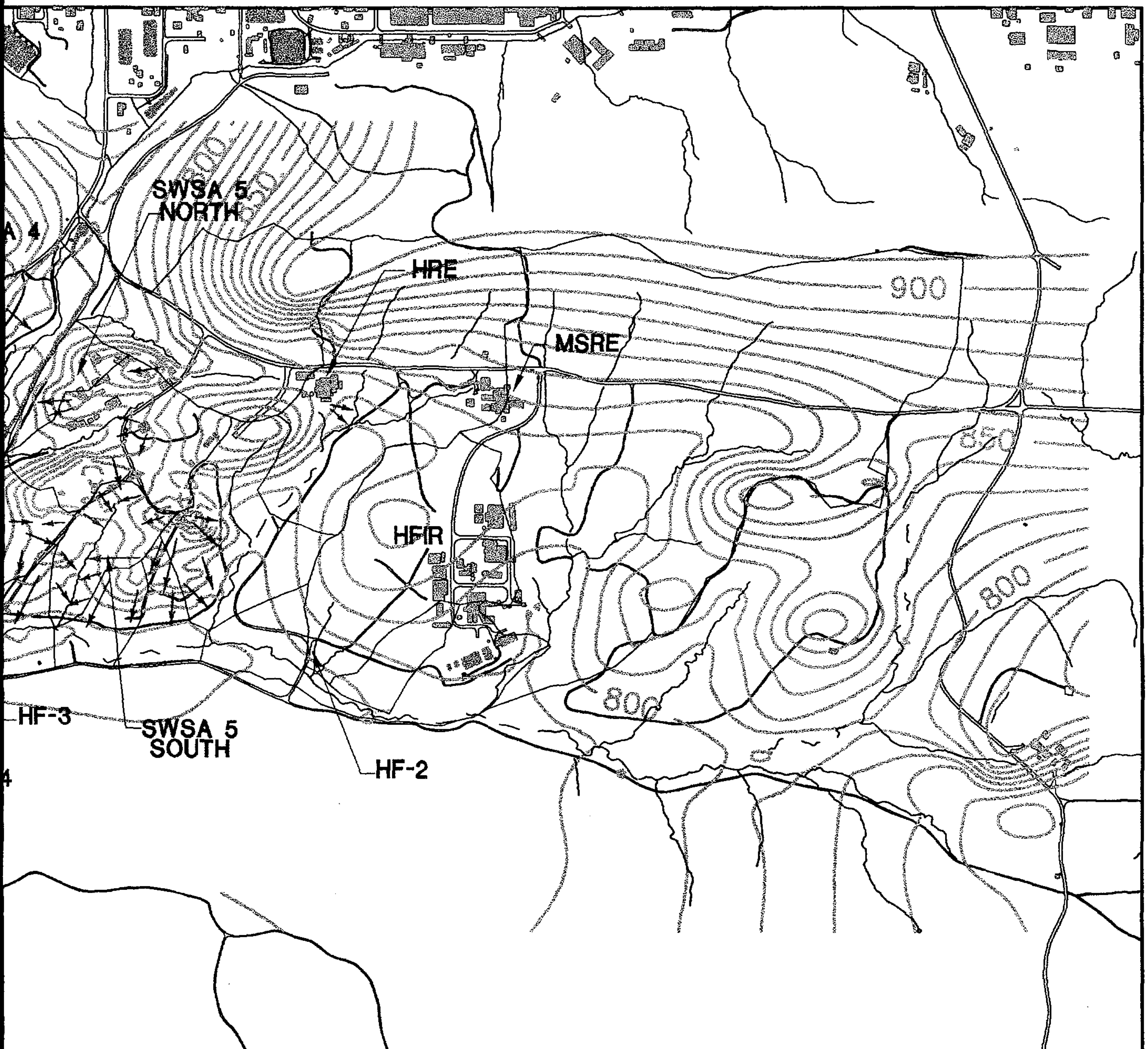


Fig. 2.9. Average water table elevation in th



ECONDARY ROADS
K & TRIBUTARIES
& IMPOUNDMENTS
...... BUILDINGS
BASIN BOUNDARY
TABLE CONTOUR
PATH DIRECTION

AVERAGE WATER TABLE ELEVATIONS

Melton Valley watershed.

seepage pathways. Shallow groundwater is observed to migrate via fractures, generally along strike, to local surface water streams. Anthropogenic features, including pipeline trenches and waste burial trenches, can conduct groundwater along their orientations and provide pathways for contaminant transport.

The hydraulic conductivity of subsurface materials is observed to decrease rapidly with increasing depth below the water table. At increasing depths below the water table, the degree of bedrock weathering decreases; thus, fractures tend not to be enlarged. Additionally, overburden pressure tends to keep fractures tightly closed at great depths. Solomon et al. (1992) state that analysis of conductivity tests in screened wells suggests that the spacing of hydraulically active fractures ranges from 7 m near the water table to >35 m at depths of >60 m. This decrease in fracture density equates to a decrease in water transmitting capability in the rock mass with increasing depths. The geochemical profile typically observed in the ORR groundwater system of $CaHCO_3$ groundwater in the water table interval, Na-Ca-HCO_3 groundwater at intermediate depths and NaCl brines at depth, reflects fresh water flushing near surface, mixing of water types at intermediate depths, and stagnation of groundwater at depth.

The groundwater zone is subdivided into three intervals based on the distribution of hydraulic properties and the chemistry of major ions (as summarized by Solomon et al. 1992, Sect. 3.13):

- A thin (~1–3 m) permeable interval may be present near the water table. This interval is referred to as the water-table interval. Spatial and temporal differences in the saturated thickness and tranmissivity of this interval explain both the configuration of the water table and most of the fluctuations in groundwater discharge to streams. The water table is near the contact between the regolith and the weathered bedrock because a larger water flux has formed regolith at shallower levels by solution of the rock cement; fresh bedrock at deeper levels indicates a smaller water flux. In the ORR aquitards, the dominant water type is $CaHCO_3$.

- The intermediate interval of the groundwater zone consists of relatively permeable fractures (or possibly fractured regions) in a relatively impermeable matrix. In the ORR aquitards, the dominant water type is $NaHCO_3$.

- The deep interval consists of permeable fractures that are widely spaced. The groundwater chemistry is dominated by $NaHCO_3$ grading to NaCl.

The interfaces between these generalized groundwater geochemical zones are irregular boundaries. The water table interval normally lies at or above the weathering interface at the top of bedrock, follows the undulations of the bedrock surface in upland areas, and saturates regolith in low-lying areas and near streams. The top of the intermediate groundwater zone defined by the occurrence of $NaHCO_3$ geochemistry tends to lie at a lower elevation in areas where freshwater circulation flushes the sodium-dominated groundwater to greater depths and may lie at shallower depths in areas where artesian pressures produce upward flow of the intermediate zone groundwater to mix in the shallow groundwater zone. The top of the brine geochemical zone is typically encountered at a depth of about 600 ft below ground surface in most of Melton Valley. Data published by Dreier (DOE 1995d) show that some stratigraphic and/or structural features in the Melton Valley area carry fresh water to depths of several hundred feet and can carry fresh water to areas beneath the intermediate zone groundwater. Such features could conceivably carry fresh water to depths extending beneath the top of the brine geochemical zone in discrete, confined locations. Natural groundwater movement apparently does occur in the brine interval (Nativ and Hunley 1993) at a very slow rate and investigations related to the hydrofracture waste disposal setting document the movement of contaminants by groundwater transport in the brine (DOE 1996b).

Conceptual Model of Valley-Wide Groundwater Flow in Melton Valley

Compilation of information from numerous investigations performed at specific locations throughout the ORR allows us to develop a valley-wide conceptual model of groundwater flow. From the large-scale groundwater flow concept we can infer general conditions that will control solute or contaminant transport at the valley-wide scale. The following discussion presents a current interpretation of the Melton Valley hydrogeologic system.

The key factors that determine the groundwater flow system are soil characteristics and land cover, topography, and stratigraphy and geologic structure. As discussed in the previous section, soil characteristics exert a strong influence on the amount of precipitation that infiltrates the soil and is available for lateral storm flow movement in undisturbed areas or percolation to the water table in areas of disturbed soil profiles. Land cover type exerts a strong influence on evapotranspiration, which effectively removes water from the shallow soils by plant transpiration. Soil characteristics are also important in groundwater flow because much of the "soil" in Melton Valley is residuum of bedrock and numerous relict fractures are retained in the deeply weathered material. These fractures form a network of avenues for percolation of recharge water downward to the water table and also provide avenues for groundwater flow in areas where the water table interval lies in the base of the soil.

Evapotranspiration is a variable process that is minimal during the winter months (November through mid-April) and is a strong factor in the regional water balance during the growing season (mid-April through October). Much of the winter season rainfall (nearly half the annual rainfall) typically occurs during about a 4-month period that usually begins in December and extends through March—the period of negligible evapotranspiration. During the remaining 8 months of the year, the other nearly half of the annual rainfall occurs, much of which is returned to the atmosphere as evapotranspiration rather than discharging to streams. Topography influences the groundwater flow system by providing the head differentials, or gradients, that cause groundwater to move in the subsurface. The elevation head differences between the water table in recharge areas and the water table or stream elevations in adjacent discharge areas create the hydraulic gradient for groundwater flow. In the Melton Valley watershed groundwater flow rates are controlled primarily by the hydraulic properties of fractures, the presence of interconnected fractures, and, to a lesser degree, by the porous matrix hydraulic conductivity. Groundwater flow paths are determined by the locations and geometries of the interconnected fractures. The role of seasonality in groundwater levels, stream flow, and contaminant discharge has been documented in the Melton Valley watershed (DOE 1995d), as has a positively correlated increase in the flux of dissolved contaminants released to the surface water system during the wet winter season. Water budget for the Melton Valley watershed is discussed in Sect. 2.2.2, Surface Water Conceptual Model.

Stratigraphy and geologic structure influence the groundwater flow system in Melton Valley by determining the types of solid material and flaws in those materials through which the groundwater flows. Most of the bedrock materials that underlie Melton Valley have extremely low effective porosity (connected intergranular pores) and most groundwater movement occurs in weathered zones (including residuum near the water table) or in fractures (either in residuum or in bedrock).

Geologic structure in Melton Valley occurs at several scales, each of which has importance to the groundwater flow system. The **regional scale** geologic structure is defined by the regional thrust faults such as the Copper Creek Fault. At the regional scale, strike and dip of geologic formations define the three-dimensional orientation and location of the geologic formations. Water-bearing and transmitting properties of the geologic formations vary with the stratigraphic makeup and degree of structural deformation. In Melton Valley the geologic formations with the best water-bearing potential include the Rome Formation and the Maryville Limestone. At the **valley-wide scale** there are zones of intraformational folds and faults and various cross-cutting fracture and shear zone orientations that are locally important to groundwater flow. The dimensions of these zones are difficult to define in the Valley and Ridge Province because of extensive soil cover over bedrock. These zones are best identified in large excavations (such as the Seepage Pits and Trenches of WAG 7). One such zone in western Bear Creek Valley was identified in several core borings and was shown to extend laterally for at least 1 km in a near stratiform orientation (Lee and Ketelle 1989). The thickness of such zones, or outcrop width, is highly variable and to date no correlations of individual features within this type of deformation zone have been demonstrated. There is evidence of such intraformational folding and faulting in the Maryville Limestone in a nearly strike-parallel band extending from the SWSA 6 area northeastward perhaps as far as the HFIR area. The hydrogeologic importance of such zones varies depending upon the types of bedrock and structural deformation involved. In cases where limestone bedrock is intensely deformed, fracture density can be increased, bedrock weathering may be enhanced, and groundwater flow may increase. Conversely, if such deformation involves mostly shaley bedrock and the deformation causes extensive shearing, fractures may become sealed with rock flour or "gouge" and such zones can become less permeable than surrounding, less deformed bedrock. At the **outcrop scale** and smaller, individual folds, fractures, or shears ranging from meter or centimeter size down to microscopic features exist. Structural features at these scales are important when they are part of a connected network of fractures and are capable of transmitting groundwater along with its dissolved or suspended constituents. Outcrop scale structural features are sometimes the observed points of groundwater emanation in seeps or springs.

Hydraulic conductivity measurements have been made in many wells in the Melton Valley watershed. Most of the test results available are from various types of single well tests such as slug tests, rising head recovery tests, and packer tests. Hydraulic conductivity values obtained by such methods in fractured rock represent a value obtained by dividing the discharge of the test by the total borehole length included in the test and thus provide an averaged conductivity value. Such tests overestimate the conductivity of unfractured materials and underestimate the conductivity of the fractures themselves. Figure 2.10 is a block model that shows the gridded hydraulic conductivity of the Melton Valley watershed. Apparently the hydraulic conductivity data available in the Melton Valley watershed show much higher conductivity in the shallow portion of the groundwater zone than at greater depths and the outcrop of the Maryville Limestone shows higher conductivities than most adjacent areas.

Borehole testing and empirical observations indicate that in the ORR the combination of stratigraphy (and the orientation of more soluble bedrock zones) and geologic structure combine to provide many dipping, strike-parallel zones of high transmissivity (Lee and Ketelle 1987, Ketelle and Lee 1992). Detailed site investigations at several sites throughout the ORR demonstrate that highly transmissive zones in bedrock are frequently on the order of one to several meters thick. Many of these transmissive zones are confined between lower transmissivity zones and groundwater flow is parallel to the direction of highest permeability. An example of this condition is seen in the confined freshwater zone in the Upper Rome Formation beneath Melton Valley (DOE 1995d). The

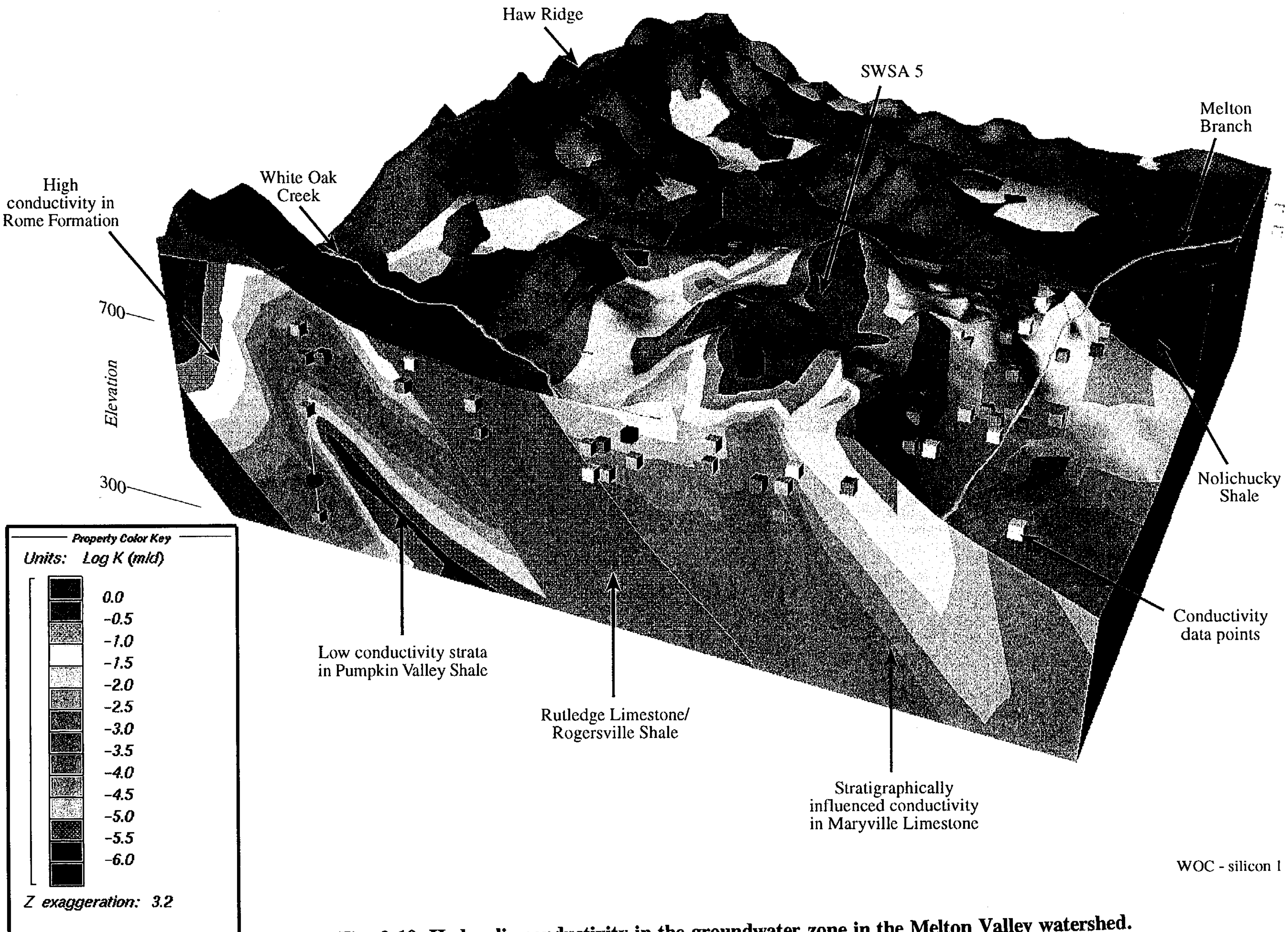


Fig. 2.10. Hydraulic conductivity in the groundwater zone in the Melton Valley watershed.

results of a three-dimensionally monitored pumping test (Lee et al. 1992) show that there may be little or no hydraulic connection in the direction perpendicular to confining beds.

In classical analyses of groundwater flow derived from porous media hydraulics, groundwater flowlines that originate from recharge areas near a stream or discharge boundary follow shallow pathways. In the same idealized porous medium case, groundwater flowlines that originate from recharge areas near a groundwater basin boundary show seepage downward and laterally beneath the shallower seepage paths to the discharge boundary. The conceptual model of groundwater movement in the Melton Valley area derived from site observations includes similarities and differences in comparison to the classical flow net concept.

Historically, groundwater system descriptions for the Melton Valley area have postulated groundwater zonation on the basis of depth below ground surface citing observed depth-dependent decreases in hydraulic conductivity measurements and geochemical stratification. These observations broadly describe the general conditions; however, they lead the reader to infer that groundwater flow zones are likewise nearly horizontally distributed. The combination of interbedded stratigraphy, dipping and fractured structural conditions, and rugged topography lead to highly discrete, local-scale groundwater flow zones with irregular geochemical interfaces in the subsurface. Hydrogeologic investigations performed in the Melton Valley watershed within the past several years reveal the strong roles that stratigraphy, geologic structure, and topographically derived head differentials play in the groundwater system. The conceptual model of groundwater flow in the Melton Valley watershed is most easily portrayed in a block diagram and description of the area.

Figure 2.11 is a cutaway block model of the Melton Valley watershed showing the geologic formations and average measured hydraulic head in wells throughout the area. The most prominent features with respect to hydraulic head are a high-head zone in the Rome Formation extending down-dip beneath Haw Ridge and extending beneath the confining layer formed by the Pumpkin Valley Shale in the SWSA 4 area. Dreier (in DOE 1995d) observed that fresh water recharge on Haw Ridge associated with the Rome Formation and fractured and weathered bedrock in the Copper Creek Fault Zone are responsible for this feature. A well that penetrated this interval flowed artesian at 40 gpm for several days before it was shut in with no apparent decrease. Fresh water was observed to flow down-dip in this system and actually lies beneath the transition zone sodium-calcium bicarbonate groundwater present in overlying beds. Wells that penetrate this zone tend to be flowing artesian, and springs are observed in this interval along Haw Ridge where stream erosion has dissected the ridge. Head pressure derived from this zone may extend down-dip in the Rome Formation beneath the axis of Melton Valley although deep monitoring data from hydrofracture associated wells indicates that artesian heads are present the water is saline in this zone at depth. No estimates have been made of the volume of groundwater flow in this confined zone.

Hydraulic head in the Rutledge Limestone and Rogersville Shale (which lie in a low-lying line of valleys and saddles between Haw Ridge and along the scarp slope of the Maryville knobs) tend to be lower than that in adjacent upland areas, but heads are not anomalously low. Low-lying areas in the Rutledge Limestone outcrop band are prone to perennial seepage at the ground surface. Significant contaminated sites that lie in this outcrop band include Seepage Pit 1, SWSA 4, and the HRE site. Artesian groundwater sources that are driven by groundwater head pressure in the Rome and Pumpkin Valley formations may limit the effectiveness of conventional hydrologic controls in these areas. Hydraulic head at the water table in the Maryville Limestone is a subdued replica of the area topography. Data from deep head measurement wells in transects across the Melton Valley watershed show that head at depths of 200 to 400 ft below ground surface in the Maryville

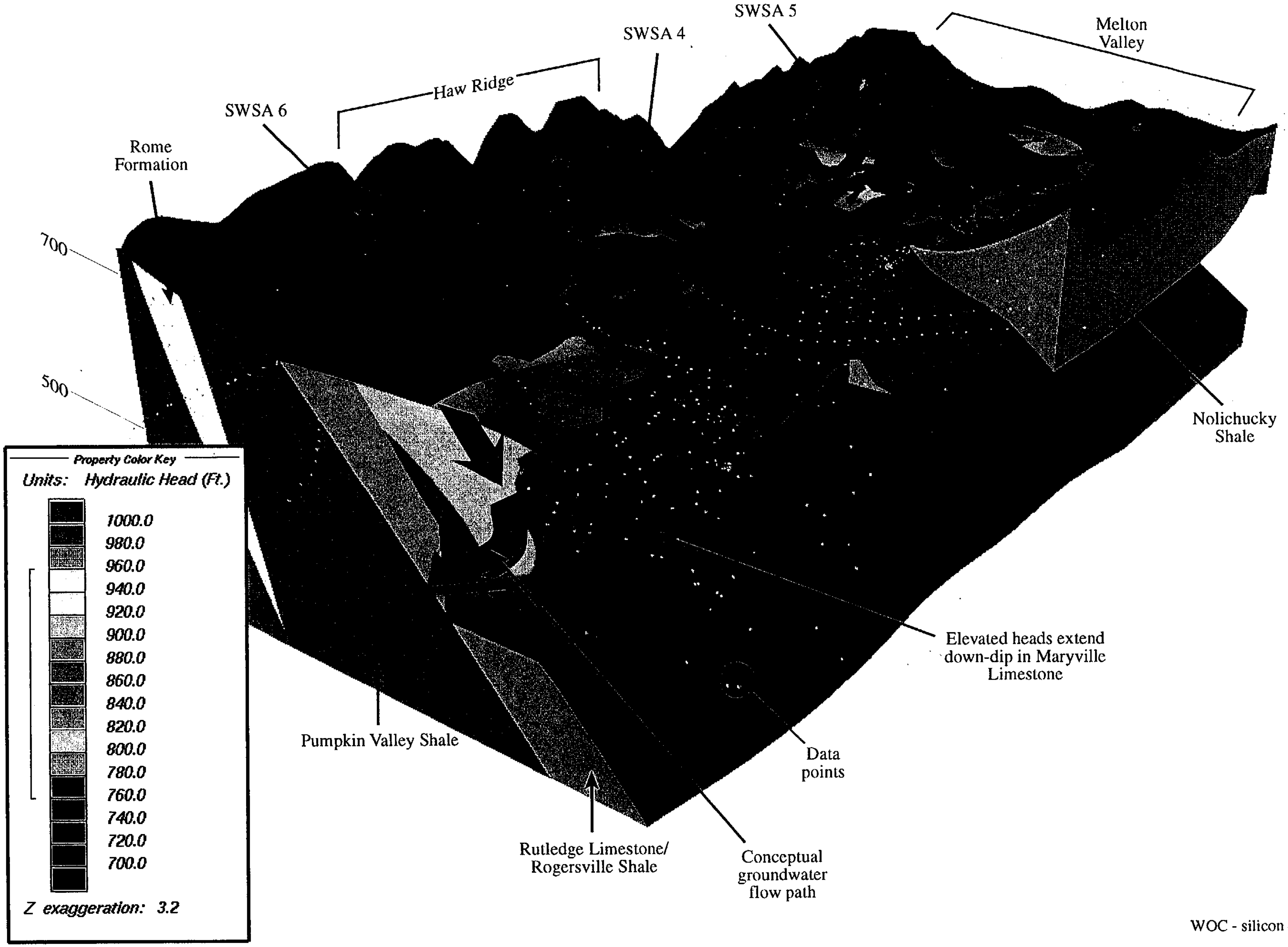


Fig. 2.11. Average hydraulic head in the groundwater zone in the Melton Valley watershed.

Limestone are similar to heads at the water table in wells along the up-dip projection of the monitored interval. Wells drilled into the Maryville Limestone in toeslope settings along its southeastern outcrop limit tend to be artesian. This condition is consistent with stratigraphic and structural control of groundwater flow paths where head from the recharge area is transmitted through the strongly connected fracture system within stratigraphic zones. This observation conforms with the findings of Lee et al. (1992) in extensive tests performed in the Maryville Limestone at a site in Bear Creek Valley. Freshwater circulation depths in transmissive zones within the Maryville Limestone in the Melton Valley watershed extend on the order of 300 ft below ground surface (Webster and Bradley 1988) and hydraulic head data suggest that groundwater flows originating from the water table surface in the Maryville discharge to the local stream system.

The Nolichucky Shale outcrops along the southeastern floor of Melton Valley and underlies Melton Branch and lower WOC and WOL. The Nolichucky acts as a weak confining unit overlying the Maryville Limestone. In general the hydraulic head observed in the Nolichucky is consistent with its low topographic position. All factors favor groundwater flow parallel to strike toward WOL and the Clinch River.

Comparison of the groundwater flow system inferred from the hydraulic head data with the flow system illustrated by the nature and extent of groundwater contamination provides useful insights. Figure 2.12 is a block model that shows the nature and extent of groundwater contamination in the Melton Valley watershed using total calculated potential human health risk from groundwater contaminants. The risk factors are based on the assumptions for the residential risk assessment scenario.

Contaminant Fate and Transport Properties

Factors that influence the migration of contaminants in the Melton Valley watershed include matrix porosity, which is a measure of the porosity of the non-fractured portions of soil and bedrock, and chemical retardation factors, including processes such as ion exchange, sorption coefficient (K_d), and chemical complexation.

The mobility of radionuclides, as with all chemicals and particularly metals, is dictated by the geochemical system in which they are found. The valence state of the element, the chemistry of the water, and the mineralogy of the medium with which they are in contact are the primary characteristics of interest in assessing release and migration potential. Solubility and distribution coefficient values for the primary radionuclide contaminants for the WOC area are present in detail in Energy Systems 1994a. The following brief discussions provide qualifiers to the use of those values.

Tritium. Normally characterized as a conservative indicator of contaminant transport, the first arrival of this radioactive isotope of hydrogen moves at the flow rate of the groundwater into which it is introduced. However, because of the matrix diffusion process, the mass flux will be retarded, leading to a longer term, lower concentration release of this radionuclide. Additional information is available in Webster 1996.

Cobalt-60. As with most metals, the mobility of cobalt is affected by water chemistry and the sorption processes on surfaces of soil organic material and clay minerals and by co-precipitation with iron, manganese, and other oxyhydroxide mineral phases. Mobility may be enhanced by the

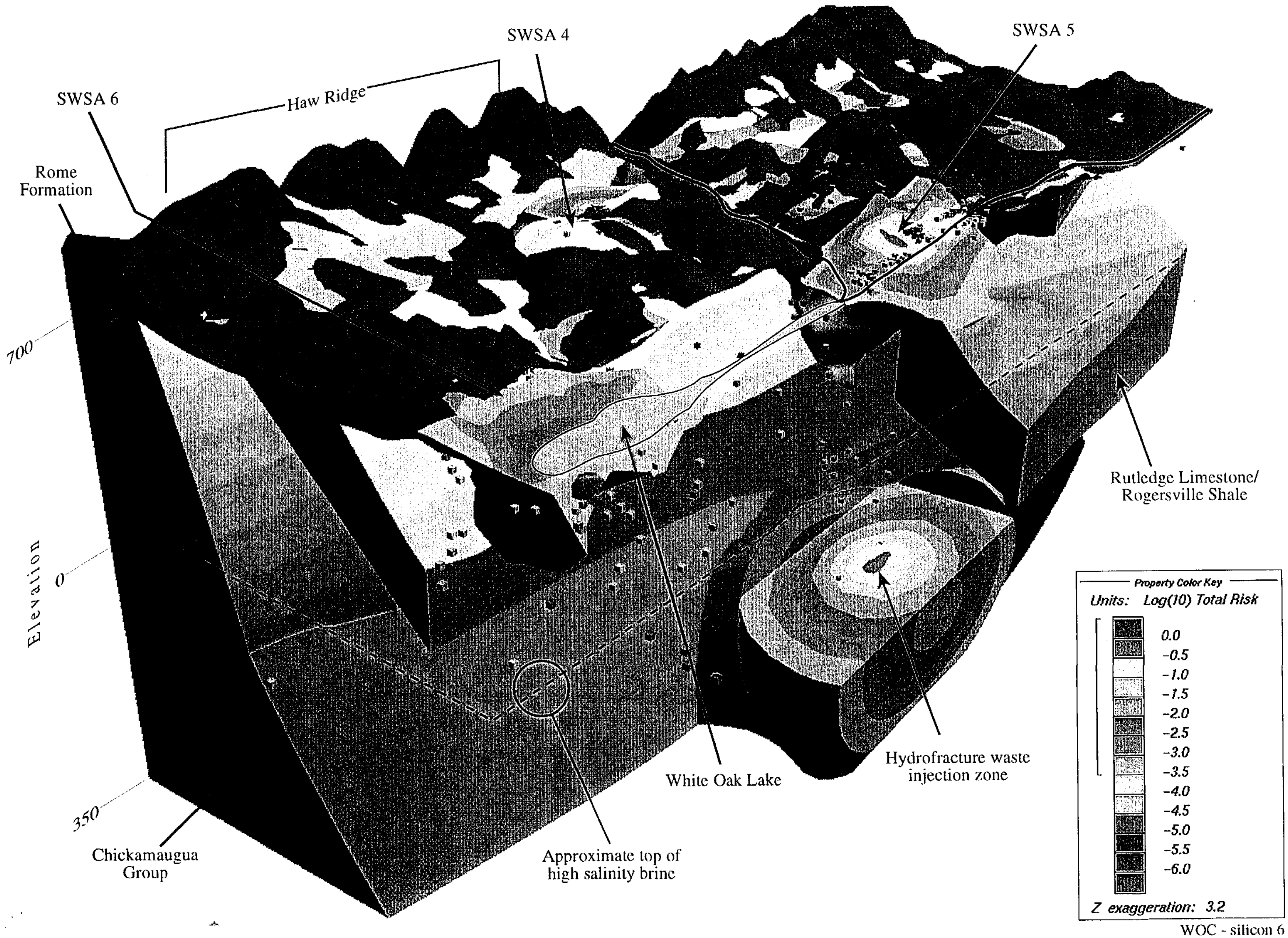


Fig. 2.12. Total carcinogenic risk in groundwater in the Melton Valley watershed.

formation of organometallic complexes or mineral colloids, both of which may lessen the effectiveness of surface sorption.

Strontium-90. Because of its chemistry, strontium behaves as a chemical analog to calcium and, at concentrations normally observed in the Melton Valley watershed, can be expected to partition with that element in the chemical system. It may be retarded through ion exchange on clay minerals but not to the extent noted for cesium. Note that a significant amount of the ^{90}Sr buried in SWSA 5 South was believed to be as colloidal-size (~0.02-um) strontium titanate particles that are of low solubility and therefore not subject to the normal dissolution release and transport (and retardation) processes. Additional information is available in McKenzie et al. 1995.

Cesium-137. Cesium behaves as a chemical analog for potassium and, as such, is strongly retarded by a strong chemical affinity to clay minerals, particularly illite, which is one of the dominant minerals in Conasauga Group rocks and in the saprolite and soils developed on them. Cesium is strongly bound to soil and sediment particles and will be transported primarily by particulate transport. For additional information see Spalding and Cerling 1979.

Uranium. As evidenced by the development of groundwater-developed uranium deposits, uranium is transportable under certain groundwater conditions. Uranium can be highly mobile as an oxide or as anionic carbonate complexes under neutral and alkaline conditions.

Thorium, plutonium, americium, curium. It has been suggested in Energy Systems 1994a (p. 4-129) that the distribution coefficient for uranium ". . . is extended to Th, Np, Pu, Am, Cm and Cf as a conservative representation of retardation."

In addition to geochemical mobility considerations for radionuclides, the natural radioactive decay process determines the longevity of risk associated with these materials as both primary and secondary contaminants.

Half-Lives

Radionuclides have been identified as chemicals of concern (COCs) in at least one medium in 18 of 35 classified subbasins. The primary radionuclide COCs are ^{90}Sr, ^{3}H, ^{137}Cs, and ^{60}Co with half-lives of 28.5, 12.3, 30, and 5.27 years, respectively. These four radionuclides compose a major portion of the estimated radionuclide inventory in the Melton Valley watershed and are widely distributed in secondarily contaminated media. Seven other radionuclides with half-lives of less than 35 years have been detected in at least one medium in at least one subbasin (^{228}Ra and ^{228}Th at 6.7 and 1.9 years, respectively; ^{152}Eu, ^{154}Eu, and ^{155}Eu at 13.3, 8.8, and 1.8 years, respectively; and ^{243}Cm and ^{244}Cm at 28.5 and 18.1 years, respectively). Other radionuclides with half-lives greater than 35 years and reported at least once in the database include ^{226}Ra, ^{99}Tc, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{238}U, ^{230}Th, ^{232}Th, ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{241}Am with half-lives ranging from 74 years for ^{232}U to 1.39E10 years for ^{232}Th. For a complete listing of half-lives refer to Energy Systems 1994a.

Contaminant Release Mechanisms

Release mechanisms for a wide variety of source unit types in the Melton Valley watershed are shown conceptually in Fig. 2.13. Release mechanisms are categorized according to the mode and duration of water contact with waste or contaminated material resulting in contaminant release. For example, contaminant sources that are perennially inundated have a higher release potential than

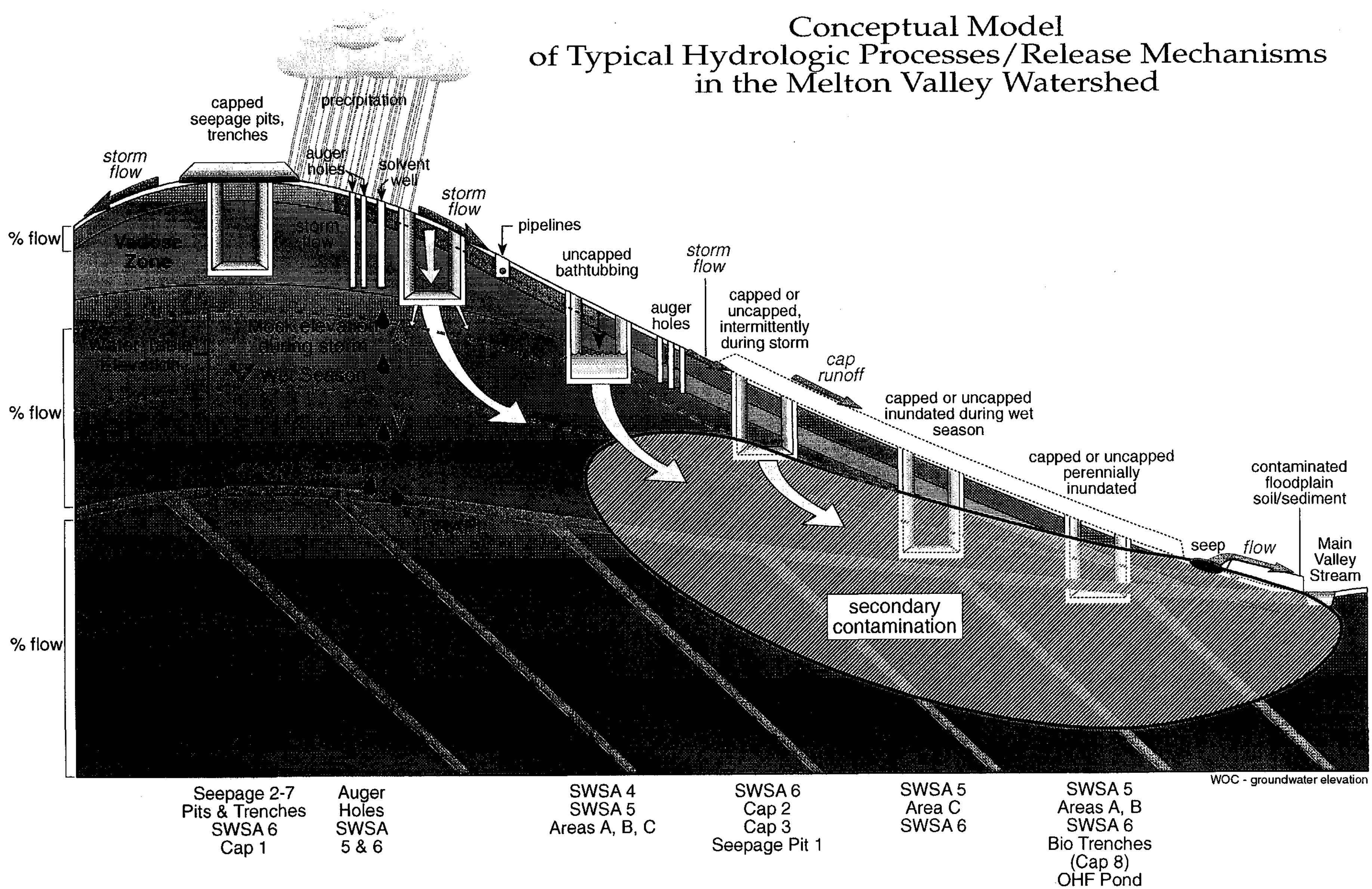


Fig. 2.13. Conceptualized contaminant release mechanisms recognized in the Melton Valley watershed.

those that are above the water table. Similarly, wastes that are intermittently inundated but not capped or contained generally have a higher release potential than those that are intermittently inundated but are capped. Waste type or mode of emplacement also affect contaminant release by affecting ease or extent of water contact with the contaminant source. Release mechanisms identified here are used in Sect. 3 to assess prevalence of mechanisms throughout the watershed.

2.2.2 Surface Water

Site Description/Hydrology

WOC rises from springs in the Knox Group (Knox aquifer) on the southeast slopes of Chestnut Ridge. In addition to natural runoff and springs, the creek receives process water discharges, treated sewage effluent, and cooling water from laboratory facilities in Bethel Valley before flowing through the water gap in Haw Ridge where it enters Melton Valley. There, WOC is joined by its primary tributary, Melton Branch, before entering WOL. WOL, impounded by White Oak Dam (WOD), has a normal pool elevation of 227.1 m (745 ft) above mean sea level (MSL), only 0.9 m (3 ft) above full pool elevation in the Clinch River. Flow from WOD discharges into the WOCE approximately 1.0 km (0.6 mile) above the confluence with the Clinch River. WOC discharges to the Clinch River through the spillway of a sheet pile coffer cell and gabion sediment retention structure. The drainage area of the Melton Valley watershed at the mouth of WOC is approximately 16.8 km^2 (6.15 $miles^2$).

The hydrology of the Melton Valley watershed is strongly influenced by local climate. The climate of the ORR is classified as humid subtropical. Precipitation is probably the most important climatic factor to the flow system because it establishes quantity and variations in runoff and stream flow. It also replenishes groundwater. Maximum, mean, and minimum annual precipitation for stations near ORNL during the period 1954–1983 was 190.0, 132.6, and 89.7 cm (74.8, 52.2, and 35.3 in.), respectively (Webster and Bradley 1988). The mean annual runoff for streams in the ORNL area is 56.6 cm (22.3 in.) (McMaster 1967). The remainder of the annual precipitation, about 76.2 cm (30 in.), is consumed by evapotranspiration.

Surface Water Monitoring

Continuous stream discharge data have been collected from surface water monitoring stations on the Melton Valley watershed for many years. Figure 2.14 shows the location of monitoring stations in lower WOC, below 7500 Bridge, for which recent data are available. The surface water flow system can be divided into a network of reaches, according to available data, to identify stream sections as measurable and manageable components of the hydrologic system. Water and contaminant mass balances can be determined at locations of surface water monitoring stations shown in Fig. 2.14. On the scale of Melton Valley the 7500 Bridge monitoring station (WC7500) below Melton Valley Drive represents surface water input to the system. WOD represents surface water output from the system. The average discharge at 7500 Bridge for the period 1993–1994 was 307 L/s (10.8 cfs) (Flohr et al. 1994, 1995, 1996) while the average discharge at WOD for the same period was 481 L/s (17.0 cfs). The difference [174 L/s (6.14 cfs)] is the average surface water discharge generated in the Melton Valley watershed above WOD. Assuming no losses or gains to the system (across divides or via deep groundwater flow paths off-site), this difference equals water falling on the Melton Valley watershed as precipitation minus evapotranspiration and process water inputs (minor) to Melton Valley.

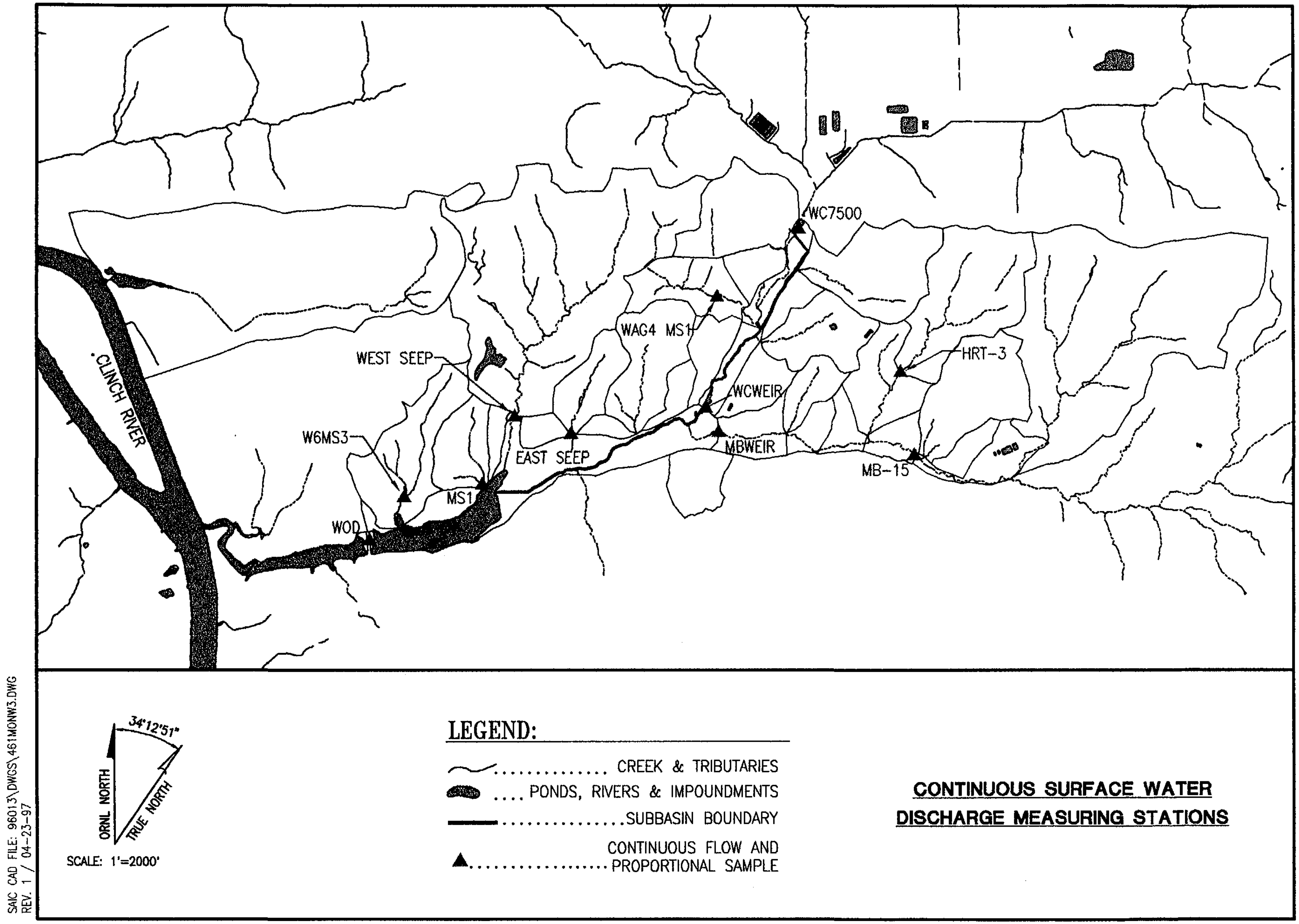


Fig. 2.14. Locations of continuous surface water discharge measuring stations.

Table 2.2 presents water balance summary data for surface water monitoring stations in the Melton Valley watershed, primarily for the period 1993–1994. Since 1993 was a moderately dry year and 1994 was an uncommonly wet year, the statistics should be adequately representative of longer-term flow conditions. Historical data records (before 1993) are available for many of these sites as well as a few not listed in Table 2.2 (e.g., the HFIR Tributary, also known as West Seven Creek). Many surface water sampling locations (e.g., SW7-5, also known as Cobalt Seep) are not equipped with weirs or flumes; therefore, discharge data, when available, are generally one-time measurements (by bucket gaging, current meter, etc.) coincident with grab sample collection. In some such cases, discharge records may be estimates based on differences between gaged stations. In addition, continuous discharge records are generally not available at seeps and tributary transect locations.

Table 2.2. Melton Valley watershed water balance data

		Discharge (L/s)[a]		
Monitoring station	Basin	Average	Maximum	Minimum
WC7500 (7500 Bridge)	Watershed Inflow	307	15900	108
White Oak Dam	Watershed Outflow	481	21700	121
WCWEIR	Subwatershed	328	15300	103
MBWEIR	Subwatershed	87.9	6660	2.35
W6MS1	SWSA 4 Main	2.14	333	0
MB-15 (MB2)	HFIR	64	NA	NA
HRT-3	HRE	6.58	160[b]	0.164
SW001[c]	SWSA 5 Trib 1	3.12	NA	0
SW002[c]	Drainage D-2	1.42	NA	NA[d]
SW003[c]	Drainage D-3	0.85	NA	0
West Seep	West Seep	15.9	2360	0
East Seep	East Seep	1.75	208	0
W6MS3[e]	W6MS3	3.73[f]	NA	NA
W6MS1[e]	W6MS1	2.1[g]	NA	NA

NA = Data not available
[a] Average for 1993 and 1994 unless otherwise noted. Maximums and minimums are instantaneous values.
[b] Maximum recorded at HRT-3 at undersized weir. Actual maximum is several times higher.
[c] Period of record is April 1993 to June 1994 (DOE 1995b)
[d] Base flow typically occurs year-round (DOE 1995b)
[e] Period of record is January–June 1995 (DOE 1996c)
[f] Discharge attributed to FA and FB: 32% and 68%, respectively (DOE 1995e)
[g] Discharge attributed to DA and DB: 60% and 40%, respectively (DOE 1995e)

Conceptual Model

Surface water is important because it represents groundwater discharge and runoff, transports soluble contamination from groundwater seeps, and erodes and transports contaminated sediments for deposition downstream. In the Melton Valley watershed, surface water is a critical component in an integrated hydrologic system. The hydrologic cycle for ORNL consists of inputs, transport processes, and outputs. Precipitation and imported water are inputs; overland flow, subsurface storm flow, and shallow and deep groundwater flow are transport processes; and evapotranspiration and surface water discharge at the site perimeter are the outputs. While contaminants can be introduced at any point in the cycle, at ORNL, the majority of contaminants are transported in the shallow groundwater, subsurface storm flow, and surface water components.

Nearly all precipitation falling on hillslopes underlain by shale formations (where most of the buried waste is located) infiltrates into the soil. In undisturbed areas, a major portion of the infiltrated water moves laterally to nearby streams via the macropores and fractures in the storm flow zone (upper 1–2 m of the surface soil layer). Moore (1988) suggests that in undisturbed areas the storm flow zone accounts for up to 90% of the water moving through the subsurface. However, this figure is uncertain in disturbed areas (especially burial grounds) and has been shown to be less than 50% in some areas within the Melton Valley watershed (Borders et al. 1996). As a component of the WAG 5 RI (DOE 1995b) a hydrologic analyses of three small drainage areas was performed to estimate the balance of water discharge via surface runoff, storm flow, and water table discharges. It was found that surface runoff in the disturbed watersheds at WAG 5 ranged from about 7% in the most heavily disturbed area to about 27% in the least disturbed area. Storm flow varied within a range from about 28% to about 34%. The discharge component attributed to the groundwater zone was about 65% in the most disturbed basin and was between 40% and 50% in the less disturbed areas. A portion of infiltrated water moves vertically to the water table, where it again tends to move laterally to the nearby stream via fractures in the saprolite (weathered rock). This shallow portion of the groundwater zone is termed the water table interval. A small portion moves downward to the intermediate and deep groundwater intervals. Contaminants leached from shallow burial trenches can be transported along all of these flow paths.

Figure 2.15 depicts the three hydrologic components responsible for subsurface contaminant transport to surface streams. Under base flow conditions, stream flow is generated entirely from groundwater contributions from lateral flows draining the shallow water table interval plus minor groundwater input from the intermediate zone. Shallow groundwater is a relatively steady (over time) conveyer of buried, soluble contaminants to surface streams. In addition, in streams receiving contaminated effluents from buried wastes, contaminant concentrations tend to be higher under base flow (groundwater only) conditions relative to those under storm flow conditions.

During moderate precipitation events, rainwater infiltrates the surface soil layer and reaches the stream via the shallow subsurface storm flow zone (lateral flow in the upper 2 m of the soil). The storm flow zone is a transient, rapid conveyor of buried, soluble contaminants from the subsurface to receiving streams (Solomon et al. 1992). Under storm flow conditions, stream discharge rates increase and contaminant concentrations tend to decrease, due to the conveyance of available contaminants by initially clean rainwater, while contaminant mass transport rates increase dramatically. The storm flow zone in the ORR aquitards moves more water downslope than in the Knox aquifer.

During extreme storm events, the intensity of precipitation in some areas can be greater than the infiltration capacity of the surface soil layer. In these areas rainwater collects on the surface and flows downslope to the stream as overland flow. Overland flow is a highly transient occurrence that dilutes soluble contaminants in streams and causes erosion of particle-reactive contaminants (e.g., ^{137}Cs) on hillslopes and floodplains. During brief occurrences of overland flow, stream discharge rates increase and contaminant concentrations decrease significantly, due to dilution from clean areas, while contaminant mass transport rates tend to remain steady. A few transient events per year can account for nearly 100% of the total contaminated soil and sediment erosion and deposition for a given source area. Valley bottoms are flatter and more subject to transient saturation, and overland

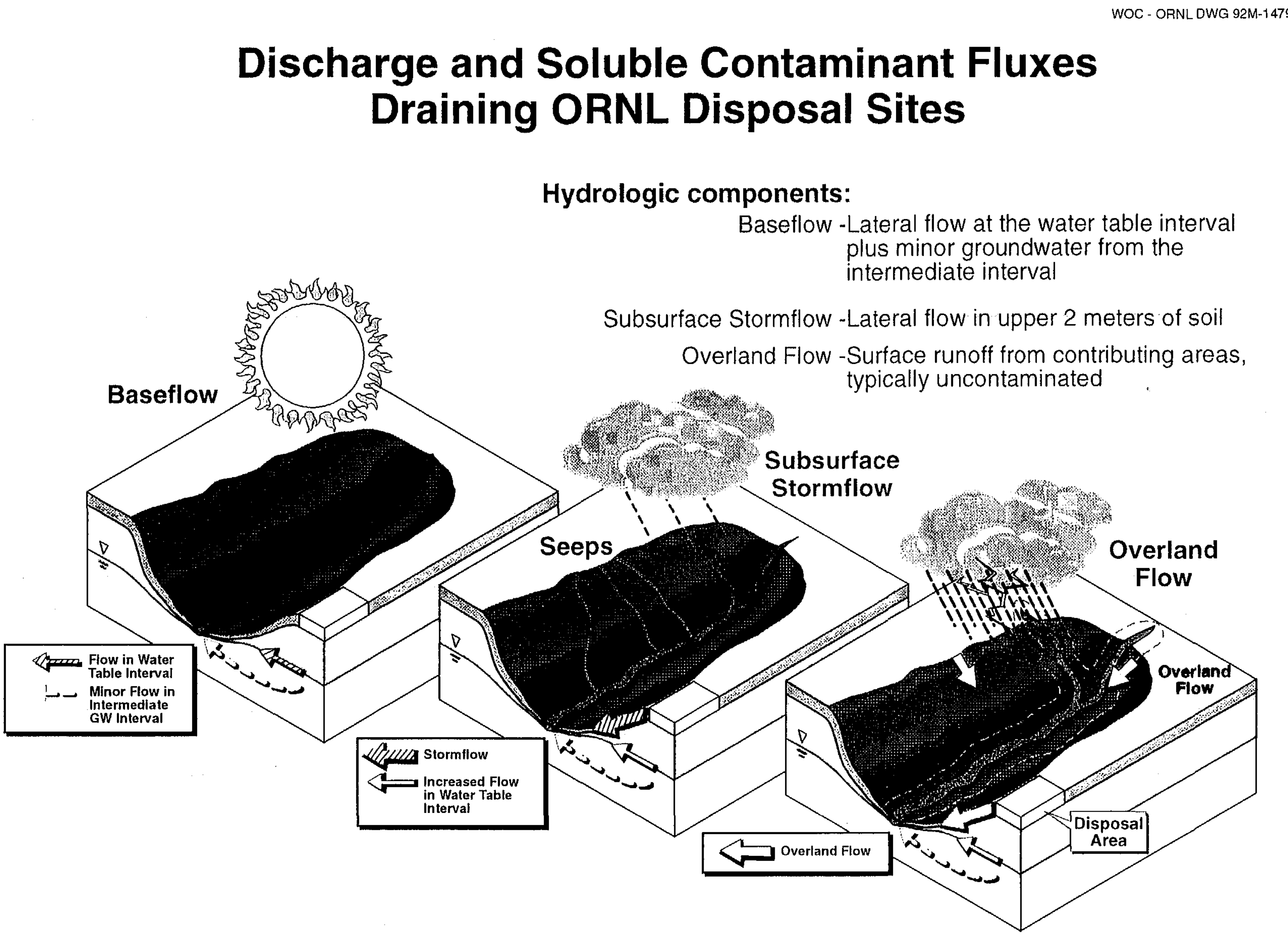


Fig. 2.15. Hydrologic components of contaminant transport to streams.

flow and flooding are more common in the aquitard areas than in areas underlain by the Knox aquifer.

The three flow regimes define the conditions that transport contaminants into tributaries and to their eventual discharge off-site. Figure 2.16 illustrates the relationships between discharge, contaminant flux, and contaminant concentration versus time, and the same information expressed by the log transformations, respectively. The log-log plot of concentration (C) versus discharge (Q) is termed the "C-Q" plot and is divided into segments. This plot shows the pattern of dilution that occurs as stream discharge increases. In the conceptual model, these segments are related to the stream flow generating mechanisms described above. The constant concentration segment corresponds to base flow (i.e., groundwater discharge), the first sloped section corresponds to shallow storm flow (reduced concentration but increased contaminant flux), and the segment with the steepest slope corresponds to overland flow (complete dilution of rainwater mixing with contaminated groundwater discharge). The C-Q model has been used effectively to quantify contaminant fluxes from source areas (Borders et al. 1996) and as a performance assessment tool (Clapp et al. 1992). Comparison of C-Q relationships before and after remediation provides a direct method for determining the effectiveness of a remedial action.

2.2.3 Ranking Releases: Identification of Priority Waste Sources

The total potential risk to human health for the residential drinking water scenario can be calculated at WOD based on the average annual concentration of contaminants. The ranking of releases of contaminants from source areas in the Melton Valley watershed, according to this scenario, is based on a mass balance approach to individual contributions to this total risk. Individual sources are quantified and ranked according to their contributions, by mass (or flux), to the total contaminant flux (flow times concentration) measured at WOD. The primary contaminants that contribute to the calculated total risk at WOD are ^{90}Sr, ^{3}H, and, to a much lesser extent, ^{137}Cs. The three radionuclides account for nearly 100% of the total calculated risk related to water ingestion as measured at WOD (^{90}Sr: 69%, ^{3}H: 25%, ^{137}Cs: 6%) (DOE 1995d). For example, if a source contributes 20% of the ^{90}Sr at WOD, with no significant contribution of ^{3}H or ^{137}Cs, its contribution to total risk is 13.8% (20% × 0.69). If another source contributes 10% of the ^{90}Sr and 8% of the ^{3}H at WOD, its contribution to total risk is 8.9% (10% × 0.69 + 8% × 0.25).

The average annual percent contributions to risk to human health, from sources in the Melton Valley watershed, as measured in surface water at WOD, are described in detail in Sect. 3. Table 2.3 ranks the key subbasins by contaminant release before the initiation of removal actions near the end of calendar year 1994. Each of these source areas contributed significantly greater than 2% of the total risk and, combined, accounted for approximately two-thirds (68%) of the total risk attributed to surface water at WOD. The percent contributions of the source areas are only approximate due to uncertainties associated with analytical results, flow measurements, and environmental variability. In addition, the analyses also suggest that an unidentified ^{90}Sr source may be located in the lower WOC/WOL subbasin area. However, the magnitude (and existence) of this source is uncertain.

Potential reasons for uncertainty in the contaminant flux mass balance include inherent uncertainty in the radiological analyses and potential uncertainty in surface water flow station rating curves. Laboratory analyses for radionuclides typically have ±10% uncertainties because measurement of radioactive decay has an inherent statistical uncertainty that gives a ±10% uncertainty at each measurement station. Mass balance of the surface water discharge volume is based on the accuracy and uncertainty of flow volume measurements at four surface water gauging

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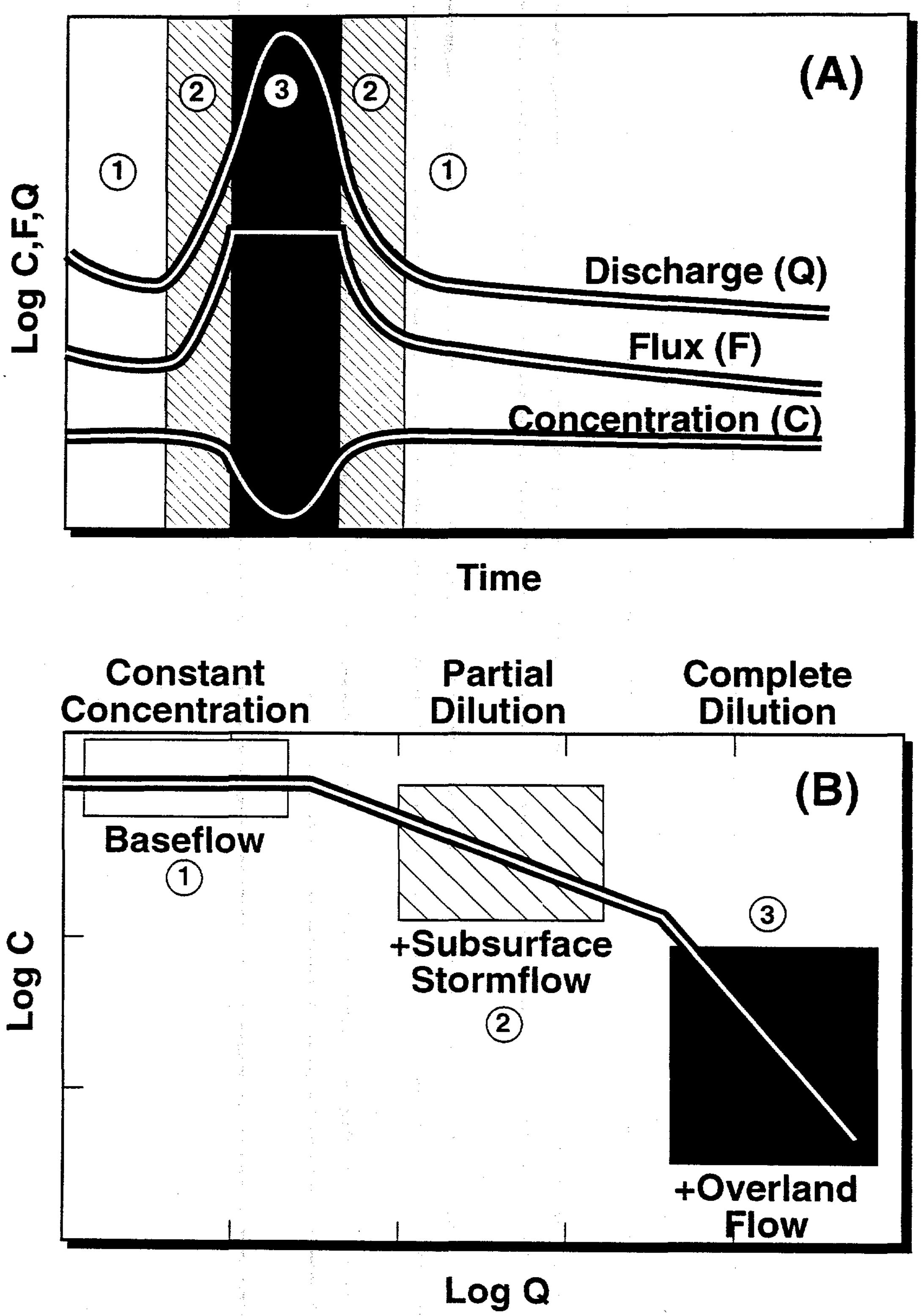


Fig. 2.16. Concentrations versus discharge relationships typical of contaminant releases in Melton Valley.

Table 2.3. Ranking of the ten highest releasing subbasins in the Melton Valley watershed[a]

Subbasin/source areas	% of ^{90}Sr at WOD	% of ^{3}H at WOD	Total contribution to risk (%)
SWSA 5 Seep C	25.5	–	17.6
SWSA 5 Seep B West	–	48.6	12.2
HRE	8.5	–	5.9
SWSA 5 Seep B East	5.4	7.7	5.6
SWSA 4 Seep Area 4	7.9	–	5.5
SWSA 4 Seep Area 6	7.3	–	5.0
SWSA 5 Seep D	6.7	–	4.6
SWSA 5 Drainage D-2	2.5	9.4	4.1
SWSA 4 Tritium Trench	–	13.9	3.5
SWSA 4 East	5.0	–	3.5
Total	68.8	79.6	67.5

[a] Subbasins are ranked according to their contribution to potential risk from a residential drinking water scenario at WOD.

stations. If there are uncertainties in rating curves at these stations for various stages of flow, then the mass balance of flow will appear to show gains or losses that are not real when flows between stations are compared in an upstream or downstream direction. Substantial effort has been dedicated to making the flow and contaminant measurements as accurate and precise as possible; however, the mass balance suggests the presence of a ^{90}Sr contribution between the confluence of Melton Branch and WOC and WOD. The confidence level that a real source exists is low. The implication of the uncertainty can be summarized by saying that another seep similar to Seep D may or may not exist in the lower reach of WOC. A practical approach to managing this uncertainty is to recognize that all records of decision will undergo 5-year reviews and ongoing monitoring of the Melton Valley watershed will provide data on the remedial effectiveness of actions taken to clean up the site. When the cleanup actions reach the point of addressing floodplain soil and groundwater in the lower WOC area, the remedial design effort will have to address groundwater inflows.

Several early removal actions have been initiated to reduce the release of ^{90}Sr from the Melton Valley watershed. In late 1994, ^{90}Sr-contaminated groundwater interception and treatment units were installed and activated on SWSA 5 Seep Areas C and D. As reported in the *1997 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation* (DOE 1997), the ^{90}Sr removal actions constructed at SWSA 5 Seeps C and D reduced the total ^{90}Sr discharge from the WOC watershed. During 1995 the collection and treatment units collected accounted for 609 mCi of the total 2233 mCi of 90Sr accounted for in the watershed or approximately 27.2% of the total potential release. During 1996 the two units collected and removed 606 mCi of the total 2359 mCi of ^{90}Sr accounted for in the watershed or approximately 25.7% of the total potential release. In the summer of 1996, grouting of trenches, for physical and chemical binding of wastes, was initiated on the SWSA 4 Seep Areas 4 and 6. These early removal actions, designed to reduce ^{90}Sr releases, have targeted four of the ten largest contributors to risk to human health in surface water, representing as much as 39% of the total contribution at WOD. In FY 1997, cryogenic isolation of wastes will be conducted on the HRE pond in the HRE basin. The HRE pond is believed to be the single largest source of ^{90}Sr in the HRE basin; however, the magnitude of its contribution is uncertain. In addition, the sources in Bethel Valley, as measured in surface water at 7500 Bridge, make up another 26% of the total risk at WOD. Therefore, the remaining source areas available for reduction represent only about one-third of the remaining risk at WOD, much of which is contributed by diffuse or poorly characterized sources. Of the five remaining sources, or source areas, contributing significantly greater than 2% of the risk at WOD, two are ^{3}H sources and two are partially attributable to ^{3}H (the rest to ^{90}Sr). The three ^{90}Sr sources are diffuse and poorly defined source areas.

2.2.4 Exposure Assessment

The selection of exposure scenarios involves evaluating land use considerations and potential exposure pathway considerations. Exposure scenarios are defined by the completed or potential exposure pathways that are likely to exist for a known or potential receptor population. The potential receptors are identified based on current and future land use considerations.

A decision on the specific land use and its exposure pathways will ultimately be reached in a consensus agreement between involved stakeholders. This represents a major goal of the CERCLA process, and the purpose of this assessment is to inform all stakeholders of the risks involved for specific land uses and exposure pathways that may be considered as target land uses for cleanup purposes. At Oak Ridge, DOE uses the Site Management Plan and the Common Ground process as two primary mechanisms for making these determinations.

The conceptual model for the industrial, residential, and recreational land use scenarios that are evaluated in this report for the Melton Valley watershed is presented in Fig. 2.17. This figure illustrates the results of the exposure pathway evaluation. The scenarios identified and exposure pathways were selected as potential pathways of concern at the Melton Valley watershed based on agreements with stakeholders regarding the scenarios and pathways to be evaluated for human health risk assessments at DOE-ORR sites and on the nature of the contaminated site (subsurface/surface soil and sediment, surface water, and groundwater).

Sources of contamination may be considered to be primary or secondary in nature. The subsurface disposal, buried wastes and trenches, underground tanks, transfer lines, surface contamination, and spills within the watershed are considered to be the primary sources of contamination. Secondary sources of contamination are the contaminated media that have been identified in the basin. For this assessment, surface water, surface soils, deep groundwater, biota, floodplain soil/sediments, and air are considered as secondary media/sources in the conceptual model. Since the source area surface soil can be resuspended and deposited in other areas, the air pathway is also considered as a potential secondary source of contamination. The evaluation of release mechanisms identifies potentially contaminated environmental media based on the physical and chemical properties of the contaminants and the characteristics of the medium where they are found. For this assessment, trench overflow, leaching, leaks, direct discharge, and erosion and runoff are the primary release mechanisms, resulting in the contamination of the Melton Valley watershed.

The location and number of media samples can affect the contaminants identified and the calculated exposure concentration. Higher densities of collected samples generally lead to more certain results for the exposure concentration. The exposure concentration recommended by EPA for calculating the reasonable maximum exposure is the minimum of the maximum of the range and the upper 95th confidence limit of the mean. This value is used as the exposure concentration for the contaminants assessed in the human health risk assessment and for the criteria exceedances developed for surface water and groundwater.

The first step in determining the exposure concentration is to determine the frequency of detection for each analyte. Half of the detection limit is used as a proxy value for all nondetected values. For analytes that have at least one detected value, a statistical test (Shapiro-Wilkes test) is

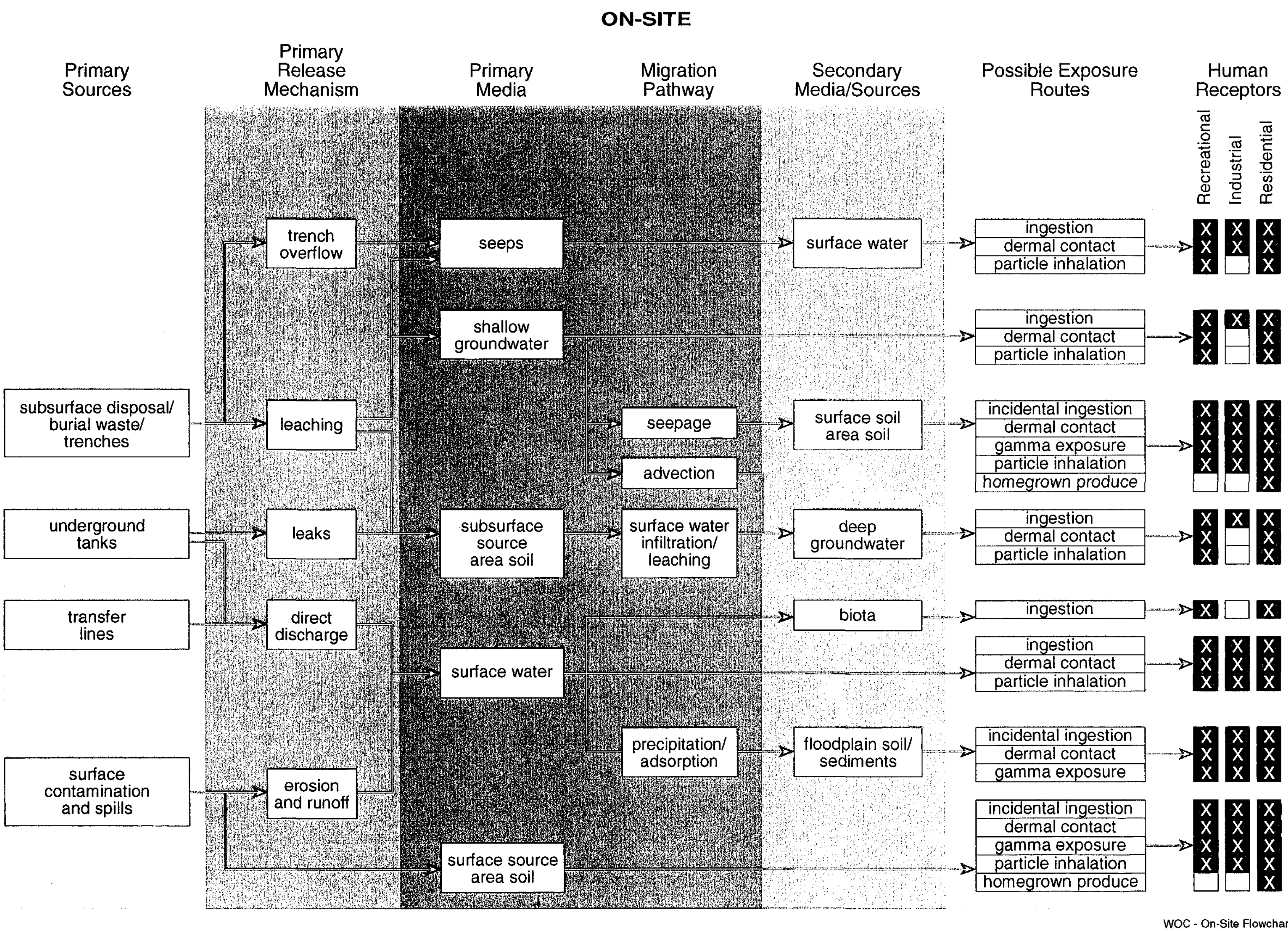


Fig. 2.17. Conceptual model of potential human health exposure scenarios.

performed to determine if a normal or lognormal distribution best fits the concentration distribution. If the distribution is lognormal, then nondetects are reassigned a value between 0 and the detection limit based on the Lifereg SAS procedure, which attempts to extrapolate the lower tail of the lognormal distribution. Based on the results of the Shapiro-Wilkes test, the analyte's mean concentration and the upper 95th confidence limit on the mean concentration are calculated appropriately (i.e., based on a normal or lognormal distribution). The maximum detected concentration is then compared against the upper 95th confidence limit; the smaller of these two measures is used as the analyte's exposure concentration. This method can moderately overestimate the exposure concentration. In addition, when the resulting individual contaminant risks are summed, the compounding conservatism will result in an overestimate of the upper 95th confidence limit of the summed risk.

The primary exposure pathways of concern chosen for each land use scenario are described in the following subsections.

Current Land Use. Since the WOC is located within the confines of ORNL, public access is currently denied. For these reasons, current land use is designated as "restricted industrial," and no current on-WOC residential, unrestricted industrial, or recreational exposure scenarios are evaluated. The land uses that are evaluated are based on current concentrations; potential future land uses are described in the next section. Risk results for the "restricted industrial" scenario are equivalent to 10% of the future industrial land use scenario.

Future Land Use. If institutional controls were removed from the Melton Valley watershed, it is possible that receptor populations could be adversely affected by existing site contamination. Because the future land use for the Melton Valley watershed has not yet been determined, the risks associated with various land use scenarios have been evaluated. Three future land use scenarios are considered in this report: industrial, residential, and recreational. The purpose of evaluating future land use scenarios as part of the risk assessment is to establish whether remedial action is necessary for considered land uses by determining the cumulative risk or hazard index from the source areas and comparing it to risk management levels of concern. The Melton Valley watershed future land use scenario is based on the assumption that industrial workers, residents, or recreational users of the Melton Valley watershed could be exposed. Current contaminant concentrations are used for the on-site assessment of future exposure. Radioactive decay of contaminants is incorporated in the slope factor used to calculate risk but not in the derivation of the exposure concentration. These exposure scenarios represent a maximum exposure to the Melton Valley watershed contaminants and will serve to define the potential human health risks that would exist if unrestricted exposures were to begin within a short time frame. The three exposure scenarios are evaluated for all the media data available for the Melton Valley watershed: groundwater, surface water, soil, and sediment. Risk results have been generated for each sample location and also aggregated within each subbasin within Melton Valley for each of the three future land uses evaluated.

- **Unrestricted Industrial Land Use Scenario**

Under this scenario, industrial workers are expected to be routinely exposed to contaminated media within a commercial area or industrial site. The future industrial scenario is evaluated using industrial default occupational values provided in EPA guidance (EPA 1989, 1991; Energy Systems 1996d), which are based on an industrial receptor exposed 250 days/year for 25 years. Since there is a potential for the use of heavy equipment and related traffic in and around the contaminated surface and subsurface soils and sediment in an unrestricted industrial scenario, soils and sediment could be disturbed, thereby producing particulate emissions that could then be inhaled by the industrial worker. Note that the assumptions and default parameters for the industrial land use scenario do not reflect the use of protective clothing or other safety precautions. Surface/subsurface soils and sediments are considered as a source of exposure to potential industrial receptors. The exposure pathways evaluated for floodplain soils and sediments include (1) incidental ingestion (0.05 g/d), (2) dermal contact (hands and forearms), (3) inhalation of wind-generated dust particulates (8 h/d), and (4) external exposure to radionuclides in the soil (8 h/d). Surface water and groundwater are also considered as a source of exposure for future unrestricted industrial workers. Pathways evaluated for the industrial exposure were limited to include water ingestion (1 L/d). Exposure equations and parameters for these injestion pathways are presented in Appendix B. Industrial risk and hazard results have been generated for each sample location and also aggregated within each Melton Valley subbasin for all media.

- **Residential Land Use Scenario**

Under residential land use, future residents are expected to be in frequent, repeated contact with contaminated media. The assumptions in this scenario account for daily exposure over the long term (350 days/year, 30 years) and generally result in the highest potential exposures and risk. In an industrial area where redevelopment for homes is not feasible now or in the foreseeable future, future land use planning scenarios would be more accurately reflected as industrial rather than residential. However, to provide a conservative assessment of risk, a residential land use scenario is assumed as one of the potential receptors for this assessment. Consequently, appropriate default parameters and equations for residential land use were evaluated. Surface/subsurface soils and sediments are considered a source of exposure to potential on-Melton Valley watershed residential receptors. The exposure routes/pathways evaluated for soils and sediments include (1) incidental ingestion (0.1 g/d), (2) dermal contact (hands, forearms, and lower legs), (3) inhalation of wind-generated dust particulates, (4) external exposure to radionuclides in the soil, and (5) ingestion of home-grown produce cultivated in contaminated floodplain soil and sediment (80 g/d).

Surface water and groundwater are also sources of exposure to potential on-Melton Valley watershed residential receptors. The exposure routes/pathways evaluated for this scenario include (1) ingestion of water (2 L/d), (2) dermal contact with water during household use (whole body), (3) inhalation of volatiles and radionuclides (^3H) in water during household use, and (4) ingestion of home-grown produce irrigated with water. Exposure equations and parameters for these pathways are presented in Appendix B. Subbasin risks for the residential land use scenario were calculated separately for groundwater, surface water from seeps and small tributaries, and surface water from streams. Residential risk and hazard results have been generated for each sample location and also aggregated within each Melton Valley subbasin for all media.

- **Recreational Land Use Scenario**

This scenario addresses exposure to people who spend a limited amount of time at or near the Melton Valley watershed while engaging in outdoor activities such as fishing, hunting, and hiking. The recreational land use scenario is also referred to as the "trespasser" or "site visitor" scenario and consists of site visitation 75 days per year for one hour per day. Surface/ subsurface soils and sediments would be a source of exposure to potential on-Melton Valley watershed recreational receptors. The exposure pathways evaluated for sediments include (1) incidental ingestion (0.48 g/d), (2) dermal contact (hands and forearms), (3) inhalation of on-site wind-generated dust particulates, and (4) external exposure to radionuclides in the soil (1 h/d).

Surface water and groundwater are also sources of exposure to potential on-Melton Valley watershed recreational receptors. The exposure routes/pathways evaluated for groundwater and surface water for the recreational land use scenario include (1) incidental ingestion of surface water (0.05 L/d), (2) dermal contact with surface water (whole body), and (3) ingestion of contaminated fish (54 g/d, 48 d/y). Recreational results are characterized with and without the fish ingestion pathway since a number of the sampled sites do not have sufficient flow to support fish populations. Subbasin risk results are calculated separately for groundwater, surface water from seeps and small tributaries, and surface water from streams within each subbasin. Recreational risk and hazard results are also generated for each sampling location.

Source Areas. The risk results presented for the subbasins are limited to secondary media in each of the subbasins. Risks from exposures to primary waste units such as pits, trenches, and auger holes are not developed because no exposure data are available for use in calculations. However, risks to primary waste areas can be expected to be higher than to secondary media (contingent on actual exposure).

Chemicals of Concern. COCs are developed for all three future land uses that are quantitatively evaluated. These contaminants are presented in the human health risk assessment (Appendix B). In general, the number of COCs identified for each point and subbasin is a function of the conservatism of the scenario with respect to exposure duration. Therefore, the residential scenario, with its long-term extensive exposures, results in the highest risks and the most COCs. The industrial scenario is intermediate in terms of risk and number of COCs and the recreational scenario is the least conservative. The main text discussion of the human health risk results in Sect. 3 identifies the shorter list of recreational COCs for each subbasin. These contaminants are also, with very few exceptions, the predominant contributors to risk for the industrial and residential scenarios and therefore serve to focus attention on the primary risk drivers independent of the particular risk scenario evaluated.

2.2.5 Baseline Ecological Risk Assessment Approach

The ecological risk assessment presents an analysis of the risks to various ecological receptors in the Melton Valley watershed. Each of the subbasins identified in the Melton Valley area will be evaluated to create a comprehensive assessment of the watershed. The ecological risk assessment serves to determine whether there are ecological risks that are of sufficient magnitude to require a removal action or some other remedial process.

The baseline ecological risk assessment is organized in terms of the standard EPA framework (EPA 1992) and follows the strategy and guidelines developed for ORR assessments (Suter et al. 1995, Suter 1996). After a problem formulation, the risks of chemicals to each of the ecological risk assessment endpoints are assessed separately. Exposure assessment, effects assessment, and characterization of risks and uncertainties are addressed for each assessment endpoint. Potential risks are summarized for each endpoint in each subbasin of the Melton Valley watershed.

Risk characterization is the phase of risk assessment in which the information concerning exposure and the information concerning the potential effects of exposure are integrated to estimate risks (the likelihood of effects given the exposure). The risk characterization is performed for each assessment endpoint by (1) screening all measured contaminants against toxicological benchmarks and background concentrations, if available; (2) considering the implications of other types of data for the hypothesis that a hazard exists that requires further assessment or other action; (3) logically integrating the screening results with the other evidence to determine whether a credible hazard exists to the endpoint; and (4) listing and discussing the major uncertainties in the assessment.

2.2.5.1 Ecological problem formulation

The problem formulation consists of the identification of ecological endpoints, description of the relevant features of the environment, description of the sources of contamination, and summarization of that information in terms of a conceptual model of the hazard posed by the contaminants to the endpoint biota.

Environmental Description

The environment considered in this assessment is the Melton Valley watershed (Fig. 2.2). The two major drainages in the watershed are WOC and Melton Branch. The streams and floodplains of the watershed have been divided into five drainage basins: Melton Branch Basin; Middle WOC; Lower WOC Tributary Basins; WOL, WOC, and WOC Floodplain; and WAG 10 Basin. This assessment focuses on the subbasins that make up the drainage basins as shown in Fig. 2.2. Surface water, sediment, and surface soil samples from each subbasin were used in the assessment.

Sources

The proximate sources considered in this assessment are the contaminated media in water, sediment, and soil. The ultimate sources of contaminants are the National Pollutant Discharge Elimination System permitted point discharges at ORNL and releases from wastes in various WAGs. DOE's operations in the Melton Valley watershed have included waste disposal, spills, and use of chemicals such as pesticides in the environment. A more detailed description of potential sources within the Melton Valley watershed is provided in Sect. 3.

Chemicals of potential ecological concern (COPECs) for ecological risks have been identified by screening media data against background concentrations for inorganic analytes (organic analytes were not screened against background). All analytes exceeding background concentrations within a subbasin were carried through the ecological assessment.

Ecological Assessment Endpoints

The problem formulation must identify both the assessment endpoints, which are explicit statements of the characteristics of the environment that are to be protected, and the measurement endpoints, which are quantitative summaries of a measurement or series of measurements that are related to effects on an assessment endpoint.

The following assessment endpoints for aquatic and terrestrial risks have been selected for this assessment.

- Reduction in species richness or abundance or increased frequency of gross pathologies in fish communities resulting from toxicity.

- Reduced species richness or abundance of benthic macroinvertebrate communities resulting from toxicity.

- Reduction in abundance or production of earthworms

- Reduction in abundance or production of piscivorous wildlife populations (kingfisher, great blue heron, osprey, river otter, and mink) resulting from toxicity.

- Reduction in production of terrestrial plant communities resulting from toxicity.

- Reduction in abundance or production of terrestrial wildlife populations (short-tailed shrew, white-footed mouse, red fox, red-tailed hawk, white-tailed deer, and wild turkey) resulting from toxicity.

The ecological assessment endpoints have been selected based on Data Quality Objective (DQO) meetings that included representatives of the DOE, EPA Region IV, and TDEC and the strategy for ecological risk assessment on the ORR, which was also a product of a DQO process (Suter et al. 1995).

Because other endpoint species are judged to be as sensitive or more sensitive than endangered species that may come to use the site, threatened and endangered species potentially occurring in the watershed were addressed similarly to more common species with the exception that the endpoint of interest was effects on individuals rather than populations. Generally representative receptor species were used in the assessment. Osprey and river otter, state-threatened piscivores, were both addressed directly in the assessment. River otter are not known to occur at ORR, but they were included because of possible range expansion. Wetlands are assumed to be protected by assessing risks to plants in the small wetland areas associated with seeps. These wetlands should be more highly exposed than those associated with the streams.

Ecological Measurement Endpoints

Three basic types of effects data are potentially available to serve as measurement endpoints: results of biological surveys, toxicity tests performed on media from the Chestnut Ridge OU, and toxicity test endpoints for chemicals found in the Chestnut Ridge OU. Measurement endpoints are presented below for each assessment endpoint.

- **Fish**

  — Biological Survey Data. Results of Biological Monitoring and Abatement Program (BMAP) surveys will be cited as supporting evidence. The BMAP measurement endpoints are assumed to be direct estimates of that assessment endpoint.

  — Biological Indicators Data. Published results of the BMAP biological indicators task will be cited as supporting evidence. Frequencies of gross pathologies are a direct measure of one aspect of the assessment endpoint. Measures of fish fecundity in largemouth bass and bluegill provide an indication of the potential contribution of reproductive toxicity to community effects. Measures of the levels of physiological and histological condition in redbreast sunfish help to confirm that exposures have occurred and may suggest mechanistic connections between exposure and effects on the fish community.

— Media Toxicity Data. Published results of the BMAP tests will be cited as supporting evidence. Test endpoints include reductions in growth and survivorship of larval fathead minnows and in fecundity and survivorship of *Ceriodaphnia dubia (C. dubia)* in 7-day tests of ambient water, and reductions in hatching and larval survival and increases in terata in Japanese medaka (*Oryzias latipes*) eggs and larvae exposed to ambient water from shortly after fertilization to 48 hours post-hatch. Responses that are statistically significantly different or are inhibited by 20% or greater relative to control or reference waters are assumed to be indicative of waters that are toxic to fish.

— Single Chemical Toxicity Data. Chronic toxicity thresholds for freshwater fish expressed as chronic EC20s or chronic values (CVs). These test endpoints correspond to the assessment endpoint for this community. That is, the sensitivity distribution of the test species is assumed to approximate the distribution of Chestnut Ridge OU species, and exceedance of the CVs and EC20s is assumed to correspond to 20% or greater reductions in abundance, with some uncertainty.

- **Benthic invertebrates**

— Biological Survey Data. Benthic invertebrate survey data were collected from areas in which fine sediments had been deposited. In addition, results of BMAP surveys of benthic invertebrates in riffles will be cited as supporting evidence. The measurement endpoints for both surveys are assumed to be direct estimates of that assessment endpoint.

— Media Toxicity Data. Sediment toxicity tests were not performed because of concerns for worker safety.

— Single Chemical Toxicity Data. Chronic toxicity thresholds for freshwater invertebrates expressed as chronic EC20s or CVs. Two types of values were extracted from Florida data on toxic concentrations in ambient sediment: thresholds for modification of benthic invertebrate community properties based on co-occurrence analyses, and thresholds for lethality in toxicity tests of contaminated sediments.

- **Piscivorous wildlife**

— Biological Survey Data. Kingfisher reproduction was surveyed in WAG 2 and reference areas. Assuming that the kingfishers in the watershed constitute a population, this is a direct measure of the assessment endpoint for avian piscivores.

— Media Toxicity Data. None were performed.

— Single Chemical Toxicity Data. Chronic toxicity thresholds for COCs in birds and mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was given to tests that included reproductive endpoints. After allometric scaling for the endpoint species, these test endpoints are assumed to correspond to effects on individuals that could result in exceedance of the population-level assessment endpoint. An extrapolation must be made to populations if effects on individuals are estimated to occur. In addition, body burdens of a kingfisher were compared to concentrations associated with toxic effects on birds.

- **Terrestrial wildlife**

  — Biological Survey Data. None were performed.

  — Media Toxicity Data. None were performed.

  — Single Chemical Toxicity Data. Chronic toxicity thresholds for COCs in birds and mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was given to tests that included reproductive endpoints. After allometric scaling for the endpoint species, these test endpoints are assumed to correspond to effects on individuals that could result in exceedance of the population-level assessment endpoint. An extrapolation must be made to populations if effects on individuals are estimated to occur.

- **Terrestrial plants**

  — Biological Survey Data. No formal plant surveys were conducted, but anecdotal observations of plant populations can be used.

  — Media Toxicity Data. None.

  — Single Chemical Toxicity Data. EC20s for growth or production of vascular plants or equivalent chronic toxicity thresholds for COCs in soil.

- **Soil invertebrates**

  — Biological Survey Data. Earthworms were collected by the WAG 2 program in a manner that produces an earthworm density estimate.

  — Media Toxicity Data. Planned earthworm toxicity tests could not be performed because of concerns for worker safety.

  — Single Chemical Toxicity Data. Chronic toxicity thresholds for earthworms have been obtained from the literature. These test endpoints vary in their relevance but they are assumed to correspond to the assessment endpoint for this assemblage if they include sublethal responses.

2.2.5.2 Conceptual models

Conceptual models are graphical representations of the relationships among sources of contaminants, ambient media, and the endpoint biota. Figure 2.18 shows a conceptual model for the streams and floodplains of the Melton Valley watershed. Figure 2.19 shows a conceptual model for wide-ranging wildlife that use the streams and floodplains as well as upland areas and nearby aquatic habitat. These conceptual models are derived from the generic models developed for the ORR and

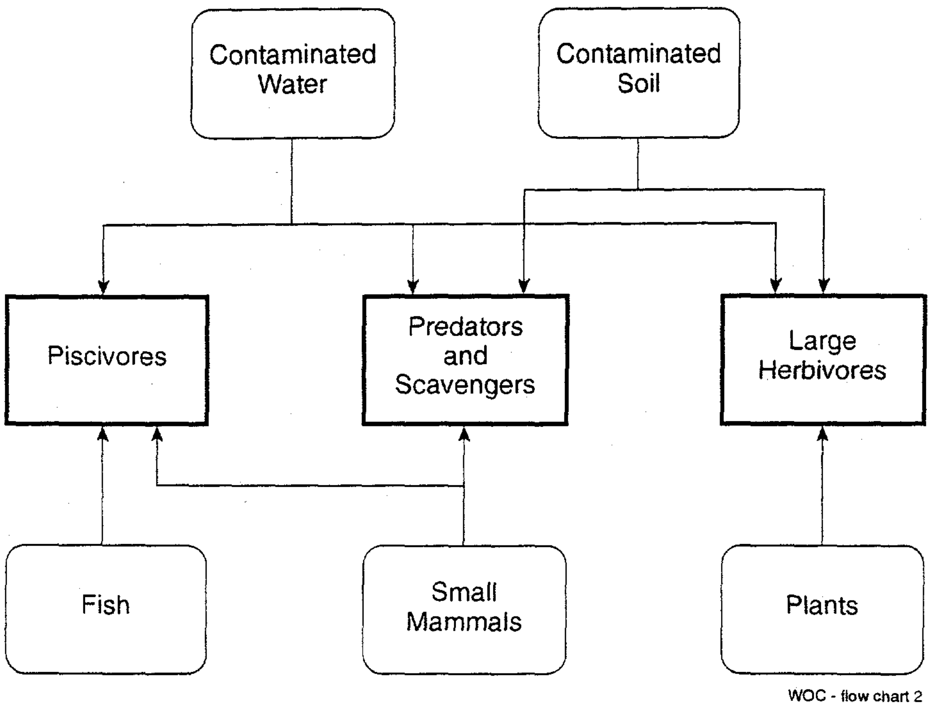


Fig. 2.18. Conceptual model of ecological risk applicable to Melton Valley streams and floodplains.

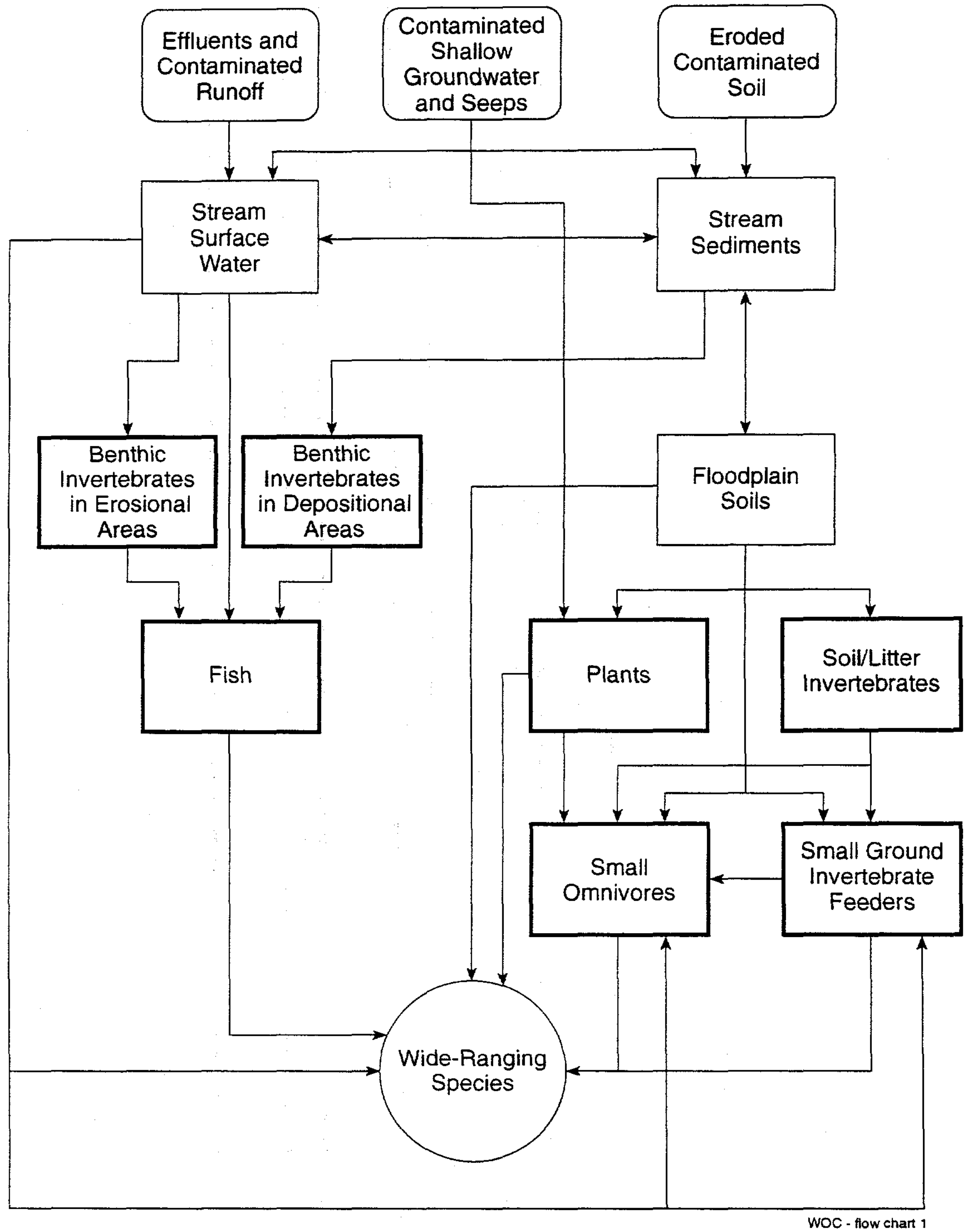


Fig. 2.19. Conceptual model of ecological risk applicable to wide-ranging wildlife.

are discussed in detail in the strategy document for ecological risk assessment on the ORR (Suter et al. 1995).

Effluents, contaminated runoff, contaminated shallow groundwater and seeps, and erosion of contaminated soil result in transport of contaminants to stream surface water and sediments. Deposition of sediments after periods of high water results in contamination of floodplain soils. Benthic invertebrates are exposed to contamination in stream water and sediments. Fish are exposed directly to contaminated water and indirectly to contaminated sediments via ingestion of contaminated prey. Plants are exposed to contaminants in water at seeps and to contaminants in floodplain soils. Soil and litter invertebrates are exposed to contaminants in floodplain soils. Small mammals may be exposed directly to contaminants in floodplain soils and surface water via ingestion or indirectly through ingestion of plants and invertebrates. Wide-ranging wildlife species such as mink, kingfisher, red fox, and white-tailed deer may also receive direct exposures via ingestion of water and soil or indirect exposures from ingestion of plants, invertebrates, fish, or avian and mammalian prey species.

A more detailed description of the exposure pathways evaluated, exposure models, and effects data will be provided in the Baseline Ecological Risk Assessment Appendix.

2.3 IDENTIFICATION OF ARARs

CERCLA §121 specifies that remedial actions for cleanup of hazardous substances must comply with requirements or standards under federal or more stringent state environmental laws and regulations that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site. Clarification of CERCLA concepts and definitions of terms used throughout this report are generally found in 40 CFR 300.5 and 40 CFR 300.430(e).

This section summarizes chemical-specific ARARs for the Melton Valley watershed in general, and location-specific ARARs for the priority subbasins and sources addressed in this report. Action-specific ARARs will be developed for the FS.

2.3.1 Chemical-Specific ARARs

Under the TDEC Underground Injection Control (UIC) regulations, all groundwater is classified for domestic and industrial water supply, livestock watering and wildlife, and irrigation [TDEC 1200-4-6-.05(1)]. However, the UIC regulations define an underground source of drinking water as meaning "an aquifer or its part that: (a) currently supplies any public water system; or (b) contains a sufficient quantity of groundwater to supply a public water system; *and* (b1) currently supplies drinking water for human consumption; *or* (b2) contains fewer than 10,000 mg/L total dissolved solids; and (c) which is not classified for underground injection use pursuant to Rule 1200-4-6-.05(3)" [TDEC 1200-4-6-.02(4)].

The TDEC Division of Water Pollution Control has proposed the addition of a new section to its "General Water Quality Criteria," at 1200-4-3. In addition, the above UIC groundwater classification (TDEC 1200-4-6-.05) would be deleted in its entirety. This proposed rule establishes several classes of groundwater based on naturally occurring levels of TDS, ability to produce an average yield of at least 1 gpm in a properly constructed 6-in. water well, and current use as a source of drinking water [proposed 1200-4-3-.07(2)]. The proposed groundwater classes are: general use groundwater, limited use groundwater, and unusable groundwater.

CERCLA mandates that nonzero maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) shall be attained by remedial actions for groundwaters and surface waters that are current or potential sources of drinking water [CERCLA §121(d)(2)(A); 40 CFR 300.430(e)(2)]. None of the surface water in the Melton Valley watershed has been designated for domestic water supply (TDEC 1200-4-4), so MCLs will not be considered by DOE to be relevant and appropriate for remediation of surface water.

MCLs/MCLGs will be relevant and appropriate for cleanup of groundwater that meets the definition of a current or potential source of drinking water. EPA has promulgated MCLs for radionuclides in community water systems (40 CFR 141), and proposed revised MCLs for radionuclides (56 FR 33050). In this proposed rule, EPA lists estimated concentrations of photon and beta particle emitters that will result in an effective dose equivalent (EDE) of 4 mrem/year (the current MCL), and concentrations of alpha emitters representing a 10^{-4} lifetime risk in drinking water. Since not promulgated, these concentration estimates are "to be considered" (TBC) guidance for remediation of groundwater in the Melton Valley watershed.

CERCLA §121(d)(2)(B)(ii) allows for the use of alternate concentration limits (ACLs) for remediation of groundwater in circumstances where there are known or projected points of entry to a surface water body; there are no significant statistical increases of contaminant concentrations in the surface water body at those points of entry, or at points downstream; and where it must be possible to reliably prevent human exposure to the contaminated groundwater through the use of institutional controls. The preamble to the National Contingency Plan advises that ACLs should be used only where active restoration is not practicable (55 FR 8754), based on the Superfund remedy selection criteria, not "technical impracticality" based on engineering analysis. If an ARAR waiver is requested for groundwater restoration, based on technical impracticability, there is no need to establish CERCLA ACLs. The three CERCLA §121 criteria for use of ACLs must be met and must be supported by site-specific information. Such information must be incorporated into the appropriate portions of the Administrative Record (i.e., the RI/FS and record of decision) (EPA 1996).

If the TDEC groundwater classification is promulgated as proposed, it is possible that much of the WOC Melton Valley groundwater could be classified as limited or unusable groundwater. Proposed TDEC 1200-4-3-.08, "Groundwater Criteria," specifies Water Quality Criteria for each class of groundwater, but allows for a site-specific groundwater standard (similar to the ACLs described above) developed through a risk assessment process (proposed TDEC 1200-4-3-.09) for both response actions as defined in TDEC 1200-1-13-.02(1) (the TDEC "Superfund" rule) or permitting activities. The request for a site-specific groundwater standard must be approved by the applicable Division and include information specified in TDEC 1200-4-3-.09(2).

EPA states that at CERCLA sites there may be certain instances where a plume of groundwater contamination is caused by releases from several distinct sources in close geographical proximity, as is the case with the Melton Valley watershed. EPA suggests that the most feasible approach is to set the point of compliance to encompass the sources of release (55 FR 8753). Remedial efforts then should focus on plume containment to prevent contaminant migration, prevent further contamination of aquifers, and prevent exposure [55 FR 8734; 40 CFR 300.430(a)(1)(iii)(F)]. In determining where to establish the point of compliance, EPA states that the lead agency shall consider such factors as the proximity of the sources, the technical practicability of remediating the groundwater aquifers at the site, and the vulnerability of the groundwater and its potential uses (55 FR 8734).

EPA in the preamble to the final National Contingency Plan states that natural attenuation may be recommended when active restoration is not practicable, cost-effective, or warranted because groundwater is not, and will not in the foreseeable future, be used for drinking water. The selection of natural attenuation to reduce contaminants in groundwater to concentrations protective of human health should occur in a time frame comparable to that of active restoration options. Institutional controls may be implemented during periods of natural attenuation to ensure that groundwater is not used for human consumption (55 FR 8734). EPA further states that natural attenuation may be an appropriate remedial action for portions of a contaminated groundwater plume when combined with other remedial measures needed to control source areas or hot spots (EPA 1996).

Although not applicable to remediation of groundwater at the ORR, 40 CFR 192 allows for natural attenuation of contaminants in groundwater at DOE-owned inactive uranium processing plants in cases where active remediation of groundwater is not appropriate. A discrete time limit of 100 years is specified for compliance with groundwater standards listed in 40 CFR 192.02, with implementation of institutional controls. Groundwater remediated in this fashion must not currently be, or be projected to be, a source of public drinking water supply regulated under the Safe Drinking Water Act (SDWA) [40 CFR 192.12(c)(2)]. This approach to remediation of groundwater via natural attenuation may be relevant and appropriate in areas of the Melton Valley watershed.

WOC, Melton Branch, and all other streams in the watershed, named and unnamed, have been classified for fish and aquatic life, recreation, irrigation, and livestock watering and wildlife uses (TDEC 1200-4-4). TDEC 1200-4-3-.03(4) lists ambient water quality criteria (AWQC) for protection of human health from consumption of aquatic organisms (the recreational AWQC) and AWQC for protection of aquatic organisms [TDEC 1200-4-3-.03(3)]; these are relevant and appropriate for surface water remediation. In instances where AWQC are relevant and appropriate to protect both human health and aquatic organisms, the more stringent AWQC applies (55 FR 8741).

There is also a narrative, but not numeric, AWQC for recreation that protects humans from body contact with toxic substances in water [TDEC 1200-4-3-.03(4)]. However, there are no numeric criteria set in the TDEC regulations for body contact to contaminants, nor is there a method presented to derive concentrations protective for body contact. Therefore, remediation of contaminants to be protective during body contact would be based on the CERCLA process, specifically the selection of remedial action goals that meet the CERCLA "protection of human health" mandate.

2.3.2 Radiation Protection Standards

The Atomic Energy Act (AEA) and its amendments delegated authority for control of nuclear materials to DOE, the Nuclear Regulatory Commission (NRC), and EPA. DOE is authorized under the AEA to regulate source material, by-product material, and special nuclear material at sites under its jurisdiction pursuant to DOE Orders. Tennessee is an NRC-Agreement state and has its own authority and licensing regulations (hereafter termed TDEC/NRC requirements). The TDEC/NRC requirements, as well as those of DOE Order 5820.2A, for disposal of LLW will be considered as potentially relevant and appropriate or TBC guidance as action-specific requirements during selection of remedial alternatives.

The radiation exposure limits for the general public defined in DOE Order 5400.5 ("Radiation Protection of the Public and the Environment," January 7, 1993) are an EDE of 100 mrem/year from all exposure pathways and all DOE sources of radiation. The overriding principle of the DOE Order is that all releases of radioactive material shall be "as low as reasonably achievable" (ALARA). In addition, effluent releases to surface water must not result in exposures to aquatic organisms that exceed an absorbed dose of 1 rad/day.

DOE Order 5400.5, Chap. IV, presents guidelines for the cleanup of residual radioactive material and for the management of sites with residual radioactivity concentrations above the specified guidelines. DOE has proposed these radiation protection standards for the public and the environment for codification at 10 CFR 834 (58 FR 16268, March 25, 1993). Due to become final in May 1997 (Houlberg et al. 1997), these standards will then be legally applicable for cleanup at DOE sites. In the interim, they may be considered TBC guidance.

DOE Order 5820.2A ("Radioactive Waste Management," September 26, 1988) pertains to the management of high-level, TRU, and low-level radioactive waste. Waste that contains TRU radionuclides below the concentration of 100 nCi/g may be managed as LLW. The Order states that the management of LLW must ensure that external exposure to the waste and concentrations of radioactive material that may be released into surface water and soil does not exceed 25 mrem/year to any member of the public. Releases to the atmosphere shall not exceed 10 mrem/year; however, reasonable effort should be made to maintain releases to the environment to ALARA levels. The committed EDE received by individuals inadvertently intruding into the facility after the loss of active institutional controls (assumed to be 100 years) must not exceed 100 mrem/year for continuous exposure or 500 mrem for a single acute exposure.

2.3.3 Location-Specific ARARs

Table 2.4 lists the major federal and state location-specific ARARs that may be pertinent to remedial actions at the priority sources. These ARARs will be addressed in greater detail when specific remedial alternatives are selected in the FS and impact on protected resources is defined.

Table 2.4. Potential location-specific ARARs for the priority sources at Melton Valley watershed

Potential locations	Specific ARARs
Wetlands as defined in Executive Order (EO) and TDEC 1200-1-7	EO 11990 10 CFR 1022 TDEC 1200-1-7
Jurisdictional wetlands as defined in 40 CFR 230.3 and 33 CFR 328.3	Clean Water Act 404 40 CFR 230
Floodplains	EO 11988 10 CFR 1022
Aquatic resources	TDEC 1200-4-7
Species "in need of management"	Tennessee Wildlife Resources Proclamation 86-29
Cultural resources	National Historic Preservation Act 106, 110 (16 USC 470 et seq.) Archaeological Resources Protection Act (16 USC 470aa-11) EO 11593 36 CFR 800

2.3.3.1 Aquatic resources

Aquatic Resource Alteration Permits (ARAPs) are normally required for any alteration of waters of the state, as defined in the Tennessee Water Quality Control Act [Tennessee Code Annotated (TCA) 69-3-103]. Although administrative requirements, such as permits, are not required for on-site CERCLA activities [CERCLA §121(*e*) and FFA §XXII], remedial actions involving stream alteration activities must comply with the substantive requirements of these permitting regulations. These activities may include use of Best Management Practices (BMPs) for erosion and sediment control, streambed and bank stabilization, minimum disturbance to riparian vegetation, etc.

Based on regulatory and statutory definitions, wetlands present in the Melton Valley watershed may be considered "waters of the United States" [33 CFR 328.3(a)] as well as "waters of the State" of Tennessee [TCA 69-3-103(29)]. Wetlands surveys and delineations, using the Corps of Engineers criteria, have been conducted in the Bethel Valley and Melton Valley Groundwater OUs (Rosensteel 1996). Rosensteel (1996) identifies 148 wetlands of various classifications and size in the Melton Valley watershed. Figure 2.20 shows the wetland areas identified in the Melton Valley watershed. The largest (9.97 hectares) occurs in the WOL/WOC floodplain. All priority sources that are bounded by WOC or Melton Branch or any of their tributaries have areas designated as wetlands (Rosensteel 1996).

TDEC regulates activities occurring in wetlands (TDEC Rule 1200-4-7), and may impose as ARARs the substantive requirements of the ARAPs permitting process for disturbance of any wetland areas that are considered "waters of the State." When trench/pit areas are more clearly defined and remedial alternatives are selected for the FS, the impact on specific wetlands areas will be addressed in the context of ARARs.

Wetlands are defined in Executive Order (EO) 11990 ("Protection of Wetlands," May 24, 1977) and DOE's implementing regulation for the Order, 10 CFR 1022; however, the definition is not limited to "jurisdictional wetlands" as regulated by the Corps of Engineers and EPA. The requirements in 10 CFR 1022 instruct DOE to avoid, to the extent possible, the adverse impacts associated with the destruction of wetlands and the occupancy and modification of wetlands, and avoid direct and indirect support of wetlands development wherever there is a practicable alternative.

Floodplains are defined in 10 CFR 1022 as any lowland adjoining inland and coastal waters with relatively flat areas that has a 1% or greater chance of flood in any given year; this definition does not include the floodway proper. As with wetlands protection, DOE requires that floodplains be protected to the greatest extent practicable (10 CFR 1022).

2.3.3.2 Terrestrial resources

In conjunction with the management of the DOE National Environmental Research Park, DOE has designated areas on the ORR as Reference Areas, Natural Areas, Aquatic Reference Areas, and Aquatic Natural Areas (Pounds et al. 1993). Natural Areas are established to protect the endangered plants located on the ORR. Threatened and endangered plant species have been identified at these locations in close proximity to contaminated sites in the Melton Valley watershed (Fig. 2.4). Threatened and endangered plants have been identified in the southern edge of SWSA 6, on the Melton Branch floodplain north of the NHF, and near the West Seep (Awl et al. 1996). Should

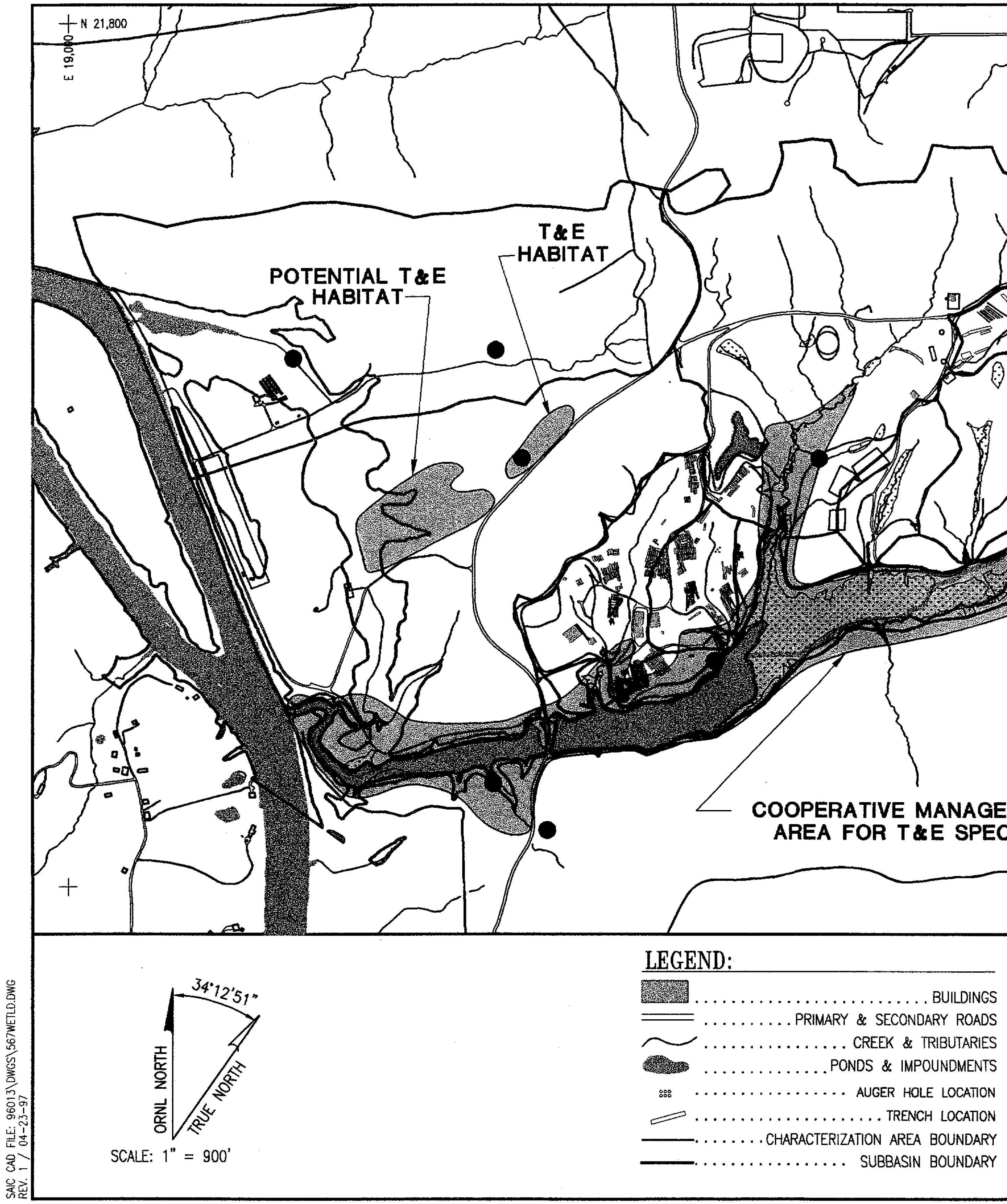
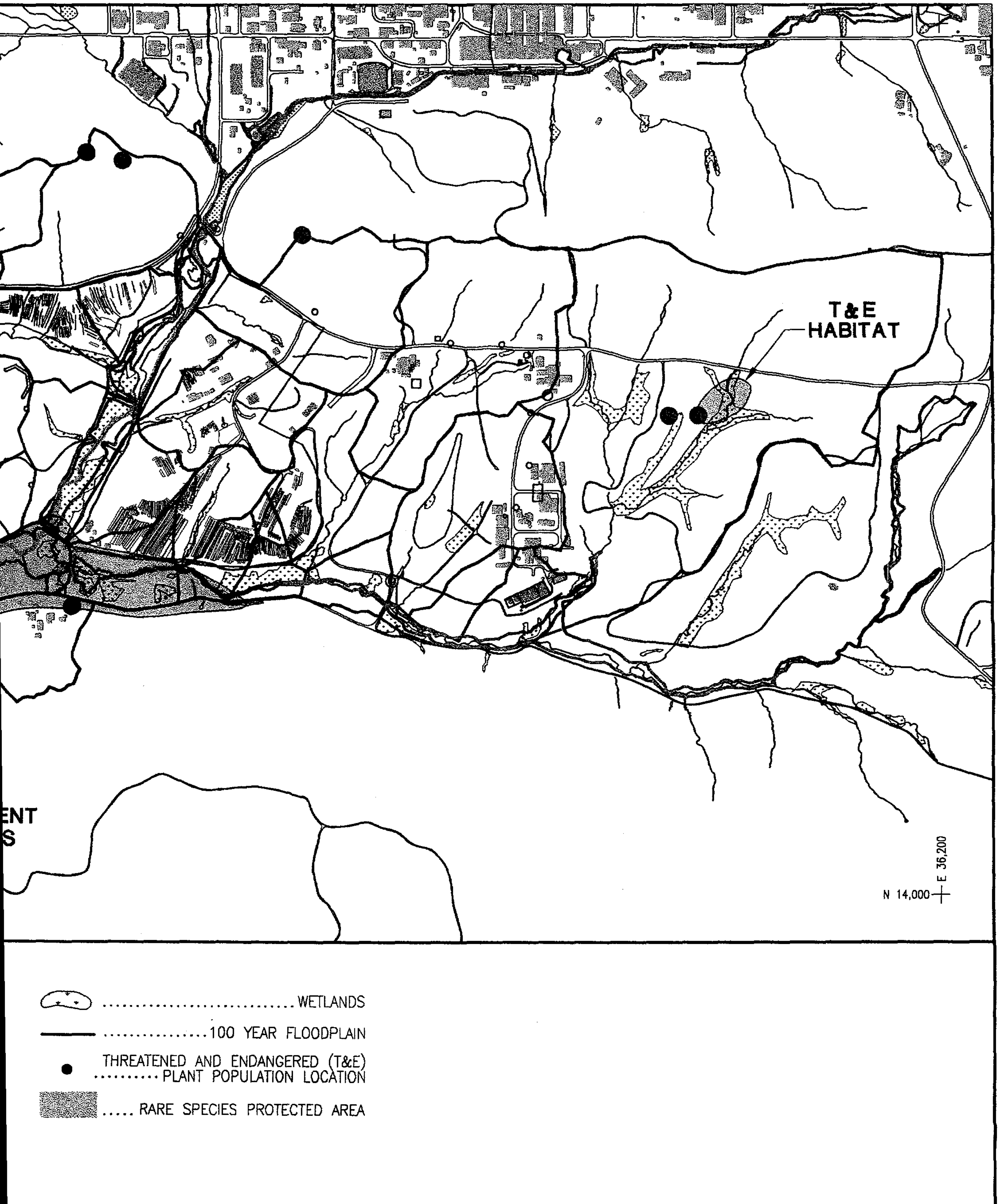


Fig. 2.20. Wetland areas identi



in the Melton Valley watershed.

remedial actions be required in these areas, mitigation actions such as plant relocation would be required to protect the individuals. Bottom land surrounding Lower Melton Branch, Lower WOC, WOL, and WOCE are included in a Cooperative Management Area for threatened and endangered species. Several of the areas considered as primary sources for this RI Report are grass fields maintained by mowing; there is generally no potential rare plant habitat in these areas. However, if remedial actions taken outside maintained areas might adversely impact potential rare plant habitat, consultation with the ORNL Research Park office is recommended (Cunningham et al. 1993).

In 1994, no federally listed threatened or endangered animal species or designated critical habitats were identified in the Melton Valley watershed (DOE 1994), nor has a recent survey of protected terrestrial vertebrates (reptiles, amphibians, birds, or mammals) indicated the presence of threatened or endangered species in the watershed (Mitchell et al. 1996).

There are no state-listed aquatic organisms in need of protection or "in need of management" in the surface waters and/or sediments of WOC, Melton Branch, or their tributaries. The red-shouldered hawk, a state species "in need of management," has been documented at WAG 7 (DOE 1994).

2.3.3.3 Cultural resources

In 1993, a reconnaissance survey and review of historical sites within and immediately adjacent to developed areas at ORNL were conducted. This survey recommends that WOL and WOD are eligible for inclusion in the National Register of Historic Places due to their significance in early waste management efforts. The authors conclude that neither the OHF and HRE Facility nor any structures at SWSAs 3, 4, 5, 6, or 7 possess sufficient significance for inclusion in the National Register (Carver and Slater 1994).

DOE-Oak Ridge Operations (ORO) has entered into a Programmatic Agreement (May 6, 1994), with the Advisory Council on Historic Preservation and the Tennessee State Historic Preservation Officer per 36 CFR 800.13. All federal agency undertakings as defined in 36 CFR 800 shall be administered in accordance with the Programmatic Agreement to satisfy the DOE-ORO's responsibilities for compliance with National Historical Preservation Act (NHPA) §106 and §110 for all individual undertakings. The mitigation of adverse effects to historic properties from an undertaking includes modifications, restoration, preservation, relocation, and documentation, which may be in the form of a Memorandum of Agreement (NHPA §106) or NHPA §110 documentation. Since a site-specific Memorandum of Agreement is an administrative requirement—in the case of remedial actions that would impact WOL or WOD—it is likely that only the NHPA §110(b) requirements to document historic properties that may be destroyed or altered as a result of federal actions or assistance would be applicable. The documentation that may be required if any remediations impact the WOL or WOD areas includes architectural, engineering, historical, oral historical, and archaeological reports.

DuVall (1994) performed an archaeological evaluation of the ORNL main facilities complex and support areas, including WAGs 4, 5, 6, 7, 12, and 13. The reconnaissance revealed extensive modifications in all areas surveyed due to earthmoving, construction, and waste disposal activities. No cultural material was observed at any of the sites surveyed, and no further investigation was recommended for these sites. A similar conclusion was drawn for the HRE Facility and the OHF and NHF. If remedial activities are implemented at sites where an archaeological survey has not been performed, requirements in the ARARs cited on Table 2.4 for cultural resources may be triggered.

2.4 DATA SOURCES

This section identifies sources of data used in the preparation of this RI.

2.4.1 Historical Data Summary

Information pertinent to characterizing the environmental situation in the Melton Valley watershed dates as far back as the 1940s, including information on process waste streams from various source and radionuclide discharges to WOC. In recent years, data have been gathered to address the requirements of RCRA and CERCLA.

Provided below is a summary of environmental management activities at ORNL that have provided historical information to this effort:

- In 1985 the Remedial Action Program was established at ORNL to respond to DOE Orders and RCRA regulations.

- As part of the Remedial Action Program, environmental data were compiled in a RCRA Facility Assessment, performed to support the RCRA 3004(u) and (v) permit application:

  — The RCRA Facility Assessment identified 243 solid waste management units (SWMUs);

  — SWMUs were grouped into 20 WAGs based on hydrologic considerations;

  — Each WAG was reviewed; 11 source WAGs and 2 environmental media WAGs in the Melton Valley watershed were determined to require additional investigation.

- In 1989 the ORR was listed on the NPL. CERCLA RI work plans were published for most source WAGs determined to require additional investigation. Although the plans were not implemented at the time, they do represent a thorough compilation of pertinent historical data on each WAG.

- More recent CERCLA data collection and documentation activities have centered around several large RIs, including RIs for WAGs 2, 5, 6, and 10, and data collection activities to support removal-action type activities, such as the WAG 4 seeps characterization effort. The current CERCLA status of the WAGs is provided in Table 2.5.

Much of the historical information on the watershed was reviewed and summarized as part of the effort to identify DQOs for the Melton Valley watershed RI/FS (Energy Systems 1996a) and to develop a sampling and analysis plan for the WAGs for which data gaps were identified during the DQO process (Energy Systems 1996b).

For the WAGs on which an RI or site characterization has occurred, these efforts are the best source of information on the sources and source releases within that WAG. Because these RI efforts incorporate historical information, resulting RI documents (work plans, RI reports) are considered the primary source of information for these WAGs.

Table 2.5. Status of ORNL waste area groupings CERCLA/RCRA characterization efforts

WAG	Description	CERCLA status
2	ORNL surface water integrator WAG	Phase 1 RI completed 1995
4	SWSA 4 and surrounding area	Ongoing removal action
5	SWSA 5, surrounding area and facilities	RI completed 1995
6	SWSA 6, surrounding facilities	RCRA Facility Investigation/RI completed 1993; deferred-action monitoring began in 1994
7	"Pits and trenches" liquid waste disposal area	Ongoing in situ treatability study on Pit 1
8	The High Flux Isotope Reactor, associated transfer lines, and disposal areas	RI Work Plan, 1988; ongoing time-critical removal action on MSRE
9	Homogeneous Reactor Test and associated areas	RI Work Plan, 1988; inactive
10	Deep Hydrofracture Waste Disposal Facility	RI Implementation Plan, 1992; ongoing characterization
13	Bethel Valley cesium plots	Removal Action, 1994

For sources in WAGs that have not been through the RI process, characterization work plans developed during the Remedial Action Program (that in some cases were never implemented) and original historical documents are the primary source of information.

Because of the sheer volume of information available in the historical documents, data summary packages were compiled for each WAG, and have been used in the Melton Valley watershed DQO process and in the development of this RI (Energy Systems 1996a). Within each WAG data package, information has been catalogued in the following manner:

- site summary (including site map) and key findings of past characterization efforts,
- nature and extent of the source,
- nature and extent of contaminant releases,
- site conceptual hydrogeologic and contaminant transport model,
- human health and ecological risk asssessment results,
- other information, and
- references.

The data packages also provide:

- a bullet summary of available data and major findings;
- a chart identifying each discrete waste unit or decontamination and decommissioning (D&D) facility within the WAG and, for each unit, a determination of the sufficiency of available data; and
- data survey forms that identify the samples types, frequencies, and analyses for each of the reviewed characterization efforts.

Data sets including radiological walkover data; reference soil, sediment, and surface water data; hydrologic and meteorological data; and media characterization data that were included in electronic datasets were compiled for use in the RI. Historic datasets dating back as far as the 1960s were included in the site database to enable the most comprehensive site analysis undertaken to date for the entire Melton Valley area at ORNL.

2.4.2 Melton Valley Watershed Remedial Investigation Data Collection Efforts

A series of DQO meetings were held in February 1996 to determine data needs for the Melton Valley watershed RI/FS project. The meetings were attended by TDEC, EPA, DOE, and contractors to DOE. As a result of the meetings, it was determined the the following data gaps should be filled by additional sampling:

- limited data to characterize the nonradiological risk at WAG 4 seeps area;
- limited data to characterize the nature and extent of radiological and nonradiological secondary contamination soil in the area downgradient of Seepage Pits 2, 3, and 4 in WAG 7;
- no data to characterize nonradiological soil contamination risk at WAG 9; and
- limited data to characterize the nonradiological surface water risk associated with releases for the HFIR impoundment.

To fill these data gaps, a total of 56 samples were collected [including quality assurance/quality control (QC) samples] during the Melton Valley watershed RI/FS supplemental sampling effort. Results of analyses performed on the samples are presented in *Validated Analytical Data Summary Report* (Energy Systems 1996c).

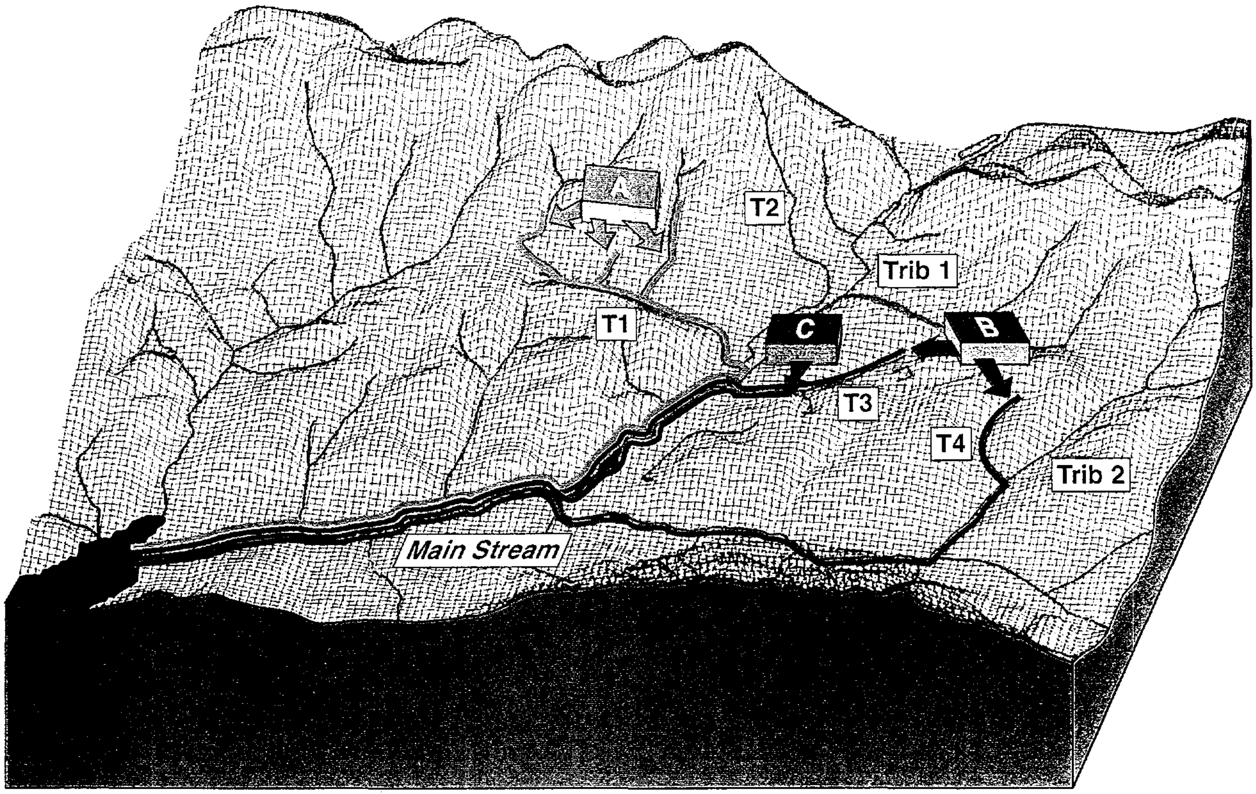
3. NATURE AND EXTENT OF CONTAMINATION

3.1 APPROACH TO WATERSHED ANALYSIS

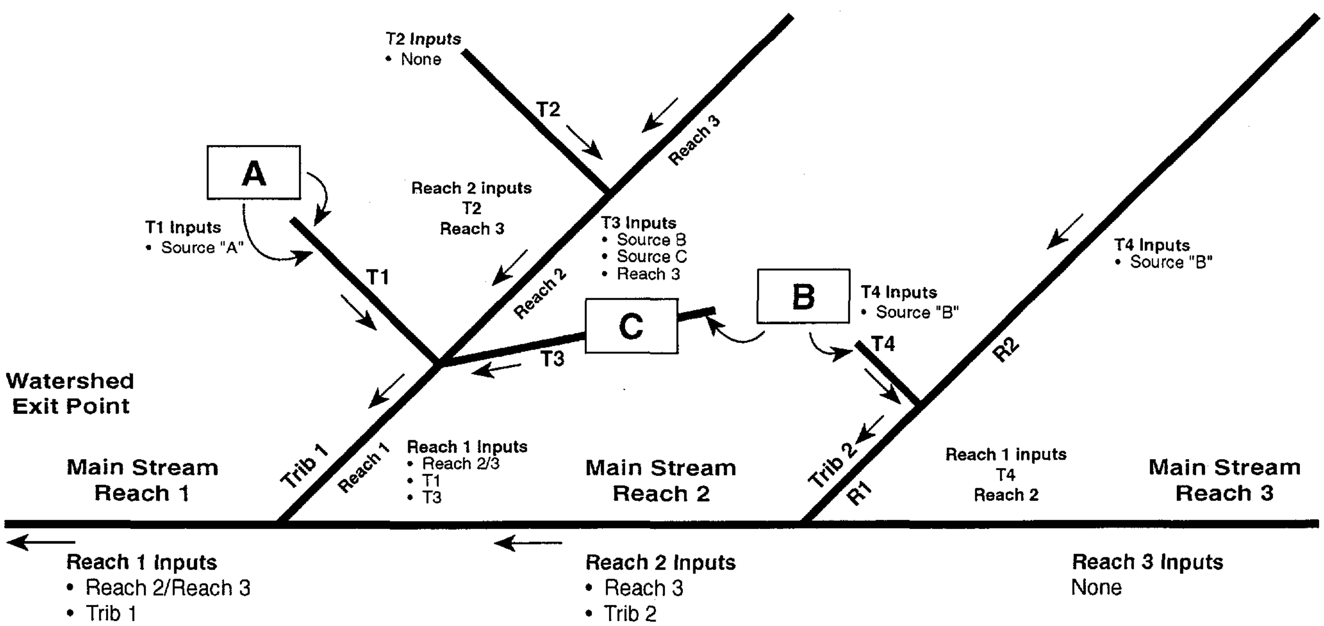
This report presents a watershed scale analysis of the Melton Valley watershed. The purpose for completing the watershed analysis is to document for the entire area the conditions and processes that cause and control the risk associated with contaminated sites. Some of these risks are related to the presence of radiation-emitting contaminants, others are related to releases of soluble contaminants into the groundwater and surface water, and others are related to potential direct contact or ingestion of contaminated media by humans or ecological populations.

The watershed approach to site analysis presented here evaluates all components (contaminant sources, contaminant transport pathways, secondary contaminated media, and human health and ecological risk) of individual subbasins within the larger Melton Valley watershed. Based on the data available for individual subbasins, several key factors such as contaminant source curie inventory and volume, significance of releases to the surface water system, secondary contaminated media volume estimates, predominant contaminant releases mechanisms, and risk assessment results are documented. Compilation of the key subbasin descriptive factors are made to create the watershed scale overview, and the importance of individual subbasins is ranked throughout the watershed. This tabulation of information and subjective ranking of several key factors enables decision makers and project planners to grasp, at a high level, the relative magnitude of importance of each factor in the overall problems of the Melton Valley watershed. The intent of preparing this RI in the format presented here is to enable remediation decision-making and project planning to approach the task of cleanup either from the spatial standpoint of working individual subbasins in a prioritized order, completing all required work for modification of area access restriction, or to approach cleanup from the standpoint that particular contaminant sources or areas may be prioritized for cleanup based on a specific endpoint objective.

The watershed scale analysis presented here is generally organized from the upstream areas toward the downstream areas in an order tiered by surface water subbasin. The watershed scale overview of results for all the subbasins is presented in Sect. 3.2 to orient the reader to the general conditions of the watershed. Detailed assessments of each subbasin are presented in Sects. 3.4 through 3.8. The concept of the watershed analysis is based on the observation that conditions at any point in a basin are influenced by upgradient inputs (true for surface water, groundwater, and atmospherically transported materials) and that each point may create an output that can influence downgradient points on a connected pathway (Fig. 3.1). As the physical complexity of a watershed increases through increase in area scale (hence a larger number of subbasins), numbers of source units, or geologic complications, the conceptual model of the watershed must become more detailed to accommodate the larger number of potential connections between parts of the system. The logic diagram shown in Fig. 3.1 depicts the potential for some contaminant sources to affect one or more subbasins with an influence on the whole watershed that is traceable by stream reach and subbasin position from the watershed mouth all the way back to the source area. A subbasin watershed structure has been created for the Melton Valley watershed combining the topographic boundaries that define surface water catchments and the locations of weirs where surface water flow volumes and contaminant release fluxes have been measured (Fig. 2.2). For the Melton Valley watershed, all surface water from the contaminant source subbasins discharges via the main stem of WOC. Negligible quantities, if any, of shallow source-derived groundwater contamination leaves the watershed without discharging into the surface water system. An uncertainty exists with respect



Watershed Analysis Logic Diagram



WOC - Watershed Combo

Fig. 3.1. Conceptual model and logic diagram of watershed analysis.

to the potential for hydrofracture waste disposal contamination to migrate beyond the watershed boundary in the non-potable deep groundwater system and upward through deep wells into the shallow groundwater system.

In the following sections each subbasin is analyzed to provide:

- description of contaminated sites, waste types and inventories, method of disposal;
- ranking of contaminant releases from the subbasin and from areas within the subbasin when possible;
- hydrologic conceptual model addressing interactions with waste units including pathways of water entering and exiting waste;
- identification of locations, quantities, and characteristics of secondary contaminated media within each subbasin;
- assessment of human health and ecological risk conditions in each subbasin;
- ARAR exceedances in each subbasin; and
- release mechanism/pathway control options.

The compilation of subbasin analyses will document, from a detailed perspective, the:

- magnitude of significance of each subbasin (hence source unit) with respect to contaminant releases from the Melton Valley watershed,
- human health and ecological risk significance of source units and contaminated media in each subbasin, and
- ARAR exceedance conditions within each subbasin.

These parameters combined with the analyses of release mechanism and pathway control options for sources contributing to the contamination problems in the watershed will provide a strong basis for remediation project planning, feasibility analysis, and remediation design.

In a watershed scale analysis, factors that are significant but variable throughout the area can be examined and linked systematically to evaluate the apparent relationships between the factors in subbasins that compose the watershed. In the following analysis of the Melton Valley watershed, values for factors such as waste inventory, contaminant release, and several others are estimated and ranked to show the relative importance of each factor and combinations of factors throughout the 35 subbasins. The factors that are evaluated include waste volume and curie estimates where available, secondary contaminated media volume estimates, contaminant release significance, and estimated risk associated with secondary media and aqueous releases. These factors are significant to decision-makers and feasibility study participants in the assembly of alternatives and prioritization of actions to reach specific goals in management of the watershed.

3.2 DISTRIBUTION OF SURFACE WATER CONTAMINANT RELEASES IN THE MELTON VALLEY WATERSHED

The following subbasin contamination descriptions primarily address radionuclides and their relative contributions (%) to the total release at WOD. The radionuclides primarily addressed are ^{90}Sr, ^{3}H, and ^{137}Cs because they account for nearly 100% of the potential risk to human health, based on a hypothetical residential scenario that assumes water ingestion at WOD. However, nonradiological contaminants (e.g., metals and organics) are also addressed because they are significant to other exposure scenarios. Radionuclide concentration data have been combined with discharge data to calculate releases of contaminants and the numbers presented are percentages of the total contribution at WOD, unless otherwise stated. Figure 3.2 shows ^{90}Sr and ^{3}H discharges from each subbasin in the Melton Valley watershed. In most cases, the values presented represent composite average contributions for 1993 and 1994. In some cases, the contributions are supplemented with 1995 or 1996 data. For subbasins where removal actions were initiated after the 1993–94 period, the effects of removals have been addressed.

Table 3.1 presents a summary of contaminant source contributions to the Melton Valley watershed, for the baseline 1993–94 period and 1995 (post-removal action period) for ^{90}Sr, expressed as percentages of total releases at WOD. In past annual Environmental Restoration Monitoring and Assessment (ERMA) reports (e.g., DOE 1995d), contaminant source assessments have been conducted on a reach or subwatershed basis. The assessment uses flow-proportional sampling data from the Office of Environmental Compliance and Documentation (OECD) to calculate fluxes at primary monitoring stations and determines sinks and sources based on a mass balance approach. The majority of the uncertainty, as identified by mass balance, shows up in the Lower WOC/WOL reach because of the calculation method. This method historically indicates a significant unidentified source of ^{90}Sr in this reach. However, Table 3.1 also presents an alternative calculation method. Source areas are summed on a subwatershed scale (in parentheses) and compared to the previous calculation method. This indicates a significant degree of uncertainty for ^{90}Sr in all three Melton Valley reaches. The alternative calculation method suggests the diffuse/ unidentified source in the Lower WOC/WOL reach, indicated by the ERMA calculation method, may be more evenly distributed across the watershed or may not exist. Comparison of the two methods suggests that the diffuse/unidentified source can be attributed to any combination of at least three things: uncertainty in analytical and flow measurements (at all locations), releases from sediments in the floodplain, and/or undetected sources (e.g., additional seep areas similar to Seep D). The two methods show better agreement for ^{3}H.

As described briefly in Sect. 2.2.3, several early removal actions were initiated late in 1994 or thereafter to reduce the release of ^{90}Sr from the Melton Valley watershed. These removal actions, groundwater interception and treatment units on SWSA 5 Seeps C and D and the Corehole 8 ^{90}Sr plume in Bethel Valley, effectively reduced the ^{90}Sr released at WOD by 30.6% in 1995. The percent removal was determined by adding the total ^{90}Sr inventory removed (0.683 Ci), determined by sampling of treated groundwater, to the total release at WOD (1.55 Ci) and dividing the amount removed by the sum (2.23 Ci). The sum is the amount (assumed) that would have been released at WOD if the removal actions had not been operational. Note that this total is significantly lower than the average annual release (2.79 Ci) at WOD for the period 1993 and 1994. This is due to the elevated release (3.28 Ci) of ^{90}Sr in 1994, which was a very wet year. The ^{90}Sr release (2.30 Ci) in 1993 was of similar magnitude compared to the assumed 1995 no-removal action release. The two years (1993 and 1995) were very similar hydrologically.

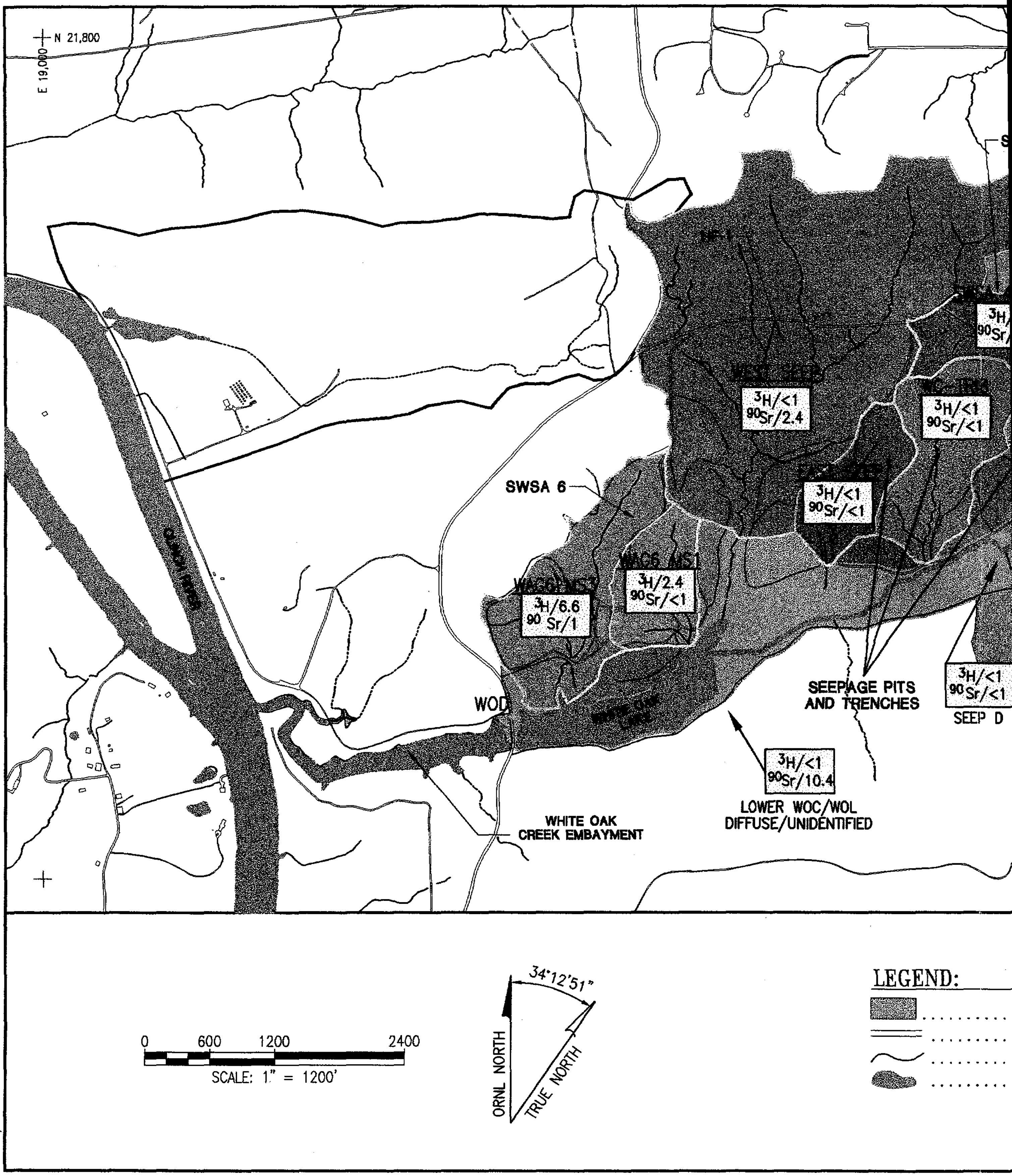


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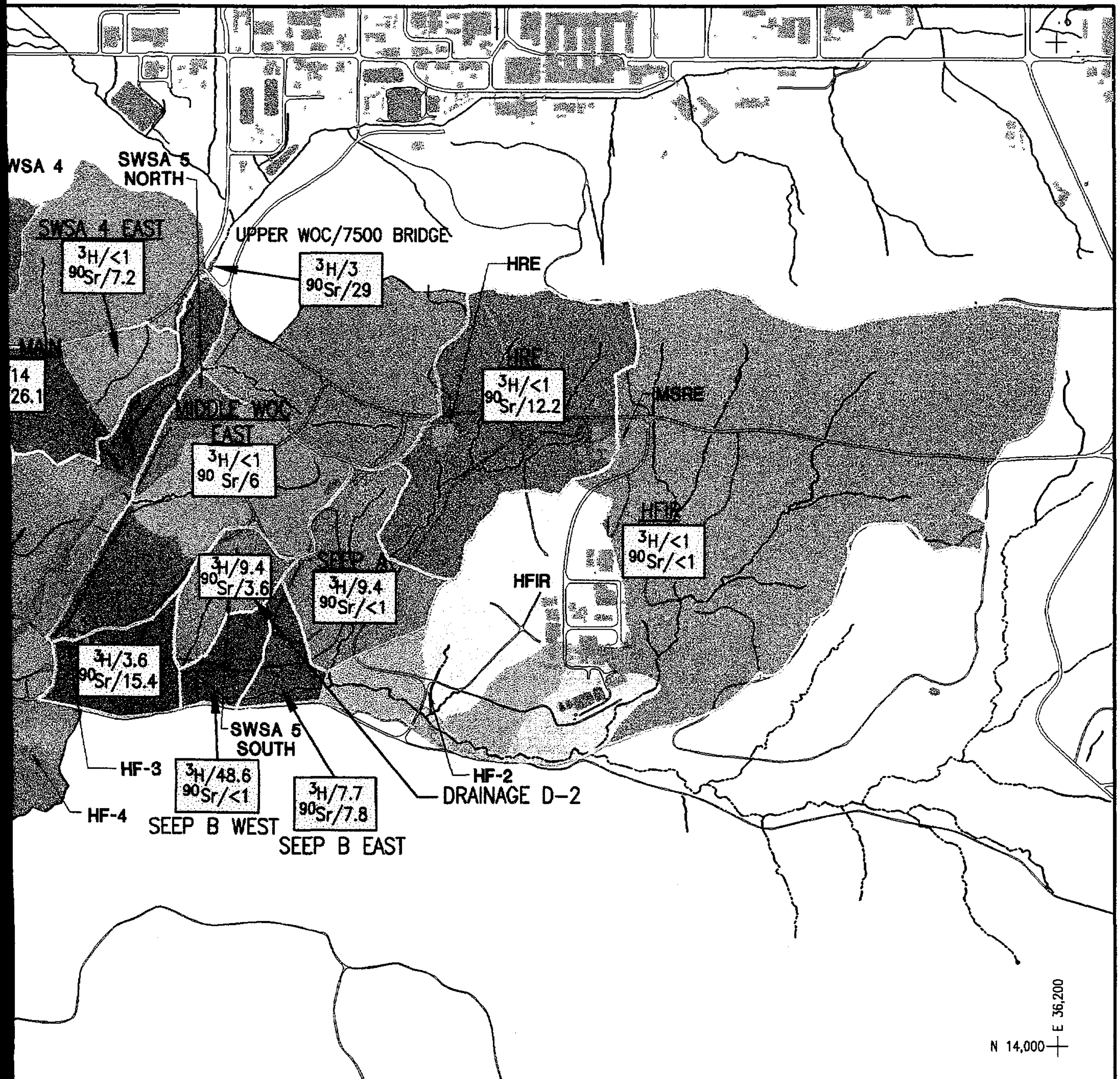
Fig. 3.2. Subbasin contributio



. . . . BUILDINGS
PRIMARY & SECONDARY ROADS
. . . . . . CREEK & TRIBUTARIES
. . . .PONDS & IMPOUNDMENTS

s to ^{3}H and ^{90}Sr releases.

Table 3.1. Contaminant source areas expressed as percentages of the total White Oak Dam release

Stream reach or subwatershed area[a]	Subbasins (source areas)	Percent of ^{90}Sr at WOD: Pre-removal action conditions (1993–94)	Percent of ^{90}Sr at WOD: Post-removal action conditions (1995)	Percent of ^{3}H at WOD (1993–94)	Percent of ^{137}Cs at WOD (1993–94)[b]
Upper WOC	WAG 1 plus WAG 3	24.4	29.0	3	145
	Intermediate Pond				10.9
	Seep Areas 1–3	1.5	2.2		
	Seep Area 4	7.9	11.4		
	Seep Area 5	1.4	2.0		
	Seep Area 6	7.3	10.5		
	Tritium Trench			13.9	
	SWSA 4 Main (MS1)	18.1	26.1	13.9	
	SWSA 4 East	5.0	7.2	0.6	
	WOC Source Area	2.9	4.2		3.6
	OHF Pond	1.3	1.9		
	SWSA 5 WOC	4.2	6.0		3.6
Middle WOC	Subtotal	19.1 (27.3)	24.3 (39.3)	14.6 (14.5)	10.7 (14.5)
	HFIR Area (MB-15)	<0.2	<0.3	<0.1	17.2
	HRE	8.5	12.2		6.0
	Drainage D-2	2.5	3.6	9.4	0.8
	Seep C	25.5	15.4	3.6	
	Seep A			9.4	
	Seep B East	5.4	7.8	7.7	2.0
	Seep B West			48.6	
Melton Branch	Subtotal	36.6 (42.0)	32.1 (39.2)	78.2 (78.7)	3.5 (26.0)
	EWB			0.3	
	West Seep	1.7	2.4	0.3	
	East Seep	<0.1	<0.1	<0.1	
	WC TRIB-1	<0.5	<0.7	<0.5	
	W6MS3	0.7	1.0	6.6	
	W6MS1			2.4	
	Seep D	6.7	0.0		
	Diffuse/Unidentified[c]	10.3 (-3.3)	10.4 (-11.6)	-5.6 (-6.0)	-59.1 (-85.5)
Lower WOC/WOL	Subtotal	19.9 (9.6)	14.5 (4.1)	4.2 (9.8)	-59.1 (-85.5)
Total (WOD)		100 (103.3)	100 (111.6)	100 (106.0)	100 (185.5)
Total WOD Release (Ci)		2.79	1.55	2340	0.569

[a] Stream Reaches/Subwatershed Areas: First number (Subtotal) = 1993–94 average release derived from OECD analytical data and surface water program flow data.
Second number (Subtotal in parentheses) = sum of subbasin/source releases in reach/area.

[b] Values greater than 100 indicate more ^{137}Cs passing a given site than WOD. This is common for ^{137}Cs because it binds to sediment particles and settles out in WOL before discharging over WOD.

[c] Diffuse/Unidentified: First number (see above) = WOD (100%) - Upper WOC - Middle WOC - Melton Branch - sum of Lower WOC/WOL releases.
Example (1993–94 ^{90}Sr from table): 100 - 24.4 - 19.1 - 36.6 - 9.6 = 10.3 (diffuse/unidentified source).
Second number (in parentheses) = WOD (100%) - sum of all subbasin/source area releases.
Example (1993–94 ^{90}Sr from table): 100 - 24.4 - 27.3 - 42 - 9.6 = -3.3 (diffuse/unidentified source).

The post-removal action conditions for ^{90}Sr, presented in Table 3.1, indicate higher relative contributions for all sources that were not mitigated by early removal actions. This occurs because the sources are effectively higher percentages of a lower total at WOD. As sources are reduced (Seep C) or essentially eliminated (Seep D), all other sources increase in relative importance. The source releases have not actually increased. The percent contribution of each ^{90}Sr source area (or subbasin) in 1995, other than those reduced by early removal actions, was determined by multiplying the 1993–94 contribution by 1.44. This factor is derived from the reduction of 30.6% (or 0.306), resulting in 69.4% (or 0.694) of the ^{90}Sr that would have been released at WOD. Therefore, each unmitigated source is effectively increased by a relative factor of $^{1}/_{0.694}$ (or $^{2.23}/_{1.55} = 1.44$).

In the Melton Valley watershed, ^{90}Sr releases from Seep areas C and D were reduced by early removal actions. The source attributed to Seep area D was essentially eliminated while the source for Seep area C was significantly reduced. Note that the post-removal action contribution of Seep C (15.4% of 1.55 Ci) is 60–70% lower than the baseline 1993–94 contribution (25.5% of 2.79 Ci).

Figure 3.3 is a schematic diagram showing distribution of contaminant releases throughout the Melton Valley watershed based on the baseline (1993–94) data presentation in Table 3.1.

3.3 SUMMARY ASSESSMENT OF THE MELTON VALLEY WATERSHED

The Melton Valley watershed presents a multifaceted management and decision-making challenge because of the very heterogeneous conditions that exist with respect to contaminant type, disposal unit age, mode of disposal, release mechanism, and potential risk-producing exposure pathways. This assessment has assembled relevant site data in a hydrogeographic context, with the intent of enabling program managers and decision-makers to understand site conditions and evaluate the necessity, relative priority, and project scope of potential remedial actions in the watershed.

This section of the report summarizes conditions throughout the Melton Valley watershed, focusing on contaminant source and secondary contaminated media distributions; contaminant release mechanisms causing discharges from each subbasin; relative importance of each subbasin to surface water contaminant releases; potential human health risk and ecological community risk; water quality criteria exceedances; and temporal projections of ^{3}H and ^{90}Sr releases based on current trends for these two contaminants.

3.3.1 Distribution of Contaminant Sources and Contaminated Media

Primary contaminant sources, including waste disposal units and contaminated facilities, and associated secondary contaminated media, such as contaminated soil and groundwater seepage areas in the Melton Valley watershed, are shown on Fig. 3.4.

Estimates of primary source areas, volumes, and inventories and secondary contaminated media areas and volumes are summarized in Table 3.2. Contaminant inventories were not estimated for secondary contaminated media due to sparse data regarding contaminant concentration distribution in these media.

Assumptions that were made and methods employed to estimate primary and secondary source areas and volumes and primary source inventories for the subbasins in the watershed are as follows.

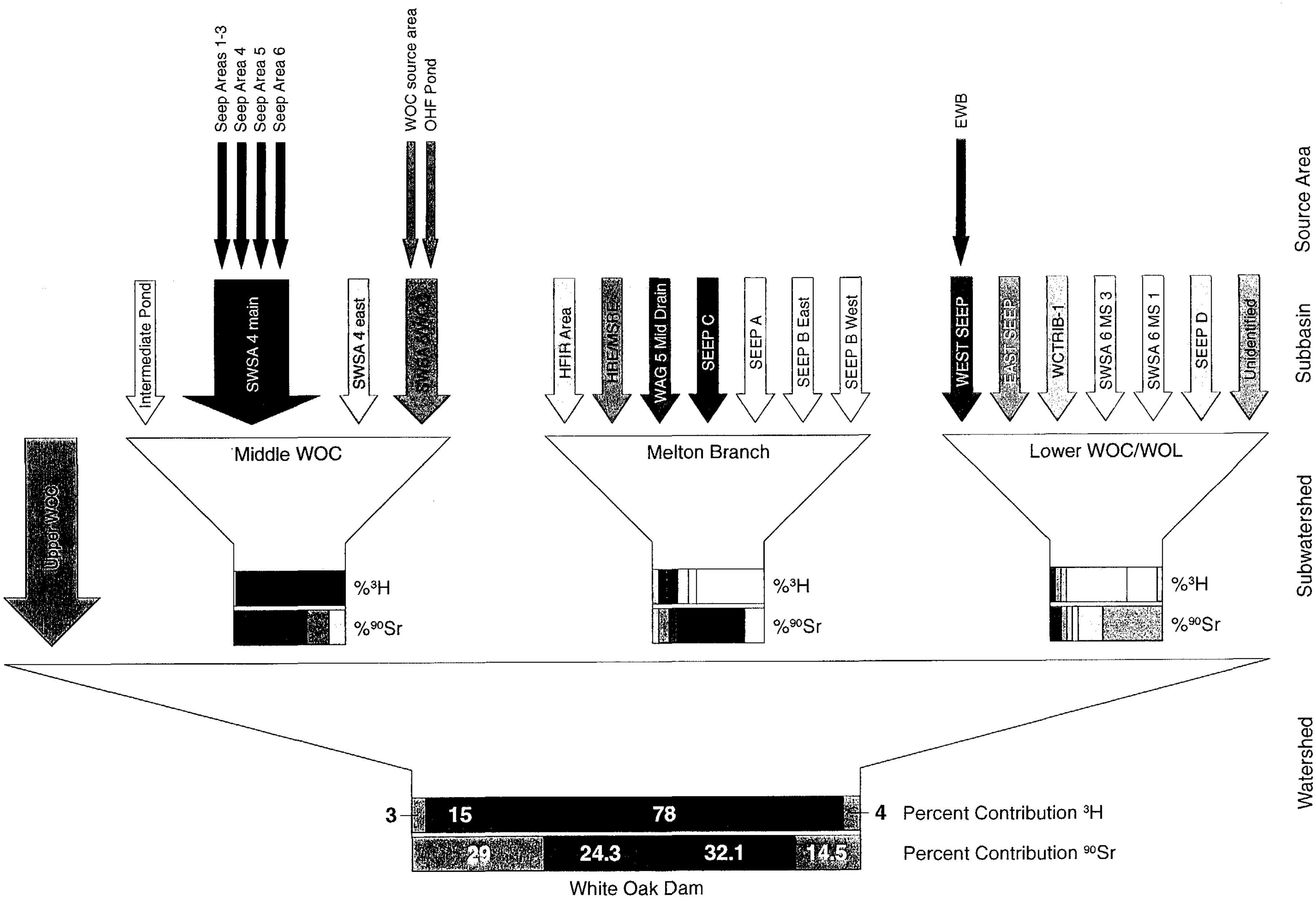


Fig. 3.3. Schematic diagram of ^{3}H and ^{90}Sr releases to surface water in Melton Valley watershed.

WOC - flux at WOD

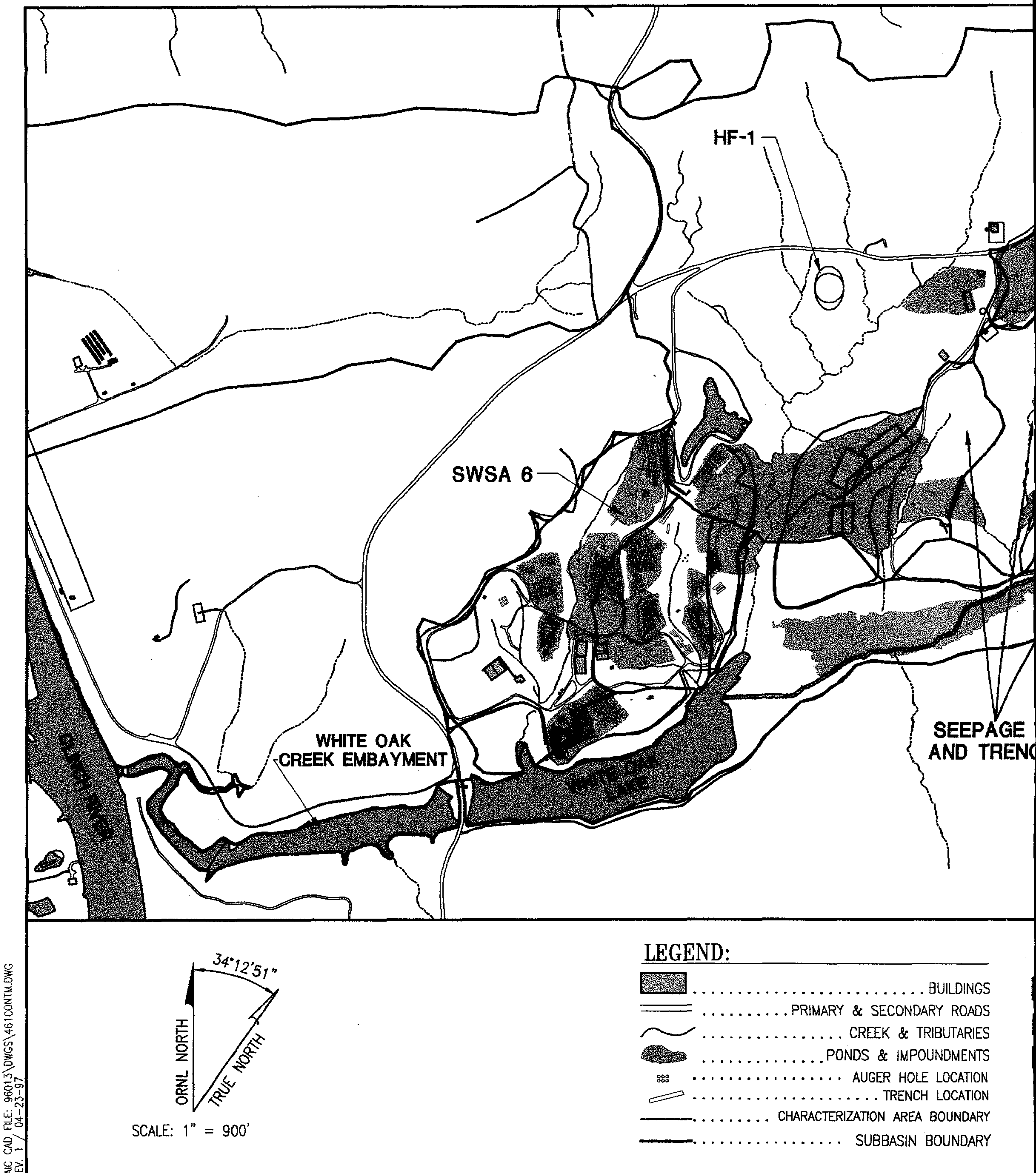
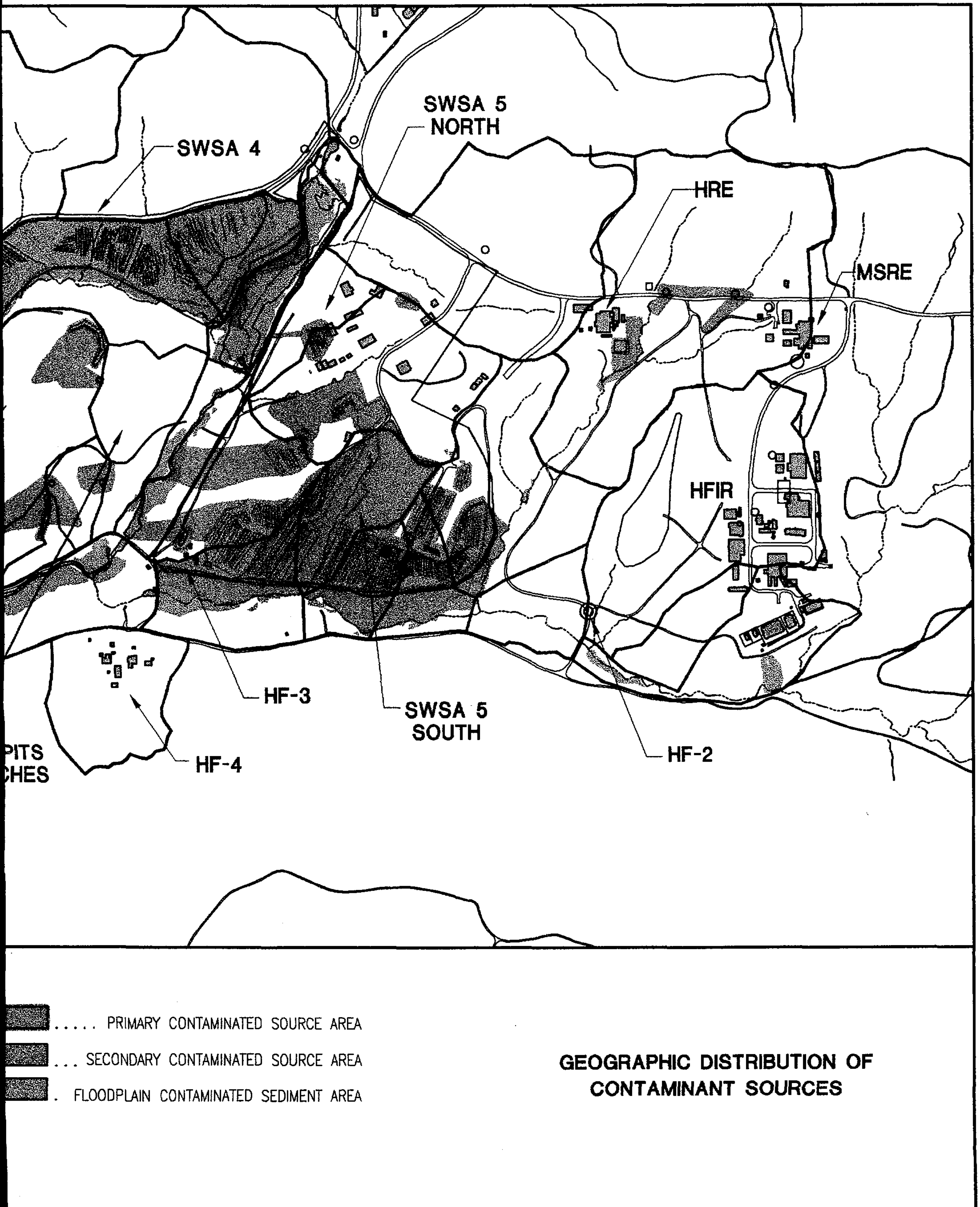


Fig. 3.4. Geographic distribution of co



ntaminant sources.

Table 3.2. Primary and secondary source areas volumes and inventories

Basin ID	Total area (acres)	Contribution to total release, %		Primary sources			Secondary contaminated media			
							Soils/sediments		Groundwater	
		^{90}Sr	^{3}H	Area (acres)	Source vol. (ft^3)	Inventory (Ci)	Soil/sed. area (acres)	Soil/sed. vol. (ft^3)	GW area (acres)	GW vol. (ft^3)
West Seep	78.7	2.4	0.3	3.0	2.0E+06	2.7E+05	16.0	6.4E+06	15.9	5.5E+05
SWSA 5 Drainage D-2	12.2	3.6	9.4	8.0	2.6E+06	2.3E+04	3.7	1.6E+06	3.7	1.3E+05
SWSA 5 Seep C	14.9	15.4	3.6	3.7	1.2E+06	2.3E+04	4.3	1.3E+06	4.3	1.5E+05
^{60}Co Seep	7.1	0.0	0.0	0.1	6.5E+04	7.5E+04	2.2	5.8E+05	1.2	4.2E+04
WC TRIB-1	34.5	<0.7	0.5	0.8	5.2E+05	1.5E+05	6.7	2.4E+06	5.5	2.0E+05
W6MS3	42.4	1.0	6.6	6.3	2.1E+06	2.3E+04	2.4	1.0E+06	2.3	7.8E+04
SWSA 5 Seep B East	7.6	7.8	7.7	1.8	5.9E+05	1.1E+04	3.4	9.0E+05	2.9	1.0E+05
SWSA 4 Main	24.9	26.1	13.9	4.1	1.3E+06	7.3E+04	2.3	7.0E+05	2.3	8.0E+04
East Seep	19.8	<0.1	0.1	1.0	6.5E+05	8.5E+04	6.3	2.7E+06	6.3	2.2E+05
SWSA 5 WOC	13.9	6.0	0.0	3.8	1.0E+06	1.4E+04	3.8	1.1E+06	3.8	1.3E+05
SWSA 5 Seep B West	7.8	0.0	48.6	3.3	1.1E+06	1.1E+04	2.5	7.0E+05	2.2	7.7E+04
W6MS1	20	0.0	2.4	6.2	2.0E+06	3.5E+05	0.5	2.2E+05	0.5	1.7E+04
SWSA 4 East	9.8	7.2	0.6	2.1	6.9E+05	3.7E+04	1.5	7.0E+05	1.5	5.2E+04
SWSA 5 Seep A	25.9	0.0	9.4	2.2	7.2E+05	1.7E+04	2.1	4.8E+05	1.5	5.2E+04
SWSA 6 East	4.7	0.0	0.0	0.5	1.6E+05	3.0E+05	2.5	1.1E+06	2.5	8.7E+04
SWSA 5 Trib 1	26.5	0.0	0.0	2.0	4.7E+05	6.0E+02	3.0	9.0E+05	3.0	1.1E+05
HRE	60.5	12.2	0.0	0.2	4.0E+04	7.5E+02	2.3	4.3E+05	0.8	2.6E+04
SWSA 6 South	7.5	0.0	0.0	1.7	5.6E+05	9.2E+03	0.0	0.0E+00	0.0	0.0E+00
SWSA 5 N WOC	7	0.0	0.0	0.2	1.1E+03	1.7E+02	0.1	3.0E+04	0.1	3.5E+03
MB-15	15.2	<0.3	0.1	0.9	8.7E+03	1.5E+00	1.0	4.3E+04	0.0	0.0E+00
Intermediate Pond	11	0.0	0.0	6.9	6.0E+05	1.3E+02	0.0	0.0E+00	0.0	0.0E+00
Pit 4 South	5.8	0.0	0.0	0.1	6.5E+04	1.0E+04	0.0	0.0E+00	0.0	0.0E+00
Lower WOC	63.7	0.0	0.0	12.5	5.5E+05	7.3E+01	0.0	0.0E+00	0.0	0.0E+00
WOC	9.6	0.0	0.0	2.0	8.5E+04	1.1E+00	0.0	0.0E+00	0.0	0.0E+00
Big No-Name	221.4	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
Little No-Name	222.3	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
Trench 5 South	3.9	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
WAG 7 WOC	12.7	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
WOD Sliver	1.6	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
Haw Ridge	37.1	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
HF-2	9	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
HFIR	42.6	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
HFIR East	175.5	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
HFIR South	7.5	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
NHF	15.9	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
MV Drive	43.2	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00
WOCE	10.3	0.0	0.0	0.0	0.0E+00	0.0E+00	0.0	0.0E+00	0.0	0.0E+00

1. Areas of primary sources were estimated by drawing a polygon around primary source units (i.e., trenches, auger holes, impoundments, etc.) within the boundaries of the subbasin and computing the area inside the polygon. This resulted in high primary source area estimates for some subbasins because areas between individual source units (e.g., trenches in SWSA 5 South) were not well known and therefore not excluded.

2. Primary source volumes were calculated by multiplying the areas estimated for assumption number 1 by average depths of source units, most of which ranged from 10 to 15 ft.

3. Primary source inventories were calculated by summing the documented inventories for the waste units within the individual subbasins. Where a waste unit straddled a subbasin boundary, the portion of the inventory within a subbasin was calculated by multiplying the total inventory of the waste unit by the percentage of the total area of the waste unit in the subbasin.

4. Secondary contaminated media include surface soils, stream sediments, seepage pathway soils, and seepage pathway groundwater. Within a subbasin, areas and volumes of soils/sediments are the sums of the areas and volumes of surface soils, stream sediments, and seepage pathway soils; the seepage pathway groundwater area corresponds to the area of seepage pathway soils.

5. Seepage pathway soil/groundwater areas were estimated by drawing a polygon around inferred seepage pathways downgradient of and/or along strike between primary source areas and receiving streams and computing the area within the polygon.

6. Seepage pathway soil volumes were calculated by multiplying the seepage pathway soil areas by inferred seepage pathway thicknesses. The seepage pathway thickness was assumed to be 7 ft in subbasins where the primary sources were predominantly in lowland areas and was assumed to be 10 ft in subbasins where primary sources were predominantly in upland areas.

7. Surface soil and stream sediment volumes were calculated by multiplying surface soil areas by an assumed thickness of 1 ft.

8. Seepage pathway groundwater volumes were calculated by multiplying the seepage pathway groundwater areas by an assumed saturated thickness of 2 ft and a soil porosity of 40%.

3.3.1.1 Subbasin rankings by radiological waste inventory

Subbasin rankings by estimated current radionuclide inventory are summarized in Table 3.3. The following criteria were used to assign subbasins to inventory ranking groups:

Group 1: inventory $\geq$1.0E+05 Ci;
Group 2: 1.0E+04 Ci $\leq$ inventory <1.0E+05 Ci;
Group 3: 1.0E+02 Ci $\leq$ inventory <1.0E+04 Ci;
Group 4: inventory <1.0E+02 Ci.

The two highest ranked subbasins for inventory are the NHF and SWSA 5 Seep C subbasins, followed by the West Seep, W6MS1, and SWSA 6 East subbasins. However, all of the inventory in the NHF subbasin and all but about 6000 Ci of the inventory in the SWSA 5 Seep C subbasin is found in the NHF and OHF grout sheets. Almost all of the inventory in the SWSA 6 East subbasin and over 100,000 Ci of the inventory in the West Seep subbasin is attributable to ^{152}Eu and ^{154}Eu in the HFIR control plates in auger holes in SWSA 6. Only minor ^{3}H releases are occurring from W6MS1 and no significant ^{3}H or ^{90}Sr releases are occurring from NHF or SWSA 6 East. Four of the ten highest ranked subbasins for inventory are in the Seepage Pits and Trenches area. Significant current contaminant releases do not appear to be taking place from primary sources in these subbasins; releases from these subbasins are apparently from seepage pathway soils. All of the subbasins that are ranked high in terms of inventory have the potential for significant future releases.

Table 3.3. Subbasin ranking by inventory

Basin ID	Inventory (Ci)	Inventory rank
NHF	5.6E+05	1
SWSA 5 Seep C	4.6E+05	1
West Seep	2.6E+05	1
W6MS1	2.1E+05	1
SWSA 6 East	2.1E+05	1
WCTRIB-1	1.5E+05	1
East Seep	1.1E+05	1
^{60}Co Seep	7.0E+04	2
SWSA 5 Drainage D-2	1.3E+04	2
SWSA 4 Main	1.2E+04	2
SWSA 4 East	6.4E+03	3
SWSA 5 Seep B West	6.0E+03	3
W6MS3	4.8E+03	3
SWSA 5 Seep A	3.3E+03	3
SWSA 5 Seep B East	3.3E+03	3
Pit 4/south	2.8E+03	3
SWSA 6 South	2.2E+03	3
SWSA 5 WOC	1.8E+03	3
SWSA 5 Trib 1	5.6E+02	3
Lower WOC	4.4E+02	3
Intermediate Pond	1.2E+02	3
HRE	3.9E+01	4
HFIR	1.0E+01	4
WOC Embayment	6.3E+00	4
SWSA 5 N WOC	5.7E+00	4
WOC	1.0E+00	4
MB-15	0.0E+00	4
Big No-Name	0.0E+00	4
Little No-Name	0.0E+00	4
Trench 5 South	0.0E+00	4
WAG 7 WOC	0.0E+00	4
WOD Sliver	0.0E+00	4
Haw Ridge	0.0E+00	4
HF-2	0.0E+00	4
HFIR East	0.0E+00	4
HFIR South	0.0E+00	4
MV Drive	0.0E+00	4

The highest ranked subbasins for inventory from which significant ^{3}H or ^{90}Sr releases are presently occurring are SWSA 4 Main, SWSA 4 East, W6MS3, SWSA 5 Drainage D-2, SWSA 5 Seep C, SWSA 5 Seep A, SWSA 5 WOC, SWSA 5 Seep B West, and SWSA 5 Seep B East. The contaminant inventories in the Intermediate Pond, WOC, and Lower WOC/WOL subbasins are predominantly the particle-bound radionuclides ^{137}Cs and ^{60}Co, which are likely to remain immobile unless significant erosion of the sediments in these subbasins takes place.

For SWSA 6, current (decayed) radionuclide inventories were calculated by applying the radionuclide distribution for all of SWSA 6 to each distinct disposal unit, decaying each radionuclide, and summing the individual decayed activities. Since virtually all of the ^{152}Eu and ^{154}Eu in SWSA 6 is found in the HFIR control plates in the Northeast Auger Holes area—comprising portions of the SWSA 6 East, W6MS1, and West Seep subbasins—these radionuclides were not included in the distribution used to calculate decayed inventories for the remainder of the disposal units in SWSA 6. For the Northeast Auger Holes area, the initial ^{152}Eu and ^{154}Eu inventories were subtracted from the total radionuclide inventory. The radionuclide distribution for the rest of SWSA 6 was used to calculate the decayed inventory of the remainder of the radionuclides in the Northeast Auger Holes area and this result was added to the calculated decayed inventories of the ^{152}Eu and ^{154}Eu.

Initial radionuclide disposal estimates for SWSA 4 and SWSA 5 are approximately 110,000 Ci and 210,000 Ci, respectively, with no internal accounting possble to define the local distribution of inventory at a scale smaller than the entire disposal area. Therefore, a uniform spatial distribution of radiological materials was assumed and initial curie loadings for subbasins in these areas were assigned based on the fraction of the total disposal area acreage within each subbasin. The SWSA 6 radionuclide distribution (not including ^{152}Eu and ^{154}Eu) was used to calculate decayed radionuclide inventories for SWSA 4 and SWSA 5 South. Since mainly TRU radionuclides were disposed of in SWSA 5 North, decayed inventories of unidentified radionuclides in this area were calculated using the SWSA 6 TRU radionuclide distribution.

For the OHF and NHF grout sheets, estimates of total activities of radionuclides in the grout/waste injections were used to estimate initial radionuclide inventories.

For the Seepage Pits and Trenches, disposed radionuclide inventories were estimated from disposal records. A significant inventory of trivalent rare earths (TRE) were disposed of in the Seepage Pits and Trenches. Since no disposal records were available for specific TREs, the SWSA 6 TRE distribution was used to estimate the inventories of TREs.

The starting point for decay in all of these calculations was the most recent disposal date for each disposal unit and decay was calculated to the end of 1996. The results of the inventory analysis described above are summarized in Appendix A, Table A.1

3.3.1.2 Subbasin rankings by secondary contaminated media

Subbasin rankings by secondary contaminated media are summarized in Table 3.4. There is a high degree of uncertainty regarding the secondary contaminated media area and volume estimates, which may bias the subbasin rankings. There is also a high degree of uncertainty regarding contaminant concentration distribution, which precludes any attempt at meaningful estimation of contaminant inventories in these media.

Table 3.4. Subbasin ranking by secondary contaminated media

Basin ID	Soil/sediment area (acres)	Soil/sediment volume (ft^3)	Groundwater area (acres)	Groundwater volume (ft^3)	Secondary media rank
W6MS1	3.9	1.2E+06	3.9	1.4E+05	2
W6MS3	3.9	1.7E+06	3.9	1.4E+05	2
East Seep	6.3	2.7E+06	6.3	2.2E+05	2
West Seep	16.0	6.4E+06	15.9	5.5E+05	1
SWSA 5 Drainage D-2	3.7	1.6E+06	3.7	1.3E+05	2
SWSA 6 East	2.5	1.1E+06	2.5	8.7E+04	2
^{60}Co Seep	2.2	5.8E+05	1.2	4.2E+04	2
SWSA 5 Seep A	2.1	4.8E+05	1.5	5.2E+04	2
SWSA 4 Main	2.3	7.0E+05	2.3	8.0E+04	2
SWSA 5 Seep B West	2.5	6.8E+05	2.2	7.7E+04	3
Pit 4 South	0.0	0.0E+00	0.0	0.0E+00	3
SWSA 5 Seep C	4.3	1.3E+06	4.3	1.5E+05	3
WC TRIB-1	6.7	2.4E+06	5.5	2.0E+05	3
SWSA 5 WOC	3.8	1.1E+06	3.8	1.3E+05	3
SWSA 5 Seep B East	3.4	9.0E+05	2.9	1.0E+05	3
SWSA 4 East	1.5	7.0E+05	1.5	5.2E+04	3
SWSA 6 South	0.0	0.0E+00	0.0	0.0E+00	3
SWSA 5 Trib 1	3.0	9.0E+05	3.0	1.1E+05	4
SWSA 5 N WOC	0.1	3.0E+04	0.1	3.5E+03	4
HRE	2.2	4.1E+05	0.8	2.8E+04	4
MB-15	1.0	4.3E+04	0.0	0.0E+00	4
Intermediate Pond	0.0	0.0E+00	0.0	0.0E+00	4
Lower WOC	0.0	0.0E+00	0.0	0.0E+00	4
WOC	0.0	0.0E+00	0.0	0.0E+00	4
Big No-Name	0.0	0.0E+00	0.0	0.0E+00	4
Little No-Name	0.0	0.0E+00	0.0	0.0E+00	4
Trench 5 South	0.0	0.0E+00	0.0	0.0E+00	4
WAG 7 WOC	0.0	0.0E+00	0.0	0.0E+00	4
WOD Sliver	0.0	0.0E+00	0.0	0.0E+00	4
Haw Ridge	0.0	0.0E+00	0.0	0.0E+00	4
HF-2	0.0	0.0E+00	0.0	0.0E+00	4
HFIR	0.0	0.0E+00	0.0	0.0E+00	4
HFIR East	0.0	0.0E+00	0.0	0.0E+00	4
HFIR South	0.0	0.0E+00	0.0	0.0E+00	4
NHF	0.0	0.0E+00	0.0	0.0E+00	4
MV Drive	0.0	0.0E+00	0.0	0.0E+00	4
WOCE	0.0	0.0E+00	0.0	0.0E+00	4

The most important areas of secondary contaminated media, from a current contaminant release perspective, appear to be the seepage pathway soils in the SWSA 4 Main and SWSA 4 East subbasins, the SWSA 5 South subbasins (Seep A, Seep B East, Seep B West, and Seep C), and the SWSA 6 subbasins (W6MS1 and W6MS3). The primary reasons for their importance are that significant releases are known to occur via these pathways and they remain, for the most part, perennially saturated. Sediments in the Drainage D-2 tributary may also be important because they contain significant concentrations of the long-lived radionuclides ^{238}Pu and ^{233}U. The seepage pathway soils in the West Seep, East Seep, ^{60}Co Seep, and WC TRIB-1 subbasins are also important sources of contaminant releases. During pit and trench operations, large quantities of radionuclides moved to surface drainages via these pathways. Due to the influence of pit and trench capping, they are likely to be less important than seepage pathway soils in SWSAs 4, 5, and 6 because the water table has been lowered and many of the seepage pathways that were active during operations are now "stranded" above the water table.

The ranking of subbasins for secondary contaminated media content was completed as follows.

1. Each subbasin was assigned to a ranking group, numbered from 1 (worst) to 4 (least), for soil/sediment area (SSA) in acres, soil/sediment volume (SSV) in ft^3, groundwater area (GA) in acres, and groundwater volume (GV) in ft^3 according to the following criteria:

Group 1	Group 2	Group 3	Group 4
SSA ≥10	3 ≤ SSA <10	0.5 ≤ SSA <3	SSA <0.5
SSV ≥2.0E+06	7.5E+05 ≤ SSV <2.0E+06	1.0E+04 ≤ SSV <7.5E+05	SSV <1.0E+04
GA ≥10	3 ≤ GA <10	0.5 ≤ GA <3	GA <0.5
GV ≥2.0E+05	7.5E+04 ≤ GV <2.0E+05	1.0E+03 ≤ GV <7.5E+04	GV <1.0E+03

2. The arithmetic mean of the soil/sediment area and soil/sediment volume ranking groups and the arithmetic mean of the groundwater area and groundwater volume ranking groups were calculated for each subbasin.

3. The aggregate secondary contaminated media ranking for each subbasin was then calculated by computing the arithmetic mean of the two means calculated in step #2, and rounding the result to the nearest integer to obtain a ranking of 1 through 4.

3.3.2 Contaminant Releases and Predominant Contaminant Release Mechanisms

Estimates were made for each of the subbasins of contaminant releases as a percentage of the total release over WOD for ^{90}Sr and ^{3}H and as a percentage of their total contribution to risk from a residential drinking water scenario at WOD. The percentage of the release occurring from each subbasin is attributable to each of the following three release mechanisms: perennial inundation; seasonal inundation and infiltration; and erosion. The basis for these estimates and subbasin rankings based on these estimates are discussed in the following subsections.

3.3.2.1 Subbasin rank by current releases

Estimates of ^{90}Sr and ^{3}H releases from each of the subbasins as a percentage of their contributions to the total releases of these contaminants over WOD and the percentage of their contributions to potential risk from a residential drinking water scenario at WOD are summarized in Table 3.5. The estimates take into account the reductions in ^{90}Sr flux due to the Seeps C and D removal actions. The assumptions and approach used to make these estimates are discussed in Sect. 3.2. The subbasins were ranked based on their contributions to risk at WOD; these rankings are also summarized in Table 3.5. The subbasin rankings were done by assigning each subbasin to a ranking group based on the following criteria:

Group 1: risk contribution ≥ 10%,
Group 2: 5% ≤ risk contribution <10%,
Group 3: 0.5% ≤ risk contribution <5%, and
Group 4: risk contribution <0.5%.

The aggregate release ranking group for each subbasin is the arithmetic mean of the ^{90}Sr and ^{3}H release ranking groups.

The highest ranked subbasin, based on current releases, is the SWSA 4 Main subbasin (Table 3.5). Even though this subbasin does not have the highest ^{90}Sr and ^{3}H release, it is ranked at the top of the list because of relatively high releases of both of these contaminants. The highest ranked subbasin for ^{90}Sr releases is SWSA 4 Main, followed by SWSA 5 Seep C and HRE. The highest ranked subbasin for ^{3}H releases is SWSA 5 Seep B West, followed by SWSA 4 Main, SWSA 5 Drainage D-2, and SWSA 5 Seep A.

3.3.2.2 Subbasin contaminant release mechanisms

Contaminant releases from source areas in the Melton Valley watershed are attributable to three contaminant release mechanisms: perennial inundation, seasonal/episodic inundation and infiltration, and erosion. Estimates of percentages of releases from individual subbasins occurring via these mechanisms are summarized in Table 3.6. These percentages are based on analyses of primary source area saturation using the following assumptions:

1. Primary source units that are more than 50% saturated under low base water table conditions are assumed to be perennially saturated;

2. Primary source units that are less than 50% saturated under low base water table conditions but more than 50% saturated under high base or high base storm water table conditions are assumed to be seasonally/episodically saturated; and

3. Primary source units that remain less than 50% saturated under high base or high base storm conditions are assumed to be perennially unsaturated.

The portions of primary source areas that are perennially inundated, episodically inundated, or perennially unsaturated based on these analyses are shown on Fig. 3.5. Subbasins from which a significant percentage of contaminant release is occurring due to perennial inundation are SWSA 4 Main, SWSA 4 East, HRE, SWSA 5 Seep B East, W6MS1, W6MS3, and SWSA 5 Seep B West.

Although only small amounts of particle-bound contaminants are observed to be discharged annually from the watershed, erosion is a potential release mechanism in subbasins containing contaminated floodplain sediments and/or contaminated surface soils. A sediment and ^{137}Cs transport study conducted as part of the WAG 2 RI (Clapp et al. 1996) concluded that releases of ^{137}Cs by erosion of surface soils and floodplain sediments during storms are relatively small and that the vegetative cover on these soils and sediments effectively controls the release of ^{137}Cs from the

Melton Valley watershed. Therefore, it appears that contaminant releases that may be occurring from subbasins in which there are contaminated floodplain sediments or surface soils are predominantly due to mechanisms other than erosion.

Table 3.5. Basin rankings by contribution to WOD risk

Basin ID	Contribution to total release, %		Contribution to risk, %	Risk contribution group
	^{90}Sr	^{3}H		
SWSA 4 Main	26.1	13.9	21.5	1
SWSA 5 Seep B West	0.0	48.6	12.2	1
SWSA 5 Seep C	15.4	3.6	11.5	1
HRE	12.2	0.0	8.4	2
SWSA 5 Seep B East	7.8	7.7	7.3	2
SWSA 4 East	7.2	0.6	5.1	2
SWSA 5 Drainage D-2	3.6	9.4	4.8	3
SWSA 5 WOC	6.0	0.0	4.1	3
SWSA 5 Seep A	0.0	9.4	2.4	3
W6MS3	1.0	6.6	2.3	3
West Seep	2.4	0.3	1.7	3
W6MS1	0.0	2.4	0.6	3
WC TRIB-1	<0.7	<0.5	<0.6	3
MB-15	<0.3	<0.1	<0.2	4
East Seep	<0.1	<0.1	<0.1	4
^{60}Co Seep	0.0	0.0	0.0	4
Big No-Name	0.0	0.0	0.0	4
Haw Ridge	0.0	0.0	0.0	4
HF-2	0.0	0.0	0.0	4
HFIR	0.0	0.0	0.0	4
HFIR East	0.0	0.0	0.0	4
HFIR South	0.0	0.0	0.0	4
Intermediate Pond	0.0	0.0	0.0	4
Little No-Name	0.0	0.0	0.0	4
Lower WOC	0.0	0.0	0.0	4
MV Drive	0.0	0.0	0.0	4
NHF	0.0	0.0	0.0	4
Pit 4 South	0.0	0.0	0.0	4
SWSA 5 N WOC	0.0	0.0	0.0	4
SWSA 5 Trib 1	0.0	0.0	0.0	4
SWSA 6 East	0.0	0.0	0.0	4
SWSA 6 South	0.0	0.0	0.0	4
Trench 5 South	0.0	0.0	0.0	4
WAG 7 WOC	0.0	0.0	0.0	4
WOC	0.0	0.0	0.0	4
WOCE	0.0	0.0	0.0	4
WOD Sliver	0.0	0.0	0.0	4

Table 3.6. Subbasin contaminant release mechanisms

Basin ID	Release mechanisms, %		
	Perennial inundation	Infiltration and seasonal inundation	Erosion
West Seep	5	>95	<5
SWSA 5 Drainage D-2	5	95	
SWSA 5 Seep C		>95	<5
^{60}Co Seep		>95	<5
WC TRIB-1		>95	<5
W6MS3	30	70	
SWSA 5 Seep B East	45	>50	<5
SWSA 4 Main	100	0	<5
East Seep		>95	<5
SWSA 5 WOC		100	
SWSA 5 Seep B West	20	>75	<5
W6MS1	40	>55	<5
SWSA 4 East	100		
SWSA 5 Seep A	10	>85	<5
SWSA 6 East		100	
SWSA 5 Trib 1		100	
HRE	>95		<5
SWSA 6 South		100	
SWSA 5 N WOC		100	
MB-15		>95	<5
Intermediate Pond		>95	<5
Pit 4 South		100	
Lower WOC/WOL		>95	<5
WOC		>95	<5
Big No-Name			
Little No-Name			
Trench 5 South			
WAG 7 WOC			
WOD Sliver			
Haw Ridge			
HF-2			
HFIR			
HFIR East			
HFIR South			
NHF			
MV Drive			
WOCE			

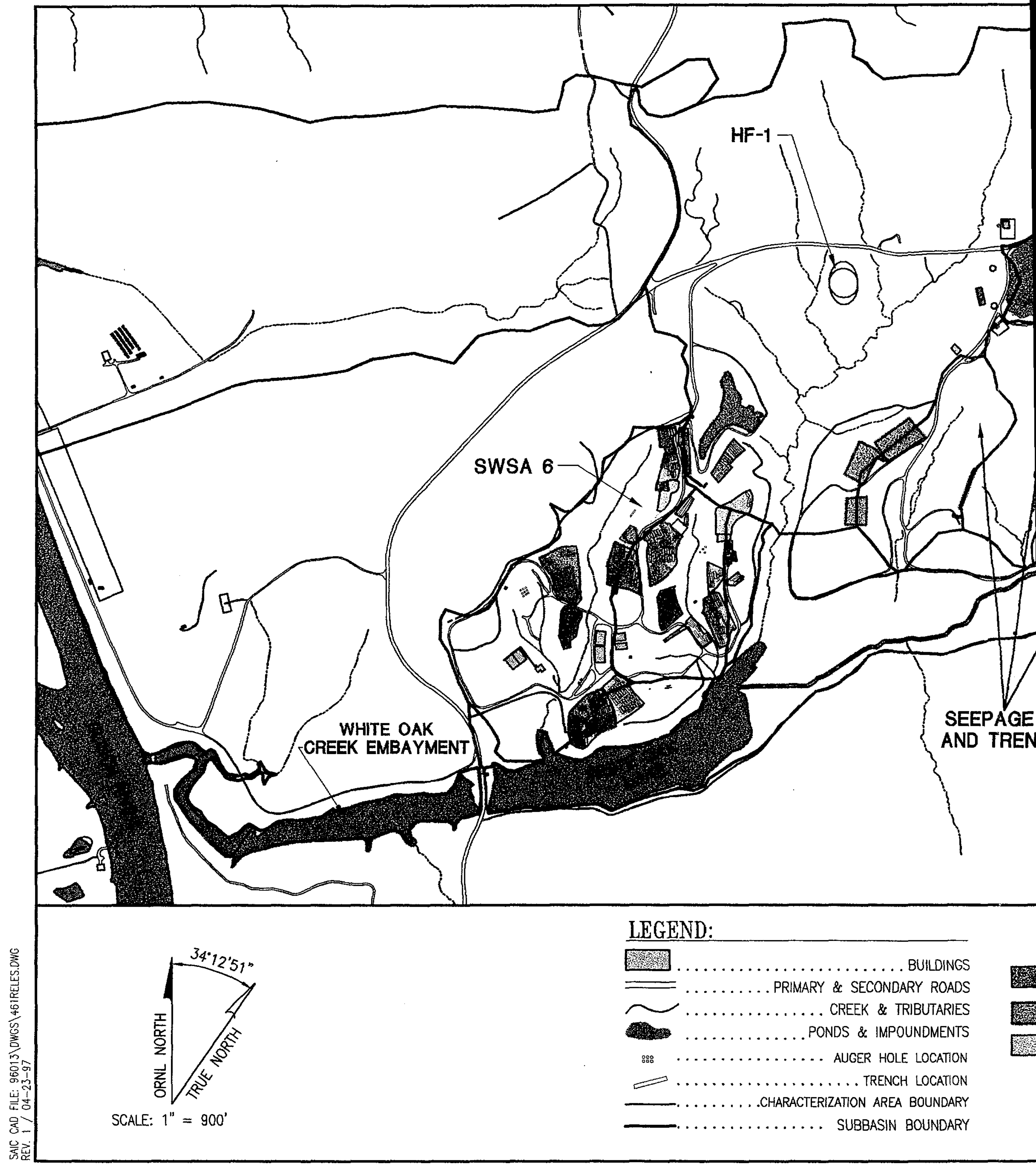
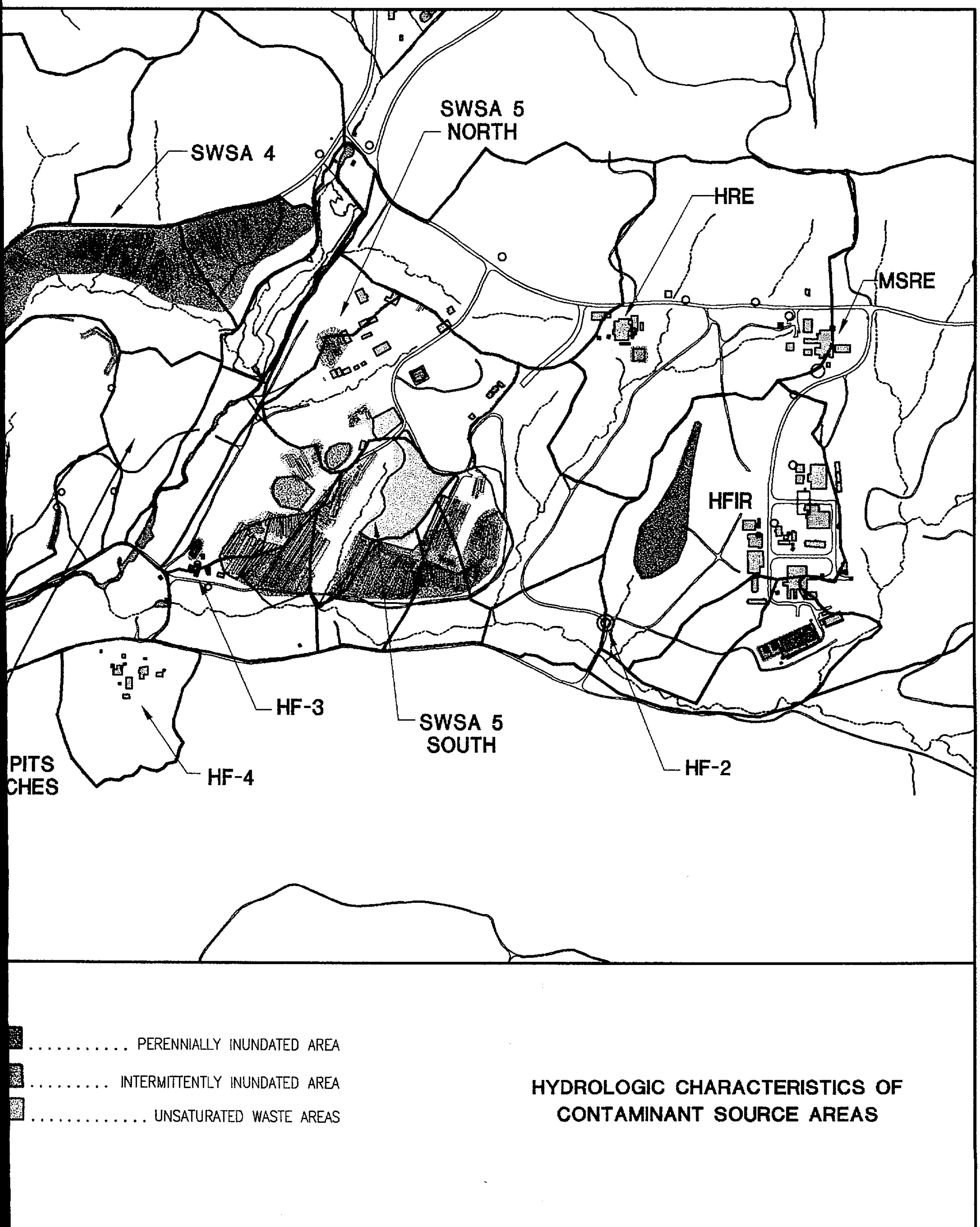


Fig. 3.5. Hydrologic characteristics of conta



inant source areas.

The release mechanism analysis performed for this RI probably overestimates the magnitude of releases due to perennial inundation because waste units that are assumed to be perennially inundated may be up to 50% unsaturated. A more rigorous release mechanism analysis would require determination of the actual primary and secondary source volumes that are inundated under low base, high base, and high base storm water table conditions. Such an analysis would require much more data than are currently available and would be costly to acquire. However, the existing analysis is still useful for comparing subbasins.

3.3.3 Potential Human Health Risk in the Melton Valley Watershed

Potential risk to humans caused by contaminants in surface water, groundwater, soil, and sediment has been assessed for the recreational, industrial, and residential exposure scenarios in each subbasin in the Melton Valley watershed. This report presents the results for the recreational exposure scenario as the reference point for identifying areas in which potential action levels are exceeded for the four media assessed. Potential human health risk for the recreational and industrial scenarios for each subbasin are discussed in Sects. 3.4 through 3.8. Complete details of the human health risk assessment are included in Appendix B of this report.

Table 3.7 includes the subbasin summary recreational risk estimates for main stem surface water, seeps and small tributary surface water, groundwater, soil, and sediment. Risk values are calculated for carcinogenic chemicals and hazard indexes (HIs) are calculated for noncarcinogenic chemicals. For the recreational scenario, estimated risk values are significantly higher for soil and sediment than for surface water or groundwater. The reason for this is the strongly particle reactive nature of radionuclides such as ^{137}Cs, ^{60}Co, and uranium and TRU isotopes. These contaminants tend to accumulate in soil and sediment by adsorption to particles, are then susceptible to transport along with the particles, and emit radiation causing direct exposure or may be ingested. For the recreational scenario, soil risk estimates exceed the 1E-04 threshold in 17 subbasins in the Melton Valley watershed, sediment risk estimates exceed 1E-04 in 7 subbasins, groundwater risks exceed 1E-04 in 6 subbasins, and surface water risk estimates exceed 1E-04 in 4 subbasins and are limited to results from seeps and small tributaries. No 1E-04 exceedances were reported for main stem surface water stations under the recreational risk scenario. Figure 3.6 shows the distribution of potential human health risk for each medium estimated for the recreational scenario throughout the Melton Valley watershed.

3.3.4 Summary of Ecological Risks Within the Melton Valley Watershed

Potential ecological risks to plants, soil invertebrates, terrestrial wildlife, aquatic invertebrates, fish, and piscivorous wildlife were assessed using soil, sediment, and surface water and seep data. The following discussion summarizes the ecological risk assessment results. Figures 3.7 and 3.8 graphically portray potential risks to aquatic and terrestrial biota within the watershed.

Soil Exposures

Ecological risks were evaluated for plants, soil invertebrates, and terrestrial wildlife exposed to radionuclide and nonradionuclide contaminants in surface soil within each subbasin in the watershed for which surface soil data were available. Nonradiological data were available from 22 subbasins; radiological data were available from 28 subbasins. Only one formal line of evidence, single chemical toxicity data, was available to evaluate potential risks for terrestrial flora and fauna. The general approach used was to compare exposure point concentrations or daily doses to available

Table 3.7. Human health, recreational sce

Basin ID	Main stem SW risk	Main stem SW HI	Seep and small trib. SW risk	Seep and small trib SW HI	Groundwater risk	Groundwater HI	Soil risk	Soil HI	Sedim risk
SWSA 5/WOC	**4.30E-04**	3.30E-02	1.10E-05	5.10E-02	**1.20E-03**	1.90E-01	3.90E-05	1.70E-02	**1.00E+**
East Seep			1.80E-05	3.90E-02	1.50E-06	1.70E-02	**2.60E-01**		
West Seep	7.00E-06	1.80E-02	2.40E-05	1.50E-01	1.20E-05	1.00E-01	**2.30E-01**	4.00E-02	
MB-15	1.10E-05	5.80E-02	2.60E-07	3.50E-03	2.50E-06	5.70E-03	**8.10E-02**		
SWSA 4 Main	1.10E-05	8.80E-02	8.70E-05	1.90E-01	**2.60E-04**	2.70E-01	**3.70E-02**	2.80E-02	**1.60E-**
SWSA 5 Trib 1	2.90E-05	3.40E-02	1.50E-05	9.40E-02	4.90E-06	8.40E-02	**4.90E-04**	6.70E-03	**1.70E-**
SWSA 5 Seep C	6.00E-06	1.30E-03	**1.40E-03**	1.20E-01	**7.70E-03**	3.00E-02	**2.80E-04**	2.70E-02	**8.10E-**
SWSA 5 Seep B West	2.30E-06		**4.70E-03**	4.10E-02	**3.70E-03**	5.70E-02	**3.00E-03**	1.20E-02	
SWSA 5 Seep B East	3.30E-05	1.90E-03	2.60E-05		7.90E-05	1.30E-01	**4.30E-03**	6.70E-03	
WCTRIB-1			6.40E-06	1.60E-03	2.80E-06	3.50E-02	**4.30E-03**		
Intermediate Pond	3.90E-06	7.70E-03	8.90E-05	3.20E-02	7.30E-06	2.80E-01	**2.80E-03**	1.00E-01	**1.60E-**
Lower WOC	4.70E-05	7.30E-02	**2.10E-03**	6.70E-02	**1.10E-04**	8.00E-02	**2.80E-04**	1.60E-02	**2.50E-**
WAG 7/WOC			3.20E-06	1.30E-02	2.00E-08		**2.4E-03**		
SWSA 5 Drainage D-2			8.60E-05	1.10E-01	**2.20E-03**	2.40E-01	3.60E-05		6.30E-
HRT-3	6.90E-06	6.90E-02	9.10E-06	5.70E-02	4.00E-05	6.60E-01	**1.70E-03**	4.90E-02	8.40E-
SWSA 5 Seep A	1.10E-05	8.80E-02	8.70E-05	2.50E-01	**1.70E-03**	6.50E-02	1.30E-05	8.10E-03	6.70E-
WOC Embayment	6.10E-07	1.70E-02							**1.40E-**
Haw Ridge					3.70E-07	5.20E-02	**8.70E-04**		
WOC	3.90E-05	1.40E-01	1.10E-05	2.30E-01	1.60E-08	9.50E-02	**2.30E-04**	2.80E-02	**6.00E-**
SWSA 4 East					**5.50E-04**	2.40E-01			
Pit 4/south			4.50E-06	9.60E-02			**4.80E-04**		**3.80E-**
HF-2	3.10E-06	2.00E-02	2.10E-05	1.00E-01	2.10E-08		**3.90E-04**	3.00E-02	1.20E-
MV Drive			6.70E-06	6.70E-02	4.30E-06	2.10E-01	**1.40E-04**		
SWSA 6 East	2.20E-06	2.80E-03			1.60E-05	**2.10E+00**	**1.10E-04**	8.60E-02	
W6MS3	2.70E-05	8.60E-02	4.40E-05	1.50E-01	8.80E-05	**1.50E+00**	4.40E-06	4.80E-02	
W6MS1	5.40E-05	7.00E-02	4.50E-05	1.60E-01	1.40E-05	9.20E-02	1.10E-05	7.30E-02	
HFIR							5.10E-05		
Little No-Name	5.90E-06	6.50E-02			2.80E-05	7.50E-02	7.50E-07	4.40E-02	
Big No-Name							2.40E-05		
SWSA 5 N/WOC	5.00E-07		7.80E-06	1.30E-01	5.90E-06	4.80E-02	1.40E-05		
SWSA 6 South					9.60E-06	4.60E-01	2.00E-06	5.30E-02	
NHF					4.70E-06	3.10E-02	5.00E-06		
^{60}Co Seep					1.70E-06	1.10E-02			
WOD Sliver					1.70E-07	8.20E-01			
HFIR/south	9.20E-08								
Trench 5/south					1.50E-08				
HFIR/east			3.20E+08		1.00E-08				

Bold = Risk greater than 1.0E-04
CCL_4 = Carbon tetrachloride
1,1-DCE = 1,1-Dichloroethene
DNO = Di-n-octylphthalate
PCE = Tetrachloroethene
VC = Vinyl chloride

rio risks for WOL Melton Valley RI Area subbasins

Sed HI	Main stem SW COCs	Seep and small trib SW COCs	Groundwater COCs	Soil COCs	Sediment COCs
1.20E-01	^{90}Sr, ^{137}Cs, ^{14}C, PCE, 1,1-DCE		VC, ^{90}Sr, ^{3}H, CCl_4, PCE		^{137}Cs, ^{60}Co, ^{226}Ra, ^{228}Ra, ^{90}Sr, ^{244}Cm, ^{228}Th, ^{241}Am, ^{238}Pu, $^{239/240}$Pu, PCB-1260
				^{137}Cs, ^{60}Co, ^{208}Tl, ^{228}Th	
				^{60}Co, ^{137}Cs, ^{40}K, ^{208}Tl	
1.10E-02				^{60}Co, ^{137}Cs	
1.10E-01			^{234}U, ^{90}Sr, ^{137}Cs, As, ^{241}Am, ^{14}C	^{137}Cs, Be, ^{90}Sr	^{137}Cs
1.40E-01				^{60}Co, ^{137}Cs, ^{226}Ra, ^{208}Tl, ^{40}K, ^{228}Ac, ^{214}Bi, ^{228}Ra	^{60}Co, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{90}Sr, ^{241}Am, PCB-1248, ^{244}Cm, ^{233}U, PCB-1260, ^{214}Bi
9.50E-03		^{90}Sr, ^{14}C, ^{3}H, Be, PCE, ^{45}Ca, 1,1-DCE	^{90}Sr, ^{3}H, ^{137}Cs, ^{14}C, VC, PCE, ^{40}K, 1,1-DCE	^{137}Cs, ^{60}Co, ^{226}Ra, Be, ^{40}K, ^{228}Ra	^{137}Cs, ^{60}Co
9.70E-03		^{90}Sr, ^{3}H, ^{14}C, Be, PCE, ^{45}Ca, $^{233/234}$U, 1,1-DCE,	^{90}Sr, ^{3}H, ^{137}Cs, ^{14}C, VC, PCE, ^{40}K, 1,1-DCE	^{60}Co, ^{226}Ra, ^{137}Cs, ^{90}Sr, ^{228}Ra, ^{40}K	
1.10E-02				^{137}Cs, ^{208}Tl, ^{40}K	
				^{137}Cs, ^{60}Co	
2.50E-02				^{137}Cs, ^{60}Co, PCB-1260, ^{228}Th	^{137}Cs, ^{60}Co, PCB-1260
2.70E-01		^{90}Sr, ^{3}H, Be, PCE	^{90}Sr, ^{3}H, As, 1,1-DCE, PCE	^{137}Cs, ^{60}Co	^{137}Cs, ^{60}Co, Be, PCB-1260
				^{137}Cs, ^{40}K	
3.80E-01			^{238}Pu, ^{3}H, ^{230}Th, PCE, ^{90}Sr, VC, 1,1-DCE, ^{40}K, $^{233/234}$U, CCl_4		
1.30E-01				^{137}Cs, ^{226}Ra, ^{154}Eu, ^{208}Tl	
3.10E-02			^{234m}Pa, ^{3}H, ^{90}Sr, ^{14}C, ^{241}Am, ^{137}Cs, VC, PCE, ^{40}K, 1,1-DCE		
9.90E-02					^{137}Cs, ^{60}Co, Be, $^{239/240}$Pu
				^{137}Cs, ^{60}Co	
1.20E-02				^{137}Cs, ^{60}Co, PCB-1260	^{137}Cs, ^{60}Co, PCB-1260, benzo(a)pyrene
			VC, ^{3}H, As, ^{90}Sr, 1,1-DCE, total Sr		
				^{60}Co, ^{137}Cs, ^{228}Th	^{60}Co
6.00E-02				^{60}Co	
				^{137}Cs, ^{60}Co	
			DNO	^{60}Co, ^{40}K, ^{228}Ra	
5.20E-02			DNO, PCB-1254, PCE		
6.50E-03					
4.40E-02					

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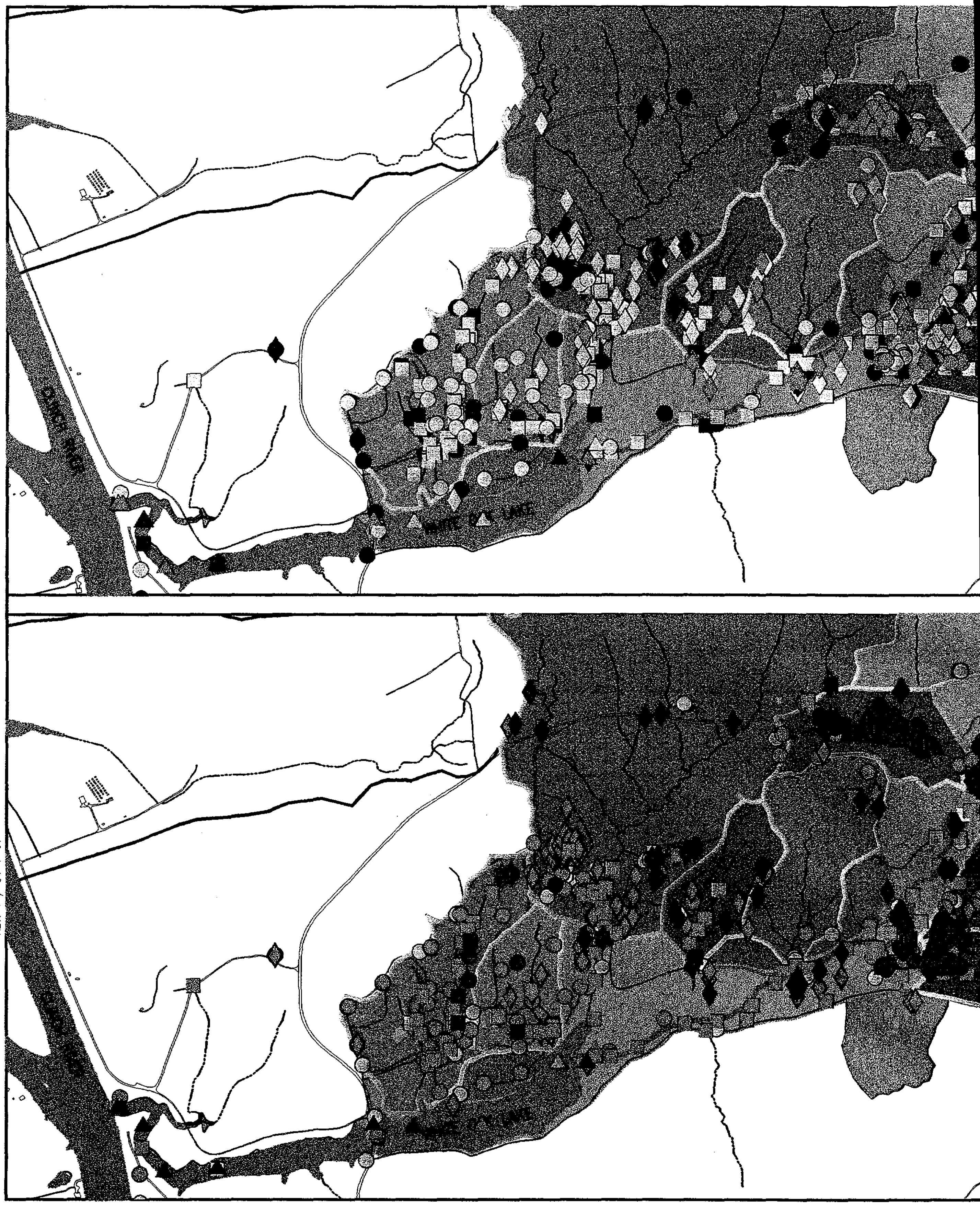
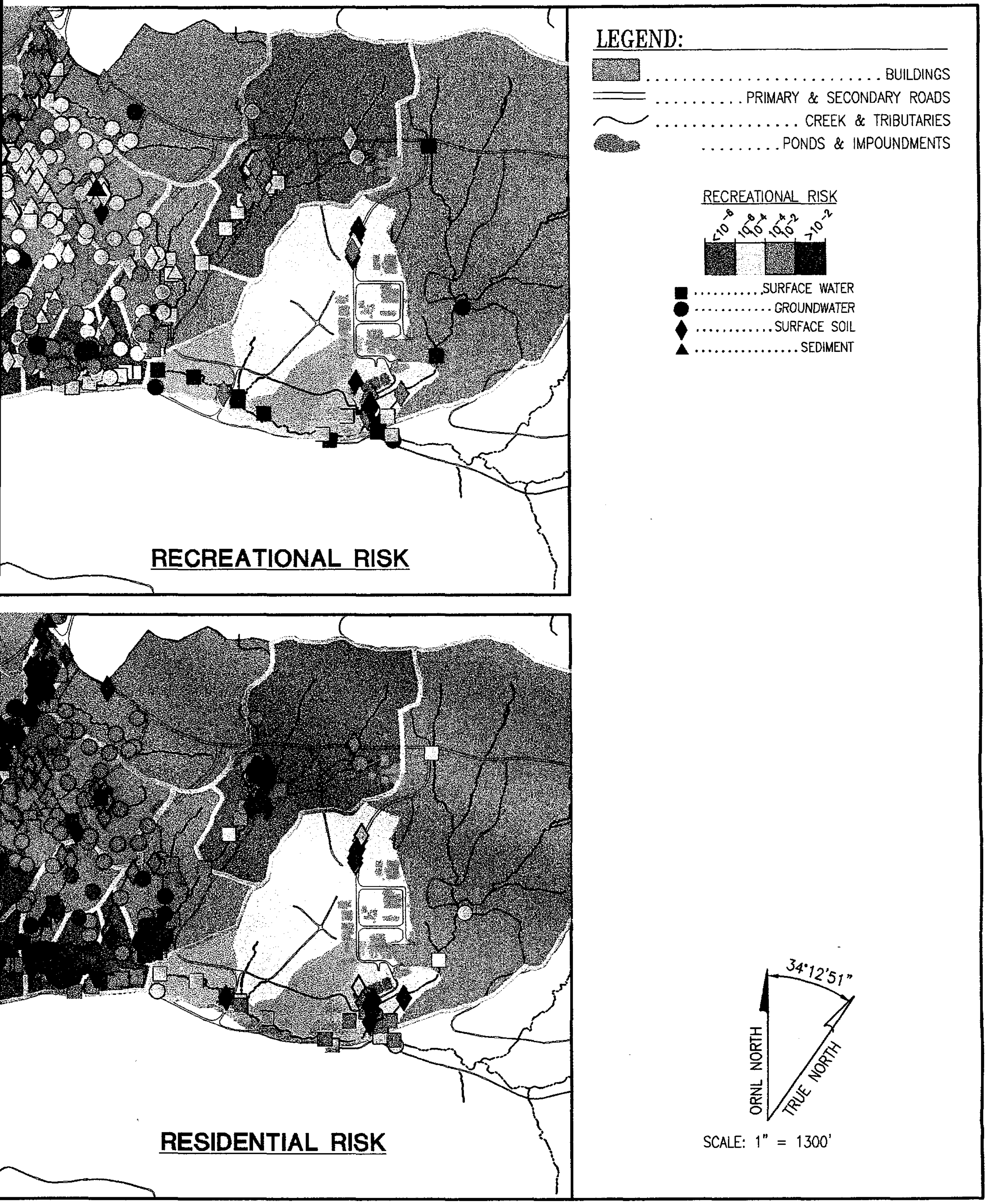
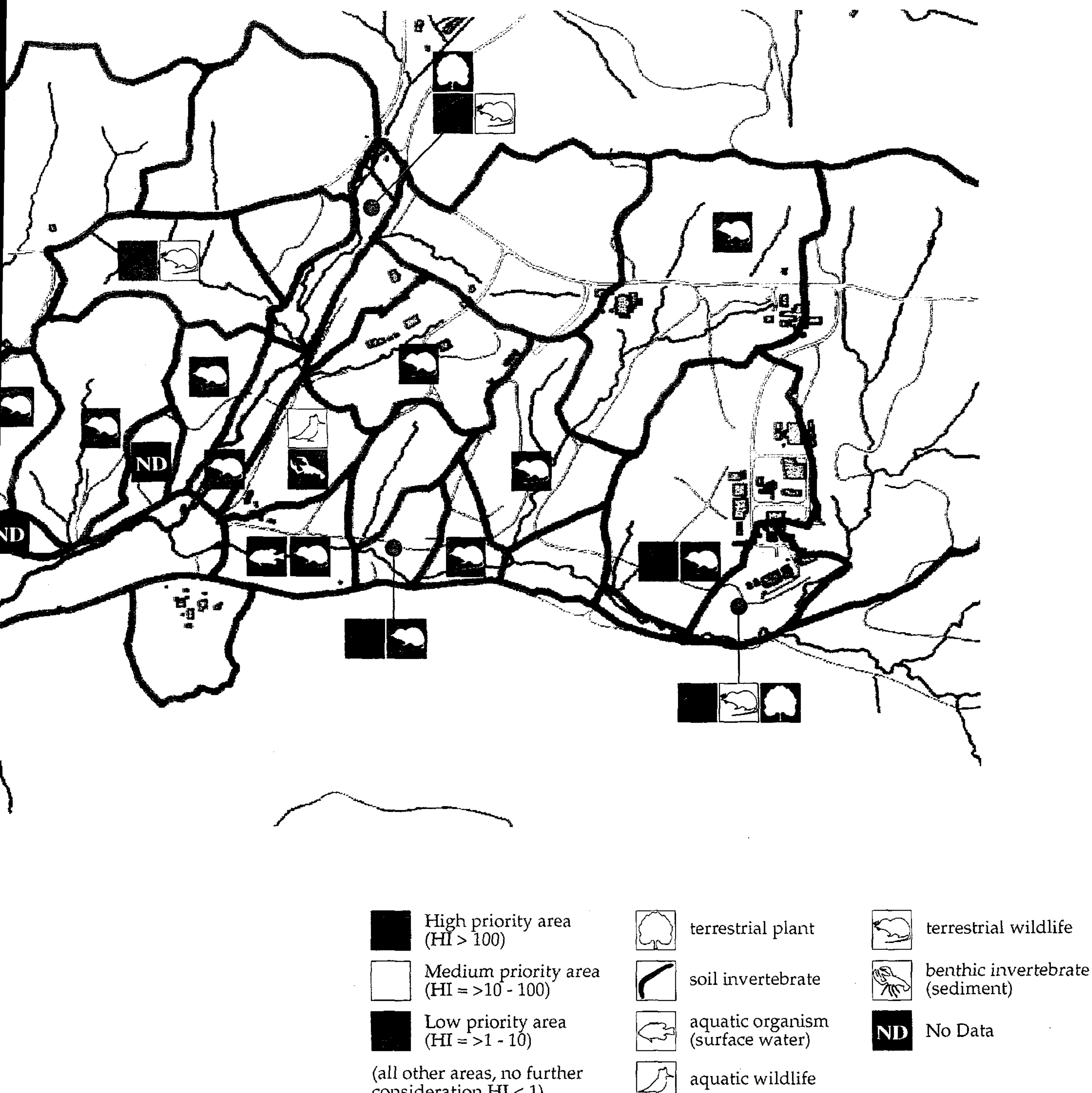


Fig. 3.6. Distribution of potential human health r



in the Melton Valley watershed.

Fig. 3.7. Estimated radiological ecorisk in subbasins of the Melton Valley wate



ned.

WOC - RAD map

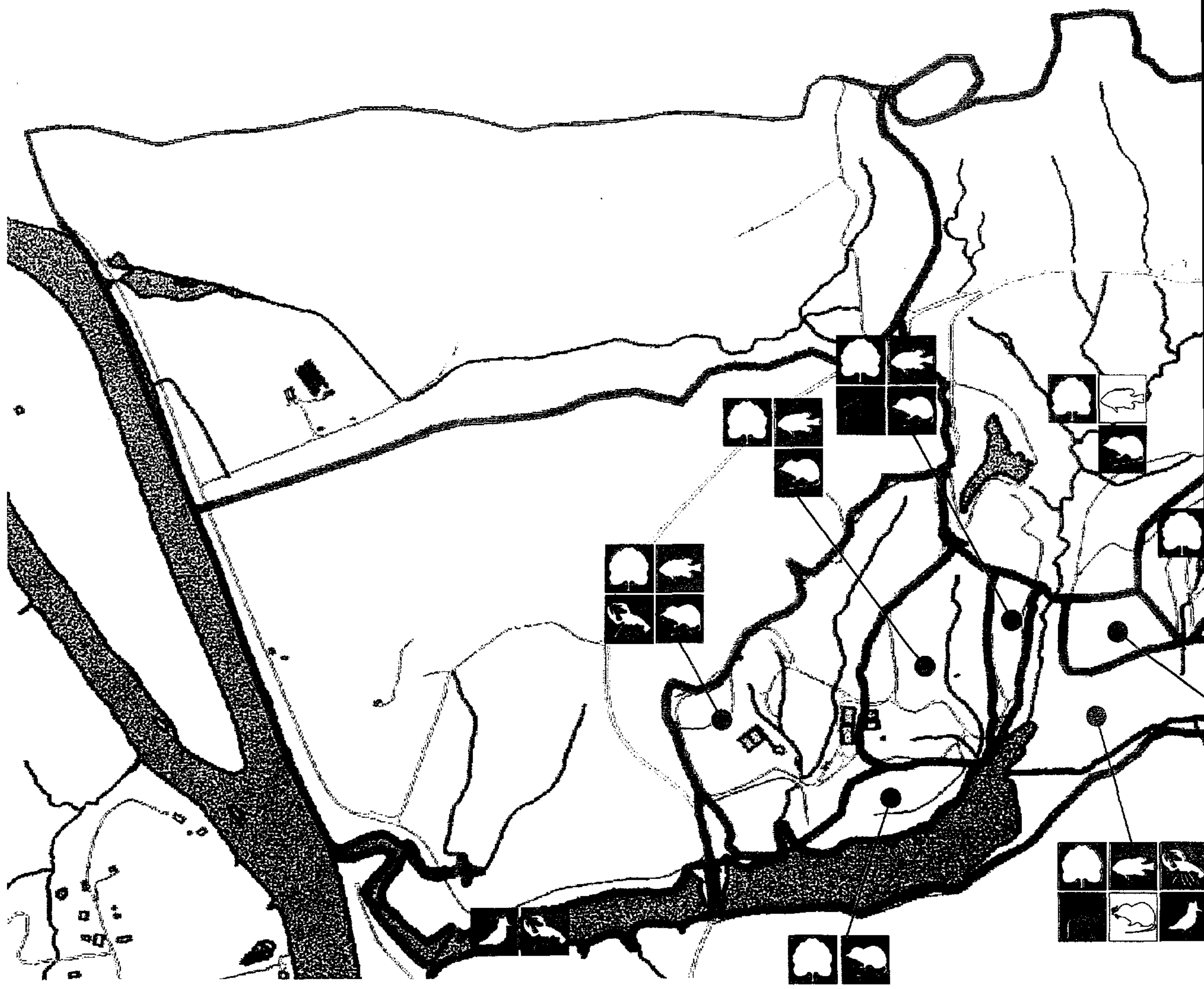
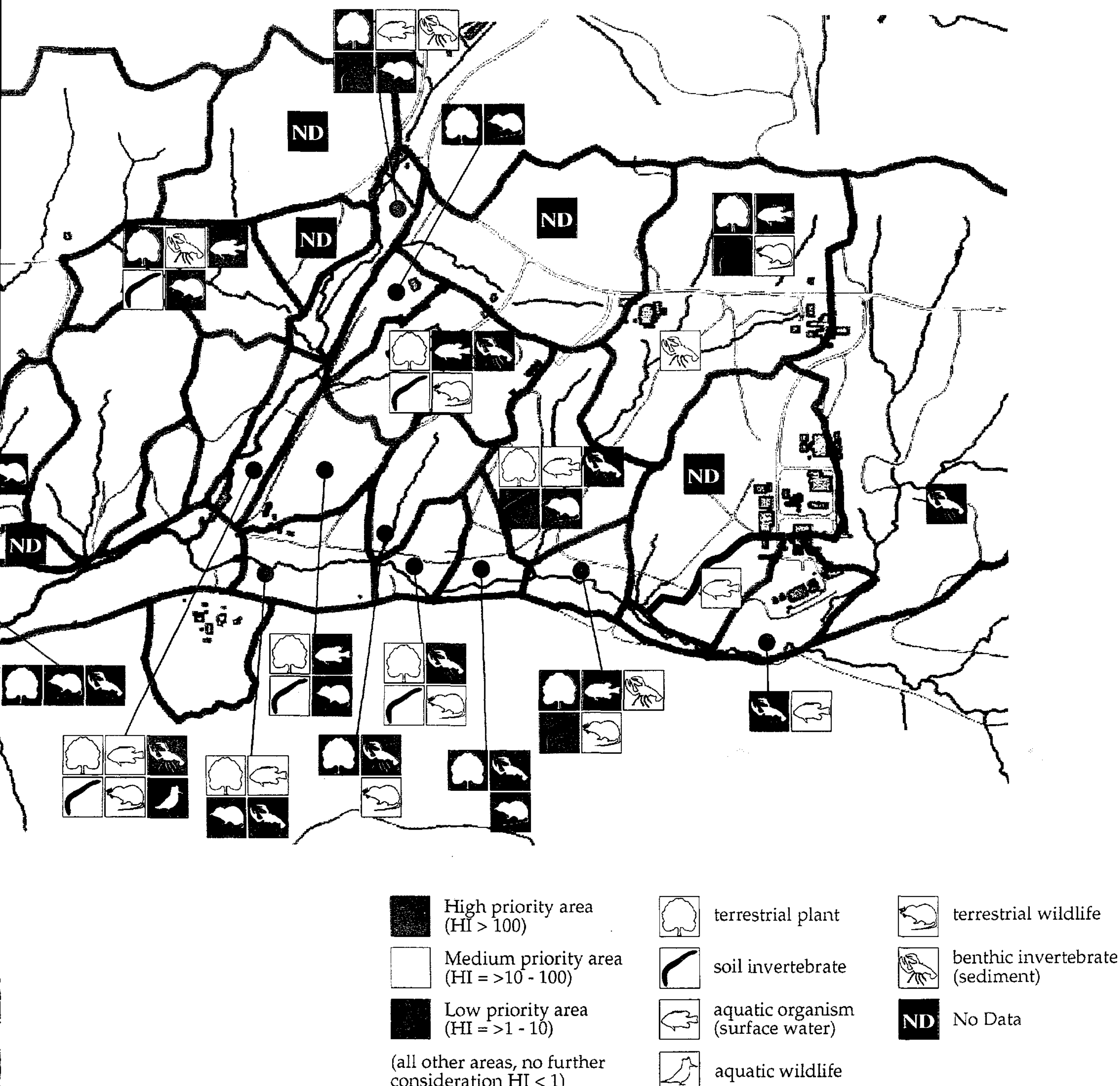


Fig. 3.8. Estimated nonradiological ecorisk in subbasins of the Melton Val



watershed.

WOC - Non-RAD map

toxicity benchmarks for each analyte to obtain hazard quotients (HQs). HQs were summed over all analytes to obtain HIs. The HIs were used as a means of comparing relative risks among subbasins, but they should not be interpreted as a measure of actual risks present within a subbasin. It is rather uncertain whether effects of various chemicals are additive, antagonistic, or unrelated, so while the HI is useful as an aid in developing a relative ranking of subbasins, actual risks to receptors should be evaluated by examining individual HQs. For radionuclides, where the overall dose rate is additive, the HI is a meaningful number.

For plants and soil invertebrates, the results are presented based on evaluation of each subbasin individually because the subbasin scale is relevant to populations of these receptors. For terrestrial wildlife, analytes potentially presenting risks were identified by screening modeled exposure doses against LOAELs [toxicological benchmarks from Sample et al. (1996)]. The ecological risk assessment (Appendix C) provides greater detail on the methods used to evaluate potential risks within the watershed.

A summary of potential risks for each receptor by subbasin for both radionuclide and nonradionuclide analytes is presented in Tables 3.8 and 3.9. The overall nonradionuclide and radionuclide exposure HIs are included and risk drivers are identified. Potential risks from nonradionuclide soil-related exposures were identified for 21 subbasins for plants, 11 for soil invertebrates, 21 for short-tailed shrews, 11 for white-footed mice, 11 for red fox, 3 for white-tailed deer, 8 for red-tailed hawks, 5 for wild turkeys, and 6 for mink (Table 3.8). The Intermediate Pond resulted in the highest risks for all receptors due to high soil mercury concentrations. Radionuclide exposures resulted in potential risks to terrestrial biota at 16 subbasins (Table 3.9). Radionuclide risks were highest in the East Seep subbasin with ^{137}Cs driving risks for all receptors.

Potential nonradionuclide risks to plants were identified in at least one subbasin from exposure to maximum concentrations of antimony, arsenic, barium, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, selenium, silver, thallium, tin, and zinc in soil (Table 3.8). HQs were generally low (<3.8) except for mercury, nickel, silver, and zinc at the Intermediate Pond; chromium and zinc at HF-2; chromium, mercury, and zinc at Lower WOC/WOL; zinc, mercury, and silver at WOC; mercury at SWSA 5 Trib 1 and Seep B West; nickel at SWSA 4 Main; chromium at HRE; and zinc and selenium at Seep A. Potential risks to plants from exposure to radionuclides were identified in five subbasins. Cesium-137 was the risk driver in East Seep soils; plutonium-239/240, at the Intermediate Pond and Lower WOC/WOL subbasins; and ^{60}Co, at MB-15 and West Seep.

Potential nonradionuclide risks to soil invertebrates were identified in at least one subbasin from exposure to maximum concentrations of chromium, copper, mercury, nickel, and zinc (Table 3.8). HQs were generally low (<4.5) with the exception of mercury at the Intermediate Pond, LWOC, WOC, SWSA 5 Trib 1, Seep B West, and SWSA 5 WOC; chromium at LWOC, HF-2 and HRE; and nickel at SWSA 4 Main. Potential risks to soil invertebrates from exposure to radionuclides in surface soil were identified in seven subbasins. Cesium-137 was the risk driver in East Seep and SWSA 4 Main. Cobalt-60 was the primary risk driver at MB-15 and West Seep, and $^{239/240}$Pu was the primary risk driver at the Intermediate Pond. Strontium-90 was the risk driver at the HFIR and Seep B West subbasins.

LOAELs for at least one wildlife receptor (short-tailed shrew, white-footed mouse, red fox, white-tailed deer, red-tailed hawk, wild turkey, or mink) were exceeded in at least one subbasin as a result of arsenic, barium, cadmium, chromium, copper, mercury, molybdenum, nickel, selenium, thallium, zinc, and PCB-1260 (Table 3.8). However, only arsenic, chromium, mercury,

Table 3.8. Summary of potential risks to terrestrial biota

Subbasin	Receptors at risk[a]	HI[b]	Hazard quotients for risk driving analytes[c]															
			Ag	As	Ba	Cd	Co	Cr	Cu	Hg	Mo	Ni	PCB-1260	Sb	Se	Sn	Tl	Zn
Intermediate Pond	Plants	286.6	8.7							255.0	2.6	10.3						6.6
	Invertebrates	767.3								764.0		1.6						1.7
	Shrew	291.0								279.0	1.8	1.2	4.6					1.0
	Mouse	41.0								39.4								
	Fox	216.5								215.0								
	Deer	3.0								2.6								
	Hawk	40.9								40.4								
	Turkey	10.6								10.5								
	Mink	66.8								66.4								
HF-2	Plants	186.6			1.9		2.0	168.0			1.5							11.6
	Invertebrates	422.9						420.0										2.9
	Shrew	39.0			3.8			29.5			1.2							3.3
	Mouse	5.8						4.2										
	Fox	4.5			1.1			2.3										
	Deer	1.6			1.3													
	Hawk	1.2																1.0
Lower WOC/WOL	Plants	150.2	3.4					116.0		17.0	2.0				1.3			8.2
	Invertebrates	343.2						290.0		51.0								2.1
	Shrew	46.4						15.4		23.2	1.5		2.3		1.2			1.6
	Mouse	6.6						2.2		3.3								
	Fox	20.3						1.2		17.9								
	Hawk	3.9								3.4								
	Turkey	1.0								0.9								
	Mink	6.0								5.5								
SWSA 4 Main	Plants	267.6										262.0			2.0			2.4
	Invertebrates	39.9										39.3						
	Shrew	165.0			1.8							159.0			2.5			
	Mouse	23.6										22.7						
	Fox	15.0										13.8						
	Deer	2.5										1.8						
	Hawk	2.0										1.6						
	Turkey	2.0										1.8						
	Mink	2.2										1.8						

Table 3.8 (continued)

Subbasin	Receptors at risk[a]	HI[b]	Hazard quotients for risk driving analytes[c]															
			Ag	As	Ba	Cd	Co	Cr	Cu	Hg	Mo	Ni	PCB-1260	Sb	Se	Sn	Tl	Zn
HRE	Plants	110.5				1.1		104.0										4.8
	Invertebrates	261.4						260.0										1.2
	Shrew	15.2			1.0			11.5					1.2					
	Mouse	2.2						1.6										
	Fox	1.6																
WOC	Plants	53.7	12.6						1.6	16.0	2.0				1.6			18.2
	Invertebrates	55.9							3.3	48.0								4.5
	Shrew	37.6							1.4	25.0	1.5		4.1		1.5			3.4
	Mouse	5.4								3.5								
	Fox	21.8								19.3								
	Hawk	4.9								3.6								1.0
	Turkey	1.2								0.9								
	Mink	6.9								6.0								
SWSA 5 Trib 1	Plants	20.6	1.6							14.3					3.3			
	Invertebrates	43.1								43.0								
	Shrew	33.8								30.3					1.7			
	Fox	24.0								23.4								
	Mouse	4.8								4.3								
	Hawk	4.5								4.4								
	Turkey	1.2								1.2								
	Mink	7.4								7.2								
SWSA 5 Seep A	Plants	13.8	1.1												5.1			6.4
	Invertebrates	1.7																1.6
	Shrew	6.8													4.7			1.1
	Fox	1.1																
SWSA 5 Seep B West	Plants	11.7								6.7	1.7			1.2	1.3			
	Invertebrates	20.1								20.0								
	Shrew	19.2								15.6	1.4				1.6			
	Mouse	2.7								2.2								
	Fox	12.4								12.0								
	Hawk	2.3								2.3								
	Mink	3.8								3.7								
SWSA 5 Seep B East	Plants	1.8																
	Shrew	2.3											1.6					

Table 3.8 (continued)

Subbasin	Receptors at risk[a]	HI[b]	Hazard quotients for risk driving analytes[c]															
			Ag	As	Ba	Cd	Co	Cr	Cu	Hg	Mo	Ni	PCB-1260	Sb	Se	Sn	Tl	Zn
SWSA 5 Drainage D-2	Plants	1.6	1.1															
	Shrew	19.9											19.0					
	Mouse	2.8											2.7					
	Fox	2.1											1.9					
SWSA 5 Seep C	Plants	15.2	2.5				2.6				3.7			2.4			1.4	
	Shrew	6.5			1.1						3.2				1.0			
SWSA 5 WOC	Plants	10.7	1.1							3.2					1.7			2.4
	Invertebrates	10.3								9.6								
	Shrew	9.8								6.5					1.3			
	Fox	5.6								5.0								
	Mouse	1.4								0.9								
	Hawk	1.1								0.9								
	Mink	1.7								1.5								
SWSA 5 N WOC	Plants	2.5	1.1												1.4			
	Shrew	1.8													1.8			
West Seep	Plants	9.6	1.5			1.7	2.0					2.3				1.7		
	Shrew	2.1										0.9						
W6MS3	Plants	5.4	1.8	1.5		1.4												
	Shrew	2.5		1.8														
W6MS1	Plants	5.4		1.3		1.6						2.2						
	Shrew	6.4		4.3								1.2						
SWSA 6 South	Plants	4.2		2.2		1.1												
	Shrew	9.2		8.1														
	Mouse	1.2		1.1														
SWSA 6 East	Plants	6.9				1.8						2.0						2.6
	Invertebrates	1.2																
	Shrew	3.8				1.0						1.2						
Pit 4 South	Plants	5.8									2.1				1.2		1.2	
	Shrew	5.1			1.1						1.8				1.5			
East Seep	Plants	4.3													1.2		2.5	
	Shrew	4.0			1.2										1.5		1.2	

No risks were identified for the NHF or WAG 7 WOC subbasin.

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, red-tailed hawk, wild turkey, and mink in each subbasin.

[b] *HI = Sum of HQs for all analytes detected above background.*

[c] HQ = Ratio of exposure concentration or daily dose to effects concentrations or LOAEL–based toxicological benchmarks. Risk-driving analytes were generally identified as those with a HQ >1.0.

Table 3.9. Summary of potential radiological risks to terrestrial biota within the Melton Valley Area

Subbasin	Max. HI[a]	Risk drivers (% of max. HI)	Receptors at risk[b]
East Seep	148.0	^{137}Cs (99.9%)	P, I, S, M, F, D, H, T, K
Intermediate Pond	41.6	$^{239/240}$Pu (77.8%), ^{241}Am (14.7%), ^{137}Cs (3.2%) [$^{233/234}$U][c]	P, I, S, M, F, T
MB-15	30.6	^{60}Co (99.7%)	P, I, S, M, F
West Seep	53.0	^{60}Co (98.7%)	P, I, S, M, F, D, H, T, K
SWSA 4 Main	18.8	^{137}Cs (98.9%)	I, S, M, F, D, H, T, K
Lower WOC/WOL	17.4	$^{239/240}$Pu (88.5%), ^{241}Am (5.7%)	P, S, M
SWSA 5 Seep B West	8.0	^{244}Cm (71.2%), ^{241}Am (13.8%) [^{90}Sr][d]	I, S, M, D, T
WOC	4.2	$^{239/240}$Pu (66.7%), ^{244}Cm (11.9%), ^{241}Am (9.5%)	S, M
HFIR	3.7	^{90}Sr (89.2%)	I, D, T
HRE	2.4	$^{233/234}$U (66.0%), ^{137}Cs (26.5%)	T
SWSA 5 Seep B East	2.2	^{137}Cs (97.2%)	S, M, F, T, K
SWSA 5 Trib 1	1.9	^{238}Pu (79.9%)	S, M
WC TRIB-1	1.8	^{137}Cs (99.4%)	S, M, F, T, K
SWSA 5 Seep C	1.8	^{244}Cm (50.0%)	S, M
WAG 7 WOC	1.5	^{137}Cs (80.0%)	S, M, T
SWSA 5 Seep A	1.0	$^{239/240}$Pu (60.0%)	S, M

No risks were identified at the HFIR East, HF-2, SWSA 5 Drainage D-2, MV Drive, SWSA 5 WOC, SWSA 5 N WOC, Haw Ridge, W6MS3, W6MS1, SWSA 6 South, SWSA 6 East, Pit 4 South, or NHF subbasins.

[a] The HI is the result of dividing the overall dose rate (mrad/d) from exposure to all detected radionuclides (and short-lived daughter products) for a given receptor by the recommended dose rate limit of 100 mrad/d for terrestrial wildlife or 1 rad/d for plants and soil invertebrates.

[b] Abbreviations are as follows: plants (P), soil invertebrates (I), short-tailed shrews (S), white-footed mice (M), red fox (F), white-tailed deer (D), red-tailed hawk (H), wild turkey (T), and mink (K).

[c] This radionuclide was a risk driver for turkeys at the Intermediate Pond.

[d] Strontium-90 was the risk driver for invertebrates, deer, and turkey at Seep B West, contributing >57% of the dose for these receptors.

molybdenum, nickel, selenium, and PCB-1260 for the shrew and mercury for the fox resulted in potential watershed-wide effects. The concentration of mercury at the Intermediate Pond was an order of magnitude higher than in any other subbasin. The WOC, Lower WOC/WOL, SWSA 5 Trib 1, and Seep B West subbasins were also major contributors to high mercury exposures. The SWSA 5 Drainage D-2 subbasin was the primary contributor to PCB-1260 exposures, followed by the Intermediate Pond and WOC. Seep C subbasin was the most significant contributor to molybdenum exposures. Selenium exposures were highest in the Seep A, SWSA 4 Main, Pit 4 South, and SWSA 5 N WOC subbasins. Nickel risks were driven entirely by a single location in SWSA 4 Main.

Potential risks from exposure to radionuclides in surface soil were identified for at least one wildlife receptor at 16 subbasins (Table 3.9). Shrews and mice generally received the highest dose rates. Cesium-137 was the primary risk driver in East Seep, SWSA 4 Main, Seep B East, WC TRIB-1, and WAG 7 WOC soils. Plutonium-239/240 was the primary risk driver at the Intermediate Pond, Lower WOC/WOL, WOC, and SWSA 5 Seep A. Cobalt-60 contributed the highest dose rate at MB-15 and West Seep. Curium-244 was the risk driver at Seep B West and SWSA 5 Seep C and was a significant contributor at WOC. Strontium-90 was a risk driver at the HFIR subbasin and at

Seep B West. Plutonium-238 was the primary risk driver at SWSA 5 Trib 1. Uranium-233/234 was the risk driver in the HRE subbasin.

Surface Water Exposures

Ecological risks were evaluated for aquatic organisms and piscivorous wildlife exposed to nonradiological contaminants in unfiltered surface water within each subbasin in the watershed for which surface water data were available. Evaluations were restricted to unfiltered surface water samples from main stem streams and large tributaries potentially providing suitable habitat for fish. Risks were estimated by subbasin by comparing the distribution of observed concentrations to different types of aquatic benchmarks. Chemicals were considered to present significant risk if at least 20% of the concentrations exceeded probable effects benchmarks. In addition, risks to terrestrial plants were evaluated based on exposure to unfiltered surface water at identified seeps. Nonradiological data were available from 20 subbasins for the fish evaluation and 21 for the plant-seep evaluation. Potential risks from exposure to radionuclides were evaluated for aquatic organisms across all 25 subbasins for which surface water and sediment radionuclide data were available. Only one formal line of evidence, single chemical toxicity data, was available to evaluate potential risks for plants. For piscivorous wildlife, three lines of evidence (limited biological survey data, media toxicity data, and single chemical toxicity data) were available. For aquatic organisms, biological survey data, biological indicators data, media toxicity data, and single chemical toxicity data were available.

Significant or potential risks were identified for aquatic organisms exposed to nonradionuclides in main stem surface water in 16 subbasins (Table 3.10) based on comparison of unfiltered surface water concentrations to aquatic benchmarks. Fourteen inorganics, ammonia, BEHP, and PCBs potentially present significant risks to aquatic organisms in the watershed. Evaluation of the HIs suggests that the HF-2 and SWSA 6 East subbasins present the highest risks although only five and three inorganics, respectively, were identified as COECs. PCBs present significant risks in the Lower WOC/WOL and WOC subbasins. Mercury presents significant risks at SWSA 6 East, W6MS3, and W6MS1. Copper, aluminum, and iron potentially present significant risks at 13, 12, and 11 subbasins, respectively. However, use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction as they may not be bioavailable.

Significant risks indicated by surface water chemical concentrations were corroborated by the biological data for five subbasins: Intermediate Pond, WOC, MB-15, Lower WOC/WOL, and WOCE. The weight-of-evidence is strongest for the WOC subbasins upstream of WOD. The fish community is less species rich relative to the community observed here in the 1950s, redbreast sunfish have experienced reproductive failures, and the water has been lethal to Medaka embryos and larvae. The total number of macroinvertebrate species and the number of sensitive species are significantly lower than the upstream and pooled reference communities.

In subbasin Seep C, the biological data contradict the chemical data. Although the weight-of-evidence is not strong, it suggests that the water in subbasin Seep C does not pose a significant risk to fish. Although copper and nickel appear to present a significant risk and were identified as COECs, the water has not been toxic in the standard toxicity tests.

Table 3.10. Summary of potential risks to aquatic organisms from exposure to contaminants in main stem surface waters

Subbasin	HI[a]	COEC[b]
HF-2	373	Al, Co, Cu, Tl, Zn
SWSA 6 East	370	Al, Fe, Hg
HRE	201	Al, Cd, Co, Cu, Fe, Ni, and Tl
Lower WOC/WOL	171	Ammonia, Al, Cd, Co, Cu, Fe, Ni, Ag, Tl, Zn, PCBs
W6MS3	168	Al, Cd, Co, Cu, Fe, Pb, Mn, Hg, Ni, Ag, Sn, BEHP
SWSA 5 WOC	126	Al, Cu
W6MS1	125	Al, Cd, Co, Cu, Fe, Pb, Hg, Ni, BEHP
SWSA 4 Main	112	Ag, Al, Cd, Cu, Fe, Ni, Pb
MB-15	72	Al, Cd, Cu, Fe, Ni, Se, Tl
Intermediate Pond	61	Al, Cu, Fe, Ag, Tl
SWSA 5 Seep A	54	Cu, Tl
WOC	43	Ammonia, Al, Cu, Fe, Pb, Ni, Tl, PCBs
West Seep	29	Al, Cd, Cu, Fe
SWSA 5 Seep C	20	Cu, Ni
HFIR South	15	Fe
SWSA 5 Trib 1	4	Ni

[a] There are a number of different effects benchmarks for screening risks to aquatic organisms. No single benchmark was available for all analytes, so UCL95 water concentrations were evaluated against all available benchmarks for a given analyte. The HQs for each analyte were averaged and then summed across all analytes detected in the subbasin to obtain an HI to be used for relative ranking purposes only.

[b] Contaminants of ecological concern were identified as analytes for which at least 20% of the concentrations exceeded at least one probable effects level benchmark.

Potential risks to aquatic organisms exposed to radionuclides in surface water within the watershed were identified for only two subbasins: SWSA 5 WOC (^{137}Cs at OHF Pond) and Seep C (^{90}Sr).

Potential risks were evaluated for five species of piscivorous wildlife: mink, river otter, belted kingfisher, great blue heron, and osprey. Evaluation of available single chemical toxicity data, toxicity test data, and field surveys suggest that the Melton Valley watershed populations of mink, great blue heron, and osprey are not at risk. However, individual river otter (listed as threatened by the Tennessee Wildlife Resources Agency) may be at risk from exposure to mercury, primarily at the Lower WOC/WOL and WOC subbasins, and kingfisher populations may be at risk from exposure to mercury and selenium.

Risks from exposure of piscivorous wildlife to radionuclides are not anticipated in the Melton Valley watershed. Exposure of piscivorous wildlife to radionuclides were modeled using available surface water data and measured fish body burden data. Potential risks were identified in only one subbasin: SWSA 5 WOC (OHF Pond). Doses were below recommended limits for all piscivorous receptors.

Potential risks to white-tailed deer exposed to thallium by drinking surface water were identified for three subbasins (WOC, HF-2, and SWSA 5 Trib 1). Risks were not identified for any other receptors, and thallium was the only analyte that exceeded the LOAEL for deer. However, it is unlikely that thallium in drinking water poses a risk to deer because of uncertainty in the thallium benchmark and use of unfiltered water data. The maximum HQ was 1.5 for deer in SWSA Seep A.

Potential risks to plants assumed to be exposed to seep water in soil solution were identified for seeps in most subbasins from which data were available (Table 3.11). The primary risk drivers were aluminum, arsenic, and/or thallium in most seeps. The aluminum and thallium benchmarks appear to be conservative as both analytes exceeded benchmarks at numerous seeps across the whole watershed, and the aluminum benchmark is below background. There is low confidence in the arsenic benchmark as it was derived from limited data on root length reduction (Will and Suter 1995). Other analytes marginally exceeding benchmarks at least one station in the watershed included boron, chromium, cobalt, copper, fluoride, iron, lead, manganese, and nickel (HQs generally <5). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. Because of the uncertainty associated with the benchmarks and analyte bioavailability, it is uncertain whether significant ecological risks are present.

Table 3.11. Summary of potential risks for plants exposed to water from seeps in soil

Subbasin	Maximum HI[a]	COCs (maximum HQ)[b]
West Seep	522	Al (485), As (23.6), Tl (15.6), Fe (9.8), Ti (9.0), Cr (2.6), fluoride (2.4), cobalt (2.4), Mn (1.8), Pb (1.6), Cu (1.1)
HF-2	224	Al (202), Fe (5.4), Pb (3.3), As (3.1), Cr (2.9), Cu (2.4), Mn (1.8), Ni (1.3)
Pit 4 South	197	Al (150), As (28.2), Tl (7.8), Fe (3.6), fluoride (2.1), B (2.0)
HRE	98	Al (88.5), As (3.6), Fe (2.9), Mn (1.4), Cr (1.2), fluoride (1.1)
SWSA 5 Seep A	64	Al (61.5), Tl (25.3), As (3.6), Mn (2.6), Fe (1.7)
SWSA 4 Main	54	As (50), Ni (18.9), Tl (16.7), Al (10.6), fluoride (3.1), Fe (2.9), Pb (2.5), Mn (1.6)
SWSA 5 Trib 1	45	Tl (21), Al (20.2), Co (4.9), As (3.7), Mn (2.0)
Lower WOC/WOL	36	Tl (25.6), Al (19), Fe (1.7), As (1.4), Pb (1.4), Cu (1.0)
SWSA 5 Drainage D-2	32	Al (29), As (2.2), Fe (2.2), Mn (1.1)
WOC	27	Tl (20.9), As (3), Mn (2.7)
W6MS3	23	Tl (15.6), Cu (8.6), As (5), Mn (1.5), Cr (1.0)
W6MS1	23	Tl (19.2), As (4), Mn (3.1)
MVDrive	17	Al (12), Tl (3.3)
East Seep	17	Tl (14.5), As (4.2), Al (3.9), Mn (1.9), Cr (1.8)
SWSA 5 Seep C	15	Al (11.5), fluoride (3.2), As (3), Mn (1.4)
Intermediate Pond	14	Tl (13.6), Al (5)
SWSA 5 WOC	9	Al (6), As (2.3)
SWSA 5 N WOC	7	Al (4.9), Mn (1.3)
WC TRIB-1	4	Al (3.8)

Note: No risks were identified for the MB-15, Seep B, or WAG 7 WOC subbasins.

[a] The maximum HI is the maximum HI of all stations evaluated within the subbasin. The HI is the sum of HQs for all analytes detected at the station.

[b] The maximum HQ is the maximum HQ for the analyte at any station within the subbasin. Therefore, the maximum HQs do not sum to the maximum HI unless the maximum HQs for all analytes were at the same station.

Sediment Exposures

Ecological risks were evaluated for benthic invertebrates exposed to nonradiological contaminants in sediment within each subbasin in the watershed for which sediment data were available. Nonradiological data were available from 21 subbasins. Potential risks from exposure to radionuclides were evaluated for aquatic organisms across all 25 subbasins for which surface water and sediment radionuclide data were available. Two lines of evidence, biological survey data and single chemical toxicity data, were used in evaluating potential risks to benthic invertebrates.

Significant or potential risks were identified for benthic invertebrates exposed to nonradionuclides in sediment in 21 subbasins (Table 3.12) based on comparison of sediment concentrations to benchmarks. Ten inorganics and 15 organic analytes potentially present significant risks to aquatic organisms in the watershed. Evaluation of the HIs suggests that the SWSA 5 Trib 1 subbasin presents the highest risks with 11 COECs. PCBs present significant risks in the WOCE, SWSA 5 Trib 1, Lower WOC/WOL, WOC, SWSA 5 WOC, Intermediate Pond, and HRE subbasins. Mercury presents significant risks at the WOCE, SWSA 5 Trib 1, WOC, SWSA 5 WOC, and Intermediate Pond subbasins. Several polyaromatic hydrocarbons present significant risks at the WOC and Intermediate Pond subbasins. Manganese, silver, and zinc potentially present significant risks at 8, 7, and 5 subbasins, respectively.

Significant risks indicated by sediment chemical concentrations were not refuted by the community survey data in the Lower WOC/WOL subbasin. That is, eight sediment COECs were identified in this subbasin and the sediment community surveys were inconclusive. The relative importance of habitat and contamination could not be determined because a good reference was not available. However, the community survey suggests that sediment in subbasin WOC does not pose a significant risk to benthic invertebrates. Chironomid taxa richness was slightly lower than in the reference pools, but total taxonomic richness of the sediment community was similar to the reference sites. Hence, all of the 11 COECs appear to be credible contributors to toxicity, but the community does not appear to be degraded.

Potential risks to aquatic organisms exposed to radionuclides in sediment within the watershed were identified for just one subbasin: SWSA 5 WOC (^{137}Cs at OHF Pond). The dose rate to large invertebrates and fish in the SWSA 5 WOC subbasin greatly exceeded the recommended dose rate limit (HI = 202 and 91) as a result of high ^{137}Cs activity associated with the OHF Pond and does not represent a widespread ecological problem. No aquatic receptors received doses above the dose rate limit in any of the other subbasins.

3.3.5 Criteria Exceedances

Groundwater and surface water concentrations for each subbasin were compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against promulgated chemicals and proposed MCLs for certain radionuclides. Subbasin surface water concentrations were screened against TDEC AWQC for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.12. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment

Subbasin	HI[a]	COEC[b]
WOCE	59	Hg, Ag, 4,4'-DDT, PCB-1254, PCB-1260
SWSA 5 Trib 1	854	Fe, Mn, Hg, Ni, Ag, Zn, 4-methylphenol, acetone, PCB-1248, PCB-1254, phenol
Lower WOC/WOL	168	Sb, Cr, Ni, Ag, Zn, PCB-1254, PCB-1260
WAG 5 Drainage D-2	136	Fe, Mn, Ag, acetone
WOC	122	Cu, Hg, Ag, Zn, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, PCB-1260, phenanthrene, pyrene
SWSA 5 WOC	117	Cu, Pb, Hg, Ag, acetone, PCB-1254, PCB-1260
Intermediate Pond	94	Hg, Ni, Ag, Zn, acenaphthene, anthracene, dibenz(a,h)anthracene, PCB-1254, PCB-1260, phenanthrene
SWSA 4 Main	47	Mn, Ni
HRE	22	Mn, PCBs
HF-2	11	Mn, Zn
HFIR East	7	Mn
W6MS3	9	Mn
Pit 4 South	8	Anthracene
SWSA 5 Seep A	7	Mn
MB-15	2	None
SWSA 5 Seep C	2	None
SWSA 5 Seep B East	2	None
SWSA 5 Seep B West	2	None
^{60}Co Seep	<1	None
West Seep	<1	None
WC TRIB-1	<1	None

[a] There are a number of different effects benchmarks for screening risks to aquatic organisms. No single benchmark was available for all analytes, so UCL95 water concentrations were evaluated against all available benchmarks for a given analyte. The HQs for each analyte were averaged and then summed across all analytes detected in the subbasin to obtain an HI to be used for relative ranking purposes only.

[b] Contaminants of ecological concern were identified as analytes for which at least 20% of the concentrations exceeded at least one probable effects level benchmark.

Table 3.13 lists the criteria exceedances for each of the 32 subbasins, and Fig. 3.9 maps these exceedances. The human health risk assessment (Appendix B) to this report contains detailed summaries of detected contaminants by subbasin. Arsenic exceeds the AWQC for recreational use in at least one subbasin of every basin except for SWSA 5 Seep B, Drainage D-2, East Seep, and the WC Trib-1 and ^{60}Co Seep. The frequency of detection varies among sites but on the average arsenic is detected in less than half of the surface water samples. The mercury AWQC for recreation was exceeded in four subbasins (HF-2, W6MS3, W6MS1, and SWSA 6 East), while the PCB AWQC was exceeded in the Middle WOC and the WOC/WOL subbasins. Thallium exceedances are also noted in the HF-2, MG-15, HRE, SWSA 5 Seep A, SWSA 4 Main, Intermediate Pond, Middle WOC, and Lower WOC/WOL. Antimony, tetrachloroethylene, carbon tetrachloride, and 1,1-dichloroethylene also exceed their AWQC for recreation in several subbasins.

Table 3.13. Summary of subbasin criteria exceedances

Basin	Subbasin	Surface water (high flow): Aquatic life AWQC	Surface water (high flow): Human health AWQC	Groundwater: Nonrad MCLs[a]	Groundwater: Rad MCLs[b]
HFIR	HFIR	–	–	–	–
	HFIR East	–	–	–	–
	HFIR South	–	–	–	–
	HF-2	Cu, Hg, Zn	As, Hg, Tl	–	–
	MB-15	Hg, Se	As, Tl	–	^{3}H
HRE	HRE	Hg	As, Tl	Antimony, nitrite, Tl, vinyl chloride	^{90}Sr
SWSA 5 Seep A	Seep A	–	As, Sb, Tl	Benzene, carbon tetrachloride, 1,1-DCE, PCE, TCE, vinyl chloride	^{241}Am, ^{14}C, ^{137}Cs, ^{90}Sr, ^{3}H
SWSA 5 Seep B	Seep B West	–	–	Benzene, carbon tetrachloride, 1,1-DCE, PCE, vinyl chloride	^{241}Am, ^{14}C, ^{60}Co, ^{228}Ra, ^{137}Cs, ^{90}Sr, ^{3}H
	Seep B East	–	–	Benzene, carbon tetrachloride, 1,1-DCE, PCE	^{90}Sr, ^{3}H
SWSA 5 Drainage D-2	Drainage D-2	–	–	Benzene, carbon tetrachloride, 1,1-DCE, Sb, PCE, Tl, TCE, vinyl chloride	^{241}Am, ^{238}Pu, ^{239}Pu, ^{228}Ra, ^{90}Sr, ^{230}Th, ^{3}H, ^{234}U
SWSA 5 Seep C	Seep C	–	As	Benzene, carbon tetrachloride, 1,1-DCE, PCE, TCE, vinyl chloride	^{14}C, ^{137}Cs, ^{90}Sr, ^{3}H
Middle WOC East	SWSA 5 Trib 1	–	As, carbon tetrachloride, 1,1-DCE, PCE	Benzene, carbon tetrachloride, 1,1-DCE, PCE	–
	MV Drive	–	–	Benzene, carbon tetrachloride, 1,1-DCE, PCE	^{228}Ra
	SWSA 5 N WOC	–	–	Benzene, carbon tetrachloride, 1,1-DCE, PCE	^{244}Cm
	SWSA 5 WOC	Cu	Carbon tetrachloride, 1,1-DCE, PCE	Benzene, carbon tetrachloride, 1,1-DCE, cis-1,2-DCE, PCE, TCE, vinyl chloride	^{137}Cs, ^{228}Ra, ^{90}Sr, ^{3}H
Middle WOC West	SWSA 4 Main	Cd, Ni, Pb, Se	As, Tl	As, Ni, Sb	^{241}Am, ^{14}C, ^{137}Cs, ^{90}Sr, ^{3}H, ^{234}U
	SWSA 4 East	–	–	1,1-DCE, cis-1,2-DCE, Ni, TCE, vinyl chloride	^{90}Sr, ^{3}H
	Haw Ridge	–	–	–	–
Middle WOC Floodplain	Intermediate Pond	–	Tl	–	^{90}Sr, ^{3}H
	WOC	Cr, Hg, PCBs, Se	As, PCBs, Sb, Tl	–	–
	WAG 7 WOC	–	–	–	–
West Seep	West Seep	Cd, Cr	As	Nitrate, Tl	^{3}H, ^{234}U, ^{238}U
East Seep	East Seep	–	–	TCE	^{60}Co
WC TRIB-1 and ^{60}Co Seep	WC TRIB-1	–	–	–	^{137}Cs, ^{90}Sr
	^{60}Co Seep	–	–	–	^{3}H
SWSA 6 Drainages	W6MS1	Cd, Cr, Cu, Hg, Pb	As, Hg	Tl	^{3}H
	W6MS3	Cd, Cr, Cu, Hg, Pb	As, 1,1-DCE, Hg	Tl, TCE, vinyl chloride	^{244}Cm, ^{90}Sr, ^{3}H
Lower WOC, WOL, and WOCE	Lower WOC/WOL	Cr, Hg, PCBs	As, PCBs, Tl	Benzene, 1,1-DCE, Tl	^{14}C, ^{90}Sr, ^{3}H, ^{234}U
	WOCE	Cd	–	–	–
	SWSA 6 South	–	–	Tl	–
	SWSA 6 East	Hg	As, Hg	Carbon tetrachloride, 1,2-DCA, Tl	^{3}H
	Pit 4 South	–	–	–	–
	Trench 5 South	–	–	–	–

[a] Promulgated for nonrads.
[b] Data were compared to promulgated MCLs for ^{3}H and ^{90}Sr and to proposed MCLs for other radionuclide isotopes.

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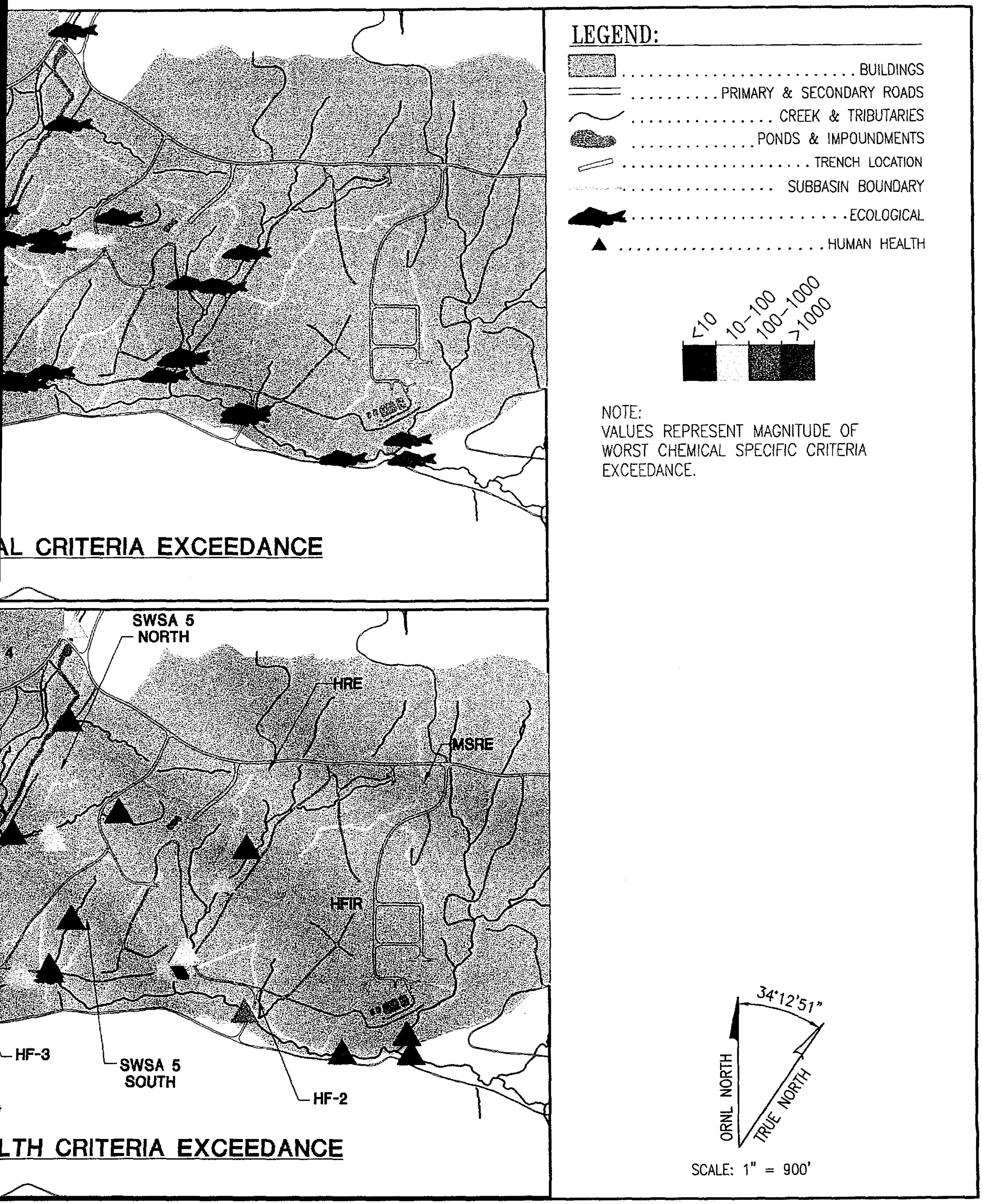
Fig. 3.9. Water quality criteria excee



nces in the Melton Valley watershed.

Table 3.13 indicates that the AWQC to protect aquatic life is exceeded for cadmium in both subbasins of SWSA 6, SWSA 4 Main, West Seep, and WOC embayment. The mercury AWQC is exceeded in the Melton Branch portions of the HFIR (HF-2 and MB-15), HRE, both SWSA 6 Drainages as well as SWSA 6 East, Middle WOC and Lower WOC/WOL. Lead, zinc, copper, chromium, selenium, and nickel show isolated exceedances, with SWSA 4 Main, SWSA 6 Drainages, and WOC showing the most contaminants in exceedance.

The predominant area exhibiting exceedances of MCLs for chemicals in groundwater is SWSA 5; Table 3.13 shows exceedances for 1,1-dichloroethene (1,1-DCE), benzene, carbon tetrachloride, and tetrachloroethylene in SWSA 5 Seeps A, B, and C, Drainage D-2, and all subbasins of Middle WOC East. Vinyl chloride exceeds the MCL in groundwater in the HRE subbasin, SWSA 5 Seep A, SWSA 5 Seep B West, Seep C, Drainage D-2, SWSA 5 WOC, SWSA 4 East, and SWSA 6 W6MS3. 1,1-DCE was also detected above the MCL in SWSA 4 East and Lower WOC/WOL; trichloroethylene was noted above the MCL in many of the SWSA 5 tributaries, SWSA 4 East and the West Seep, and W6MS3. Other isolated groundwater exceedances include nickel, arsenic, nitrates/nitrites, thallium, antimony, cis-1,2-dichloroethylene, and 1,2-dichloroethane (Table 3.13).

Radionuclide contamination in groundwater exceeded promulgated MCLs (^{3}H and ^{90}Sr) and proposed MCLs for other isotopes in at least one subbasin of all basins. Tritium and ^{90}Sr were the predominant radionuclide contaminants; however, ^{241}Am was found above the MCL in SWSA 5 Seeps A, B West, Drainage D-2, and SWSA 4 Main. Other long-lived radionuclides detected above MCLs were ^{238}Pu, ^{230}Th, and ^{234}U (SWSA 5 Drainage D-2), and ^{238}U (West Seep). Uranium-234 was also detected above its MCL in SWSA 4 Main, West Seep, and Lower WOC/WOL. Cesium-137 exceeded its MCL in SWSA 5 Seep A, SWSA 5 Seep B West, Drainage D-2, SWSA 5 WOC, SWSA 4 Main, and WC Trib-1.

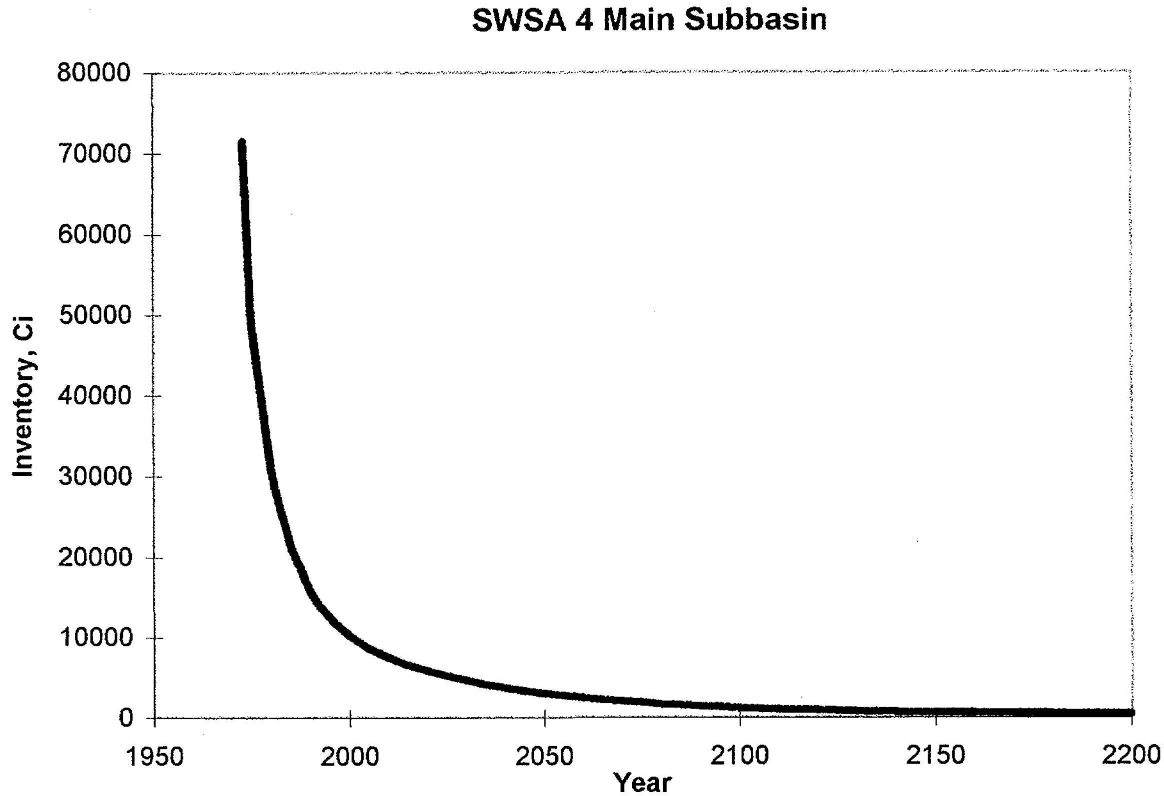
It can be seen from Table 3.13 and Fig. 3.9 that exceedances of AWQC for protection of human health or aquatic life occur in about half of the subbasins in the watershed. Most prevalent exceedances are for arsenic, mercury, and thallium, with SWSA 4 Main, the SWSA 6 Drainages, Middle WOC, and Lower WOC/WOL exhibiting the most exceedances. Exceedances of MCLs for chemicals and radionuclides occur in groundwater in virtually all basins, with the exception of the HFIR.

Although WOC has not been designated for use as a domestic water supply, it flows into the Clinch River which has that designation. Therefore, surface water concentrations at the WOD were compared to MCLs. Thallium, ^{3}H, and ^{90}Sr were found to exceed the promulgated MCL. In screening against AWQC and thallium, the human health criteria was exceeded for arsenic, thallium, and PCBs, and the aquatic life criterion was exceeded for mercury, copper, and total chromium.

3.3.6 Significant trends and uncertainties

Several significant trends are important to consider in the Melton Valley watershed. These trends include the natural decay of radioactive materials disposed in the area, the historic releases of contaminants via the surface water system, observed trends in groundwater contaminant concentrations, and projections of future contaminant concentrations in surface water.

Trends in estimated future primary source area radionuclide inventories until the year 2200 in the SWSA 4 Main and West Seep subbasins are shown on Fig. 3.10. In the Melton Valley watershed,



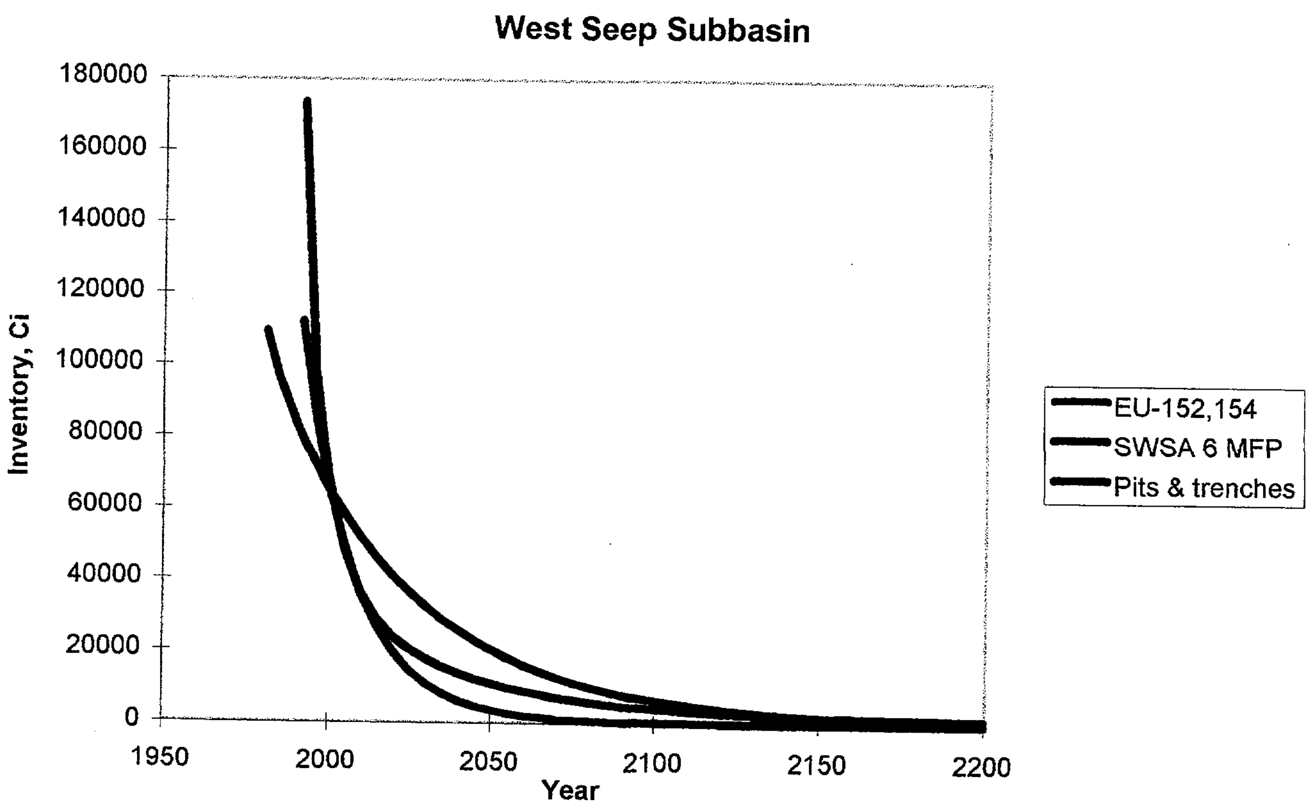


Fig. 3.10. Source decay trend for West Seep subbasin & SWSA 4 main.

SWSA 4 Main is the highest ranked subbasin based on its contribution to risk at WOD and West Seep is the highest ranked subbasin based on current radionuclide inventory (not counting the inventory in the OHF and NHF grout sheets) (see Tables 3.3 and 3.5). Decay of radionuclides in these primary source areas will result in radionuclide inventories of less than 10% of the disposed activities by the year 2050 and less than 1% of the disposed activities by the year 2200. The relatively rapid initial decrease in radionuclide inventories in these source area is due primarily to decay of short-lived beta-emitters (e.g., ^{106}Ru, ^{60}Co, and trivalent rare earths). The bulk of the remaining inventory consists of ^{137}Cs and ^{90}Sr with half-lives of 30.2 and 28.5 years, respectively. Long-lived TRU and uranium isotopes account for less than 25 Ci out of a total of more than 500,000 Ci disposed of in the West Seep subbasin and less than 10 Ci out of a total of about 71,500 Ci disposed of in the SWSA 4 Main subbasin.

About 112,400 of the approximately 500,000 Ci initially disposed of in the West Seep subbasin can be attributed to ^{152}Eu and ^{154}Eu in the HFIR control plates in several auger holes in the Northeast Auger Hole area of SWSA 6. Due to the relatively short half-lives (13.3 and 8.8 years, respectively) of these radionuclides, by the year 2050 only about 3,500 Ci of this activity will remain and by 2200 the activity will have decreased to about 1 Ci. By the year 2200, only about 1,300 of an initial 173,000 Ci of mixed fission products disposed of in the SWSA 6 portions of the West Seep subbasin and about 640 of an initial 110,000 Ci disposed of in the West Seep portions of Pits 2, 3, and 4 will remain.

In the SWSA 4 Main subbasin, the initial disposed inventory of about 71,500 Ci, consisting primarily of mixed fission products of short to medium half-lives (<1 to 30 years), will have declined to about 3,000 Ci by the year 2050 and less than 500 Ci by the year 2200.

Surface Water Contaminant Release History

Release of radiological and other contaminants into the surface water of WOC at ORNL started in 1943 with the construction of the Graphite Reactor and associated radiochemical processing facilities. Throughout the history of operation of ORNL, improvements in waste handling and treatment have been made to reduce the release of contaminants into the environment. Record keeping to document the total annual contaminant releases started in 1949 for ^{90}Sr (Fig. 3.11) and in 1964 for ^{3}H (Fig. 3.12). Total annual precipitation is also shown on these figures. Several significant observations can be made from these release plots. During the 1950s the ^{90}Sr releases were as much as 50 times as great as recent releases of about 1.5 to 3 Ci per year. During the 1950s liquid radioactive wastes were discharged into the Seepage Pits and Trenches in WAG 7 and some discharges continued in the Main Plant Area. During the 1960s and 1970s liquid wastes were concentrated in the waste evaporator and the waste concentrate was mixed with dry grout and additives and was injected 800 to 1000 ft below ground into the Pumpkin Valley Shale using the hydrofracture process. This change in waste handling reduced the liquid waste release and consequently the 90Sr releases. The release records show that the maximum annual ^{3}H releases occurred during the early 1970s with between 5 and 10 times the current annual release of 1500 to 2000 Ci per year.

Comparison of the annual release of ^{90}Sr and ^{3}H to total annual rainfall over the period of record shows an increase in contaminant release coincident with periods of elevated annual rainfall. Causes for this include flushing of soluble contaminants out of soil areas and inundation of wastes in burial trenches in low-lying portions of the site. The historic record shows that overall radiological releases from ORNL have diminished substantially form the period of major radiochemical processing activities.

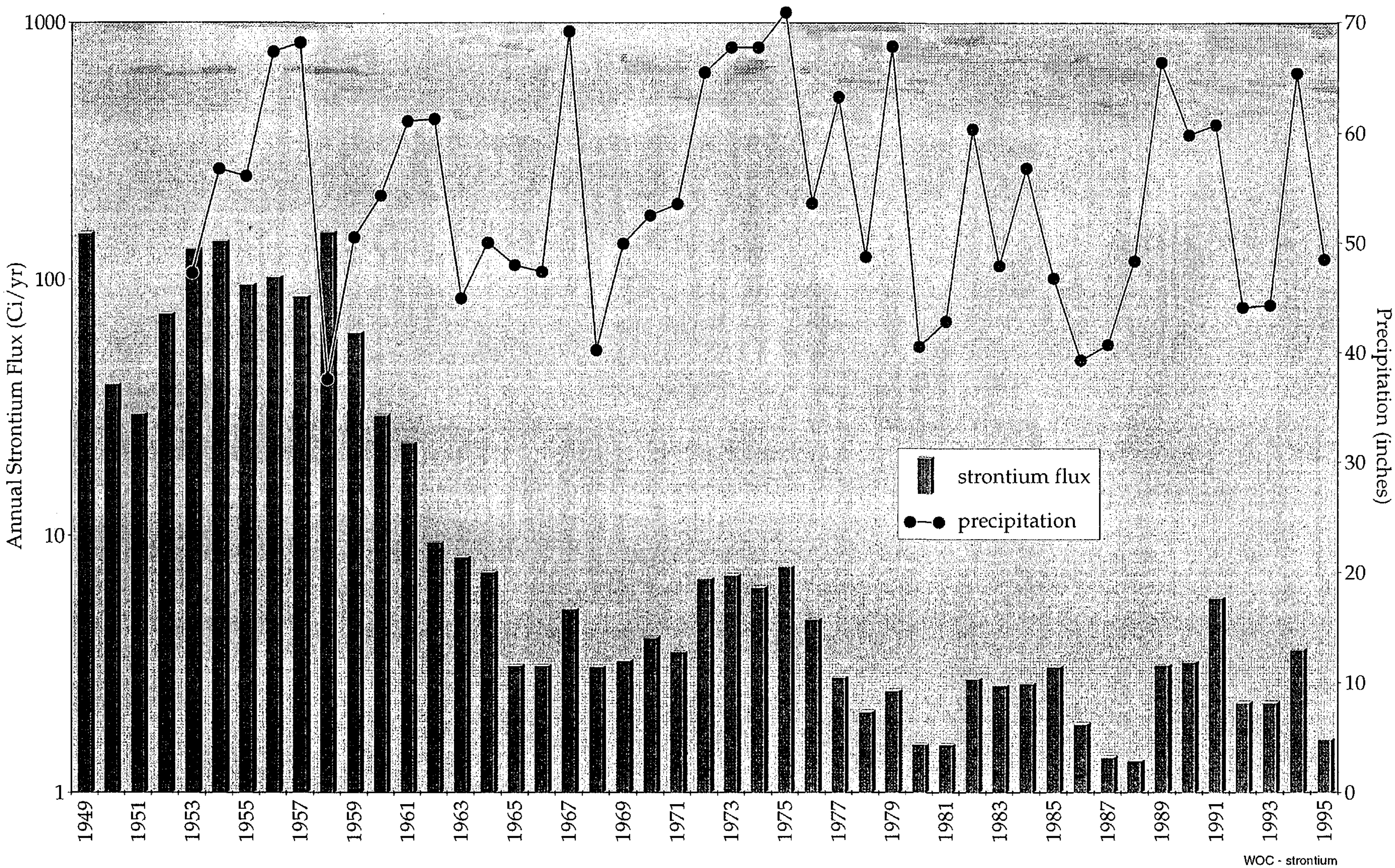


Fig. 3.11. Historic annual radioactive strontium flux over White Oak Dam.

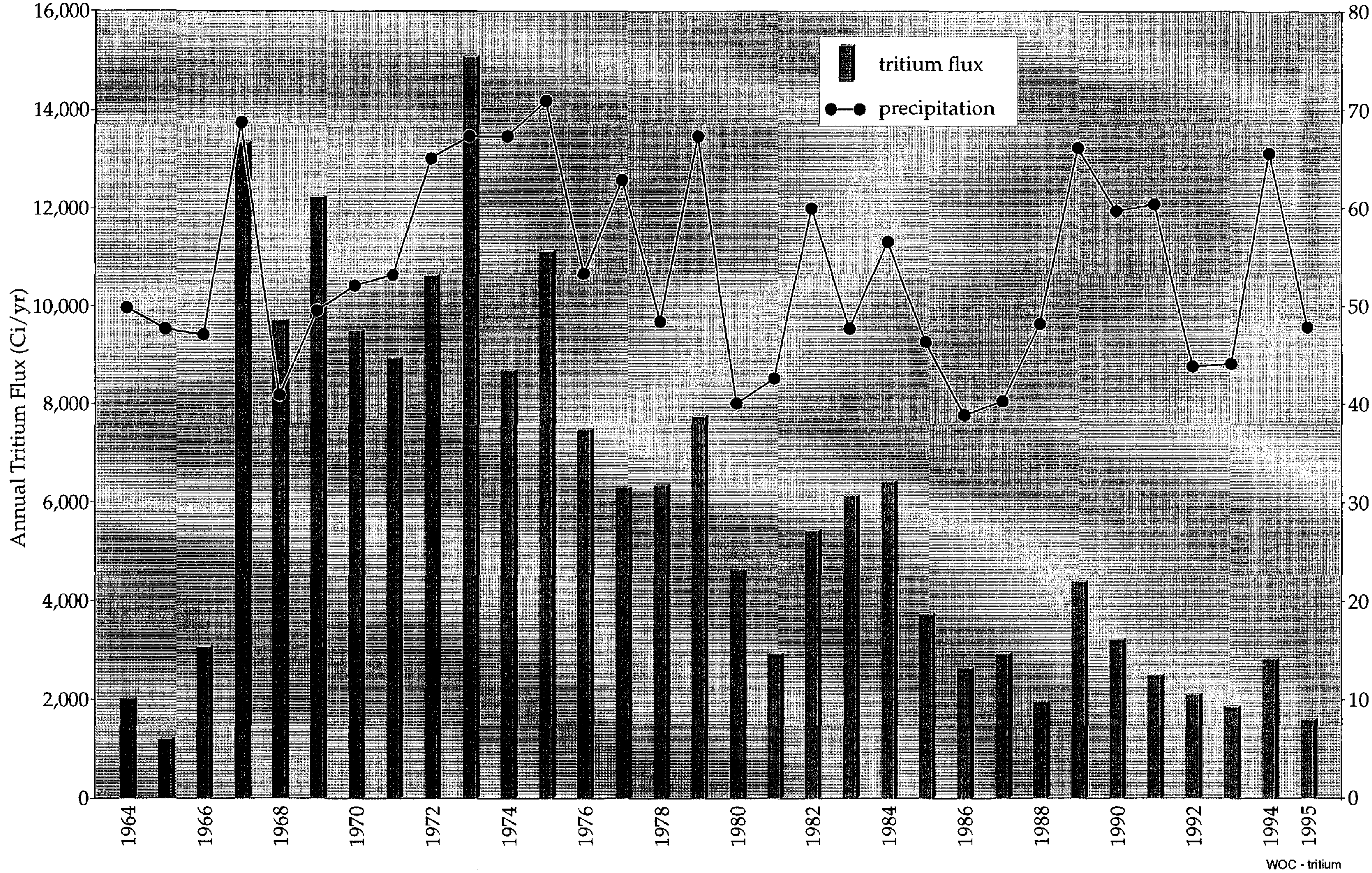


Fig. 3.12. Historic annual tritium flux over White Oak Dam.

Contaminant releases are not static or constant at an average rate that accounts for the total annual release. As described in Sect. 2.2.1.2, Conceptual Model of Valley-Wide Groundwater Flow in Melton Valley, strong seasonal variations in recharge, contaminated leachate formation, and release to surface water occur every year. Seasonal variation in evapotranspiration accounts for a great deal of the variation in runoff generated per unit of rainfall. The net effect of this variability is seasonal pulsing of contaminant release to the surface water system.

Concentrations of ^{90}Sr and ^{3}H in surface water are variable, depending on season and rainfall patterns. For several years, data have been obtained that resolve monthly discharge of ^{90}Sr and ^{3}H at WOD and other main stem weirs in Melton Valley. Measurements have also been made that show the effect of ^{90}Sr seep interception and treatment on reduction of total ^{90}Sr discharge from the WOC watershed. For the period January 1990 through September 1996, Fig. 3.13 illustrates the monthly data collected at WOD in terms of a hypothetical residential ingestion pathway. Statistically significant overall decreases in total risk and ^{90}Sr are shown over the time period. These data have been used to prepared predictions of the future release behavior of ^{90}Sr and ^{3}H from the Melton Valley area. The purpose of these predictions is to project a trend in releases and to demonstrate the effect of radioactive decay in reducing future releases. Assumptions used in preparing these estimates include:

- starting point concentrations are those observed at WOC in 1995,

- potential reductions in concentration assume actions may be taken on sources within the Melton Valley watershed,

- no new sources of ^{90}Sr or ^{3}H begin releasing to the surface water system, and

- radioactive decay reduces the currently releasing sources.

The assumption concerning no new significant sources of ^{90}Sr and ^{3}H releasing to the WOC system is necessary for the purposes of estimating future releases. Although the possibility of previously unknown releases cannot be totally discounted, the longer-term historical record of diminishing fluxes at WOD (Figs. 3.11 and 3.12) combined with the radiological source term decay assessment suggest that the probability of major new releases is diminishing.

Discerning an overall trend in radionuclide concentrations at WOD is complicated by cyclical seasonal trends in contaminant concentrations. Other reports (e.g., DOE 1995c) have shown that during storm events, contaminant concentrations tend to decrease with increasing stream flow. However, the monthly data do not show this relationship. Instead, concentration tends to increase with increasing flow. This trend develops as an increase in radionuclide flux at the beginning of the wet season in late fall/early winter. This same trend is present in the flow-weighted concentration data. Fluxes and contaminant concentrations then tend to diminish through the spring and into the summer until they jump again in the first month of the following wet season. This wet season transition month is usually between October and January (DOE 1995c).

To account for these seasonal factors, the seasonal nonparametric Mann-Kendall test for trend (Hirsch, Slack, and Smith 1982; van Bell and Hughes 1984) was used to determine trends in monthly contaminant concentration data. The method is advantageous in that it can identify and account for the proportion of the trend attributable to water discharge fluctuations. The test shows statistically significant downward trends for the 1990–1994 time period in concentrations of ^{137}Cs, ^{90}Sr, and ^{3}H

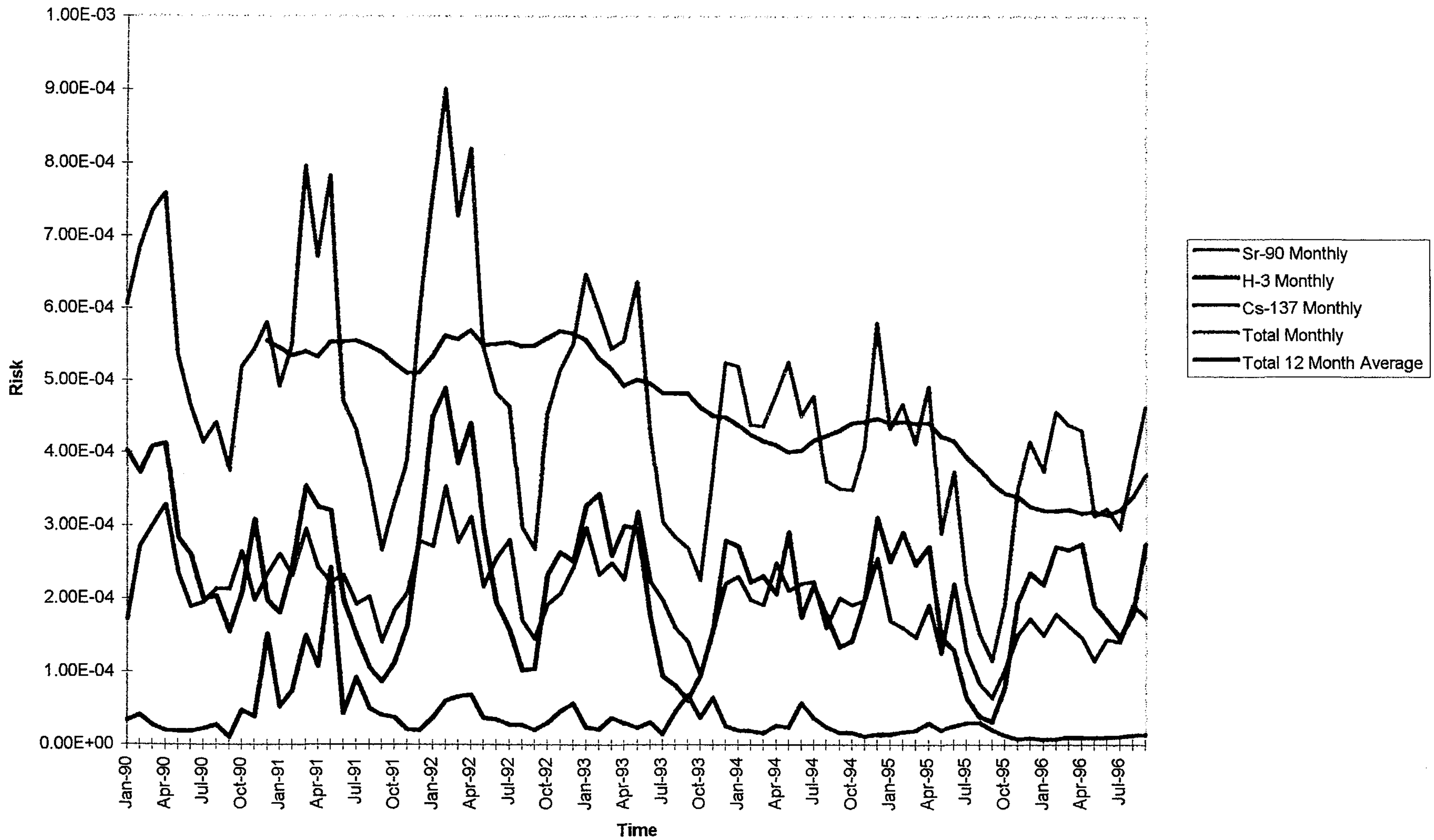


Fig. 3.13. Hypothetical risk estimates for recent monthly radionuclide discharges over White Oak Dam.

while showing no overall trend in the flow data at WOD. An important assumption of the test is no changes in the system; therefore, 1995 to present data collected after implementation of various ^{90}Sr related remedial cannot be compared to the 1990–1994 data statistically using this test. These measured trends in ^{90}Sr and ^{3}H concentrations are used in the following discussion of future release trends.

Two basic scenarios are used in the ^{90}Sr release estimates, and estimated future concentrations at WOD are shown on Fig. 3.14. The first scenario (Sr.decay) uses the 1995 ^{90}Sr concentration measured at WOD and assumes decay of the releasing sources to provide a baseline for comparison. This ^{90}Sr decay curve shows a long-term decrease in concentration. Additional concentration curves have been calculated to analyze the potential effect of 50% (Sr.decay.50) and 80% (Sr.decay.80) reductions in ^{90}Sr concentrations in releases from all the subbasins included in the Melton Valley watershed. These release curves show a more rapid decrease in ^{90}Sr concentration than the basic decay rate in proportion to the assumed release reduction factors. The second scenario (Sr.trend) that has been analyzed is a projection of the observed trend in ^{90}Sr release from the watershed that has been corrected to reflect the effect of seep interception projects and estimated performance of the trench grouting at SWSA 4. The shape of this trend curve in the 1995 portion of the plot shows the effect of seep interceptions completed in 1995 and decreases at a slower rate than the decay-only curve because the observed trend for ^{90}Sr releases has shown a gradual increase in the release over the past several years. Estimated reductions in the trend-based release for the 50% (Sr.trend.50) and 80% (Sr.trend.80) reductions in ^{90}Sr concentrations in area releases are shown as they were for the basic decay case to assess the potential effects of remediation actions in Melton Valley on decreasing the WOD ^{90}Sr concentrations.

Two horizontal lines on Fig. 3.14 indicate the current and proposed primary drinking water standard MCLs for ^{90}Sr of 8 pCi/L and 38 pCi/L. The various estimated future release curves for ^{90}Sr show a range of time required to reach concentrations as low as the MCL values under the assumptions used in preparing these estimates. The potential shortening of the time to reach the proposed revised ^{90}Sr MCL (56 FR 33050, July 18, 1991) under the assumption of an aggressive 80% reduction of releases depends on the effectiveness of remedial actions.

The source decay and current release trend estimates for ^{3}H are shown on Fig. 3.14. The relatively short half-life of ^{3}H causes the fairly rapid decrease in concentration for both the decay-only and the observed trend analyses. Current and proposed revised primary drinking water standard MCLs for ^{3}H of 20,000 pCi/L and 61,000 pCi/L are shown on Fig. 3.13. Under the assumptions of this analysis, the rate of observed decrease in ^{3}H concentration could result in concentrations near the proposed new MCL (56 FR 33050, July 18, 1991) within about 20 years.

Trends Observed in ORNL Groundwater Contaminant Data

Trends observed in groundwater contaminant concentrations measured since 1988 in the ORNL WAG perimeter wells were calculated for risk levels derived from contaminant concentrations. The ORNL WAG perimeter monitoring wells are constructed of stainless steel and have dedicated groundwater sampling pumps. Sampling and analysis of groundwater has been conducted in this well network since the late 1980s. The high quality of the wells coupled with the relatively long record of sampling and analysis make the dataset from these wells the best and only opportunity for groundwater trend analysis at ORNL. Concentrations were measured form unfiltered samples when available; results from filtered samples were used to fill gaps whenever possible if unfiltered sample

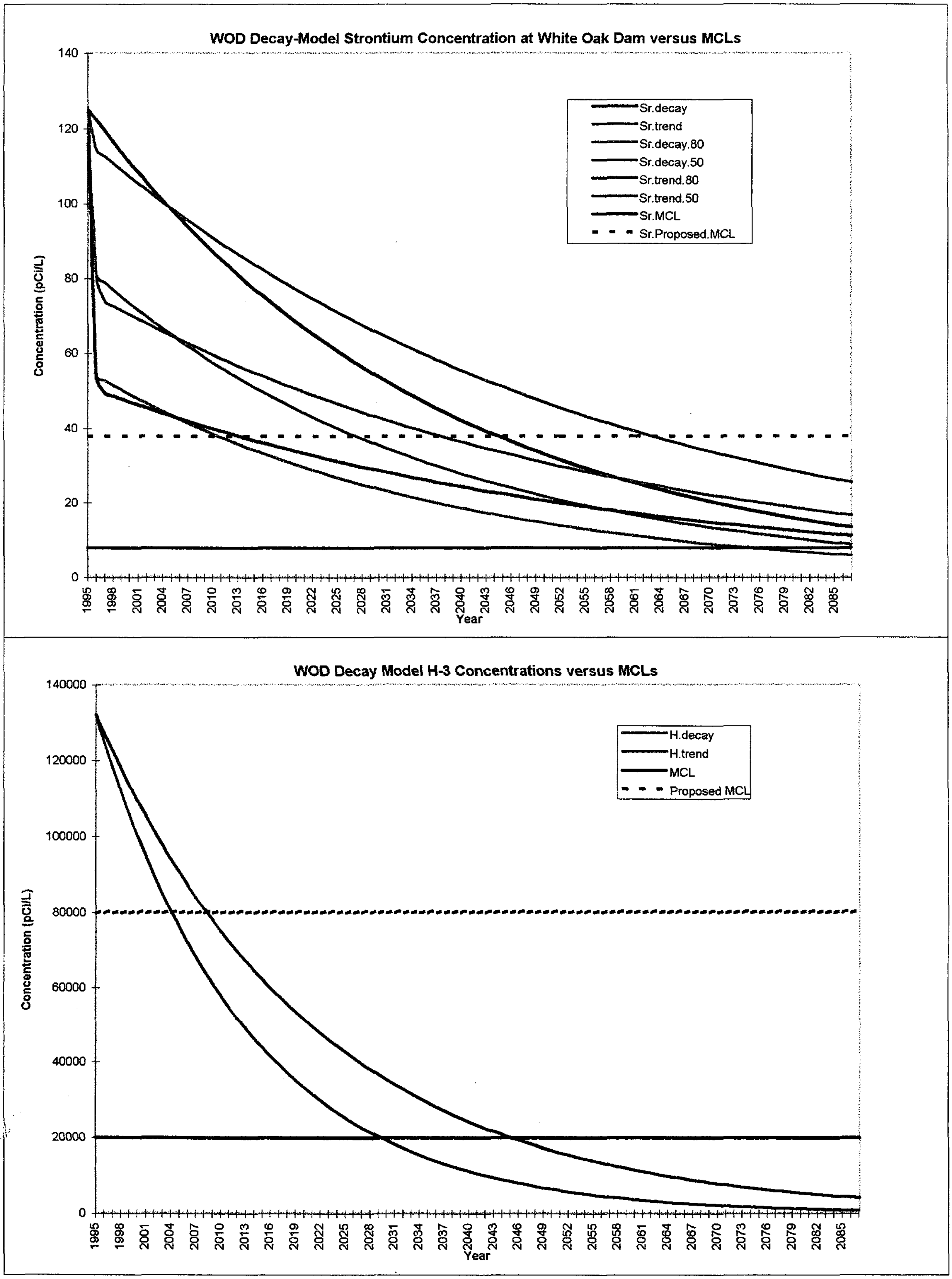


Fig. 3.14. Projection of ^{90}Sr and ^{3}H concentration trends.

data were unavailable. Beryllium results obtained in 1988 and 1989, primarily from SWSA 6, were excluded from consideration because of suspected laboratory problems.

An effective way to assess the potential cancer risk at a specific location is to view its risk history. Only analytes with cancer risk that were detected and quantified at the well during its sampling were included in the analysis. Estimated values below the quantitation limit, J-qualified organics, are not treated as detected values when determining an analyte's inclusion as a risk contributor. Results for all wells with significant contamination are included in this assessment and only analytes that account for 90% of the risk are included. Total risk for a sampling event is the sum of the individual analyte cancer risks for the event.

To identify and calculate statistically significant concentration trends in the ORNL groundwater data, Kendall's tau, a nonparametric measure of correlation, and a robust line-fitting procedure using the Kendall-Theil estimate of slope were used to assess within-well time trends. These methods were used in lieu of standard correlation and regression methods because the datasets have missing values (due to nondetections) and distributions that do not conform to the assumptions of standard parametric methods.

In this application Kendall's tau is a measure of correlation between either a single constituent risk, or total risk, and time. A significant nonzero correlation implies a temporal trend. The form of the trend is unspecified and could be linear or nonlinear, but necessarily monotonic, which is to say that it is assumed that concentrations have not increased and then decreased or vice versa during the monitoring period. The term "M" is used to describe the annual multiplier factor that is derived from the temporal trends observed in this analysis. When M values are greater than 1, a concentration increase over time is indicated, and when M is a value less than 1, contaminant concentrations show a decrease over the monitoring period.

The Melton Valley watershed contains 109 of the WAG perimeter wells as shown on Fig. 3.15. Of these 109 wells, 36 exhibit significant trends of contaminant concentration variation through their period of monitoring. Wells that do not exhibit trends include a broad range of contaminant levels and their data records indicate either relatively constant contaminant concentrations or statistically nonsignificant variations. Figure 3.15 also shows the locations of wells that exhibit significant trends and indicates whether trends are increasing or decreasing at each well. Table 3.14 summarizes risk trends observed in the WAG perimeter wells located in the Melton Valley watershed. In Table 3.14 the following information is summarized for each well in which a trend was detected: the total carcinogenic risk based on the most recent sampling and analysis event, trend computed for total risk if significant, identification of principal contaminants in the well and their trend if significant, and identification of secondary contaminants present in the well if they had a significant concentration trend. Principal contaminants was defined as those with risk greater than about 1.0E-04 and secondary contaminants were those at risk levels less than about 1.0E-04. Some wells that exhibit contaminant concentration trends have no principal contaminants identified since when total risk computed at the well is less than 1.0E-04 and/or only intermittent detection of contaminants is observed.

Uncertainties

Investigations performed in the Melton Valley watershed leading tot his RI provided extensive data sets for analysis of the physical and environmental systems. Such data are used to show long-term historic changes in contaminant releases and to document the role of climatological variability

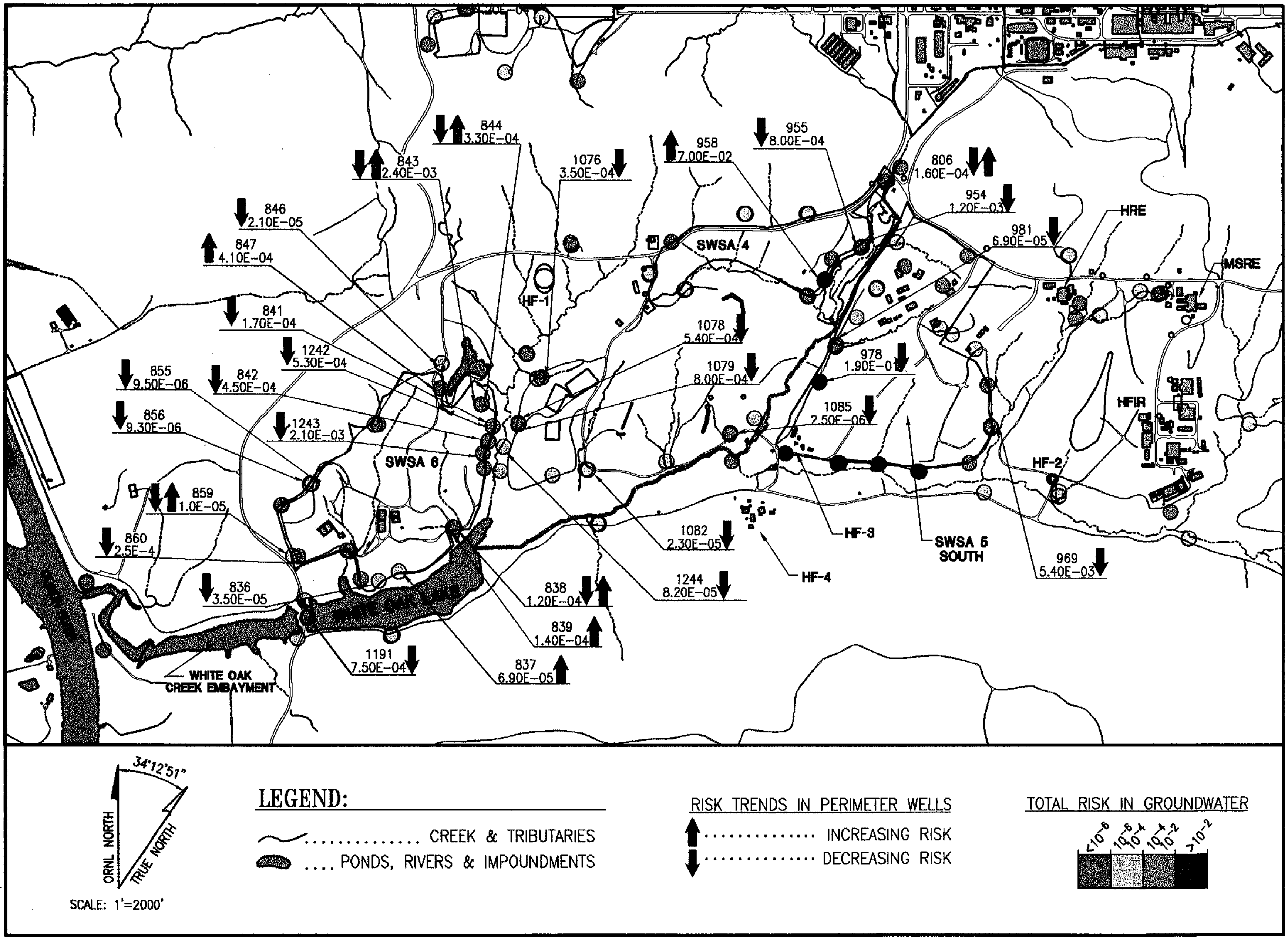


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Fig. 3.15. Locations of wells with significant contaminant concentration trends.

Table 3.14. Groundwater contaminant trends in the Melton Valley watershed

Well	Total risk	Total risk M	Principal contaminants	M	Secondary contaminants	M
0836	3.51E-05	–	^{3}H	–	^{137}Cs	0.86
0837	6.89E-05	–	^{3}H	1.18		
0838	1.17E-04	1.08	^{3}H	1.15	^{137}Cs ^{60}Co	0.87 0.87
0839	1.41E-04	1.16	^{3}H	1.18		
0841	1.72E-04	–	^{3}H	0.89		
0842	4.47E-04	0.81	Chloroform 1,2-Dichloroethane Carbon tetrachloride Trichloroethene ^{3}H ^{60}Co	0.88 0.87 0.86 0.85 0.75 0.62		
0843	2.45E-03	1.13	^{3}H	1.14		
0844	3.27E-04	1.16	^{3}H	1.17	^{89}Sr/^{90}Sr	0.87
0846	2.07E-05	–	None	–	^{3}H	0.93
0847	4.06E-04	1.06	^{3}H	1.05		
0855	5.70E-05	–	None	–	^{60}Co	0.94
0856	5.60E-05	–	None	–	^{3}H	0.94
0858	6.90E-04	–	None	–	Methylene chloride	1.00
0859	9.51E-06	–	^{3}H	1.33	^{60}Co	0.87
0860	2.47E-04	–	None	–	^{60}Co ^{137}Cs	0.91 0.88
0954	1.18E-03	–	^{3}H	0.71		
0955	7.96E-04	0.93	^{3}H	0.94		
0958	7.02E-02	–	1,1-DCE Vinyl Chloride ^{3}H	1.28 – –	Trichloroethene	1.37
0969	5.36E-03	0.77	^{3}H ^{89}Sr/^{90}Sr	– –		
0978	1.86E-01	–	Vinyl Chloride	–	^{3}H 1,1-DCE	0.77
0981	6.86E-05	0.77	^{3}H	0.81		
0992	1.18E-04	0.82	^{89}Sr/^{90}Sr	0.77		
1076	3.45E-04	0.70	^{3}H	0.68		
1078	5.44E-04		^{60}Co	0.86		
1079	8.03E-04		^{3}H	0.93		
1082	2.30E-05	0.89	^{3}H	0.89		
1085	2.54E-06	0.86	None	–	^{3}H	0.90
1191	7.50E-04	0.83	^{89}Sr/^{90}Sr	0.77		
1196	8.56E-06	–	None	–	^{3}H	0.86

Table 3.14 (continued)

Well	Total risk	Total risk M	Principal contaminants	M	Secondary contaminants	M
1197	1.14E-05	–	None	–	^{3}H	1.21
1198	1.71E-05	0.73	^{3}H	0.83		
1199	1.43E-05	0.85	^{3}H	–	$^{89}Sr/^{90}Sr$	0.92
1200	1.21E-05	0.83	^{3}H	–		
1242	5.32E-04	–	^{3}H	0.80		
1243	2.12E-03	0.93	^{3}H	–	^{60}Co	0.66
1244	8.24E-05	0.79	^{60}Co	0.72	^{3}H	0.90

in causing variations in releases of contaminants to the surface water system. While this variability may be viewed by some as an uncertainty, it is a factor present at nearly all CERCLA sites.

The greatest uncertainty in the analysis of the Melton Valley watershed is the limited quantitative data available to define the waste sources including contaminant types and inventories. Data records for liquid waste disposal in the Seepage Pits and Trenches and the hydrofracture injection sites are good. Solid waste disposal records for SWSA 6 are fairly good. The solid waste disposal records for SWSA 4 and a portion of SWSA 5 were lost in a fire in 1964; consequently, knowledge of the waste types and volumes is poorly known for those areas. Disposal records for most of SWSA 5 South indicate the type of waste and types of radionuclides present; however, no estimates of curies associated with each disposal is available. Estimates of the contaminant inventories in secondary media such as soils and pond, lake, and floodplain sediment are based on sampling and analysis data.

The second greatest uncertainty, that is somewhat compounded by the limited solid waste contaminant inventory records, is the condition of waste packaging and the likelihood that significant new releases will occur. Many of the poorly contained wastes have already been released into the subsurface. There is no way to reliably forecast the extent of waste container deterioration or the potential for major new releases to occur. In this report best estimates of radionuclide inventories have been compiled (Appendix A) and decay corrections have been made to arrive at approximate 1997 inventories for each waste disposal area. These estimates are approximate and they are useful to indicate the general rate of source term decline from radioactive decay. These estimates do not incorporate waste received at ORNL from off-site sources including classified disposals. DOE is pursuing issuance of an unclassified report to document environmental concerns related to the disposal of classified waste at ORNL before issuance of the Melton Valley watershed FS to satisfy the requirements of FFA Appendix I.

3.4 MELTON BRANCH BASIN

Melton Branch receives drainage primarily from three areas: the HFIR Area, the HRE subbasin, and portions of SWSA 5 South that contribute water and contaminant fluxes to Melton Branch. Subbasins and contaminant source areas in the Melton Branch Basin are shown in Fig. 3.16. These drainage areas include one operating nuclear reactor and two inactive reactors, numerous D&D facilities, and a variety of waste units including buried waste in SWSA 5 South; tanks, impoundments, leak/spill sites, and surface structures in the HFIR Area; surface structures and

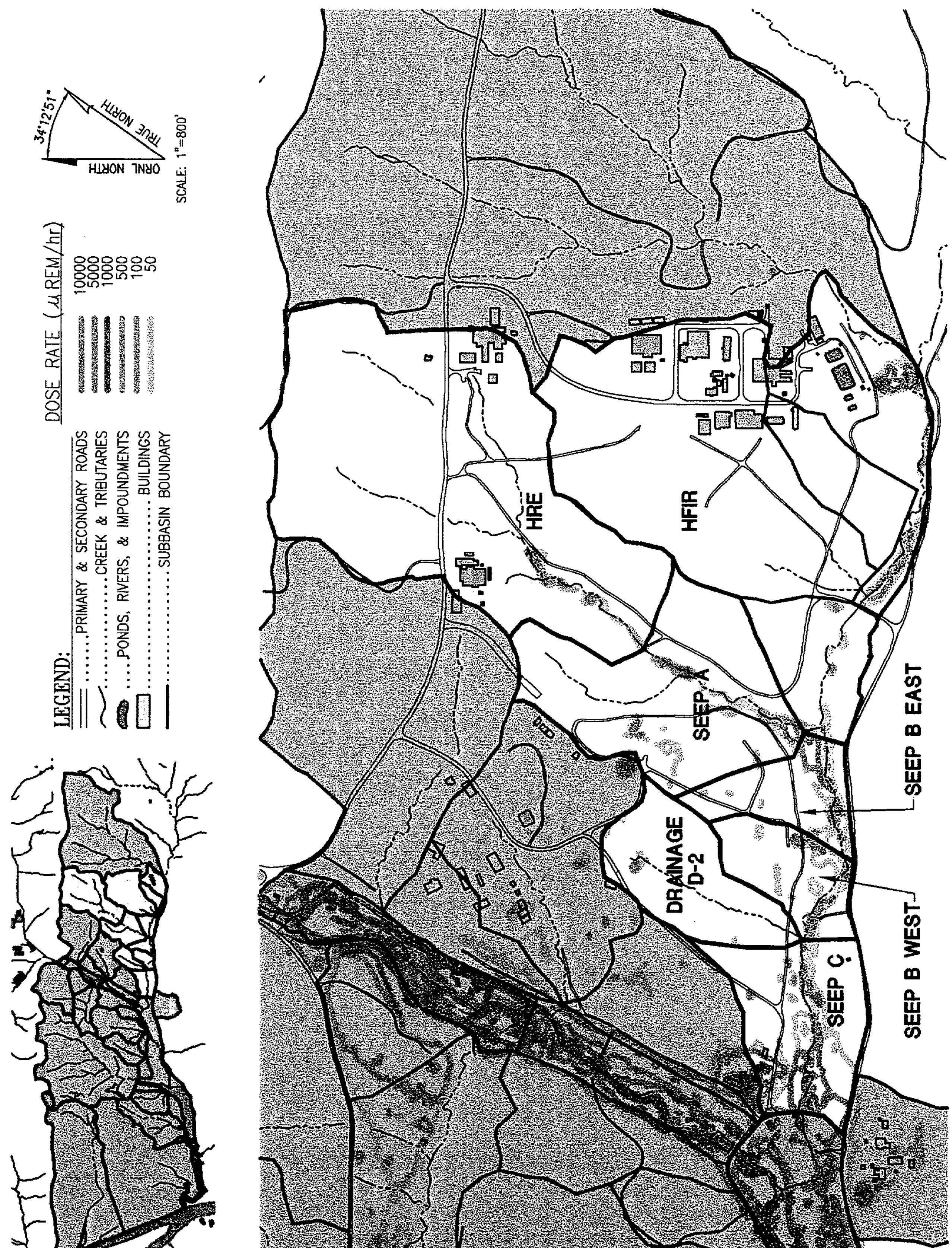


Fig. 3.16. Subbasins contained in the Melton Branch area.

leak/spill sites in the MSRE area; and tanks, impoundments, and surface structures in the HRE area. The following sections discuss the sources, contaminant transport pathways, releases, media of concern, and human and ecological risk for these areas and the Melton Branch floodplain soils and sediments.

3.4.1 HFIR Area

The HFIR Area includes four subbasins encompassing about 74 acres (Fig. 3.17). The HFIR, which is an operating research reactor and is not a CERCLA unit, lies in this area. The major CERCLA units in the area include four inactive surface water impoundments, contaminated soil and sediment associated with historic releases from the impoundments, a closed and covered impoundment used in association with airplane reactor development experiments, an inactive septic tank, the HFIR Cooling Tower, and a closed contractors spoil area.

3.4.1.1 Contaminated sites

The inactive HFIR subbasin lies within the area formerly referred to as WAG 8. WAG 8 included the HFIR, the Transuranium Processing Plant, and the Transuranium Research Facility (TURF) (Fig. 3.16).

The area includes several FFA Appendix C sites (Fig. 3.17) (Appendix A). The sites include impoundments, waste pipeline and ancillary equipment, waste storage tanks, waste storage facilities, a sewage treatment plant (site 8.9), Silver Recovery Process 7934 (site 8.10), a rubble/dump area located to the west of the HFIR (site 8.13), electrical substation, fuel tanks, and the HF-2 Experiment area. Detailed descriptions of the Melton Valley FFA Appendix C sites are given in Appendix A.

The primary waste source units known to have released contamination in the HFIR area are the four HFIR impoundments that lie along Melton Branch south of the HFIR building. Since no CERCLA RI has been performed on WAG 8, characterization of other FFA Appendix C sites is limited. Details of impoundment characteristics and the known characteristics of other areas are provided in Appendix A.

An LLLW pipeline leak in the 7920 Ditch Line (located northwest of Building 7930) is known to have released contaminated liquids causing contamination of soil in the nearby roadside swale. Little is known about contaminant releases from the other FFA Appendix C sites in the HFIR Area including the Silver Recovery Process, TURF Waste and Filter Pit, and HFIR LLW Tank, Sewage Treatment Plan, Building 7900 Waste Oil Storage Tank, PCB Waste Storage Area, Aircraft Reactor Surface Impoundment, the Building 7917 Abandoned Sanitary Sewage System, or the four LLW tanks.

3.4.1.2 Pathway model of contaminated release

In the late 1970s the cooling water blowdown from the HFIR stored in impoundments 7905 and 7906 (Fig. 3.17) was a major source of ^{60}Co in the Melton Branch watershed. Cerling and Spalding (1981) measured significantly elevated concentrations of ^{60}Co in stream gravels in the HRE Tributary downgradient of the impoundments. An average gross beta activity of 1431 pCi/L, which can probably be attributed to ^{60}Co from the ponds, was detected in well 894 downgradient of impoundments 7905 and 7906 over four quarters of sampling in 1986. The average gross beta activity in the two upgradient wells over the year was 12 pCi/L (Montford et al. 1986). In 1987, ^{60}Co

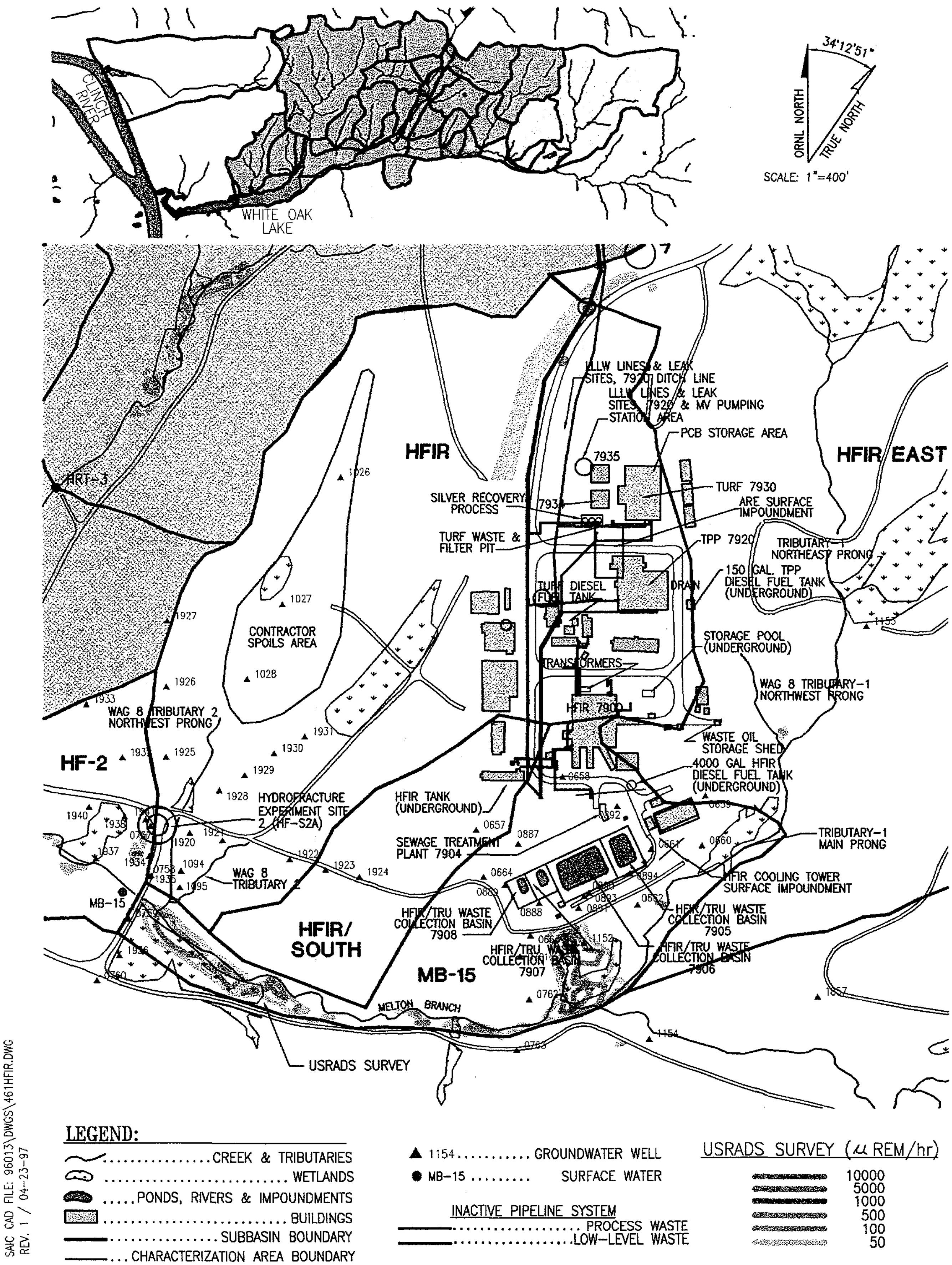


Fig. 3.17. HFIR area subbasins, source areas, monitoring locations.

activities were 1080 and 594 pCi/L, respectively, in wells 893 and 894 located downgradient of 7905 and 7906 (Baughn 1987).

The elevation of the bottom of impoundments 7905 and 7906 is between 795 and 800 ft above MSL and the average water table in the area is about 792 ft above MSL. Therefore, the pond sediments are not saturated on a perennial basis. Thus, the primary release mechanism is probably episodic saturation of the pond sediments during rising water table conditions during the wet part of the year and during storm events. If the release is still occurring, the contamination is likely moving downgradient with shallow groundwater to discharge locations along the HFIR Tributary.

The surface water monitoring station on Melton Branch, MB2 (MB-15), is just downstream from the drainage area/basins surrounding HFIR. Results from Office of Environmental Compliance and Documentation (OECD) monitoring conducted in 1993 and 1994 indicate that the source areas upstream from MB2 only contributed <1% and < 0.2%, respectively, of the ^{3}H and ^{90}Sr fluxes at WOD. Data from stream transect sampling conducted by the WAG 2 RI suggest that most of the ^{3}H is entering the lower reach of West 7 Creek (HFIR tributary) just east of HFIR (Hicks 1996). Limited WAG 5 RI data (DOE 1995b) indicate a significant ^{137}Cs contribution at MB2; however, OECD monthly composite data generally show non-detects for ^{137}Cs at MB2.

Average ^{60}Co activities in monthly surface water samples collected from station W-8, located on Melton Branch about 300 ft upstream from its confluence with the HRE Tributary, were 300 pCi/L in 1986, declining to 110 pCi/L in 1987 (Oakes et al. 1987). Levels of ^{60}Co in the stream water at MB-15 were below detection during the WAG 2 RI sampling events in 1992 and 1993 (DOE 1995a and Hicks 1996). However, these events were primarily during base flow conditions. Earlier storm sampling conducted in 1988 at the downstream location, MBWEIR (Solomon et al. 1991), found measurable amounts of ^{60}Co associated with the suspended sediments that may have been transported from the HFIR area.

3.4.1.3 Secondary contaminated media

Areas of radiologically contaminated surface soils identified in the HFIR area are shown on Fig. 3.16. Contamination in the area between MB-15 and the HFIR/TRU Waste Collection Basins was mapped using the USRADS method. The contaminated area at the 7920 Ditch Line was mapped using hand-held instruments. A small area of contaminated surface soil is noted in the HF-2 experimental site. This contaminated area lies between the HF-2 injection well and Melton Branch.

Secondary contaminated media in the MB-15 subbasin include approximately 0.6 acre (0.24 ha) of surface soils downgradient of the HFIR ponds and 0.4 acre (0.16 ha) of contaminated sediments along the HFIR Tributary. Assuming a 1-ft (0.31-m) thickness for these soils and sediments, there are about 26,000 ft^3 (741 m^3) of contaminated surface soils and 17,000 ft^3 (494 m^3) of contaminated sediments in the MB-15 subbasin. No significant groundwater contamination has been detected in the HFIR subbasin.

3.4.1.4 Human health risk, ecological risk, and criteria exceedances

The HFIR Area subbasin discussion consists of risk and criteria exceedance results for the following subbasins that are analyzed in this assessment: HFIR, HFIR East, HFIR South, HF-2, and MB-15. The media evaluated are groundwater, sediment, soil, and two categories of surface water. The surface water categories for the human health and ecological risk assessments are surface water-seeps and surface water-streams. The surface water-seeps category consists of samples taken at both seeps and small tributaries. The surface water-streams category includes samples collected in Melton Branch and from large tributaries. The human health COCs for each of the media are presented based on recreational land use. Risk results are presented for recreational and industrial land use. COCs and risk results for all three scenarios evaluated can be found in the human health risk assessment. Figure 3.18 presents available carcinogenic risk results by sample location for groundwater, soil, sediment, and surface water.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.15 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The subbasins within the HFIR Area have not been as comprehensively sampled as a number of the other subbasins analyzed in this report; therefore, the associated uncertainty in the risk results and the identified COCs is considered to be greater.

Table 3.15. Media data summary for the HFIR Area subbasin

Basin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
HFIR	Groundwater	2	86	70	383	92	991	21
HFIR	Soil	14	105	56	0	0	0	0
HFIR East	Groundwater	1	75	62	307	149	734	14
HFIR East	Sediment	8	0	0	209	169	0	0
HFIR East	Soil	2	14	0	0	0	0	0
HFIR East	SW-seeps	1	8	7	0	0	0	0
HFIR South	SW-streams	1	7	7	50	22	0	0
HF-2	Groundwater	1	69	54	306	156	698	17
HF-2	Sediment	8	0	0	321	268	88	1
HF-2	Soil	3	29	20	59	57	138	3
HF-2	SW-seeps	1	601	401	575	414	464	57
HF-2	SW-streams	3	329	155	448	288	132	9
MB-15	Groundwater	3	89	75	336	165	736	16
MB-15	Sediment	17	0	0	546	476	55	0
MB-15	Soil	9	40	40	0	0	0	0
MB-15	SW-seeps	2	22	20	68	18	26	0
MB-15	SW-streams	4	15	15	112	96	66	16

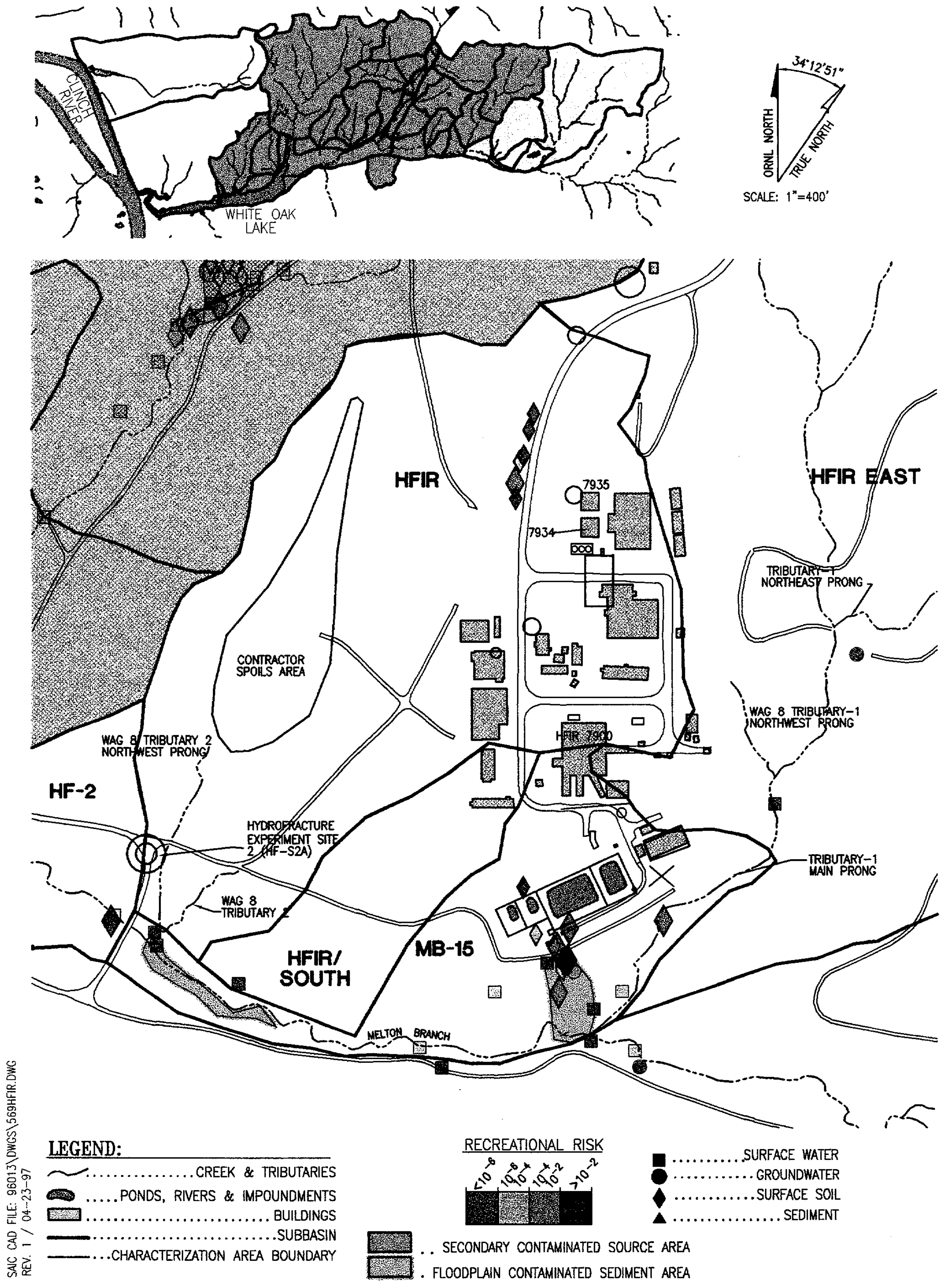


Fig. 3.18. Risk estimates at sampling locations in HFIR area subbasin.

HFIR Area Soil

Radionuclide soil data are available for four of the five subbasins that compose the HFIR Area subbasin. Fourteen soil samples were analyzed for a number of radionuclides in the HFIR subbasin. The risk-driving contaminants present at this location were ^{137}Cs, ^{60}Co, ^{90}Sr, and ^{288}Th. However, the representative concentrations for these detected radionuclides correspond to a recreational risk of 5.1E-05, with ^{137}Cs being the highest risk contributor. Since the recreational soil risk for the HFIR subbasin is less than the EPA's target risk range, no recreational COCs are identified for this subbasin. The industrial risk for the HFIR subbasin is 1.2E-03. Two soil samples were collected in the HFIR East subbasin and analyzed for ^{137}Cs and ^{60}Co. No detects were found, so no risk result was calculated. No soil samples were collected in HFIR South. Nine samples detected ^{137}Cs and ^{60}Co in MB-15. The detected concentrations yield a recreational risk of 8.1E-02 attributed primarily to ^{60}Co, but the carcinogenic risk from ^{137}Cs also exceeds the target risk range. The industrial risk for the MB-15 subbasin is 8.5E-01. None of the soil samples collected in MB-15 were analyzed for metals or organics. HF-2 has three sample locations, which yield a recreational risk of 3.9E-04 and an industrial risk of 8.6E-03. The recreational COC for the HF-2 area is ^{60}Co. The recreational and industrial HIs for HF-2 are 3.0E-02 and 8.1E-02; therefore, no noncarcinogenic COCs based on the HI are identified for these land areas.

The recreational COCs for the HFIR subbasin based on detected soil samples in the MB-15 and HF-2 subbasins are ^{60}Co and ^{137}Cs. No COCs for noncarcinogenic risk or for nonradionuclide carcinogenic risk are identified for the soil based on the recreational land use scenario. COCs for the industrial and residential scenarios are identified in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides in soil in the HFIR subbasin. Nonradionuclide data were unavailable for soil. Potential risks from exposure to the seven radionuclides detected in soil were identified for soil invertebrates (HI = 2.0), white-tailed deer (HI = 3.1), and wild turkey (HI = 3.7) (Table 3.16). Strontium-90 was the primary risk driver, contributing >89% of the HI for all receptors.

Risks to terrestrial biota were evaluated for radionuclides in soil in the HFIR East subbasin. Nonradionuclide data were unavailable for soil. Only one radionuclide (^{40}K) was detected in three samples from this subbasin, and no risks are anticipated for terrestrial biota (Table 3.16).

Risks to terrestrial biota were evaluated for radionuclides in soil in the MB-15 subbasin. Nonradionuclide data were unavailable for soil. Potential risks from exposure to the two radionuclides detected in soil were identified for all receptors with HIs ranging from 1.1 for plants to 30.6 for shrews and mice (Table 3.16). The primary risk driver was ^{60}Co, contributing >95% of the HI for all receptors.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the HF-2 subbasin. Overall dose rates from exposure to the eight radionuclides detected were well below the recommended dose limits for all receptors (Table 3.16). Potential risks were identified for plants (HI = 186.6), soil invertebrates (HI = 422.9), short-tailed shrews (HI = 39.0), white-footed mice (HI = 5.8), red fox (HI = 4.5), white-tailed deer (HI = 1.6), and red-tailed hawk (HI = 1.2) from exposure to nonradionuclides. Inorganics contributed 100% of the HI for all receptors. HQs exceeding one were estimated for five inorganics (chromium, zinc, cobalt, barium, and molybdenum) for plants, two inorganics (chromium and zinc) for invertebrates, four inorganics (chromium, barium, zinc, and molybdenum) for shrews, two inorganics (chromium and barium) for foxes, and one inorganic each for mice, deer, and hawks (chromium, barium, and zinc, respectively). With the exception of chromium, most exceedances of toxicological benchmarks were relatively low (less than a factor of 3). This subbasin was not a major contributor to the estimated watershed-wide population effects for shrews exposed to molybdenum.

Table 3.16. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at the HFIR Area subbasin

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
HF-2	Plants	186.6	CrVI (168.0), Zn (11.6), Co (2.0), Ba (1.9), Mo (1.5)	<0.1	
HF-2	Invertebrates	422.9	CrVI (420.0), Zn (2.9)	<0.1	
HF-2	Shrew	39.0	CrVI (29.5), Ba (3.8), Zn (3.3), Mo (1.2)	0.1	
HF-2	Mouse	5.8	CrVI (4.2)	0.1	
HF-2	Fox	4.5	CrVI (2.3), Ba (1.1)	0.1	
HF-2	Deer	1.6	Ba (1.3)	0.1	
HF-2	Hawk	1.2	Zn (1.0)	<0.1	
HFIR	Invertebrates	NA		2.0	^{90}Sr (1.9)
HFIR	Deer	NA		3.1	^{90}Sr (3.0)
HFIR	Turkey	NA		3.7	^{90}Sr (3.3)
HFIR East	All	NA		<0.1	
MB-15	Plants	NA		1.1	^{60}Co (1.1)
MB-15	Invertebrates	NA		6.0	^{60}Co (6.0)
MB-15	Shrew	NA		30.6	^{60}Co (30.5)
MB-15	Mouse	NA		30.6	^{60}Co (30.5)
MB-15	Fox	NA		22.8	^{60}Co (24.0)
MB-15	Deer	NA		11.3	^{60}Co (11.3)
MB-15	Mink	NA		22.3	^{60}Co (22.9)
MB-15	Hawk	NA		1.2	^{60}Co (2.4)
MB-15	Turkey	NA		11.7	^{60}Co (11.7)

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.

[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.

[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

Chromium was the primary risk driver for plants, invertebrates, shrews, mice, and foxes, contributing 51–99% of the HI for each. Chromium was detected in both of the soil samples collected at HF-2, but at levels higher than background in only one, and then at a concentration only about twice as high (168 mg/kg for HF-2 versus 78 mg/kg background). The analytical data did not specify the valence state of the chromium. Chromium (VI) is more toxic and bioavailable than chromium (III) (Will and Suter 1995), but in most soils chromium (VI) is likely to be reduced to chromium (III) (Will and Suter 1995). However, the toxicological benchmark used to estimate effects of chromium is based on chromium (VI) studies. The use of the benchmark for the more toxic and available chromium (VI) when exposures may be predominantly from chromium (III) may lead to overestimation of the risks of adverse phytotoxic effects. Terrestrial wildlife exposures to chromium were below the no observed adverse effect level (NOAEL) for chromium (III) for all receptors.

HFIR Area Sediment

Eight sediment samples were collected in the HFIR East subbasin and analyzed for a variety of inorganics. Seventeen sediment samples were collected in the MB-15 subbasin and analyzed for inorganics; some of these samples were also analyzed for organic constituents. No radionuclide data are available for these sediment samples, and no sediment samples were collected in the HFIR and HFIR South subbasins. The HFIR East results indicate a total recreational HI of 4.4E-02 and an industrial HI of 1.5E-01. The MB-15 results indicate a total recreational HI of 1.1E-02 and an industrial HI of 2.9E-02. There were no detected metals or organics that passed the reference and preliminary remediation goal (PRG) screening steps, so carcinogenic risk for this subbasin is not calculated. HF-2 was also sampled for inorganic sediment contaminants but did not yield any recreational COCs. Recreational and industrial risks for HF-2 are 1.2E-09 and 8.1E-08, respectively, while the HIs are 6.0E-02 and 1.8E-01.

Therefore, no COCs are identified for the sediment in the HFIR subbasin based on recreational land use. However, no radionuclide data are available for the sediment in this subbasin, so no conclusions concerning the absence of COCs can be drawn. COCs for the industrial and residential land use scenarios are presented in Appendix B.

Significant risks were identified for benthic invertebrates exposed to sediment in the HFIR East subbasin, based on the one available line of evidence (sediment chemistry). The definition of significant risk is provided in Appendix C, Sect. 4.2.3.1. Manganese was the only analyte presenting a significant risk and was identified as a chemical of ecological concern (COEC) (Table 3.17). Antimony presented a marginal risk, but no other analytes exceeded possible effects levels.

Table 3.17. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment in HFIR basin

Subbasin	Risk category[a]	COECs/COPECs[b]
HF-2	Significant	Mn, Zn
	Marginal	Sb, Cr
	Negligible	Cu
HFIR East	Significant	Mn
	Marginal	Sb
	Negligible	None
MB-15	Significant	None
	Marginal	Sb, Zn
	Negligible	None

[a] Analytes were ranked based on the percentile of the concentration distribution within the subbasin that exceeded or failed to exceed possible or probable effects levels. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels are listed as contaminants of potential ecological concern.

The weight-of-evidence suggests that sediment in subbasin MB-15 does not pose a significant risk to benthic invertebrates. The sediment community was similar to reference sites and none of the detected chemicals exceeded probable-effects benchmarks (i.e., there are no COECs; Table 3.17). Antimony and zinc presented marginal risks, but no other analytes exceeded possible effects levels.

Significant risks were identified for benthic invertebrates exposed to sediment in the HF-2 subbasin, based on the one available line of evidence (sediment chemistry). Manganese and zinc were the only analytes presenting a significant risk and were identified as COECs (Table 3.17). Antimony and chromium presented a marginal risk, and copper exceeded a possible effects level and was considered a negligible risk. No other analytes exceeded possible effects levels.

HFIR Area Groundwater

Seven sample locations within HFIR, HFIR East, HF-2, and the MB-15 subbasin have been analyzed for a comprehensive list of radionuclides, inorganic, and organic contaminants. The HFIR South subbasin within the HFIR Area had no groundwater samples. Table 3.18 summarizes the industrial and recreational risk results along with the recreational COCs. No recreational risks were greater than the target risk range, so no groundwater COCs are identified for the HFIR Area subbasin.

Table 3.18. Summary of risk results for HFIR Area groundwater

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index
HFIR	–	–	–	–
HFIR East	1.0E-07	–	1E-08	–
HF-2	2.0E-07	–	2.1E-08	–
MB-15	1.8E-04	3.3E-01	2.5E-06	5.7E-03

The groundwater data from the subbasins within the HFIR Area were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. The only criteria exceedance noted was for ^{3}H in the MB-15 subbasin.

HFIR Area Surface Water

Surface water locations were analyzed for ^{90}Sr and ^{3}H at HFIR East, HFIR South, and MB-15. In addition, organics were sampled at MB-15 and inorganics were collected at HFIR South. HF-2 was evaluated for a comprehensive list of contaminants. No surface water samples were collected at the HFIR subbasin. Table 3.19 summarizes the carcinogenic risk and the noncarcinogenic HI for the four HFIR areas where surface water data were collected.

The recreational risk estimates for HFIR East, HFIR South, HF-2, and MB-15 are all below EPA's target risk range and, therefore, no carcinogenic COCs are identified for the HFIR Area. The concentrations of the inorganics that were detected at MB-15 did not exceed the reference and PRG screens and noncarcinogenic contaminants were not analyzed for in the other subbasins, so HIs were not calculated for HFIR East and HFIR South. COCs for the residential and industrial land use scenarios can be found in Appendix B.

Table 3.19. Summary of risk results for HFIR Area surface water

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index
HFIR East-seeps	2.9E-06	–	3.2E-08	–
HFIR South-streams	8.5E-06	–	9.2E-08	–
HF-2-seeps	1.2E-03	8.1E-01	2.1E-05	1.0E-01
HF-2-streams	3.3E-05	6.6E-01	3.1E-06	2.0E-02
MB-15-seeps	2.4E-05	2.8E-01	2.6E-07	3.5E-03
MB-15-streams	1.6E-04	4.4E-01	1.1E-05	5.8E-02

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the HFIR East subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from the HFIR East subbasin; water concentrations were below wildlife lowest observed adverse effect levels (LOAELs) for all receptors and all analytes.

Significant risks to aquatic organisms exposed to contaminants in HFIR South surface water were identified, based on the one available line of evidence (surface water chemistry). Iron was the only COEC (Table 3.20). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction as they may not be bioavailable.

Table 3.20. Summary of potential risks to aquatic organisms from contaminants in main stem surface water in the HFIR basin

Subbasin	Risk category[a]	COECs/COPECs[b]
HF-2	Significant	Al, Co, Cu, Tl, Zn
	Marginal	Ba, B, Hg, carbon disulfide
	Negligible	Be
HFIR South	Significant	Fe
	Marginal	None
	Negligible	None
MB-15	Significant	Al, Cd, Cu, Fe, Ni, Se, Tl
	Marginal	Be
	Negligible	Co, Hg, Li, Sn

[a] Risks were estimated by subbasin for each COPEC by comparing the distribution of observed concentrations to each aquatic benchmark. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

No risks were identified for terrestrial wildlife drinking surface water from the HFIR South subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

The weight-of-evidence suggests that water in the MB-15 subbasin poses a significant risk to benthic macroinvertebrates, but not to fish. The benthic invertebrate community is significantly less species rich and dense than the reference communities and seven metals (Al, Cd, Cu, Fe, Ni, Se, and Tl) appear to result in significant risks and are identified as COECs. However, the water has not been toxic in the standard toxicity tests. Hence, there appears to be an adverse effect on the community, and metals appear to be the causal agent based on the available data. The fish community is somewhat less species rich than a similar reference stream (two species versus three or four species), but it is more dense than the reference.

No risks were identified for terrestrial wildlife drinking surface water from the MB-15 subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes. No risks were identified for plants exposed to seep water in soil solution; maximum water concentrations were below plant soil solution benchmarks for all analytes.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the HF-2 subbasin, based on the one available line of evidence (surface water chemistry). Aluminum, cobalt, copper, thallium, and zinc appear to result in significant risks and are identified as COECs (Table 3.20). However, it is unlikely that aluminum is actually toxic to fish and aquatic biota in the Melton Valley watershed, because of the low solubility of aluminum in circa neutral water.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the HF-2 subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

Potential risks to white-tailed deer drinking surface water from the HF-2 subbasin were identified based on comparison of the lower of the maximum or UCL95 water concentration to water concentration LOAELs. Risks were not identified for any other receptors, and thallium was the only analyte that exceeded the LOAEL for deer (HQ = 1.3). It is unlikely that thallium in drinking water poses a risk to deer. The thallium benchmark is conservative, based on a reduction in sperm motility, and was derived using a subchronic to chronic uncertainty factor of 10. In addition, the frequency of detection was low, only 1 of 9 samples in the subbasin.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at station 05.SW005 (HQ = 202). The aluminum benchmark appears to be conservative as it is below the background concentration. However, the aluminum concentration at this station was well above background and substantially higher than concentrations at other seeps across the watershed. Other analytes marginally exceeding benchmarks (HQs <5.4) at this station were arsenic, chromium, copper, iron, lead, manganese, and nickel. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

The contaminant surface water concentrations for the HFIR Area subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. No contaminants in any of the HFIR Area subbasins exceeded either the human health or the ecological criteria.

3.4.1.5 Options for release mechanism intervention

The principal solid waste management unit in the HFIR subbasin that is known to have released contaminants affecting the surface water system is the HFIR Impoundments. Residual waste inventory in these units consists of 12,000 ft^3 of sludges containing approximately 1.5 Ci of ^{60}Co and ^{137}Cs. COCs for the area are primarily ^{60}Co and ^{137}Cs. Releases of ^{60}Co from the impoundments have diminished to the point that this contaminant is no longer detectable in surface water near the source. The source term for future exposure or releases of ^{60}Co from the impoundments and associated sediment and soil diminishes at a relatively rapid rate because ^{60}Co has a half-life of 5.3 years. The release mechanism at the impoundments is intermittent saturation of residual sediment in the pond floor that lies above the average groundwater table elevation. Stabilization of the impoundments and associated soils must assess the rate of radionuclide decay and the duration of risk associated with this area. The declining release, limited contaminant source term, and hydrologic conditions offer the option of stabilizing residual contaminants in one or more of the existing impoundment cells.

Contaminated sediment along the Melton Branch stream channel downstream of the HFIR facility is potentially susceptible to erosion and transport downstream. Sediment analyses show the presence of ^{60}Co and ^{137}Cs. Stabilization options for this sediment include removal and consolidation in a contaminated soil/sediment storage area, or covering/containment through the time duration of potential risk based on contaminant decay.

3.4.2 HRE Subbasin

The HRE subbasin is located in the upper portion of the HRE Tributary to Melton Branch and encompasses 60.5 acres (Fig 3.19). Contaminant source areas and monitoring locations are shown on Fig. 3.19. The HRE and the MSRE, along with their associated facilities, are both located within this subbasin.

3.4.2.1 Contaminated sites

MSRE is east of HRE and drains toward the East Prong of the HRE Tributary. Solid waste management units and AOCs within the MSRE area include (Fig. 3.19) the MSRE Storage Well, Tank WC-20 (SWMU 8.5), Tanks T1 and T2 (SWMU 8.7a,b), and a septic tank that reportedly never received hazardous wastes (SWMU 8.11).

In the northern portion of the MSRE area, there are documented leaks along the liquid waste transfer pipelines (SWMU 8.3d–g) that have resulted in contamination of surface soils. There is uncertainty regarding the precise locations of these leak sites. Contaminants present in these soils include ^{90}Sr, ^{137}Cs, and ^{60}Co.

The HRE was originally constructed in 1951 to house the Homogeneous Reactor Experiment No. 1 (HRE-1), the first of two experimental aqueous reactors. The second reactor, HRE-2, was constructed within the same facility from 1953 to 1956 and operated until 1961. Since that time, portions of the HRE Area have been used by Nuclear Safety Pilot Plant personnel.

Waste generated at HRE-1 was treated on-site, and some waste was also disposed of or stored on-site or on nearby sloped areas adjacent to the HRE Tributary. Gaseous waste was collected and routed through charcoal absorber beds for treatment, via the HRE vent system, then discharged to the atmosphere via a steel stack. Existing records indicate that wastes were typically radiological in nature and may also have contained acids and metals (Energy Systems 1988b) (Appendix A).

The HRE-1 liquid waste system consisted of a waste evaporator, underground pipelines, other ancillary equipment, and an underground waste storage tank (Tank 7560). Liquid waste, generated

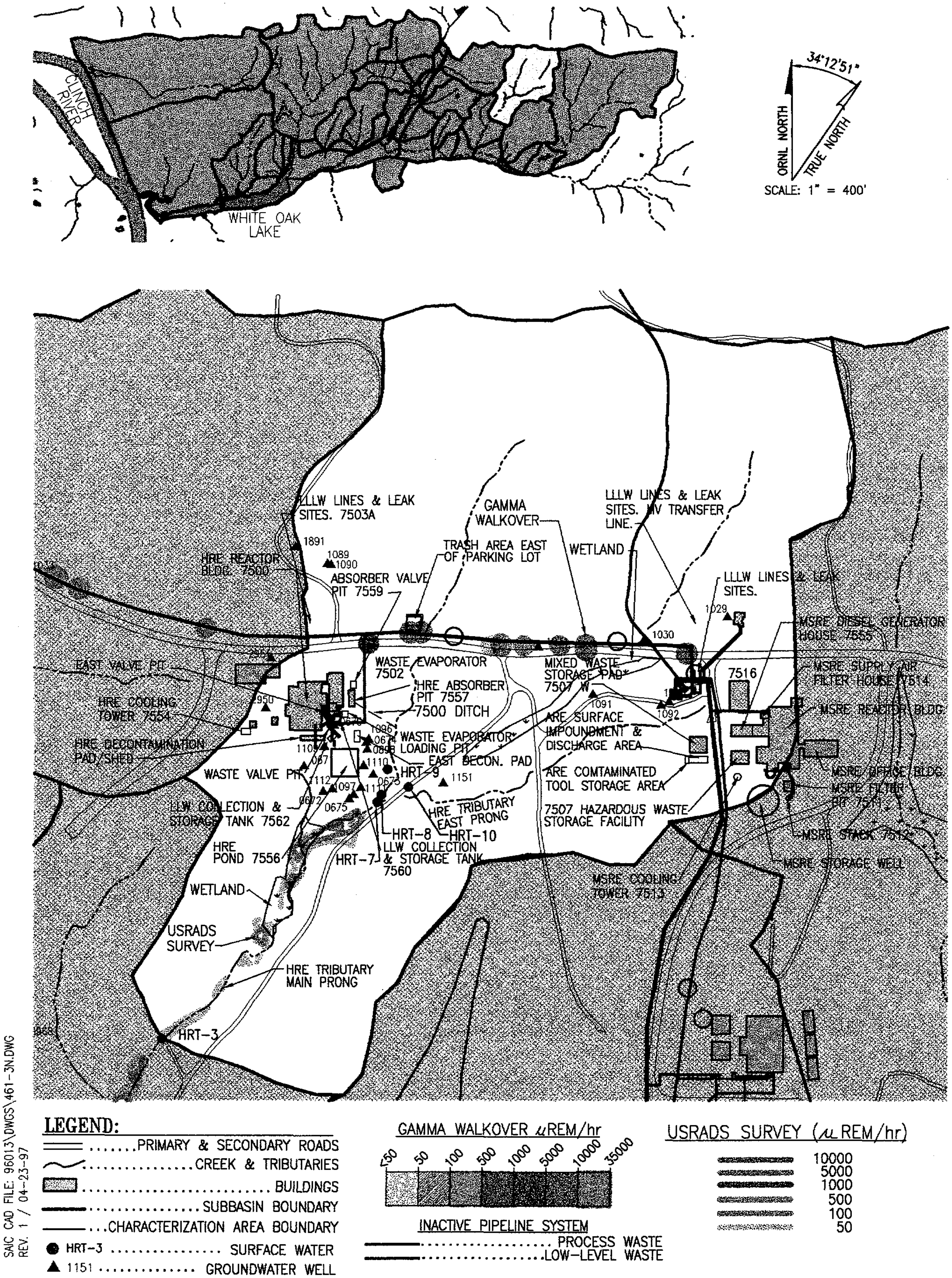


Fig. 3.19. HRE subbasin, source areas, and monitoring locations.

by removal of corrosion products from the primary reactor system and by routine maintenance activities, was jetted (using an ejector-type jet pump) to the underground storage tank. Depending upon the level of radioactivity, the waste was then either transferred to the evaporator in batches or discharged onto a hillside behind Building 7500 through a ditch and into the HRE Tributary. The concentrated waste from the evaporator was jetted to the evaporator loading pit, loaded onto shielded transfer trucks, and taken to the ORNL liquid waste handling system (Lee 1986). On several occasions, liquid waste was also released from the evaporator into the drainage ditch as a result of overflow from the condensers (Energy Systems 1988b). Purge water from the storage pool in Building 7500 discharged on the ground along a natural drainage east of Building 7500 and entered the HRE Tributary to Melton Branch. The amounts of these discharges and their radioactive contents are unknown (Lee 1986).

The HRE-2 liquid waste system consisted of a waste evaporator, two underground waste storage tanks, pipelines, other ancillary equipment and a surface impoundment. Tank 7560, used originally as the liquid waste tank for HRE-1, was used as the clean vapor condensate tank for the evaporator during HRE-2. A second tank, Tank 7562, was installed for HRE-2 and used as the primary liquid waste tank (Energy Systems 1988b).

Depending on the level of radioactivity (less than or equal to 1000 cpm/mL), the lower activity waste was sent either to the surface impoundment or to Tank 7562 for processing in the evaporator. The lower level wastes were discharged into the impoundment for subsequent precipitation of radionuclides using flocculants, followed by controlled drainage to the HRE Tributary of Melton Branch. Concentrated wastes from the evaporator were transferred off-site via an underground pipeline to the Melton Valley intermediate-level liquid waste (ILLW) transfer line and the ORNL liquid waste handling system. Condensate from the evaporator was jetted to Tank 7560, where its level of activity was checked. The waste was either discharged to the impoundment or returned to the evaporator depending on the level of activity (Chapman 1964).

Potential contamination may have resulted from leaks within the tanks, pipes, valves, and associated ancillary equipment used to transfer or treat liquid wastes. These include the HRE Surface Impoundment (SWMU 9.1), Storage Tanks 7560 and 7562 (SWMU 9.2), waste evaporator, evaporator loading pit, west valve pit, east valve pit, the WAG 9 ILLW pipeline, and areas of discharge from Buildings 7500 and 7502. Given that the charcoal absorber pit was used to treat gaseous radioactive waste, this site is included as an AOC because of the potential for contamination. The area adjacent to the west decontamination pad had high direct radiation readings thought to be the result of rinsate leaching into the ground (Lee 1986). Therefore, both the east and west decontamination pads have been included as AOCs.

The septic tank (SWMU 9.3) serviced the HRE facility and currently serves existing lavatories. There is no evidence that the septic tank ever received hazardous or radioactive waste. The HRE Parking Lot (SWMU 9.4) was the site of an old farmhouse, which was used for storage during HRE-1 and HRE-2. Reportedly, some stored material was contaminated with radioactivity (Energy Systems 1988b). All of the stored material was removed for disposal, the farmhouse was demolished, and most of the debris was removed. The electrical substation has been added as an AOC, because PCBs have been detected in the surface impoundment. It is suspected that contaminated soils from the area of the electrical substation may have been used as fill, given that this is the only likely source of PCBs in the HRE area.

Based on historical information, site surveys, and soil sampling, the following areas have known contamination:

- areas adjacent to the surface impoundment;
- areas adjacent to the Tank 7560;
- areas adjacent to the waste evaporator;
- areas adjacent to the Building 7500;
- areas adjacent to the west decontamination pad;
- areas adjacent to storm drains;
- areas adjacent to the Melton Valley liquid waste transfer pipelines;
- buried sediments in the surface impoundment;
- the area around and including the cement culvert to the east of the HRE fence;
- Tank 7562 and adjoining area;
- area southwest of HRE marked as a burial ground;
- area east of HRE where various contaminated waters were released on the slope;
- the buried charcoal filtration system;
- the various valve pits;
- the lines connecting the valve pits, tanks, pits, pool, north sump, and the pond; and
- Building 7500, including the reactor cell, generating equipment, some of the cells, the storage pool, and possibly the north pump.

With the exception of the buried sediments in the surface impoundment, there is little information available regarding contaminant inventories in these areas.

3.4.2.2 Pathway model of contaminant releases

Results from the watershed-wide grab sampling conducted by a WAG 2 RI task in 1993 and 1994 indicated that the HRE basin was a source of approximately 8.5% of the ^{90}Sr in the watershed (Hicks 1996) (Table 3.1). However, the sampling was conducted primarily during different base flow conditions. Intensive storm event and base flow sampling data from another WAG 2 RI task (Borders et al. 1996) suggests that the HRE basin was a greater source of ^{90}Sr to the watershed. A significant part of this discrepancy is due to the extremely wet conditions monitored during the 1994 wet season. The later WAG 2 results indicate that the ^{90}Sr contribution from this basin was approximately 11% in 1994. However, approximately 65% of this total occurred in a 3-month period

(February through April) in which approximately 29 in. of precipitation (Borders et al. 1995) were recorded on the Melton Valley watershed. Apparently, a near-surface source is activated during extremely wet conditions. Presumably, the contribution from this basin would be less in dryer years and agree more closely with the 8.5% estimate.

According to the WAG 5 RI Report (DOE 1995b), the HRE basin is also a source of ^{137}Cs to the watershed (6%). However, ^{137}Cs was not detected in samples collected as part of the WAG 2 RI in 1993 (Hicks 1996).

Figure 3.20 is a cross section of the HRE Pond showing physical construction elements. Based on site characterization data, the decommissioned HRE No. 2 impoundment is a significant source of ^{90}Sr contamination of groundwater in the HRE area and surface water in the HRE Tributary to Melton Branch. The bottom elevation of the impoundment is approximately 802.6 ft above MSL. The average water table elevation in the area of the impoundment is about 810 ft above MSL. Borings were advanced into the impoundment, which encountered mixed fill/sediment waste at an elevation of about 813 ft above MSL. Therefore, all but about 3 ft of the approximately 10 ft of mixed fill/sediment waste is perennially saturated. The primary release mechanism for contaminants is thus inundation and leaching of the mixed fill/sediment waste.

Four groundwater monitoring wells (1109, 1110, 1111, and 1112), screened in bedrock, were installed in 1985 around the site of the HRE impoundment (Fig. 3.21). These wells were sampled quarterly over a 1-year period from February 1985 to January 1986 (Francis and Stansfield 1986) and during the first and second quarters of 1987 (Francis and Sealand 1987b). Gross beta activities measured in groundwater samples from these wells are summarized in Table 3.21.

Table 3.21. Gross beta activities in HRE wells

	Gross beta (pCi/L)						
Well	February 1985	May 1985	September 1985	January 1986	February 1987	July 1987	May 1996
1109	270	27	27	27	<54	149	92
1110	19440	25650	21870	22680	75600	102600	24451
1111	648	108	54	27	<54	756	11.5
1112	24300	5670	1755	1647	702	432	88

As can be seen from the groundwater monitoring results, the gross beta activities, attributable to ^{90}Sr, are generally higher in the downgradient wells (1110, 1111, and 1112) than in the upgradient well (1109), with the highest activities being measured in well 1110, located along geologic strike to the east of the impoundment. The boring log for this monitoring well describes highly weathered, intensely fractured bedrock in the screened interval. Thus, it appears that contaminants are moving predominantly along strike in weathered and fractured bedrock.

More recent samples collected yearly from 1991 to 1994 from well 1097, located downgradient of the HRE impoundment (Fig. 3.21) contained elevated ^{90}Sr activities, ranging from 95 to 919 pCi/L, indicating that ^{90}Sr continues to leach out of the mixed fill/sediment waste in the former impoundment and move downgradient toward the HRE basin.

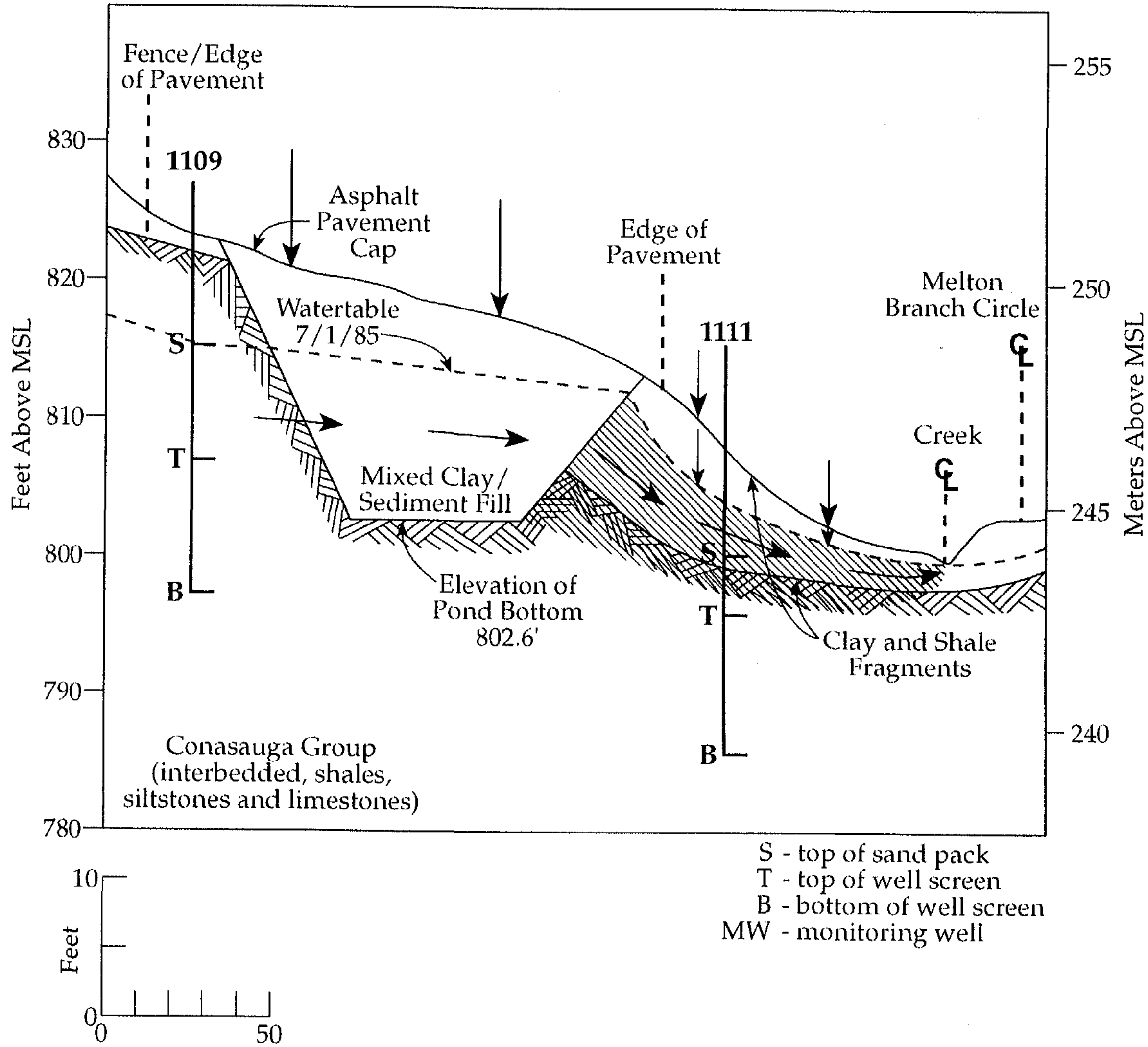


Fig. 3.20. HRE Pond cross section.

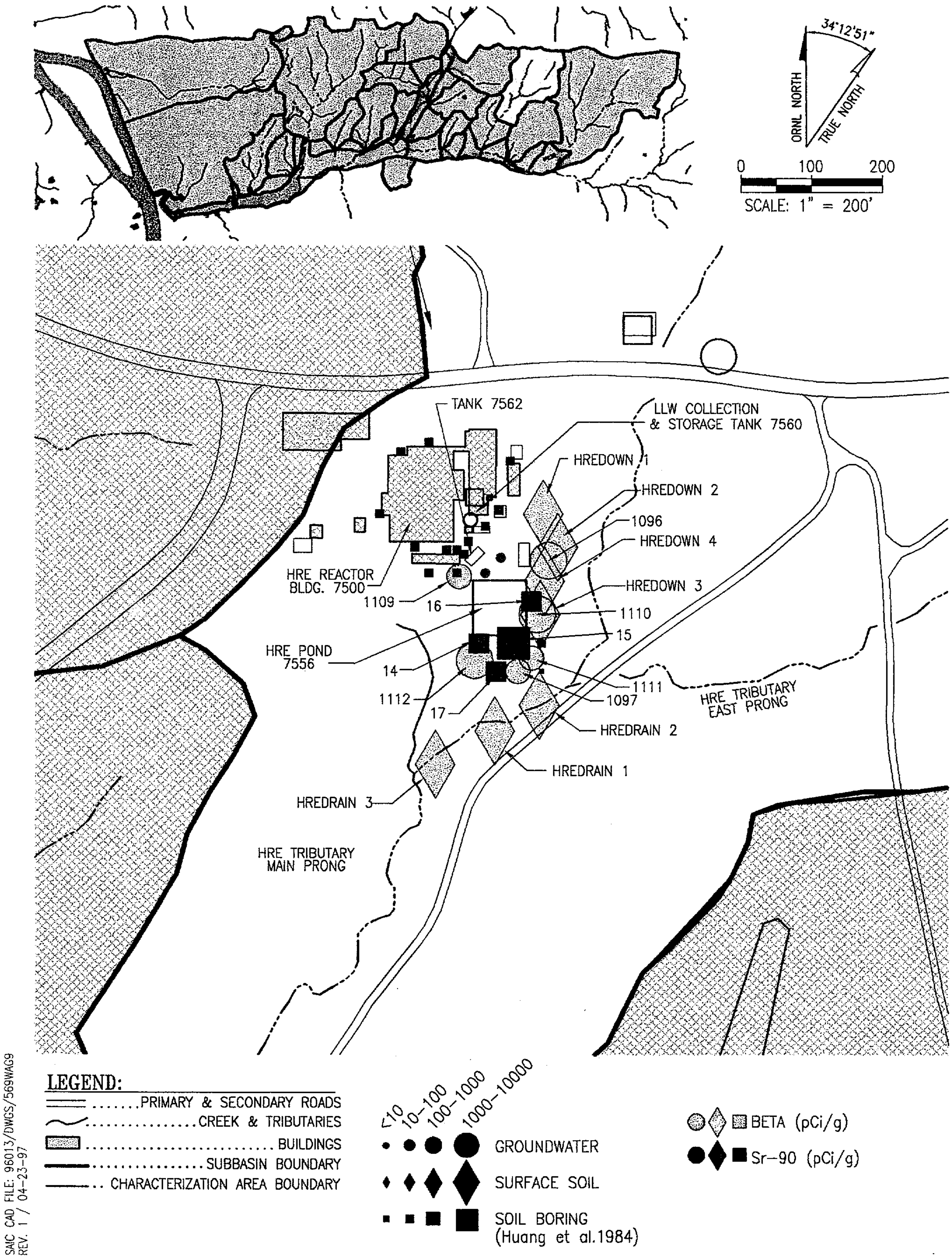


Fig. 3.21. Soil and groundwater sample locations in the HRE subbasin.

Huang et al. (1984) analyzed deep soil cores from borings around the HRE site for radionuclides, including ^{90}Sr and ^{137}Cs. Locations at which the highest ^{90}Sr activities were detected are shown on Fig. 3.21. As can be seen from this figure, the highest ^{90}Sr activities were found in borings 14, 15, 16, and 17, downgradient to the south and east of the HRE impoundment. With the exception of boring 17, most of the contamination was found in the depth interval from about 4 to 10 ft below ground surface, which roughly corresponds to the interval of mixed fill/sediment waste encountered in borings advanced through the impoundment described previously. This is further evidence that contaminants have been leaching out of the sediment in the impoundment and moving downgradient in groundwater. As the contaminated groundwater has moved through the soil, contaminants have been adsorbed to the soil. In addition to the deeper contamination found in these borings, elevated ^{90}Sr and ^{137}Cs activities were also found in the 0–4 ft interval in boring 17. The highest ^{137}Cs activity was found in the 0–1 ft interval, with activities decreasing with increasing depth. A source for the shallow contamination found in this boring could be a spill of contaminated liquids on the surface, possibly from an overflowing impoundment.

Surface water sampling locations for the WAG 2 RI (Hicks 1996) in the vicinity of the HRE Tributary are shown on Fig. 3.19. Results of stream transect sampling suggest that much of the elevated ^{90}Sr found in the HRT Tributary enters the stream between HRT-8 and HRT-9, downgradient of the HRE Impoundment. However, ^{90}Sr was detected at activities ranging from 725 to 2038 pCi/L in four samples collected from HRT-9 between February and August 1994 (Hicks 1996), indicating that ^{90}Sr is entering the north prong of the HRE Tributary upstream of HRT-9. Some of the ^{90}Sr detected at HRT-9 may be attributable to contamination moving along strike to the east from the HRE Impoundment. However, radiological contamination (i.e., elevated gross alpha, gross beta, ^{137}Cs, $^{233/234}U$, and ^{238}U) was found in surface soil samples HREDOWN 1 and HREDOWN 2 (Fig. 3.19) collected in June 1996 from a swampy area located to the northeast of the HRE impoundment, directly to the west of the north prong of the HRE Tributary (Energy Systems 1996c). In addition, ^{90}Sr was detected at activities ranging from approximately 700 to 2000 pCi/L in yearly samples collected from well 1096 from 1991 to 1994 as part of ORNL Environmental Compliance monitoring. Well 1096 is located upgradient of the HRE Impoundment and immediately south (downgradient) of the contaminated swampy area (Fig. 3.19).

Possible sources of this contamination include contaminated soils and stream sediments resulting from leaks, spills, and intentional discharges of liquid waste associated with Building 7500, the waste evaporator, the east and west decontamination pads, Tanks 7560 and 7562, the WAG 9 ILLW transfer pipeline, and the Melton Valley ILLW transfer pipeline. Surface soil contamination was found during a radiological survey conducted in 1984 in the vicinity of the east and west decontamination pads, the waste evaporator, and tanks 7560 and 7562 (Huang et al. 1984). A leak of approximately 2100 gal of liquid waste occurred in 1969 from the Melton Valley ILLW Transfer Pipeline at a location about 400 ft northeast of Building 7500, north of Melton Valley Drive and adjacent to the north prong of the HRE Tributary (7500 Area LLW Spill Site on Fig. 3.19). A portion of this spill apparently reached the north prong of the HRE Tributary. Purge water from the storage pool in Building 7500 was discharged to the ground along a natural drainage east of Building 7500, subsequently entering the north prong of the HRE Tributary. Also, condensate from the waste evaporator or Tank 7560 was episodically discharged to the north prong. Undocumented leaks may have occurred in the WAG 9 ILLW Transfer Pipeline. Trench backfill along this pipeline may also have served as a pathway for movement of contaminants into the area from off site (e.g., from spill sites along the Melton Valley ILLW Transfer Pipeline).

Elevated ^{90}Sr activities, ranging from 127 to 367 pCi/L, were found in stream transect samples collected from HRT-10 between February and August 1994 (Hicks 1996). HRT-10 is located on the east prong of the HRE Tributary, just upstream of its confluence with the north prong (Fig. 3.19). Possible sources for this release are contaminated soils and sediments resulting from documented and undocumented low-level waste line leaks and spills in the MSRE area, in particular the leak site designated Pump Station Area LLW Spill Site on Fig. 3.19. There is considerable uncertainty about locations of leak sites in the HFIR and MSRE areas. However, several leaks are known to have occurred in the lines between Building 7920 and the Melton Valley Pumping Station (Building 7567) and in the Melton Valley ILLW Transfer Pipeline north of Melton Valley Drive.

Leaching of contaminated soils and sediments by percolating rainwater, followed by recharge of shallow groundwater by contaminated leachate, and subsequent discharge of contaminated groundwater to the stream is the probable release mechanism for contaminants found in the north prong of the HRE Tributary upstream of the HRE Impoundment and in the east prong of the HRE Tributary downstream of the MSRE area.

3.4.2.3 Secondary contaminated media

Areas of radiologically contaminated surface soils and sediment in the HRE subbasin are shown in Fig. 3.19. Areas of surface contamination that exceed the 50 μR/h recreational exposure scenario threshold occur in the area immediately east of the inactive HRE reactor (Building 7500), in the vicinity of pipeline leak sites west of the inactive MSRE reactor area and north of Lagoon Road, and in local hot spots along Lagoon Road and as discontinuous patches of contaminated sediment in the HRE Tributary channel downstream of the HRE Pond. Gamma radiation exposure data along the HRE Tributary were obtained by the USRADS walkover method while data in other areas were obtained by manual measurement. Cesium-137 is the greatest contributor to the radiological exposure, although ^{90}Sr and isotopes of uranium are present in soils near the HRE Pond.

Secondary contaminated media in the HRE subbasin include:

1. Contaminated seepage pathway soils in the swampy area to the east and downgradient to the south of the former HRE pond—0.8 acre (0.3 ha) with a thickness of 10 ft (3.05 m) and a volume of 350,000 ft^3 (9,900 m^3);

2. Contaminated sediments along the HRE tributary—0.3 acre (0.12 ha) with a thickness of 1 ft (0.31 m) and a volume of 13,000 ft^3 (370 m^3);

3. Contaminated soils in two pipeline leak sites along Melton Valley Drive—1.1 acre (0.45 ha) with a thickness of 1 ft (0.3 m) and a total volume of 48,000 ft^3 (1,400 m^3); and

4. Contaminated groundwater in the seepage pathways to the east and south of the former impoundment with an approximate volume of 28,000 ft^3 (800 m^3).

3.4.2.4 Human health risk, ecological risk, and criteria exceedances

The HRE subbasin consists of one subbasin evaluated for the human health risk assessment, the ecological risk assessment, and for criteria exceedances. The media evaluated are groundwater, sediment, soil, and two categories of surface water. The surface water categories for the human health and ecological risk assessments are surface water-seeps and surface water-streams. The surface water-seeps category consists of samples taken at both seeps and small tributaries. The surface water-streams category includes samples collected in Melton Branch and larger tributaries. The human health COCs for the HRE subbasin for each of the media are presented based on recreational and industrial land use. COCs and risk results for residential land use in addition to the recreational and industrial land uses are presented in the human health risk assessment. Figure 3.22 presents recreational carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.22 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The HRE subbasin has not been comprehensively sampled with the exception of groundwater and seeps; therefore, the associated uncertainty in the sediment, soil, and stream risk results and the resulting identified COCs is considered to be high.

Table 3.22. Media data summary for the HRE subbasin

Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
Groundwater	16	598	522	2237	1480	4367	301
Sediment	8	0	0	310	265	4	4
Soil	28	228	141	147	122	49	49
SW-seeps	7	428	260	785	444	788	76
SW-streams	4	109	94	1077	775	0	0

HRE Soil

Twenty-eight soil samples were analyzed for various contaminants in the HRE subbasin. Cesium-137 was analyzed for 32 times and detected in all but 2. Other radionuclide contaminants detected include strontium, radium, uranium, and thorium isotopes. The total recreational risk is 1.7E-03 and the industrial risk is 3.6E-02. These results are mostly attributed to ^{137}Cs. The recreational risk result is high enough to warrant the inclusion of ^{137}Cs as a COC for this area. The soil samples collected were also analyzed for noncarcinogenic contaminants. The HIs are 4.9E-02 for a recreational receptor and 1.0E-01 for an industrial receptor. However, no COCs for noncarcinogenic risk are identified for the soil in the HRE subbasin based on recreational land use. COCs for the industrial and residential land uses are presented in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the HRE subbasin. Seventeen radionuclides were detected in 21 samples from this subbasin, but risks are only anticipated for wild turkey. The overall HI for turkeys was 2.4 with $^{233/234}$U and ^{137}Cs as the

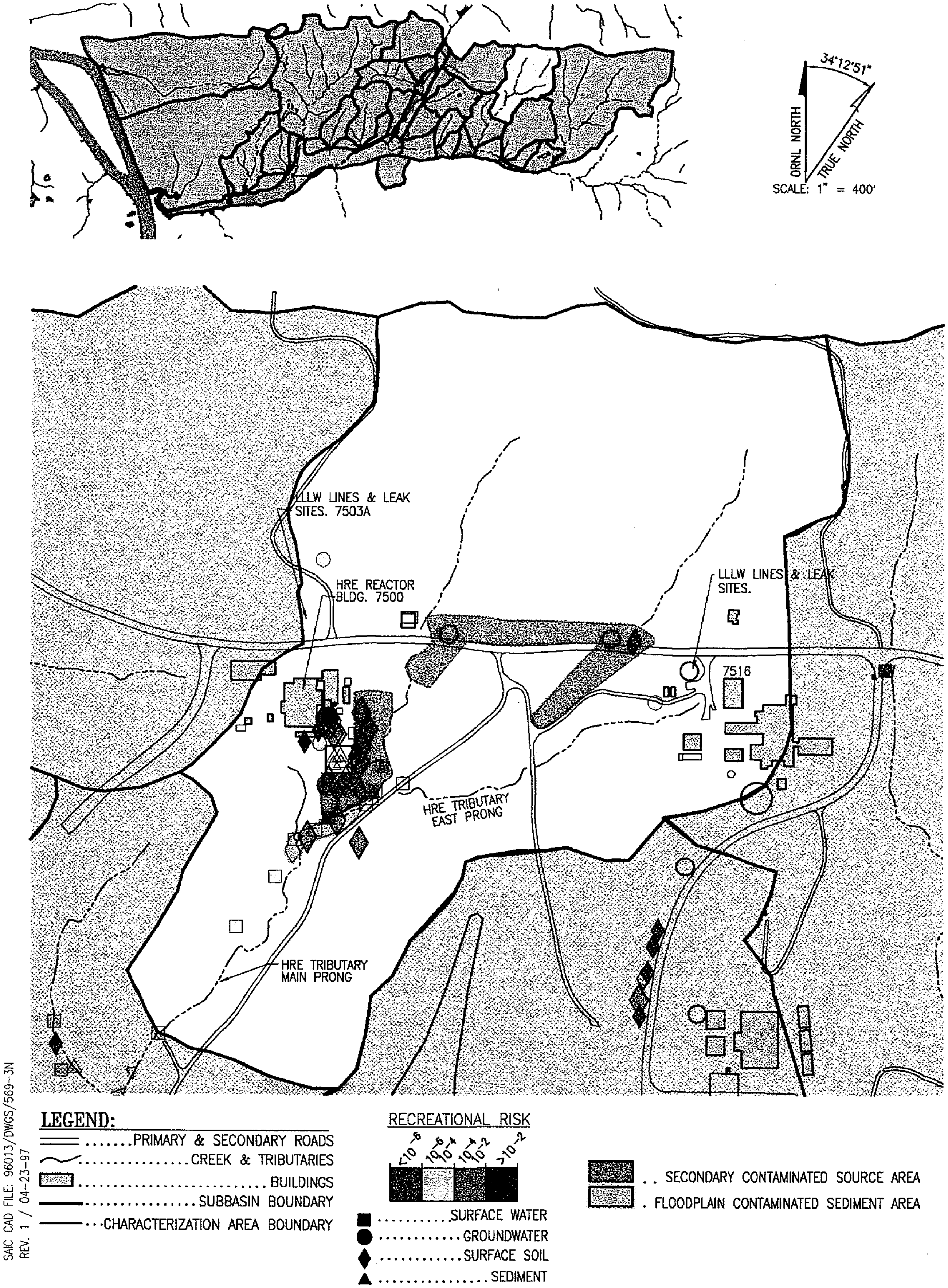


Fig. 3.22. Risk estimates at sampling locations in HRE subbasin.

risk drivers. Overall dose rates for all other receptors were below recommended dose limits for all receptors.

Potential risks from exposure to nonradionuclides in HRE soil were identified for plants, soil invertebrates, shrews, mice, and foxes. Three inorganics (chromium, cadmium, and zinc) exceeded toxicological benchmarks for plants with HQs of 1.1, 104, and 4.8, respectively. Chromium and zinc exceeded benchmarks for soil invertebrates with HQs of 260 and 1.2. Barium, chromium, and PCBs exceeded LOAELs for shrews, and chromium exceeded the LOAEL for mice. While chromium was the primary risk driver in this subbasin, it was detected at only 1.3 times background. The analytical data did not specify the valence state of the chromium. Chromium (VI) is more toxic and bioavailable than chromium (III) (Will and Suter 1995), but in most soils chromium (VI) is likely to be reduced to chromium (III). The toxicological benchmarks used in this assessment were based on chromium (VI) studies. The use of benchmarks for the more toxic and available chromium (VI) when exposures may be predominantly from chromium (III) may lead to overestimation of risks. Wildlife exposures to chromium were below the no observed adverse effects level (NOAEL) for chromium (III) for all receptors.

HRE Sediment

Eight sediment samples were collected in the HRE subbasin and analyzed for a variety of inorganics and for PCBs. The HRE results indicate a total recreational risk of 8.4E-06 and a recreational HI of 1.3E-01. The industrial risk is 1.6E-05 and the HI is 3.6E-01. These values do not exceed EPA's target risk range. Therefore, no COCs are identified for the sediment in the HRE subbasin based on recreational land use. However, no radionuclide data are available for the sediment in this subbasin.

Significant risks were identified for benthic invertebrates exposed to sediment in the HRE subbasin, based on the one available line of evidence (sediment chemistry). Manganese and PCBs were the only analytes presenting a significant risk and were identified as COECs (Table 3.23). Antimony and nickel presented a marginal risk; three other inorganics exceeded possible effects levels and were considered a negligible risk. No other analytes exceeded possible effects levels.

Table 3.23. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment in the HRE subbasin

Subbasin	Risk category[a]	COECs/COPECs[b]
HRE	Significant	Mn, PCBs
	Marginal	Sb, Ni
	Negligible	Cd, Cr, Cu

[a] Analytes were ranked based on the percentile of the concentration distribution within the subbasin that exceeded or failed to exceed possible or probable effects levels. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels are listed as contaminants of potential ecological concern.

HRE Groundwater

Groundwater samples were collected at 16 locations in the HRE subbasin and analyzed for a full suite of radionuclides, inorganics, and organics. The recreational risk for this subbasin is

4.0E-05 and the HI is 6.6E-01. The industrial risk is 1.8E-03 and the HI is 5.1. The recreational values are below the target risk range and, therefore, no COCs are assigned to the HRE subbasin based on recreational land use. COCs based on industrial and residential land uses can be found in the human health risk assessment (Appendix B).

The groundwater data from the HRE subbasin were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. Criteria exceedances were noted for ^{90}Sr, vinyl chloride, thallium, nitrite, and antimony.

HRE Surface Water

Surface water samples were collected at eleven locations and analyzed for a number of organics, inorganics, and radionuclides. Strontium-90 has been extensively analyzed for in this subbasin at these locations. The recreational risk for the seeps in this subbasin totals to 9.1E-06 and the industrial risk is 6.3E-04, mostly because of the presence of ^{90}Sr. The HI sums to 5.4E-02 for a recreational receptor and 7.0E-01 for an industrial receptor at the seeps. For the stream samples, the recreational risk is 6.9E-06 and the industrial risk is 4.4E-04. The HIs for the stream samples are 6.9E-02 for the recreational receptors and 5.3E-01 for the industrial receptor. The recreational results for the seeps and streams do not exceed the target risk range and, therefore, no COCs are identified for surface water at HRE based on recreational land use. COCs based on industrial and residential land use scenarios are presented in Appendix B.

Significant risks were identified for aquatic organisms exposed to chemicals, but not radionuclides, in HRE subbasin surface water. Seven metals appear to present significant risks and are identified as COECs (Al, Cd, Co, Cu, Fe, Ni, and Tl). Eight metals appear to present marginal risks (Ba, B, and Mn) or negligible risks (Ag, Be, Hg, Li, and Sn) and are identified as COPECs. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits. No risks were identified for terrestrial wildlife drinking surface water; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at station 05.SW004 (HQ = 88.5). The aluminum benchmark appears to be conservative as it is below the background concentration. While the maximum aluminum concentration at this station was well above background and substantially higher than concentrations at other seeps across the watershed, the mean for the station was below background. Other analytes marginally exceeding benchmarks (HQs <3.6) at this station were arsenic, chromium, iron, and manganese. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

The contaminant surface water concentrations for the HRE subbasin were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic and thallium were exceeded for the human health criteria and mercury showed an exceedance for the ecological criteria.

3.4.2.5 Options for release mechanism intervention

The dominant contaminant release mechanism for HRE Pond sediment and pipeline leak site contaminated soil is perennial or episodic contact of primary or secondary contaminants with groundwater and subsequent contaminant release to adjacent groundwater and surface water. Under these conditions, the opportunities for intervention in the release process include removal of contaminated media, chemical fixation of media to reduce contaminant solubility, and hydrologic isolation of the contaminated media for the period of risk (considering intrinsic processes and radiological decay) to minimize the movement of water through the media and minimize the release to the environment.

Contaminated soil and sediment masses in and adjacent to the HRE Tributary channel are potentially susceptible to scour and erosion during heavy precipitation runoff events. Sediment analyses show the presence of ^{137}Cs and ^{60}Co. Stabilization options for this sediment include removal and consolidation in a contaminated soil/sediment storage area, or covering/containment through the time duration of potential risk based on contaminant decay.

3.4.3 SWSA 5 Seep A Subbasin

The SWSA 5 Seep A Subbasin encompasses 26 acres and drains the lower portion of the HRE Tributary valley including the Seep A source area within SWSA 5 South, the Drainage D-3 Area from the northeastern portion of SWSA 5 South, and uncontaminated areas between the HRE Tributary and the HFIR area (Fig. 3.23). Contaminant source areas and monitoring locations in the Seep A Subbasin are shown on Fig. 3.23.

3.4.3.1 Contaminated sites–SWSA 5 Seep A subbasin

Primary contaminant sources in Area A are auger holes and trenches used for disposal of LLW as part of SWSA 5 South. SWSA 5 is one of the major burial grounds used for the disposal of low-level radioactive solid waste at ORNL. Waste disposal operations occurred from 1959 to 1973 and consisted of shallow land burial in excavated trenches and drilled auger holes, which was the standard practice at that time. During that time over 220 unlined trenches and nearly 1,000 unlined auger holes were used for the disposal of approximately 3 million ft^3 of solid waste containing 210,000 Ci of radioactivity in SWSA 5 South. Between 1959 and 1964, ORNL was designated as the Southern Regional Burial Ground for the Atomic Energy Commission and received radioactive waste from over 100 off-site facilities. This waste received from off-site facilities accounts for the greater volume of waste disposed of in SWSA 5 (DOE 1995b).

During its operation, SWSA 5 South has received a large diverse quantity of solid wastes packaged in a variety of containers and some unpackaged waste. Historical disposal records are poorly documented and in some cases nonexistent (i.e., "undefined trenches area"). Based on the available historical records, most of the SWSA 5 waste can be classified in five categories: (1) low-level radioactive, (2) high activity beta-gamma, (3) TRU, (4) fissile, and (5) special case. SWSA 5 also received wastes contaminated with organic and inorganic chemicals. Figure 3.23 identifies the location and distribution of waste by this classification by trench area.

The Seep A source area identified as part of the WAG 5 Source Areas Investigation (Newsom et al. 1993) encompasses 5 acres and contains 66 auger holes and 45 trenches. Auger holes were generally used to dispose of higher activity and fissile waste. However, research into historical

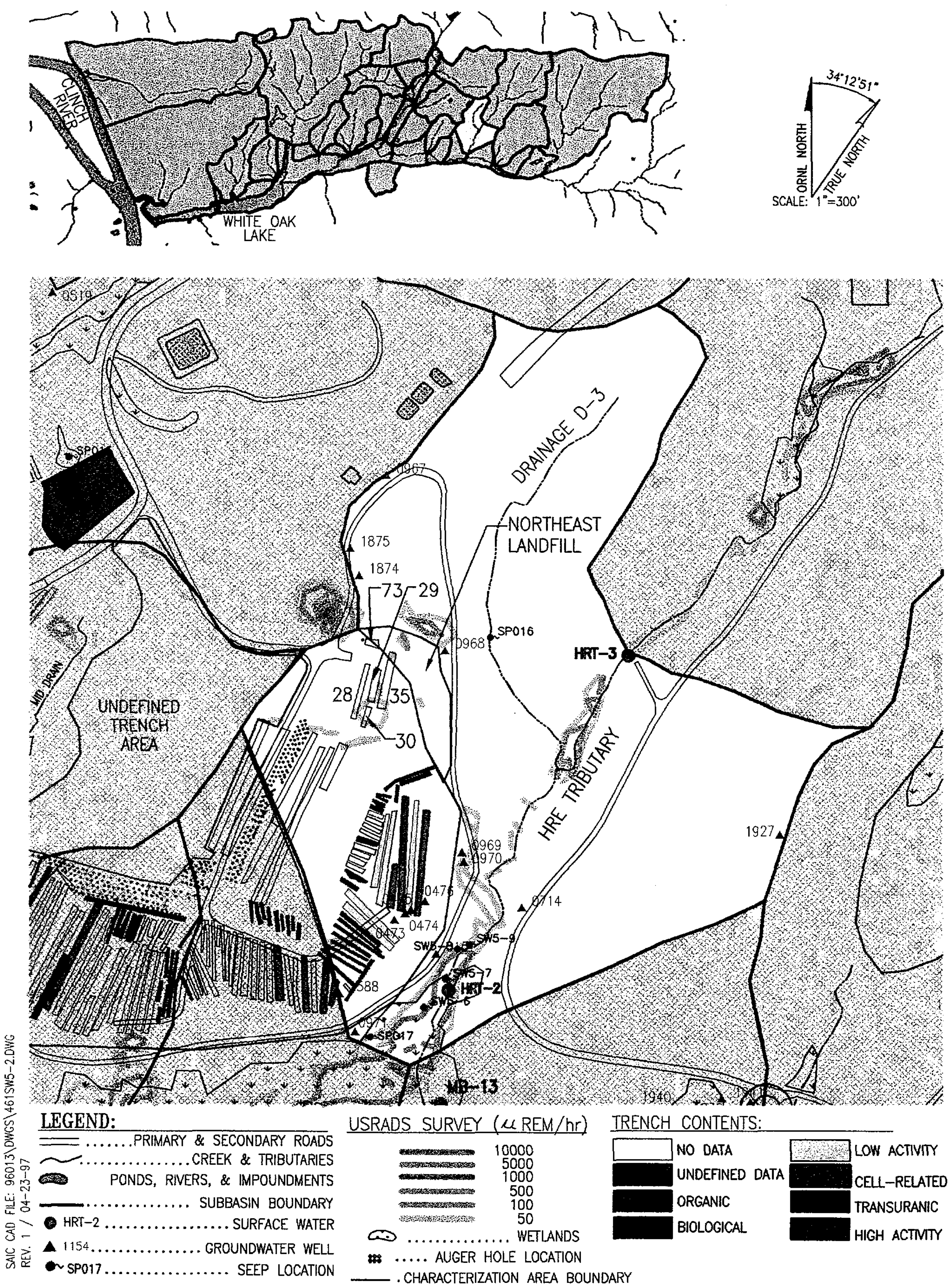


Fig. 3.23. Seep A subbasin, source areas, and monitoring locations.

records indicates that the auger holes in this area were used for the disposal of biological waste (DOE 1995b). The trenches contained primarily high activity hot cell waste and low activity/general radioactive waste with some 26 trenches containing biological waste. Disposal records also show that concrete casks with TRU wastes were placed in four trenches (DOE 1995b). Trenches 28, 29, 30, 35, and 73 were designated for "Y-12 special burial" using a new trench design. These trenches contain drummed waste with the exception of Trench 35, which was used for the disposal of "sludge," and Trench 73, which contains Y-12 classified waste (thought to be sodium and potassium solutions).

Drainage D-3 encompasses an area of 9.3 acres, which is primarily forested except for a gravel road and the WAG 5 decontamination facility. The Northeast Landfill comprises 0.5 acre of this drainage area and is composed of an accumulation of both contaminated and uncontaminated solid waste that has been dumped on the hill slope. The USRADS survey in this area showed high gamma exposure rates associated with several discrete accumulations of debris. Waste material present on the surface includes metal ammunition boxes, scrap metal, corrugated pipe, concrete debris, a B-25 box, miscellaneous equipment parts, and a 55-gal plastic drum (DOE 1995b). Some of the waste in the upper portion of the landfill area was partially buried.

In addition to the Seep A subbasin, SWSA 5–Melton Branch Drainage also has three other subbasins: Seep B, Drainage D-2 (includes undefined trench area), and Seep C. Appendix A summarizes the source information for all of these subbasins. The SWSA 5 area is described in more detail in the WAG 5 RI Report (DOE 1995b) with a summary of the other subbasins provided in the following sections.

3.4.3.2 Pathway model of contaminant releases

Interaction of shallow groundwater with trench and auger hole contents is the primary release mechanism for contaminants in the trenches and auger holes in SWSA 5 South. Figures 3.24 and 3.25 are cross sections showing contaminant sources and pathways for the Seep A area as well as other subbasins in SWSA 5 South. Contaminants move with the shallow groundwater to seeps and to the HRE Tributary where they enter the surface water system. During the dry season in 1993, nearly all of the trenches in the southern and western portions of the Seep A area were at least partially inundated (DOE 1995b). During the wet season, trenches in the central portion of the area and some of the trenches in the upland area on the northeast perimeter became inundated. The primary contaminant release mechanism in the southern and western portions of the area is direct contact of the trench contents with groundwater and flow downgradient to discharge areas. In the upland areas in the northwestern portion of the Seep A subbasin, the primary release mechanism is infiltration of precipitation through the trench and auger hole wastes and subsequent movement downgradient to discharge areas. There has been no evidence of trench "bathtubbing" in the Seep A area.

Field sampling activities for the WAG 2 RI (DOE 1995a) and the WAG 5 RI (DOE 1995b) identified a number of seeps along the HRE Tributary in the Seep A subbasin that were each discharging groundwater containing greater than 1×10^6 pCi/L of ^{3}H, with the highest activity (1.5×10^8 pCi/L) being found in SW5-7. The WAG 2 RI stream transect sampling results indicate that the discharge from Seep SW5-7 is the predominant source of ^{3}H to the HRE Tributary. Investigations of subsurface contaminant transport upgradient of this seep suggest that most of the transport is fairly discrete along a conductive fracture zone oriented along geological strike (Hicks et al. 1992 and DOE 1995c). Elevated levels of ^{90}Sr, ranging up to 47,449 pCi/L in SW5-6, were also

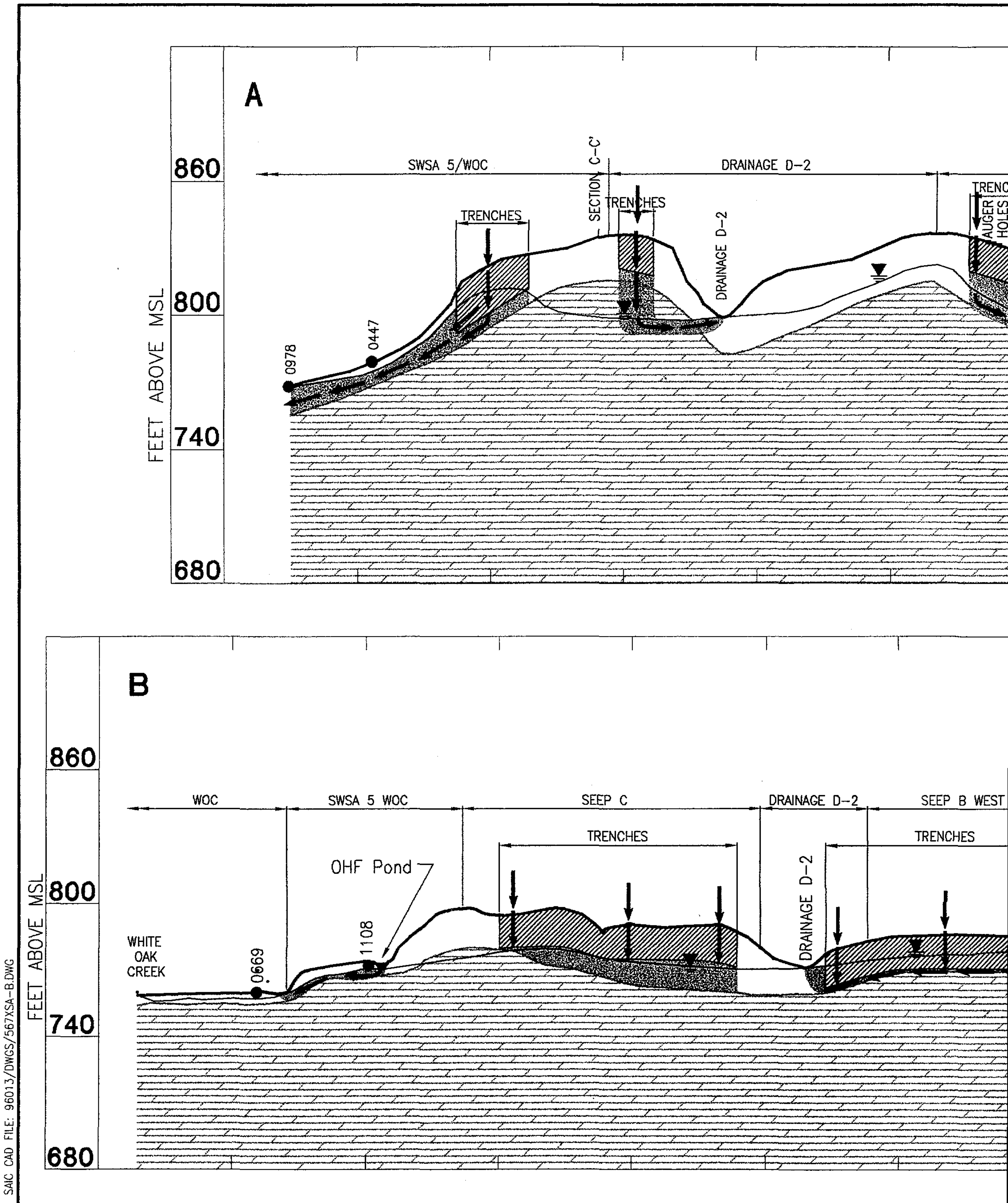
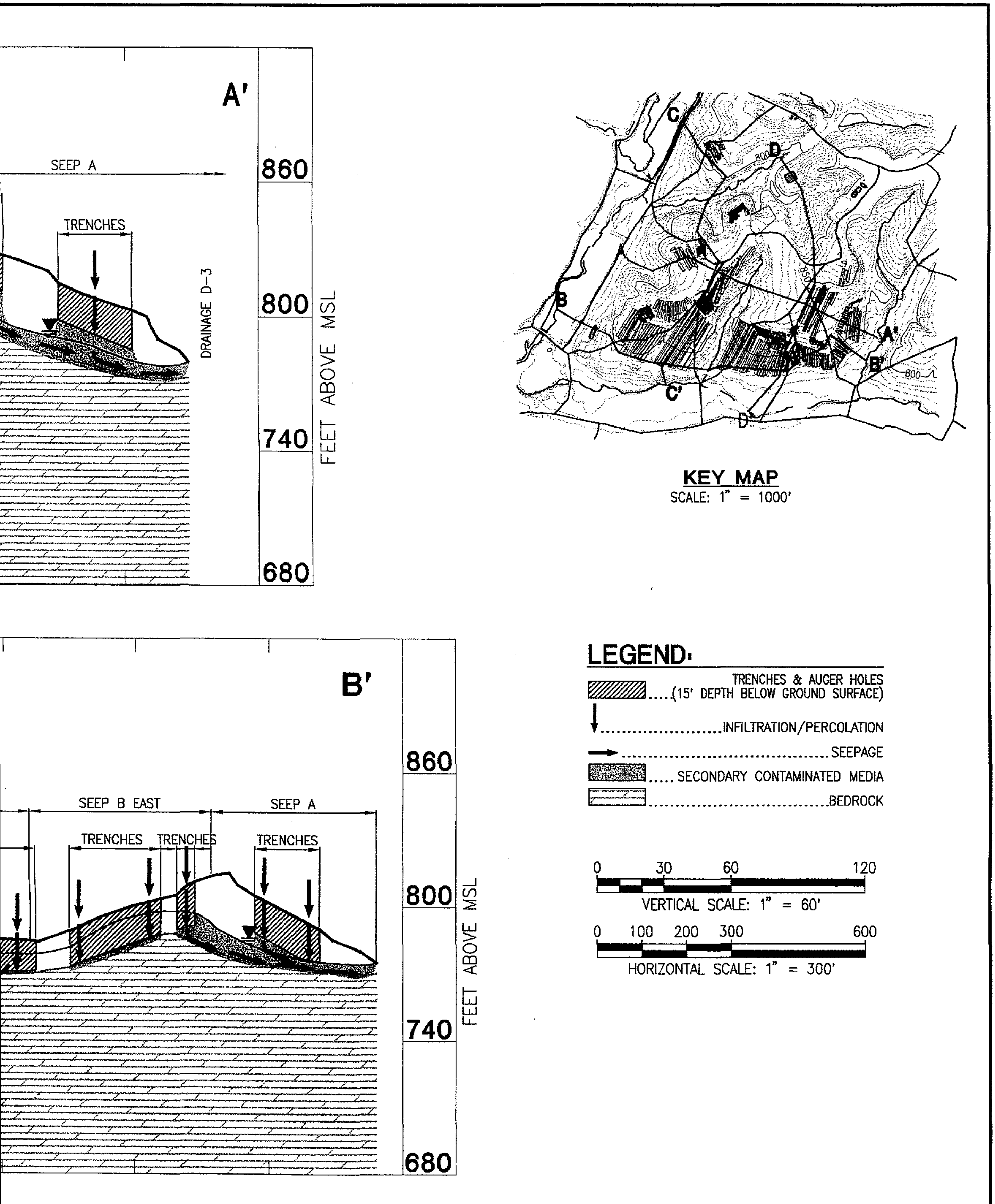


Fig. 3.24. East-west cross section thr



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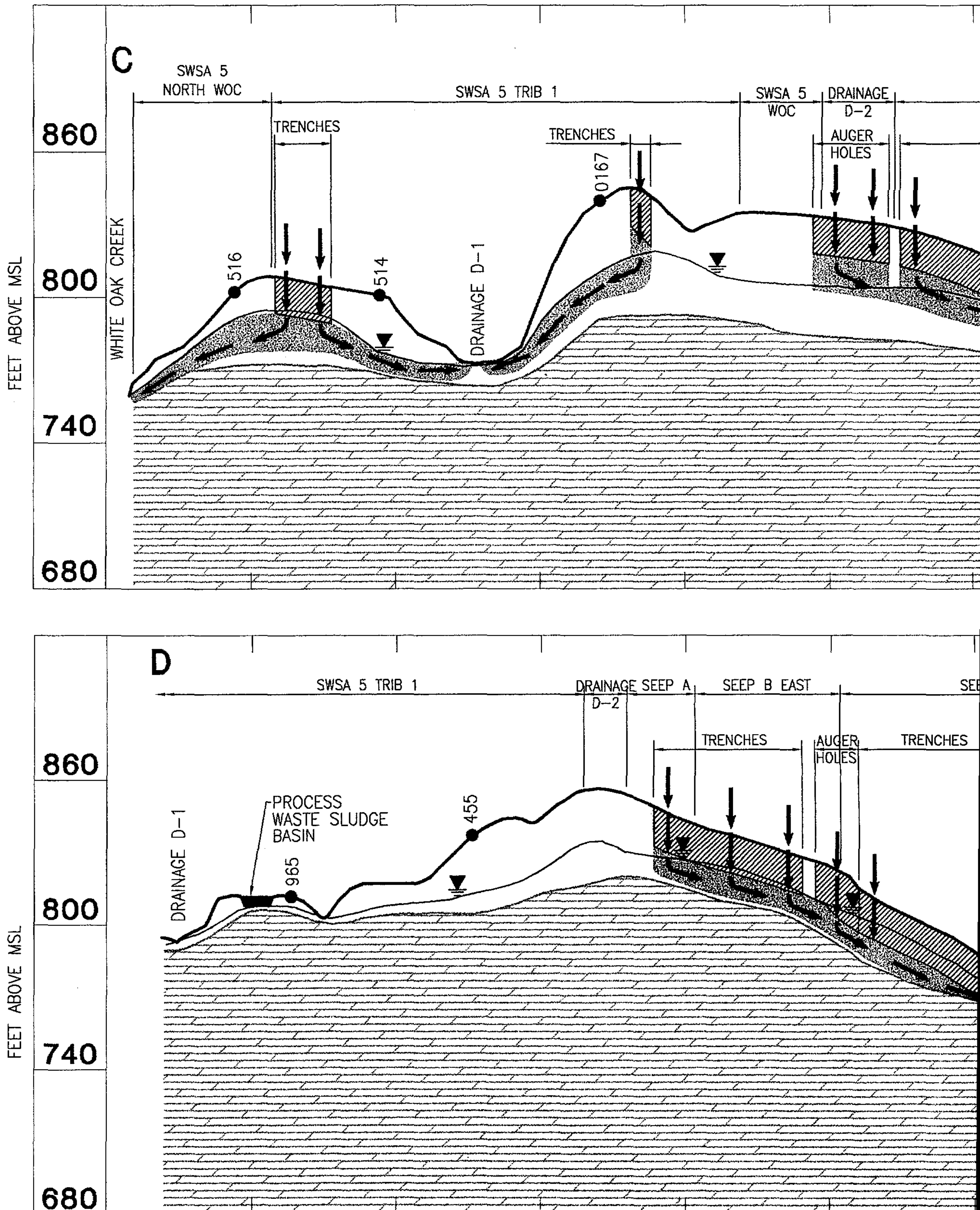

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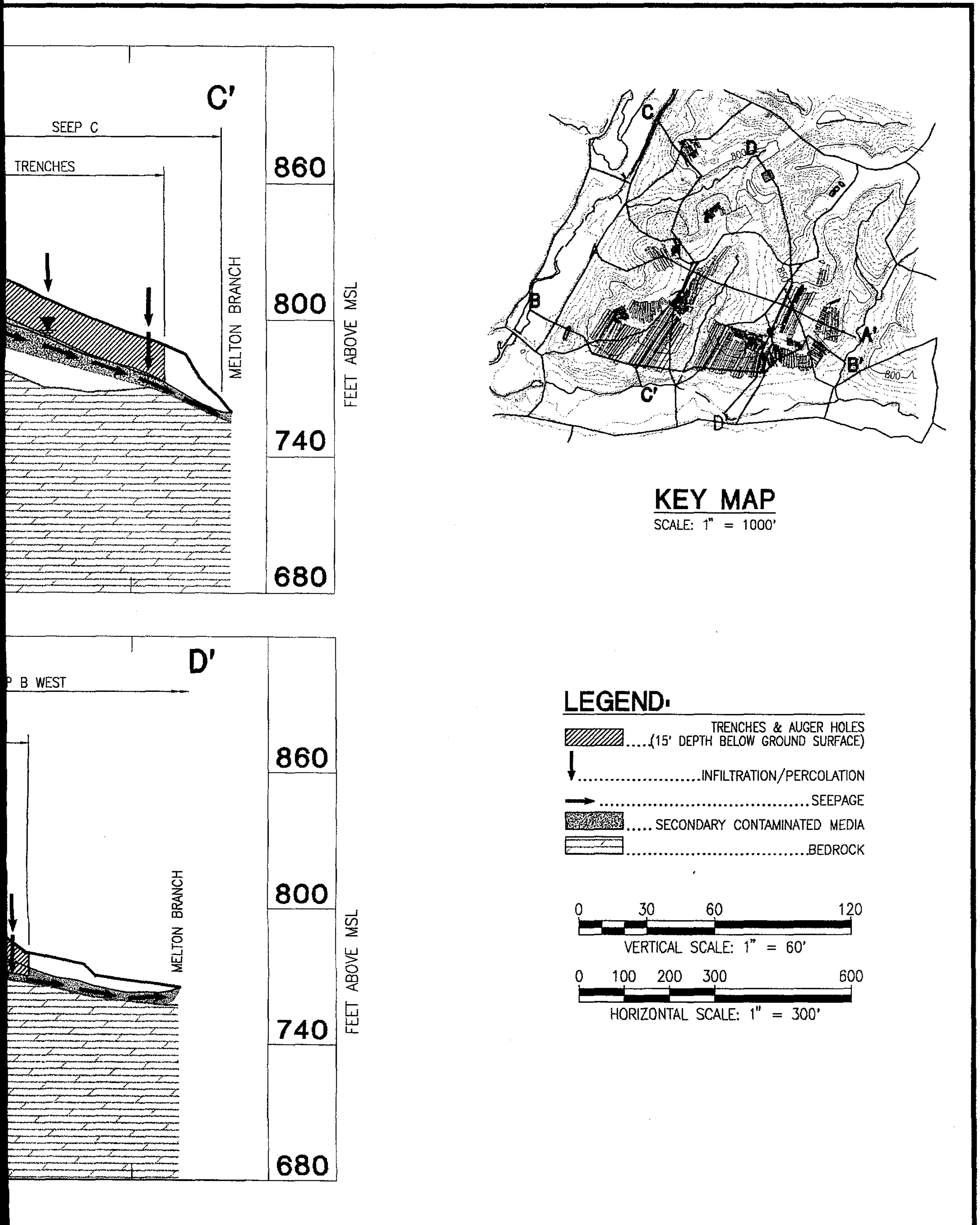
Fig. 3.25. North-south cross section thro



gh SWSA 5 south area.

found in the seeps along the HRE Tributary. Samples from SW5-6 also contained the highest levels of gross alpha (811 pCi/L) in the area; however, because this seep is near the subbasin boundary, groundwater related to this seep may discharge into the stream reach of the Seep B East subbasin.

The surface water reach covered by the Seep A subbasin extends from HRT-3 at the V-notch weir on the HRE Tributary downstream to HRT-2, a monitoring location approximately 200 ft above the confluence of the HRE Tributary with Melton Branch. Results from the WAG 2 RI indicate that approximately 9.4% of the ^{3}H in the Melton Valley watershed enters this stream reach (Hicks 1996).

There are no major sources or areas of contamination in the Drainage D-3 area in the northern portion of this subbasin. There are discrete areas of contamination associated with surface debris in the Northeast Landfill; however, no significant contamination has been detected in areas downgradient of the landfill. Releases from the eastern portion of this subbasin westward to the HRE Tributary have not been measured although they are expected to be insignificant because there are no known sources in this area.

3.4.3.3 Secondary contaminated media

Areas of radiologically contaminated surface soil in the Seep A subbasin are shown on Fig. 3.23. All data for the area were obtained by the USRADS walkover method. Areas in the Seep A subbasin that exceed the 50 μR/h recreational scenario exposure threshold predominantly lie along the HRE Tributary channel, though a small area of surface contamination is apparent between the northern waste burial trenches and the Drainage D-3 channel. Surface contamination along the HRE Tributary primarily originates from HRE area releases and ^{137}Cs is the principal gamma emitting radionuclide.

Secondary contaminated media in the SWSA 5 Seep A subbasin include contaminated soils and groundwater in the seepage pathways between the trenches and the Melton Branch Tributary and contaminated sediments and surface soil along Melton Branch Tributary. The approximate area of contaminated seepage pathway soils is 1.5 acres (0.6 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 457,000 ft^3 (13,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 52,000 ft^3 (1,500 m^3). The approximate area of contaminated sediments along Melton Branch Tributary is 0.6 acre (0.24 ha), with an average thickness of 1 ft (0.31 m), and an approximate volume of 26,000 ft^3 (740 m^3).

3.4.3.4 Human health risk, ecological risk, and criteria exceedances

The SWSA 5 Seep A subbasin consists of one subbasin, Seep A, evaluated for the human health risk assessment, the ecological risk assessment, and criteria exceedances. The media evaluated are groundwater, sediment, soil, and two categories of surface water. The surface water categories for the human health and ecological risk assessments are surface water-seeps and surface water-streams. The surface water-seeps category consists of samples taken at both seeps and small tributaries. The surface water-streams category includes samples collected in Melton Branch and larger tributaries. The COCs for the SWSA 5 Seep A subbasin for each of the media are presented based on recreational land use. Risk results are presented for both recreational and industrial land uses. COCs and risk results for all three scenarios are presented in the human health risk assessment. Figure 3.26 presents recreational carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

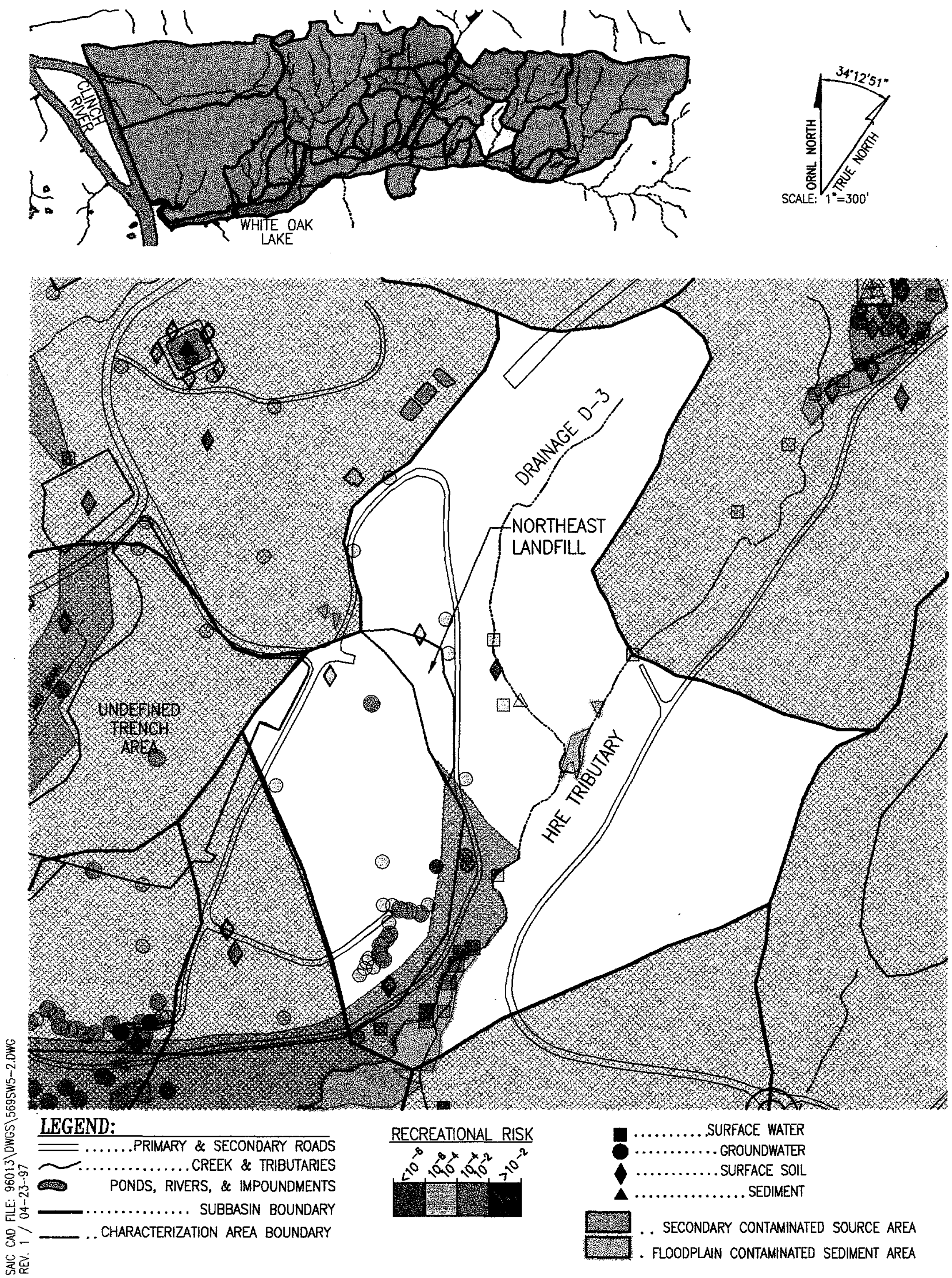


Fig. 3.26. Risk estimates at sampling location in Seep A subbasin.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.24 provides a summary of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this section. The subbasins within the SWSA 5 Seep A subbasin have been comprehensively sampled as part of the WAG 5 and WAG 2 RIs so sufficient data are available for the assessment. This dataset includes data that were collected from the Close Support Laboratory which does not have the analytical confidence as the majority of data that has been sent off to off-site laboratories. Therefore, due to the methods used in the Close Support Laboratory, some contaminants (in particular ^{14}C) have a relatively high probability of being present as false positives.

Table 3.24. Media data summary for the SWSA 5 Seep A subbasin

Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
Groundwater	30	1679	1156	1816	1147	3824	466
Sediment	3	25	23	80	71	164	14
Soil	5	144	122	126	119	530	107
SW-seeps	9	1077	684	1320	765	1650	259
SW-streams	3	88	79	385	231	132	5

SWSA 5 Seep A Soil

Five soil samples were analyzed for a comprehensive list of radionuclides, organics, and inorganics in the Seep A subbasin as part of the WAG 5 RI effort. Of the 185 constituents analyzed, 23 inorganics, 43 organics, and 28 radionuclides were detected. The total recreational risk is 1.3E-05 and the industrial risk is 2.7E-04. These results are mostly attributed to a few radionuclides. However, the recreational risk result is not high enough to warrant the inclusion of any carcinogenic COCs for this area. Industrial and residential COCs can be found in the human health risk assessment (Appendix B). The recreational noncarcinogenic HI for this area is 8.1E-03 and the industrial HI is 2.1E-02. Since the recreational result is less than one, no noncarcinogenic COCs are identified for the Seep A subbasin. Therefore, no soil COCs for either carcinogenic or noncarcinogenic risk are identified in the Seep A subbasin based on recreational land use.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 5 Seep A subbasin. Overall dose rates from exposure to the 27 radionuclides detected marginally exceeded recommended dose limits for shrews and mice (HI = 1.0) but were well below the recommended dose limits for all other receptors (Table 3.25). Plutonium-239/240 was the primary risk driver, contributing 60% of the dose for both mice and shrews. Potential risks from nonradionuclides were identified for plants (HI = 13.8), soil invertebrates (HI = 1.7), short-tailed shrews (6.8), and fox (1.1) but no risks were identified for any other receptors (HIs <1). Inorganics contributed >90% of the HI for all receptors. HQs exceeding one were estimated for three inorganics (zinc, selenium, and silver) for plants, one (zinc) for invertebrates, and two (selenium and zinc) for shrews. This subbasin was the major contributor to the estimated watershed-wide population effects for shrews exposed to selenium.

Table 3.25. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at the SWSA 5 Seep A Basin

Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
Plants	13.8	Zn (6.4), Se (5.1), Ag (1.1)	0.1	
Invertebrates	1.7	Zn (1.6)	0.1	
Shrew	6.8	Se (4.7), Zn (1.1)	1.0	$^{239/240}$Pu (0.6)
Mouse	0.9		1.0	$^{239/240}$Pu (0.6)
Fox	1.1		<.1	

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

SWSA 5 Seep A Sediment

Three sediment samples in the Seep A subbasin were analyzed for a comprehensive list of contaminants. The sediment results indicate a total recreational risk of 6.7E-06 and an industrial risk of 1.5E-04. The recreational HI totaled 3.1E-02 and the industrial HI was 1.1E-01. Therefore, no recreational COCs are identified for the sediment in the Seep A subbasin. Residential and industrial COCs can be found in Appendix B.

Significant risks were identified for benthic invertebrates exposed to sediment in the Seep A subbasin, based on the one available line of evidence (sediment chemistry). Manganese was the only analyte presenting a significant risk and was identified as a COEC. Carbon disulfide presented a marginal risk. Total PAHs exceeded a possible effects level but were considered a negligible risk. No other analytes exceeded possible effects levels.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the Seep A subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

SWSA 5 Seep A Groundwater

Over 120 samples have been analyzed at 30 locations in the Seep A subbasin for about 200 radionuclide, inorganic, and organic contaminants. However, a number of these samples were analyzed for a limited set of radionuclides as part of the WAG 5 Seeps removal action. The recreational risk for this subbasin is 1.7E-03 and the HI is 6.5E-02. The industrial risk is 1.4E-01 and the HI is 6.3E-01. Identified recreational COCs include ^{90}Sr , ^{3}H, tetrachloroethylene, vinyl chloride, ^{14}C, ^{241}Am, ^{137}Cs, and 1,1-DCE.

The groundwater data from the Seep A subbasin were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. Criteria exceedances were noted for ^{90}Sr, ^{3}H, ^{137}Cs, ^{14}C, ^{241}Am, vinyl chloride, benzene, carbon tetrachloride, methyl chloride, 1,1-DCE, tetrachloroethylene, and trichloroethylene.

SWSA 5 Seep A Surface Water

Twelve samples have been analyzed for a comprehensive list of organics, inorganics, and radionuclides in SWSA 5 Seep A surface water. In addition, a number of key contaminants have been analyzed up to 40 times. For seeps, the recreational risk is 8.7E-05 and the industrial risk is 7.4E-03, due primarily to the presence of ^{3}H and ^{90}Sr. The recreational HI for this area is 2.5E-01 and the industrial HI is 2.4. For stream samples, the recreational risk is 1.1E-05 and the industrial risk is 8.2E-04. The recreational HI is 8.8E-02 and the industrial HI is 6.0E-01. No recreational COCs are identified for the Seep A stream and seep samples. COCs based on industrial and residential land use are presented in Appendix B.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the Seep A subbasin, based on the one available line of evidence (surface water chemistry). Copper and thallium were the only analytes presenting a significant risk and were identified as COECs. Boron and carbon disulfide presented a marginal risk, and beryllium and cobalt were considered a negligible risk. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction as they may not be bioavailable.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the Seep A subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

No risks were identified for terrestrial wildlife drinking surface water; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at stations 05.SP009, 05.SP016, 05.SW003, SW5-6, and SW5-9 with HQs from 3.6 to 61.5. Thallium exceeded at stations SW5-6, SW5-8, and SW5-9 with HQs ranging from 21.9 to 25.3. The aluminum and thallium benchmarks appear to be conservative as both analytes exceeded benchmarks at numerous seeps across the whole watershed, and the aluminum benchmark is below background. Other analytes marginally exceeding benchmarks at least one station in this subbasin included arsenic, iron, and manganese (HQs all <3.6). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. It is unlikely that aluminum is of ecological concern with the possible exception of station 05.SP016.

The contaminant surface water concentrations for the Seep A subbasin were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic, thallium, and antimony were exceeded for the human health criteria and no contaminants showed an exceedance for the ecological criteria.

3.4.3.5 Options for release mechanism intervention

Contaminant sources in the Seep A subbasin include numerous unlined waste burial trenches, a portion of the waste disposed in the Undefined Trench Area, contaminated soil along groundwater seepage pathways between source trenches and the stream, and sediment in and adjacent to the HRE Tributary channel. COCs being released from the area include ^{90}Sr and tritium.

A large percentage of trenches in the Seep A subbasin have water in contact with the buried waste perennially. Dissolved contaminant concentrations in source trenches, shallow groundwater wells, and seeps indicate that contaminant seepage pathways in the Seep A area are relatively shallow. The predominant mechanism that drives the release from the area is direct infiltration of precipitation into source trenches, downslope flow within trenches, and seepage through adjacent soils, sometimes via discrete fracture pathways, to the stream. There is little evidence of trench overflow and overland flow of contaminated water in the Seep A area. The principal contaminants being released in the subbasin are ^{90}Sr and tritium. Options to reduce releases from the Seep A area include source removal, in situ stabilization, and hydrologic isolation.

Contaminated soil along the seepage pathway between source trenches and the stream contains tritium, ^{60}Co, and ^{137}Cs as dissolved contaminant in soil pore space. Tritium migrates unretarded by advection and diffusion while the ^{60}Co and ^{137}Cs may be exchangeable or fixed. Control of inflows to these soils by any method listed for the source trenches will minimize the continued inflow of contaminants. Under this condition tritium is expected to gradually diminish in concentration by decay (12.3 year half-life) and seepage discharge.

Contaminated soil and sediment masses in and adjacent to the HRE Tributary channel are potentially susceptible to scour and erosion during heavy precipitation runoff events. Sediment analyses show the presence of ^{60}Co and ^{137}Cs. Stabilization options for this sediment include removal or covering/containment through the time duration of potential risk based on contaminant decay.

3.4.4 SWSA 5 Seep B Subbasin

3.4.4.1 Contaminated sites

The SWSA 5 Seep B Subbasin encompasses 7.4 acres immediately west of Area A along the southern portion of SWSA 5 South as indicated in Fig. 3.27. Contaminant source areas and monitoring locations are shown on Fig. 3.27. As discussed in Sect. 3.4.3.1, SWSA 5 South was used for the burial of solid LLW in trenches and auger holes from 1959 to 1973. A total of 75 and 236 auger holes and trenches, respectively, are located in Seep B subbasin, downslope of the undefined trench area. Waste buried in these trenches includes solid LLW, debris (glassware, scrap material, etc.), and biological wastes (animal carcasses, bedding, waste) contaminated with mixed fission products, actinides (uranium/thorium and transuranic radionuclides), and organic solvents (DOE 1995b).

3.4.4.2 Pathway model of contaminant releases

Figures 3.24 and 3.25 are cross sections that show contaminant sources and release pathways for the Seep B area. Sources of the contaminants entering Melton Branch from the Seep B subbasin are the trenches in the southern portion of the area. Principal release mechanisms from these trenches include trench inundation and bathtubbing and overflowing of trench liquids onto the

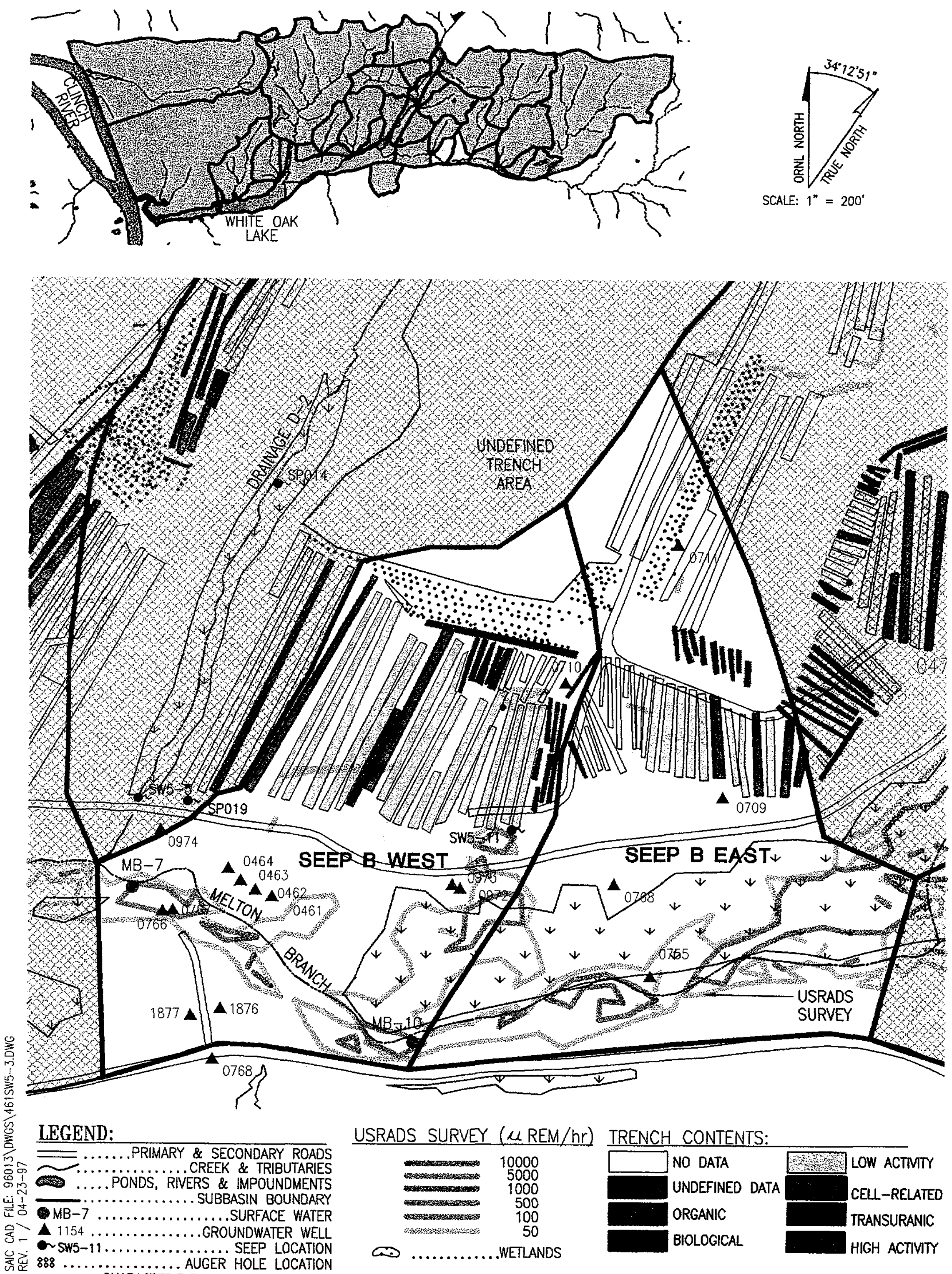


Fig. 3.27. Seep B subbasin, contaminant sources, and monitoring locations.

ground surface (DOE 1995b). There is an active storm flow zone in the Seep B area, which may be an important contaminant migration pathway during wet weather conditions when the trenches are full of water and are recharging the storm flow zone. Contaminants move in the shallow groundwater and either enter Melton Branch directly as diffuse discharges or discharge to discrete seeps, which then flow overland to Melton Branch.

Drive point samples collected from trenches and the Melton Branch floodplain as part of the WAG 5 RI had ^{3}H levels ranging from 2500 to 8.5×10^{8} pCi/L (DOE 1995b). The ^{3}H concentrations in the floodplain samples indicate that the contaminants migrate from the trenches to Melton Branch across a relatively broad front. The surface water reach covered by the Seep B West subbasin extends from WAG 2 RI transect sampling location MB-10 downstream to location MB-7 (Hicks 1996) just upstream from where the WAG 5 Drainage D-2 enters Melton Branch. Contaminated groundwater discharge along this reach is the greatest contributor to ^{3}H release at WOD. Data from the WAG 2 RI indicated that approximately 48.6% of the ^{3}H flux at WOD is released along this reach. Stream transect sampling and field walkovers have found that most of the release is diffuse and directly to the stream bed rather than discrete identifiable seeps.

High ^{90}Sr activities have been detected in trench drive point samples and samples from SW5-11 at the downgradient end of Trench 117. WAG 2 RI surface water data are inconclusive for ^{90}Sr releases in the Seep B West subbasin but do not show significant contributions. Elevated gross alpha activities, ranging from 30 to 57,000,000 pCi/L unfiltered, have also been detected in trench drive point water samples (DOE 1995b). However, unfiltered gross alpha activities were much lower in floodplain drive point samples and samples from SW5-11, indicating that alpha-emitting isotopes are not migrating out of the trenches in significant quantities.

The surface water reach covered by the Seep B East subbasin extends from HRT-2 on the HRE Tributary downstream past the confluence of the HRE Tributary with Melton Branch to the monitoring location MB-10 on Melton Branch. It is estimated that approximately 7.7% and 5.4%, respectively, of the ^{3}H and ^{90}Sr fluxes at WOD were released along this reach based on surface water data from the WAG 2 RI (Hicks 1996). The amount of ^{3}H or ^{90}Sr released was calculated by subtracting the estimated flux at HRT-2 from the estimated flux at MB-10.

3.4.4.3 Secondary contaminated media

Areas of radiologically contaminated surface soils in the Seep B East and West subbasins are shown on Fig. 3.27. Data for the area were collected using the USRADS method. Areas that exceed the recreational scenario exposure threshold are shown within the 50 μR/h isopleth. Most of the surface-contaminated area lies along the Melton Branch floodplain and originates from the ^{137}Cs and ^{60}Co releases from the upstream HFIR Area and HRE subbasin. A contaminated area extends from the southern tip of Trench 117 across the valley floor to Melton Branch. Trench 117 has historically released ^{90}Sr from a seep at its downslope end.

Secondary contaminated media in the SWSA 5 Seep B East and Seep B West subbasins include contaminated soils and groundwater in the seepage pathways between the trenches and Melton Branch and contaminated sediments and surface soil along Melton Branch. The approximate area of contaminated seepage pathway soils in Seep B East is 2.9 acres (1.2 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 880,000 ft^{3} (25,000 m^{3}). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils in the Seep B East subbasin is about 100,000 ft^{3} (2,900 m^{3}). The approximate area of contaminated sediments and surface soils in the

Seep B East subbasin along Melton Branch Tributary is 0.5 acre (0.2 ha), with an average thickness of 1 ft (0.31 m), and an approximate volume of 20,000 ft^3 (600 m^3). The approximate area of contaminated seepage pathway soils in Seep B West is 2.2 acres (0.9 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 670,000 ft^3 (19,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils in the Seep B West subbasin is about 77,000 ft^3 (2,200 m^3). The approximate area of contaminated sediments and surface soils in the Seep B West subbasin along Melton Branch Tributary is 0.3 acre (0.1 ha), with an average thickness of 1 ft (0.31 m), and an approximate volume of 13,000 ft^3 (400 m^3).

3.4.4.4 Human health risk, ecological risk, and criteria exceedances

The SWSA 5 Seep B subbasin consists of two subbasins, Seep B West and Seep B East, evaluated for the human health risk assessment, the ecological risk assessment, and criteria exceedances. The media evaluated are groundwater, sediment, soil, and two categories of surface water. The surface water categories for the human health and ecological risk assessments are surface water-seeps consisting of samples taken at both seeps and small tributaries and surface water-streams which includes samples collected in Melton Branch and large tributaries. The COCs for the SWSA 5 Seep B subbasin for each of the media are presented based on recreational land use. Risk results are presented for residential and industrial land use. COCs and risk results for all three scenarios evaluated can be found in the human health risk assessment. Figure 3.28 presents available recreational carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.26 provides a summary by subbasin of the analytical data that was used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. Most of the media within the SWSA 5 Seep B subbasins with the exception of sediment and nonradionuclides in surface water have been comprehensively sampled as part of the WAG 5 and WAG 2 RIs.

SWSA 5 Seep B Soil

Five soil samples were analyzed for a comprehensive list of radionuclides, organics, and metals in the Seep B West soil subbasin. The total recreational risk is 3.0E-03 and is due primarily to ^{60}Co. Other identified COCs for Seep B West soil include ^{137}Cs, ^{90}Sr, ^{228}Ra, and ^{226}Ra. The HI for Seep B West sums to 1.2E-02, so no noncarcinogenic COCs are identified. The industrial risk for this area is 6.4E-02 and the HI is 3.2E-02. Two soil samples were also sampled for a comprehensive contaminant list in Seep B East. The total recreational risk is 4.3E-03 and the industrial risk is 9.1E-02. These results are due almost solely to ^{137}Cs. The only other contaminant with recreational carcinogenic risk greater than 1E-06 was ^{208}Tl. The recreational HI for Seep B East is 6.7E-03 and the industrial HI is 1.7E-02.

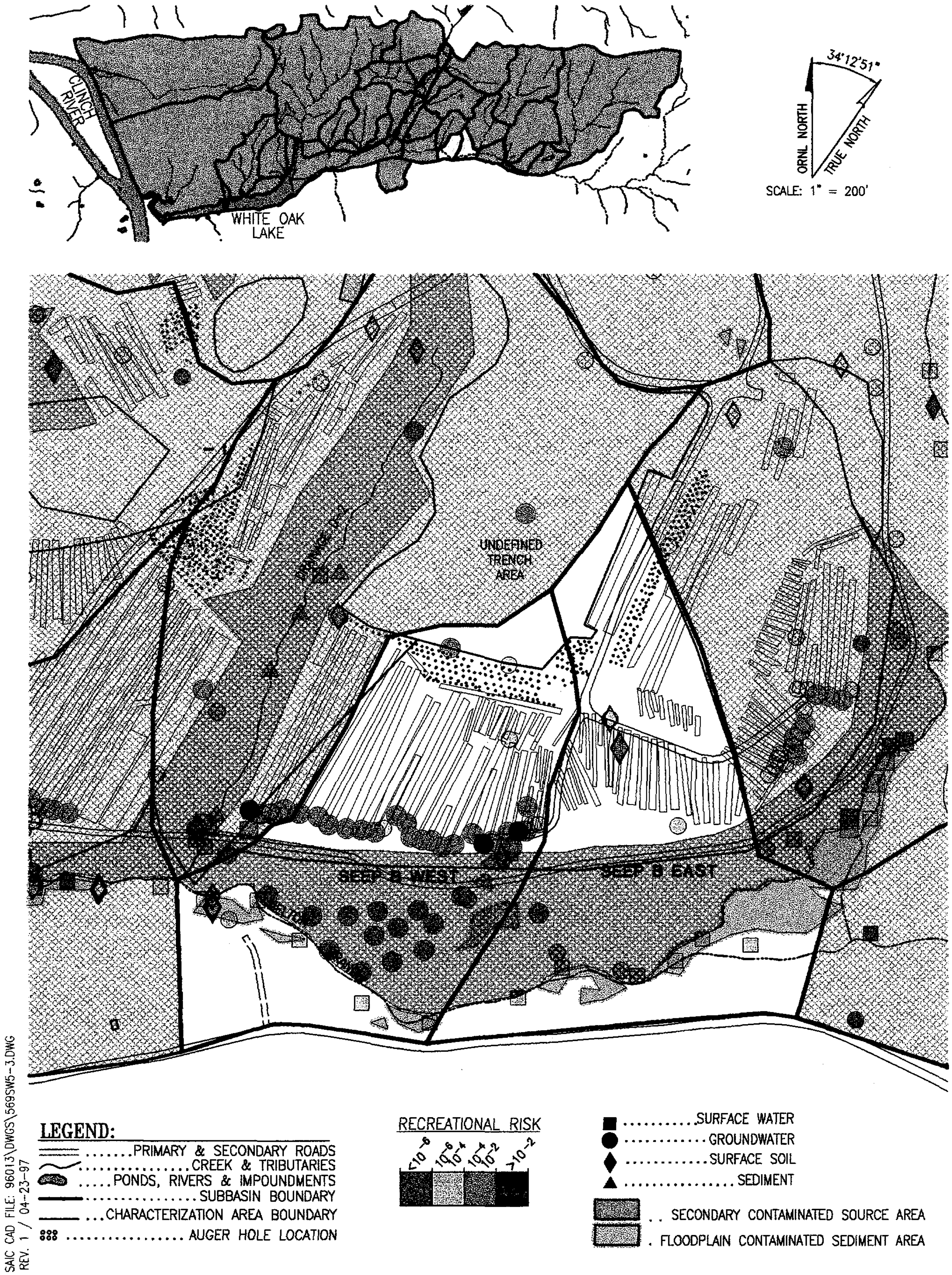


Fig. 3.28. Risk estimates at sampling locations in Seep B subbasin.

Table 3.26. Media data summary for the SWSA 5 Seep B subbasin

Basin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
Seep B West	Groundwater	42	1227	1036	926	683	2067	523
Seep B West	Sediment	5	0	0	158	133	0	0
Seep B West	Soil	5	59	50	53	48	179	17
Seep B West	SW-seeps	1	87	58	118	64	184	20
Seep B West	SW-streams	5	163	163	0	0	0	0
Seep B East	Groundwater	5	223	120	219	154	375	69
Seep B East	Sediment	6	0	0	187	159	0	0
Seep B East	Soil	2	64	51	67	57	252	53
Seep B East	SW-seeps	2	41	41	0	0	0	0
Seep B East	SW-streams	4	121	120	8	6	0	0

COCs for recreational land use identified for Seep B Area soil include ^{60}Co, ^{137}Cs, ^{90}Sr, ^{228}Ra, ^{226}Ra, and ^{208}Tl. No nonradionuclide COCs were identified for either carcinogenic or noncarcinogenic risk. Residential and industrial COCs are presented in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the Seep B West subbasin. Overall dose rates from exposure to the 18 radionuclides detected exceeded recommended dose limits for soil invertebrates (HI = 1.2), shrews and mice (HI = 8.0), deer (HI = 1.4), and turkeys (HI = 2.3), but were below the recommended dose limits for all other receptors (Table 3.27). Strontium-90 was the risk driver for soil invertebrates, deer, and turkey, contributing >57% of the dose rate, while ^{244}Cu and ^{241}Am contributed 71% and 14%, respectively, to the dose rate received by shrews and mice. Potential risks from nonradionuclides were identified for plants (HI =11.7), soil invertebrates (HI = 20.1), short-tailed shrews (HI = 19.2), white-footed mice (HI = 2.7), red fox (HI = 12.4), red-tailed hawk (HI = 2.3), and mink (HI = 3.8). Inorganics contributed >99% of the HI for all receptors. HQs exceeding one were estimated for four inorganics (mercury, molybdenum, selenium, and antimony) for plants, three (mercury, selenium, and molybdenum) for shrews and one (mercury) for soil invertebrates, mice, fox, hawk, and mink. While not as significant as the Intermediate Pond, this subbasin was a significant contributor to estimated watershed-wide risks to shrews and foxes from exposure to mercury. It is also a contributor to estimated watershed-wide risks to shrews from exposure to selenium.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in Seep B East subbasin. Overall dose rates from exposure to the 13 radionuclides detected marginally exceeded recommended dose limits for short-tailed shrews (HI = 2.2), white-footed mice (HI = 1.8), red fox (1.6), wild turkeys (1.7), and mink (1.3) but were below the recommended dose limits for all other receptors (Table 3.27). Cesium-137 was the risk driver for all receptors, contributing >91% of the dose rate. Potential risks from nonradionuclides were only identified for short-tailed shrews (HI = 2.2) and plants (1.8). While PCB-1260 contributed >72% of the HI for the shrew and was the only analyte resulting in a HQ exceeding one, this subbasin was not a major contributor to estimated watershed-wide risks to shrews from exposure to PCB-1260.

Table 3.27. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at the SWSA 5 Seep B Basin

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
Seep B East	Plants	1.8		0.1	
Seep B East	Shrew	2.3	PCB-1260 (1.6)	2.2	^{137}Cs (2.1)
Seep B East	Mouse	0.3		1.8	^{137}Cs (1.7)
Seep B East	Fox	0.3		1.6	^{137}Cs (1.6)
Seep B East	Mink	0.1		1.3	^{137}Cs (1.3)
Seep B East	Turkey	<0.1		1.7	^{137}Cs (1.6)
Seep B West	Plants	11.7	Hg (6.7), Mo (1.7), Se (1.3), Sb (1.2)	0.8	
Seep B West	Invertebrates	20.1	Hg (20.0)	1.2	^{90}Sr (0.8)
Seep B West	Shrew	19.2	Hg (15.6), Se (1.6), Mo (1.4)	8.0	^{244}Cm (5.7), ^{241}Am (1.1)
Seep B West	Mouse	2.7	Hg (2.2)	8.0	^{244}Cm (5.7), ^{241}Am (1.1)
Seep B West	Fox	12.4	Hg (12.0)	0.5	
Seep B West	Deer	0.2		1.4	^{90}Sr (1.2)
Seep B West	Mink	3.8	Hg (3.7)	0.2	
Seep B West	Hawk	2.3	Hg (2.3)	0.1	
Seep B West	Turkey	0.6		2.3	^{90}Sr (1.4)

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

SWSA 5 Seep B Sediment

Five samples were analyzed for inorganics in SWSA 5 Seep B West sediment. No carcinogenic contaminants survived the reference and PRG screening process and, therefore, carcinogenic risk was not calculated. The recreational noncarcinogenic HI also did not yield any COCs since it summed to 9.7E-03. The industrial HI is 2.5E-02. The Seep B East subbasin had six samples that were also analyzed for inorganics. Carcinogenic risk was again not calculated. The recreational HI was 1.1E-02 and the industrial HI was 2.8E-02. Therefore, no COCs were identified for SWSA 5 Seep B sediment for recreational land use. However, no radionuclide or organic data are available for the sediment in this subbasin. Discussion of COCs based on industrial and residential land use can be found in Appendix B.

Potential risks were identified for benthic invertebrates exposed to contaminated sediment in the Seep B West subbasin. However, no COECs were identified, and antimony and zinc were the only analytes presenting even a marginal risk. No other analytes were of potential concern.

Potential risks were identified for benthic invertebrates exposed to contaminated sediment in the Seep B East subbasin. However, no COECs were identified, and antimony and zinc were the only analytes presenting even a marginal risk. No other analytes were of potential concern.

SWSA 5 Seep B Groundwater

Radionuclide, organic, and inorganic contaminants have been sampled at 42 locations in the Seep B West and at 5 locations in the Seep B East subbasin. A number of these locations were drive point samples that were analyzed in the Close Support Laboratory for a limited set of radionuclides to support the WAG 5 Seeps removal action. The recreational risk for Seep B West is 3.7E-03 and for Seep B East is 7.9E-05. The industrial risk is 2.9E-01 at Seep B West and 6.4E-03 at Seep B East. The HIs for these subbasins are 5.7E-02 and 1.3E-01 for recreational use, and 4.9E-01 and 7.3E-01 for industrial use, respectively. The identified recreational COCs for SWSA 5 Seep B West groundwater include ^{90}Sr, ^{3}H, vinyl chloride, tetrachloroethylene, 1,1-dichloroethane, ^{14}C, ^{137}Cs, and ^{228}Ra.

The groundwater data from the Seep B subbasin were screened against federal and state primary drinking water standards and against radionuclide specific proposed and promulgated primary drinking water standards. Criteria exceedances were noted for ^{90}Sr, ^{3}H, benzene, 1,1-dichloroethane, carbon tetrachloride, and tetrachloroethylene in the Seep B West subbasin. For the Seep B East subbasin, exceedances were observed for ^{90}Sr, ^{3}H, ^{241}Am, ^{14}C, ^{60}Co, ^{137}Cs, ^{220}Ra, 1,1-dichloroethane, benzene, vinyl chloride, carbon tetrachloride, and tetrachloroethylene.

SWSA 5 Seep B Surface Water

Six samples at SWSA 5 Seep B West were analyzed for a variety of organic, inorganic, and radionuclide constituents as part of the WAG 5 RI. The recreational risk results for the seeps in Seep B West and Seep B East were 4.7E-03 and 2.6E-05, respectively. The industrial risks are 3.5E-01 and 3.1E-03. At both locations the risk is due again primarily to ^{3}H and ^{90}Sr. The HI for Seep B West was 4.1E-02 for recreational use and 2.7E-01 for industrial use. The HI was not calculated at Seep B East since noncarcinogenic contaminants were not analyzed for at that location. The stream samples for Seep B West and Seep B East showed recreational risks of 2.3E-06 and 3.3E-05 and industrial risks were 2.1E-04 and 3.1E-03, respectively. The HIs were all below unity for the stream samples. Therefore, the recreational COCs for the Seep B surface water are limited to carcinogenic contaminants in Seep B West. The COCs include ^{90}Sr, ^{3}H, beryllium, ^{23X}U, ^{14}C, 1,1-dichloroethane, and tetrachloroethylene.

No risks were identified for aquatic organisms exposed to chemicals and radionuclides in surface water in the Seep B West subbasin. None of the detected chemicals exceeded benchmarks (i.e., there are no COPECs). Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from the Seep B West subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

No risks were identified for aquatic organisms exposed to chemicals and radionuclides in surface water in the Seep B East subbasin. None of the detected chemicals exceeded benchmarks (i.e., there are no COPECs). Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from the Seep B East subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes. No risks were identified for plants exposed to seep water in soil solution; water concentrations were below plant soil solution benchmarks for all analytes.

The contaminant surface water concentrations for the Seep B subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. No contaminants showed exceedances for either the human health or the ecological criteria.

3.4.4.5 Options for release mechanism intervention

The Seep B subbasin includes a hill slope area containing waste burial trenches and auger holes, contaminated soil along groundwater seepage pathways between source trenches and the stream, and sediment in and adjacent to the Melton Branch channel. COCs being released from the area include ^{3}H, vinyl chloride, and ^{90}Sr into the valley floor and floodplain of Melton Branch. Primary contaminant sources remain in the trenches and auger holes and secondary contaminants in this area include a large ^{3}H plume downslope from the burial trenches in Seep B West in addition to contaminated soils and floodplain and channel sediments of Melton Branch. Other COCs migrate at a retarded rate with respect to the ^{3}H plume because of geochemical processes. The location of the ^{3}H source that created this plume is not known. The broad extent of high tritium concentration within trench sampling locations and across the Melton Branch floodplain suggests that the release, which occurred long ago by advection and diffusion of tritium through the pores of regolith and within bedrock fractures, has been extensive. Tritium has migrated several hundred feet from the Seep B West trench area boundary and extends beneath Melton Branch as indicated by elevated ^{3}H in well 0577, which samples bedrock groundwater south of the creek. The downslope ends of waste burial trenches in the Seep B subbasin are perennially saturated, and during the wet season water overflows from the low end of some trenches.

Controlling this ^{3}H release along with the Seep A ^{3}H release is estimated to reduce the ^{3}H flux of the Melton Valley watershed by approximately 60–70%. It is estimated that approximately 80% of this release migrates within the upper 10–15 ft below ground surface. With no viable method to treat or remove the ^{3}H from water, options to alter the release from this area are somewhat limited. Excavation of material in trenches may reduce the source release somewhat and shift the tritium release from groundwater/surface water to an atmospheric release. Encapsulation of the waste by grouting is expected to have a minimal impact on this tritium release since the affected area is so broad and includes much secondary media in addition to the source trenches themselves. Another option is to attempt hydrologic isolation of the source area to sharply reduce water flow into and through the trenches, thereby moderating water level fluctuations in the trenches, reducing the release, and allowing the ^{3}H to decay within the source area.

3.4.5 SWSA 5 Drainage D-2

SWSA 5 Drainage D-2 subbasin encompasses 12.2 acres and drains the central portion of SWSA 5 South. The contributing area contains waste burial trenches, auger holes, and a portion of the undefined trench areas. Contaminant source areas and monitoring locations for the Drainage D-2 subbasins are shown on Fig. 3.29.

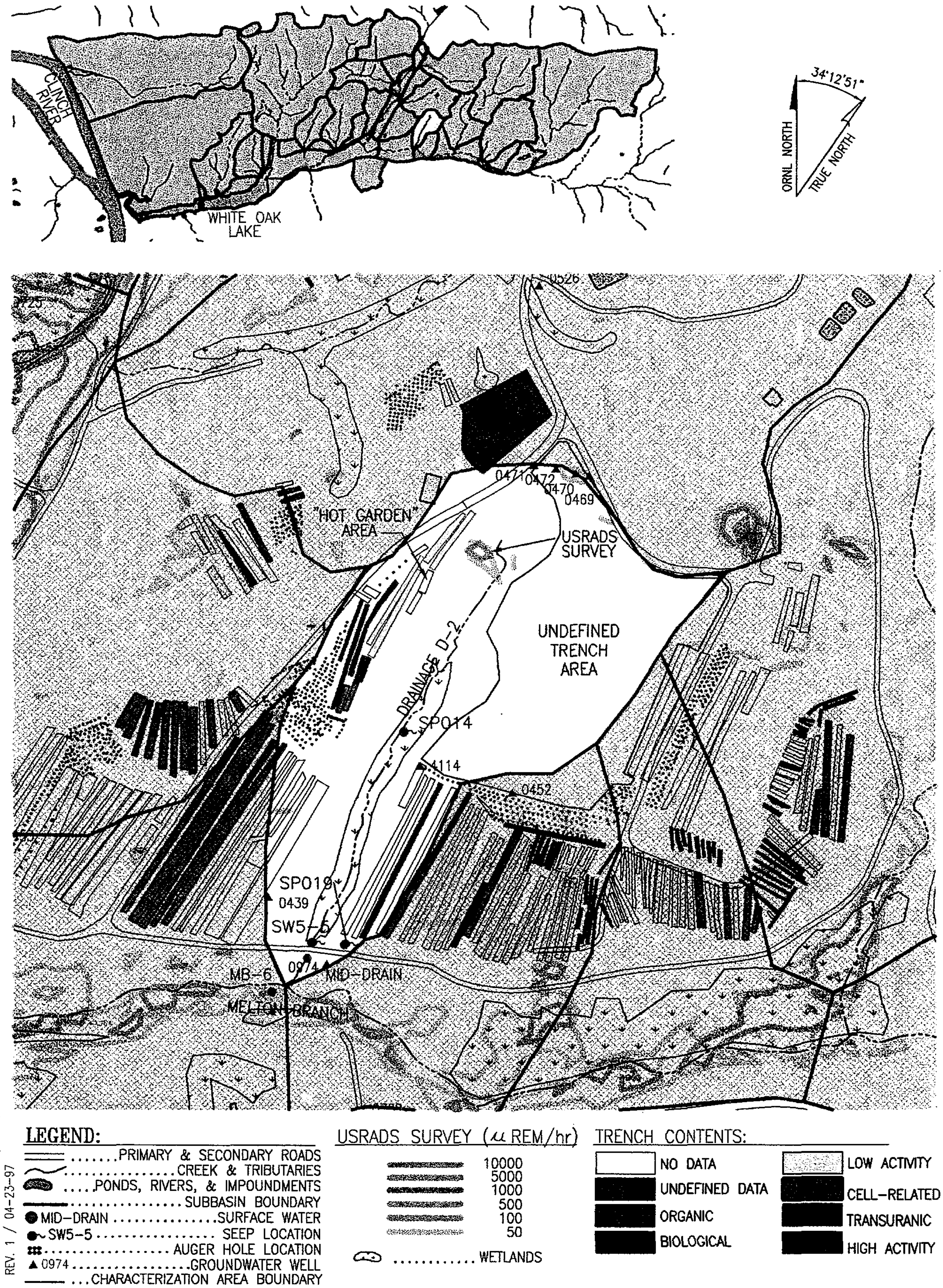


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Fig. 3.29. SWSA 5 Drainage D-2 subbasin, contaminant sources, and monitoring locations.

3.4.5.1 Contaminated sites

The SWSA 5 Drainage D-2 and undefined trench area encompass 12.2 acres in the middle portion of SWSA 5 South as shown on Fig. 3.29. The Drainage D-2 area receives runoff from an area of 10.6 acres composed of grassed-over trenches with wooded areas along the stream channel. A total of 25 trenches and 199 auger holes are located in the Drainage D-2 area, downslope of the undefined trench area. Waste buried in these trenches includes an area set aside for disposal of high activity waste with some of the trenches in this area containing TRU waste buried in concrete casks and mixed with beta-gamma contaminated waste. There is also a large group of unlined auger holes that were evidently used for the disposal of waste with high beta-gamma activity levels (DOE 1995b). Other waste types buried in this area include cell wastes, organic solvents mixed with radioactive contaminants, uranium/thorium waste, depleted uranium, and miscellaneous salvage materials. Adjacent to these auger holes there are five concrete-lined auger holes used for the disposal of control rods from the Yankee Atomic Nuclear Power Plant operated by New England Power and Light Company in 1963 that are contaminated with high levels of ^{60}Co (DOE 1995b). Two other groups of concrete vaults were constructed in this area for disposal of Building 3019 hot cell waste.

The undefined trench area was the first portion of SWSA 5 to receive waste for burial in its northern section. This area was used from 1959 to 1962 to dispose of waste in approximately 27 trenches (DOE 1995b). The limited historical information that is available indicates that waste disposed in this area was segregated alpha-contaminated waste that was buried in the trenches, then covered with a slab of concrete. Other waste types include TRU waste, biological waste, and a variety of beta-gamma waste (DOE 1995b).

3.4.5.2 Pathway model of contaminant releases

Figures 3.24 and 3.25 show cross sections through the Drainage D-2 subbasin showing contaminant sources and migration pathways. Wet and dry season sampling during the WAG 5 RI in 1993 identified significant alpha contamination in groundwater in Well 4114, located between the southwest corner of the undefined trench area and Drainage D-2 (DOE 1995b). The principal alpha-emitting isotopes were ^{238}Pu and ^{233}U, which were present at levels of 2600 pCi/L and 4200 pCi/L, respectively, in the wet season sample and 48.8 pCi/L and 29.1 pCi/L, respectively, in the dry season sample. The source of this alpha contamination is likely the wastes in the undefined trenches immediately upgradient of well 4114. The increase in alpha levels in groundwater during the wet season indicates that contaminants are released when these trenches are inundated during high water table conditions. A probable migration pathway for these contaminants to Drainage D-2 is inferred from seep, stream transect, and sediment sampling in and along Drainage D-2. Samples from SP014, a seep close to well 4114 but just upgradient, did not contain any transuranics and only low activities of other alpha-emitting isotopes. However, dry season and storm event sampling of Drainage D-2 at SW002, just north of its confluence with Melton Branch, yielded ^{238}Pu and ^{233}U concentrations of 10–17 pCi/L and 2–5 pCi/L, respectively. Based on these sampling results, the discharge of contaminated groundwater from the undefined trench area apparently occurs between SP014 and SW002; however, the precise location of the discharge is not known. Elevated gross alpha and gross beta detected in well 0452, located immediately downgradient of the undefined trench area and to the east of well 4114, indicate that contaminants are being released from the undefined trench area and migrating to the south toward the lower trenches in the Seep B West area and then to Melton Branch. The undefined trench area may also be a source of other radionuclides in groundwater and surface water, as indicated by the presence of elevated concentrations of ^{3}H, ^{90}Sr,

^{234}Th, ^{228}Ra, and uranium isotopes in samples from the six groundwater wells in the area. The presence of volatile organic compounds (VOCs) in well 4114 and high concentrations of VOCs in sediments in Drainage D-2 indicate that the undefined trench area is also a source of chlorinated VOCs and that these VOCs are entering the stream channel via discharges of contaminated groundwater.

Another source of contamination entering Drainage D-2 is the high activity trench and auger hole "hot garden" area in the uplands to the west. Wells in this area had elevated, but relatively low, ^{3}H and ^{90}Sr activities, indicating that this area is not a significant source of contamination. Well 0439, located downgradient of this area, had elevated concentrations of VOCs. Contamination from this area appears to be discharging to Drainage D-2 at seeps SP014 and SP007 (SW5-5), mixing with contamination from the undefined trench area, and subsequently moving downstream into Melton Branch. The release mechanism in this upland area is primarily contact of wastes and auger holes with water during transient perched saturation in "bathtubbing" trenches or auger holes and/or percolation of rainwater through the wastes, with the contaminants then moving downgradient in shallow groundwater to discharge locations along Drainage D-2 (DOE 1995b).

WAG 2 RI surface water data (Hicks 1996) indicate that the contribution of ^{90}Sr and ^{3}H from the WAG 5 Drainage D-2 measured at MID. DRAIN. was approximately 2.5% and 9.4%, respectively, of the ^{90}Sr and ^{3}H release over WOD during 1993–1994. The concentration of ^{137}Cs was below detection in the samples collected by the WAG 2 RI effort; however, the WAG 5 RI estimated a ^{137}Cs contribution of 0.8% to the Melton Valley watershed (DOE 1995b).

3.4.5.3 Secondary contaminated media

USRADS walkover data shown on Fig. 3.29 show small areas of radiologically contaminated surface soil in the upstream end of the subbasin. These areas are presumed to be associated with contaminant releases from nearby waste burial trenches.

Secondary contaminated media in the SWSA 5 Drainage D-2 subbasin include contaminated soils and groundwater in seepage pathways between trenches in SWSA 5 South and the Undefined Trench Area and Drainage D-2. The approximate area of contaminated seepage pathway soils is 3.7 acres (1.5 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 1,600,000 ft^{3} (46,000 m^{3}). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 130,000 ft^{3} (3,700 m^{3}).

3.4.5.4 Human health risk, ecological risk, and criteria exceedances

The SWSA 5 Drainage D-2 subbasin was evaluated for the human health risk assessment, the ecological risk assessment, and criteria exceedances. The media evaluated are groundwater, sediment, soil, and surface water seeps. The surface water-seeps category consists of samples taken at both seeps and small tributaries. The COCs for the SWSA 5 Drainage D-2 subbasin for each of the media are presented based on recreational land use. Risk results are presented for recreational and industrial land use. COCs and risk results for all three scenarios evaluated can be found in the human health risk assessment. Figure 3.30 presents available recreational carcinogenic risk results by sample location for each of the groundwater, sediment, soil, and surface water.

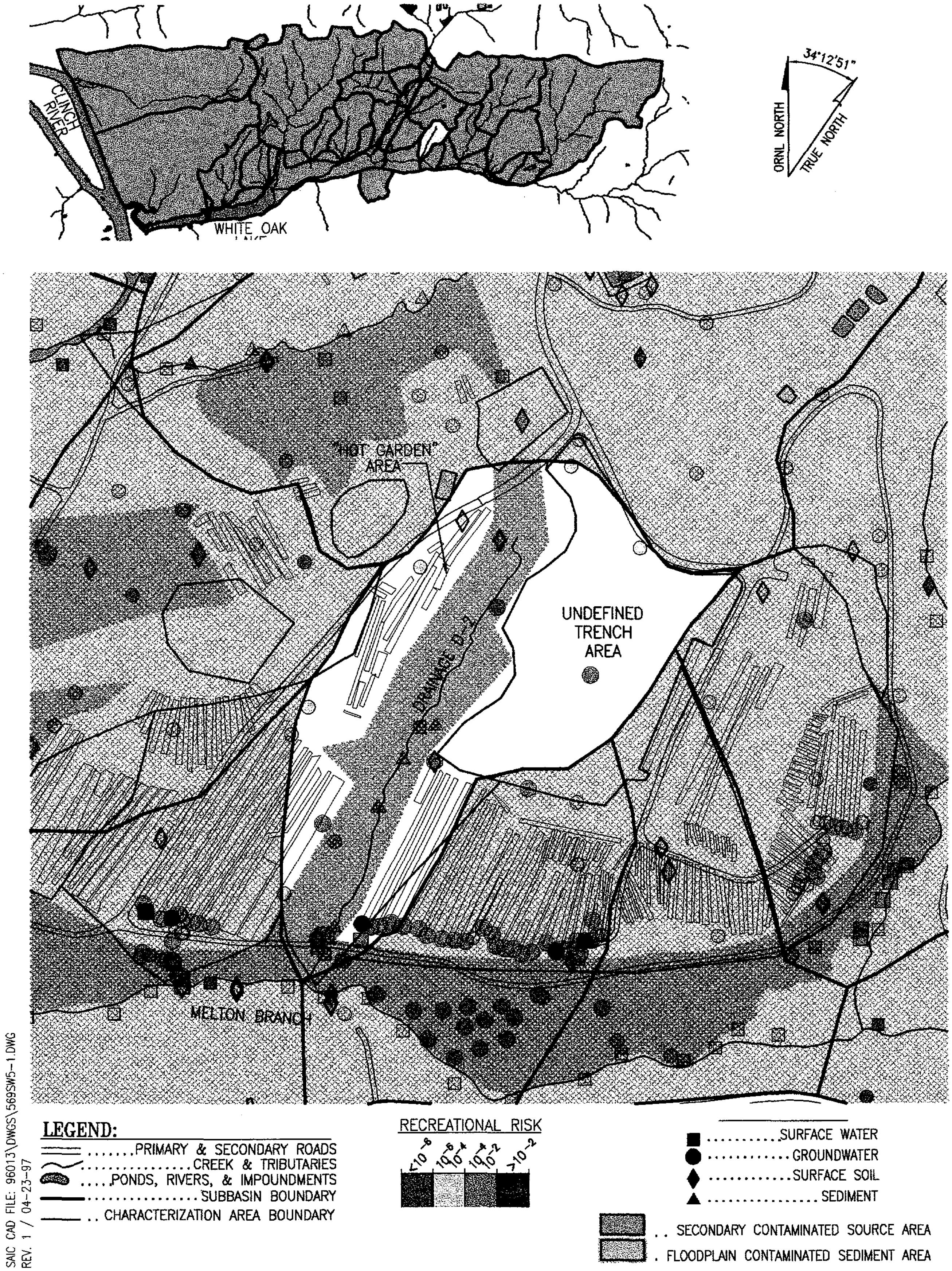

Fig. 3.30. Risk estimates at sampling locations in Drainage D-2 subbasin.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of humanhealth during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.28 provides a summary of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. Most of the media within the SWSA 5 Drainage D-2 subbasins have been adequately sampled as part of the WAG 5 and WAG 2 RIs. There are no streams or large tributaries within this subbasin so the SW-streams media are not evaluated.

Table 3.28. Media data summary for the SWSA 5 Drainage D-2 subbasin

Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
Groundwater	18	1153	830	985	714	1617	328
Sediment	4	125	117	92	73	434	62
Soil	7	127	110	103	83	514	53
SW-seeps	5	839	663	665	427	986	170

SWSA 5 Drainage D-2 Soil

The SWSA 5 Drainage D-2 subbasin was sampled for a comprehensive list of radionuclides, organics, and inorganics. The seven samples yielded a recreational risk of 3.6E-05 and an industrial risk of 6.9E-04. The HI was not calculated since all of the detected noncarcinogenic contaminants were screened out by the risk assessment. Therefore, no recreational COCs are identified for SWSA 5 Drainage D-2 soil.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 5 Drainage D-2 subbasin. Overall dose rates from exposure to the 18 radionuclides detected were well below the recommended dose limits for all receptors (Table 3.29). Potential risks were identified for plants (HI = 1.6), short-tailed shrews (HI = 19.9), white-footed mice (HI = 2.8), and red fox (HI = 2.1) from exposure to nonradionuclides. The inorganic silver (HQ = 1.1) contributed >68% of the HI for plants, but silver was detected in only two of five samples. The organic PCB-1260 was the risk driver for other receptors, contributing >90% of the HI. The PCB-1260 HQ for the shrew was 19.0. This subbasin was the primary contributor to the watershed-wide risks estimated for shrews from exposure to PCB-1260. PCB-1260 was detected in two of five samples within the subbasin.

SWSA 5 Drainage D-2 Sediment

Four samples were collected from the SWSA 5 Drainage D-2 sediment and analyzed for a comprehensive list of radionuclides, organics, and inorganics. The recreational risk totaled 6.3E-05 and was primarily due to the presence of vinyl chloride. The industrial risk was 3.4E-03. The recreational HI was 0.38 and the industrial HI was 1.3 due to the presence of manganese. However, these risk values are not high enough to assign recreational COCs for the SWSA 5 Drainage D-2 sediment.

Table 3.29. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at the SWSA 5 Drainage D-2 Basin

Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
Plants	1.6	Ag (1.1)	<0.1	
Shrew	19.9	PCB-1260 (19.0)	0.1	
Mouse	2.8	PCB-1260 (2.7)	<0.1	
Fox	2.1	PCB-1260 (1.9)	<0.1	

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

Significant risks were identified for benthic invertebrates exposed to sediment in the SWSA 5 Drainage D-2 subbasin, based on the one available line of evidence (sediment chemistry). Three inorganics and one organic potentially present a significant risk and were identified as COECs (Table 3.30). Three inorganics and two organics, including PCB-1260, present a marginal risk, and four organics exceeded possible effects levels and were considered a negligible risk. No other analytes exceeded possible effects levels.

Table 3.30. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment in SWSA 5 Drainage D-2 basin

Risk category[a]	COECs/COPECs[b]
Significant	Fe, Mn, Ag, acetone
Marginal	As, Cu, Hg, 1,1-dichloroethane, PCB-1260
Negligible	Carbon tetrachloride, 1,2-dichloroethane, 1,2-dichloroethene, naphthalene

[a] Analytes were ranked based on the percentile of the concentration distribution within the subbasin that exceeded or failed to exceed possible or probable effects levels. See the ecological risk assessment (Appendix C) for details.
[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels are listed as contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the SWSA 5 Drainage D-2 subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

SWSA 5 Drainage D-2 Groundwater

Radionuclide, organic, and inorganic contaminants have been sampled up to 50 times at 18 locations in the SWSA 5 Drainage D-2 subbasin. The recreational risk for groundwater in this subbasin is 2.2E-03 and the industrial risk is 1.9E-01. The recreational HI is 2.4E-01 and the industrial HI is 1.7. The recreational carcinogenic COCs identified for this area include ^{3}H, ^{90}Sr, ^{230}Th, ^{238}Pu, ^{23X}U, vinyl chloride, tetrachloroethylene, 1,1-dichloroethene, and carbon tetrachloride.

The groundwater data from the Drainage D-2 subbasin were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. Criteria exceedances were noted for ^{90}Sr, ^{3}H, ^{241}Am, ^{238}Pu, ^{228}Ra, ^{230}Th, ^{23X}U, vinyl chloride, benzene, 1,1-dichloroethane, carbon tetrachloride, methyl chloride, tetrachloroethylene, trichloroethylene, thallium, and antimony.

SWSA 5 Drainage D-2 Surface Water

For the SWSA 5 Drainage D-2, three samples were analyzed for organics, 12 for inorganics, and 24 for ^{3}H and ^{90}Sr at five seep locations. The recreational risk for these results sums to 8.6E-05 and the industrial risk is 6.0E-03 due to the presence of vinyl chloride, ^{90}Sr, and ^{3}H. The recreational HI is 1.1E-01 and the industrial HI is 1.5. These results do not exceed the recreational target risk ranges, so no surface water COCs are identified for recreational use for seep samples. Residential and industrial COCs are presented in Appendix B.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the SWSA 5 Drainage D-2 subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

No risks were identified for terrestrial wildlife drinking surface water; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at stations 05.SP007, 05.SP014, 05.SW002, and SW5-5 with HQs from 6.1 to 29.0. The aluminum benchmark appears to be conservative as aluminum exceeded benchmarks at numerous seeps across the whole watershed, and the aluminum benchmark is below background. Other analytes marginally exceeding benchmarks at least one station in this subbasin included arsenic, iron, and manganese (HQs all <2.2). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. It is unlikely that aluminum is of ecological concern at seeps in this subbasin.

The contaminant surface water concentrations for the Drainage D-2 subbasin were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. No contaminants were found to exceed the human health criteria and ecological criteria.

3.4.5.5 Options for release mechanism intervention

Contaminant sources in the SWSA 5 Drainage D-2 subbasin include the undefined trench area to the northeast and the high activity trench and auger hole "hot garden" area in the uplands to the west. COCs being released from the area include ^{3}H, ^{90}Sr, ^{238}Pu, ^{233}U, VOCs, and others. The precise location and orientation of source trenches are unknown.

The predominant mechanism that drives the release from this upland area is direct infiltration of precipitation into source trenches, downslope flow within trenches, contact of the trench wastes with water during transient perched saturation in bathtubbing trenches, and seepage through adjacent soils, sometimes via discrete fracture pathways, to the stream. Options to affect releases from the

SWSA 5 Drainage D-2 area include source removal, in situ stabilization, and hydrologic isolation. However, before source control options can be implemented, locations and orientations of trenches in the undefined trench area would need to be determined.

3.4.6 SWSA 5 Seep C Subbasin

3.4.6.1 Contaminated sites

The SWSA 5 Seep C Subbasin encompasses 14.9 acres immediately west of Drainage D-2 along the southern portion of SWSA 5 South with only 3.5 acres used for trench disposal as indicated in Fig. 3.31. As discussed in Sect. 3.4.3.1, SWSA 5 South was used for the burial of solid LLW in trenches and auger holes from 1959 to 1973. A total of 17 trenches and 31 auger holes are located in Seep C Subbasin. Waste buried in these trenches include solid LLW, debris (glassware, scrap material, etc.), mixed fission products, and organic solvents in metal/plastic containers and drums mixed with radioactive wastes (DOE 1995b).

3.4.6.2 Pathway model of contaminant releases

The lower ends of the southern trenches in the Seep C subbasin are perennially inundated. The principal release mechanism is contact of water with trench wastes during inundation of the trenches due to a rising water table and, during wetter years, the downslope movement of trench water from upland areas into the toes of the trenches. Contamination appears to be moving from the trenches to Seep C (SW5-4) in shallow groundwater along a discrete flow path, as evidenced by the relatively high contaminant concentrations in wells and drive points in the flow path as compared with wells and drive points adjacent to the flow path (DOE 1995b). The maximum ^{90}Sr activity in trench drive points during the WAG 5 RI was 5,312,442 pCi/L in a filtered sample from well 4175, located in the lower end of Trench 69 just upgradient of SW5-4.

Seep C (SW5-4), with typical concentrations of ^{90}Sr of around 400,000 pCi/L, has historically been the greatest contributor in SWSA 5 South to ^{90}Sr in Melton Branch. WAG 2 RI data (Hicks 1996) indicate that the contribution of ^{90}Sr from the Seep C subbasin was between 20.3% and 31.2% of the total flux at WOD during 1993–1994. The WAG 5 RI Report (DOE 1995b) indicates that the ^{90}Sr contribution from the subbasin was 25.5% before the WAG 5 removal action was completed. As shown in Table 3.1 the percent contribution from the Seep C subbasin decreased to approximately 15% in 1995 after the removal action. Because the total ^{90}Sr release over WOD decreased significantly in 1995 as a result of all the removal actions in the Melton Valley watershed, the 15% contribution corresponds to a 60–70% reduction in ^{90}Sr release from the Seep C subbasin. Other discrete flow paths in shallow groundwater from the trenches to Melton Branch may be present in the subbasin, and some contamination from deeper groundwater may be discharging to shallow groundwater in the floodplain. Seep SW5-3 in the Melton Branch floodplain downstream from the Seep C input also had elevated ^{90}Sr levels (DOE 1995a). Stream transect data indicate that discharges from the specific Seep C area account for most of the contaminant flux entering Melton Branch from this subbasin.

The highest tritium activity found during the WAG 5 RI was about 105,000,000 pCi/L in well 1734 in the lower end of Trench 105 just upgradient of Seep C. The tritium concentration in Seep C in July 1994 was about 8,600,000 pCi/L. Similar ^{3}H concentrations were found in Seep SW5-3 (DOE 1995a), which is downgradient from the trenches and the OHF. WAG 2 RI surface water data (Hicks 1996) indicate that the ^{3}H release from the Seep C subbasin is highly variable but probably

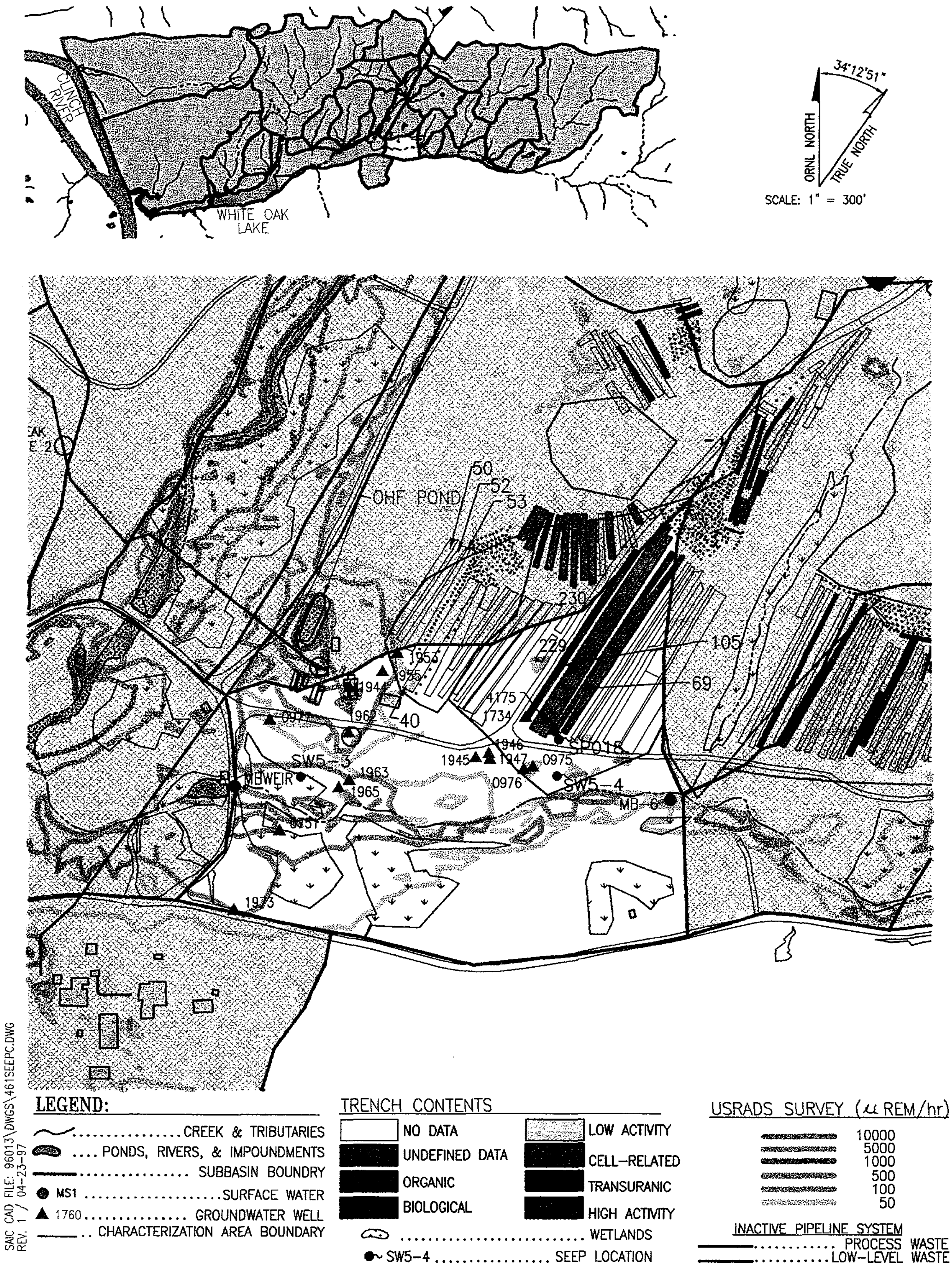

Fig. 3.31. Seep C subbasin, contaminant sources, and monitoring locations.

contributes less than 2% of the ^3H release at WOD. The WAG 5 RI report indicates that the ^3H contribution from the subbasin was 5.3%.

A plume of alpha contamination was identified in groundwater in drive points in the Melton Branch floodplain to the south of the OHF (DOE 1995b). A possible source for this contamination is the group of trenches to the west of the road (Trenches 40–50, 52–53, 229, and 230). Although there is little inventory or monitoring data for these trenches, they may have a significant inventory of alpha-containing waste. The elevated alpha activities in floodplain drive point groundwater samples were found in unfiltered samples and were associated with high alkalinity.

3.4.6.3 Secondary contaminated media

Areas of radiologically contaminated surface soil detected by the USRADS method in the Seep C subbasin are shown on Fig. 3.31. Most of the surface contamination in this subbasin lies in the floodplain soils of Melton Branch and originates form upstream sources. Some surface soil contamination is present near the OHF surface facilities located northwest of Seep C subbasin and near Well 1962; however, much of the area indicated as contaminated in that portion of the subbasin is more influenced by "shine" from the OHF Pond than by local soil contamination.

Secondary contaminated media in the SWSA 5 Seep C subbasin include contaminated soils and groundwater in the seepage pathways between the trenches and Melton Branch. The approximate area of contaminated seepage pathway soils is 4.3 acres (1.7 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 1,300,000 ft^3 (37,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 150,000 ft^3 (4,200 m^3).

3.4.6.4 Human health risk, ecological risk, and criteria exceedances

The SWSA 5 Seep C subbasin consists of one subbasin that is evaluated for the human health risk assessment, the ecological risk assessment, and criteria exceedances. The media evaluated are groundwater, sediment, soil, and two categories of surface water. The surface water categories for the human health and ecological risk assessments are surface water-seeps, which consists of samples taken at both seeps and small tributaries, and surface water-streams, which includes samples collected in Melton Branch and large tributaries. The COCs for the SWSA 5 Seep C subbasin for each of the media are presented based on recreational land use. Risk results are presented for recreational and industrial land use. COCs and risk results for all three scenarios evaluated as part of the risk assessment can be found in the human health risk assessment. Figure 3.32 presents recreational carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

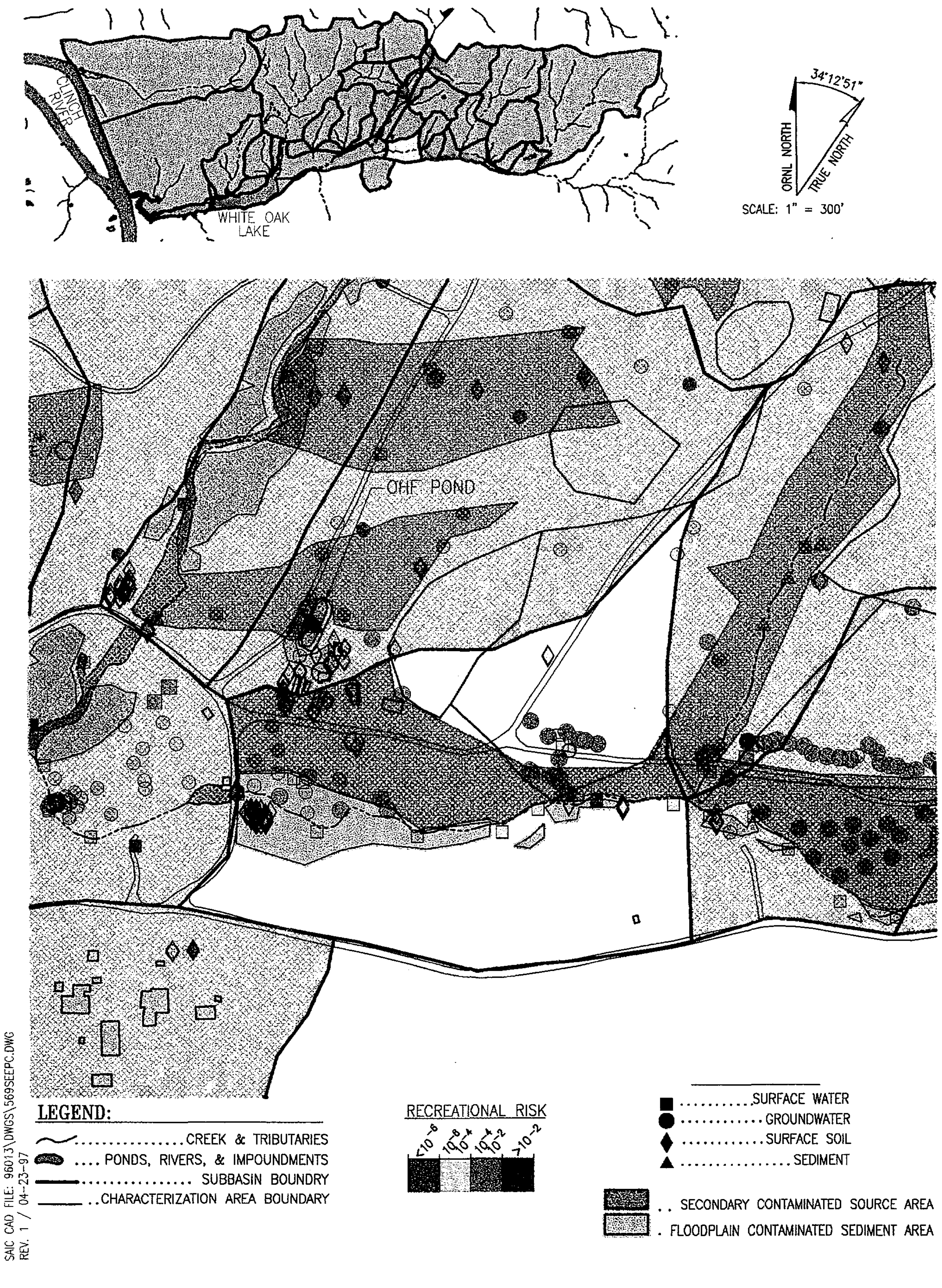

Fig. 3.32. Risk estimates at sampling locations in Seep C subbasin.

Table 3.31 provides a summary of the analytical data that was used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The subbasins within the Seep C area have been comprehensively sampled as a part of the WAG 5 RI; therefore, the associated uncertainty in the risk results and the identified COCs is considered to be low compared to the other subbasins.

Table 3.31. Media data summary for the SWSA 5 Seep C subbasin

Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
Groundwater	39	1306	1027	1116	761	2613	566
Sediment	10	13	13	272	227	80	7
Soil	37	457	380	352	305	1522	154
SW-seeps	4	289	220	661	389	411	80
SW-streams	6	260	210	78	64	0	0

SWSA 5 Seep C Soil

A total of 37 samples were collected from the SWSA 5 Seep C soil and analyzed for a comprehensive list of radionuclides, organics, and inorganics. The recreational carcinogenic risk was 2.8E-04 and the industrial risk is 6.3E-03; both can be attributed to the presence of ^{137}Cs. Other contaminants present at recreational risk levels greater than 1E-06 include ^{60}Co, beryllium, ^{228}Ra, and ^{226}Ra. The recreational HI is 2.7E-02 and the industrial HI is 7.1E-02, so no noncarcinogenic COCs were identified.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 5 Seep C subbasin. Overall dose rates from exposure to the 22 radionuclides detected exceeded recommended dose limits for shrews and mice (HI = 1.8), but were below the recommended dose limits for all other receptors (Table 3.32). Curium-244 contributed >50% of the dose rate received by shrews and mice. Potential risks from nonradionuclides were identified for plants (HI = 15.2) and short-tailed shrews (HI = 6.5). Inorganics contributed >99% of the HI for both receptors. HQs exceeding one were estimated for five inorganics (molybdenum, cobalt, silver, antimony, and thallium) for plants and three (molybdenum, barium, and selenium) for shrews. This subbasin was the primary contributor to estimated watershed-wide risks to shrews from exposure to molybdenum.

Table 3.32. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at SWSA 5 Seep C subbasin

Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
Plants	15.2	Mo (3.7), Co (2.6), Ag (2.5), Sb (2.4), Tl (1.4)	0.2	
Shrew	6.5	Mo (3.2), Ba (1.1), Se (1.0)	1.8	^{244}Cm (0.9)
Mouse	0.9		1.8	^{244}Cm (0.9)

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.

[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.

[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

SWSA 5 Seep C Sediment

A total of 10 sediment samples in the SWSA 5 Seep C sediment were sampled for 48 organic, inorganic, and radionuclide contaminants. The only radionuclides evaluated were ^{137}Cs and ^{60}Co. The recreational risk is 8.1E-04 and the industrial risk is 1.8E-03. These results are due primarily to ^{60}Co. Cesium-137 is the other risk contributor and its risk also exceeded EPA's target risk range. The recreational HI is 9.5E-03 and the industrial HI is 2.5E-02, so no noncarcinogenic COCs were identified.

The weight-of-evidence suggests that sediment in this subbasin does not pose a significant risk to benthic invertebrates. The sediment community was similar to reference sites and none of the detected chemicals exceeded probable-effects benchmarks (i.e., there are no COECs). Antimony, zinc, and PCB-1254 presented marginal risks, but no other analytes exceeded possible effects levels.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the Seep C subbasin. Dose rates estimated for large invertebrates and large fish were well below recommended dose rate limits and did not represent a significant contribution to the overall dose rate from combined surface water and sediment exposures.

SWSA 5 Seep C Groundwater

Radionuclide, organic, and inorganic contaminants were sampled up to 100 times at 39 locations in the Seep C subbasin. A number of these locations were drive point samples that were analyzed in the Close Support Laboratory for a limited set of radionuclides to support the WAG 5 Seeps removal action. These samples have a lower degree of analytical confidence associated with them. The recreational risk for groundwater in this subbasin is 7.7E-03 and the industrial risk is 5.1E-01. These results are due almost exclusively to the presence of ^{90}Sr. Other recreational carcinogenic COCs that exceed a risk of 1E-06 include ^{137}Cs, ^{14}C, tetrachloroethylene, 1,1-DCE, ^{3}H, and vinyl chloride. The recreational HI for this subbasin is 3.0E-02 and the industrial HI is 2.5E-01. Therefore, no noncarcinogenic COCs are identified.

The groundwater data from the Seep C subbasin were screened against federal and state primary drinking water standards and against radionuclide specific proposed and promulgated primary drinking water standards. Criteria exceedances were noted for ^{90}Sr, ^{3}H, ^{137}Cs, ^{14}C, vinyl chloride, benzene, tetrachloroethylene, carbon tetrachloride, 1,1-dichloroethane, and trichloroethylene.

SWSA 5 Seep C Surface Water

Ten samples of surface water were analyzed for a suite of inorganic, organics, and radionuclides at SWSA 5 Seep C. The recreational risk for the seeps in this area is 1.4E-03 and the industrial risk is 1.2E-01. These results are due almost entirely to the presence of ^{90}Sr. Other contaminants detected at concentrations that correspond to recreational risk greater than 1E-06 are 1,1-DCE, beryllium, tetrachloroethylene, ^{14}C, and ^{3}H. The stream samples show a recreational risk of 6.0E-06 and an industrial risk of 4.3E-04. The recreational and industrial HIs for seeps and streams in this area are less than one. Therefore, no noncarcinogenic COCs are identified.

Although the weight-of-evidence is not strong, it suggests that water in this subbasin does not pose a significant risk to fish. Copper and nickel appear to present a significant risk and were identified as COECs (Table 3.33), but the water has not been toxic in the standard toxicity tests.

Boron presented a marginal risk, and beryllium was considered a negligible risk. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction as they may not be bioavailable.

Table 3.33. Summary of potential risks to aquatic organisms from contaminants in main stem surface water in the SWSA 5 Seep C basin

Risk category[a]	COECs/COPECs[b]
Significant	Cu, Ni
Marginal	B
Negligible	Be

[a] Analytes were ranked based on the percentile of the concentration distribution within the subbasin that exceeded or failed to exceed possible or probable effects levels. See the ecological risk assessment (Appendix C) for details.
[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

Radionuclides in surface water in the Seep C subbasin result in some of the highest dose rates to aquatic organisms of all the subbasins in the watershed. The HI for large aquatic invertebrates was 2.2, and the HI for large fish was 0.4. Strontium-90 contributed virtually all (99.6%) of the dose rate. The ^{90}Sr activity recorded at station SW5-4 was two orders of magnitude higher than at any of the other stations and may represent a hot spot.

Risk estimates for piscivorous wildlife based on measured fish tissue data are available from one sampling location in the Seep C subbasin (MEK 0.2). No adverse effects from exposure to mercury or PCBs were predicted for any of the piscivorous receptors. No risks were predicted from exposure to radionuclides in surface water.

No risks were identified for terrestrial wildlife drinking surface water; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at station 05.SP005 and SW5-3 (HQ = 11.5). The aluminum benchmark appears to be conservative as it is below the background concentration. Other analytes marginally exceeding benchmarks (HQs <3.2) at this station were arsenic, fluoride, and manganese. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. Aluminum is unlikely to be of ecological concern at seeps in this subbasin.

The contaminant surface water concentrations for the Seep C subbasin were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic was exceeded for the human health criteria and no exceedances were observed for the ecological criteria.

3.4.6.5 Options for release mechanism intervention

The Seep C subbasin was the greatest single contributor to ^{90}Sr flux over WOD in the Melton Valley watershed before the seep interception and treatment removal action was initiated on Seep C in 1995. Even after construction of the interceptor and treatment system the Seep C subbasin still releases approximately 15% of the ^{90}Sr discharged from the entire Melton Valley watershed.

Contaminant sources in the Seep C subbasin include unlined waste burial trenches, contaminated soil along groundwater seepage pathways between source trenches and the stream, and sediment in and adjacent to the Melton Branch channel. COCs being released from the area include ^{90}Sr, ^{3}H, and others. The primary contaminant sources in this subbasin are the trenches immediately upgradient of Seep C; secondary contaminant sources include soils along the seepage pathway from the source trenches to Seep C and floodplain and channel sediments of Melton Branch.

The lower ends of the southern trenches in the Seep C area are perennially inundated. The principal release mechanism is contact of water with trench wastes during inundation of the trenches due to a rising water table and, during wetter years, the downslope movement of trench water from upland areas into the toes of the trenches. Options to affect releases from the Seep C area include: source removal, in situ stabilization by grouting, and hydrologic isolation with or without collection of a small groundwater seepage component likely to persist after the source area is capped.

Contaminated soil and sediment masses in and adjacent to the Melton Branch channel are potentially susceptible to scour and erosion during heavy precipitation runoff events. Sediment analyses show the presence of ^{60}Co and ^{137}Cs. Stabilization options for this sediment include removal and consolidation in a contaminated soil/sediment storage area, or covering/containment through the time duration of potential risk based on contaminant decay.

3.5 MIDDLE WHITE OAK CREEK

Ten subbasins encompassing 196 acres are included in the Middle WOC area (Fig. 3.33). The waste management units included in the area include SWSA 4, SWSA 5 North, a portion of SWSA 5 South, the PWSB, and facilities associated with the OHF.

3.5.1 Middle White Oak Creek East Subbasins

The middle WOC East subbasins, located east of WOC floodplain, include four subbasins: SWSA 5 WOC, SWSA 5 Trib 1, SWSA 5 N WOC, and MV Drive totaling 75 acres (Fig. 3.34). These four subbasins receive drainage primarily from five contaminated areas: (1) SWSA 5 North, (2) PWSB, (3) SWSA 5–fissile storage area, (4) SWSA 5–WOC drainage area, and (5) OHF. These drainage areas are composed of a variety of waste units including buried waste in SWSA 5; impoundment in PWSB; and tanks, impoundments, leak/spill sites, and surface structures at OHF. The following sections will discuss the sources associated with these drainage areas.

3.5.1.1 Contaminated sites

SWSA 5 N WOC Subbasin

The SWSA 5 Northwest subbasin contains portions of liquid waste transfer lines and portions of TRU waste trenches in SWSA 5 North. This subbasin also receives runoff from other TRU storage facilities in SWSA 5 North. A description of SWSA 5 North operations is included in the SWSA 5 Trib 1 subbasin discussion.

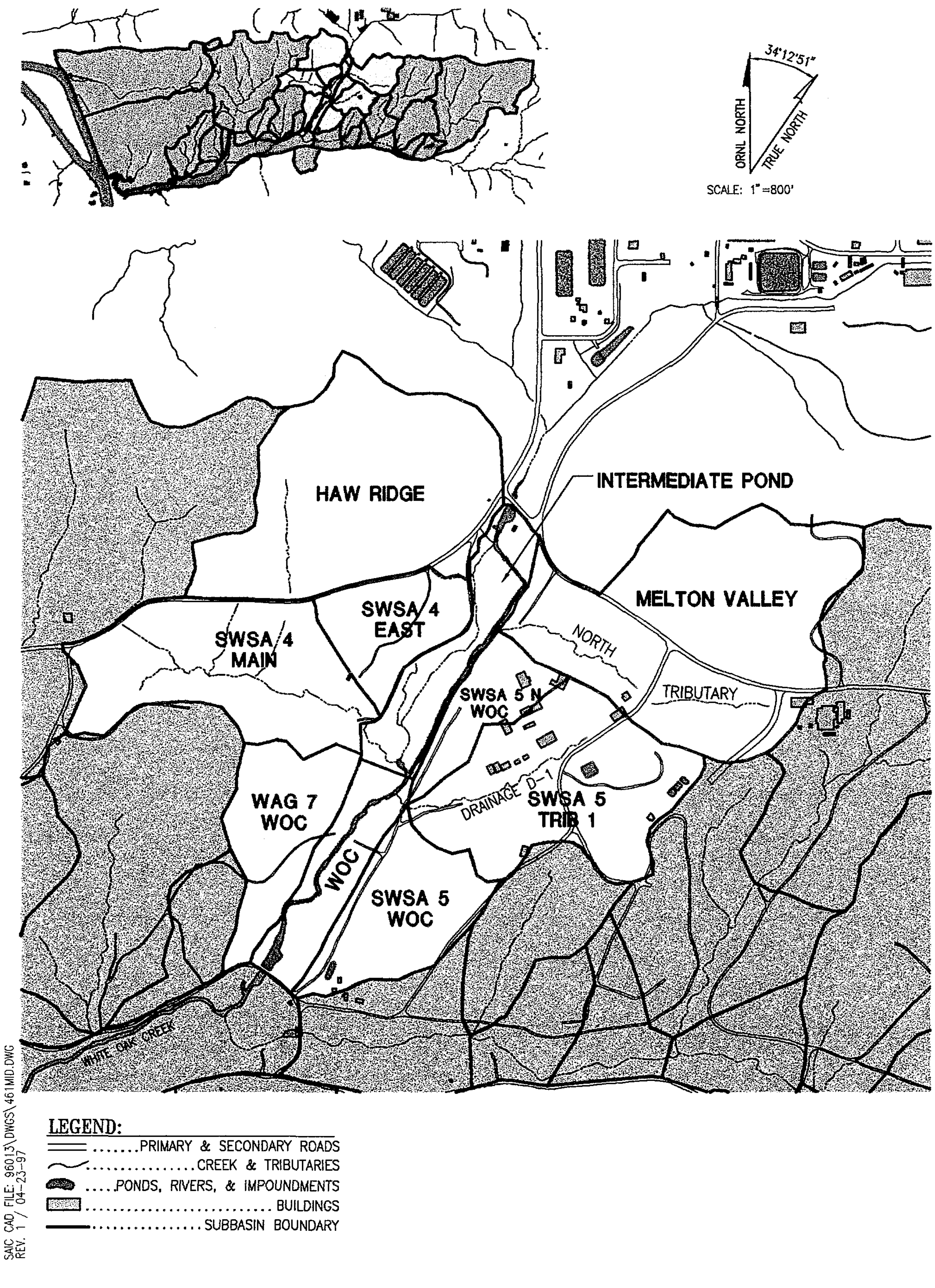

Fig. 3.33. Subbasins contained in Middle White Oak Creek area.

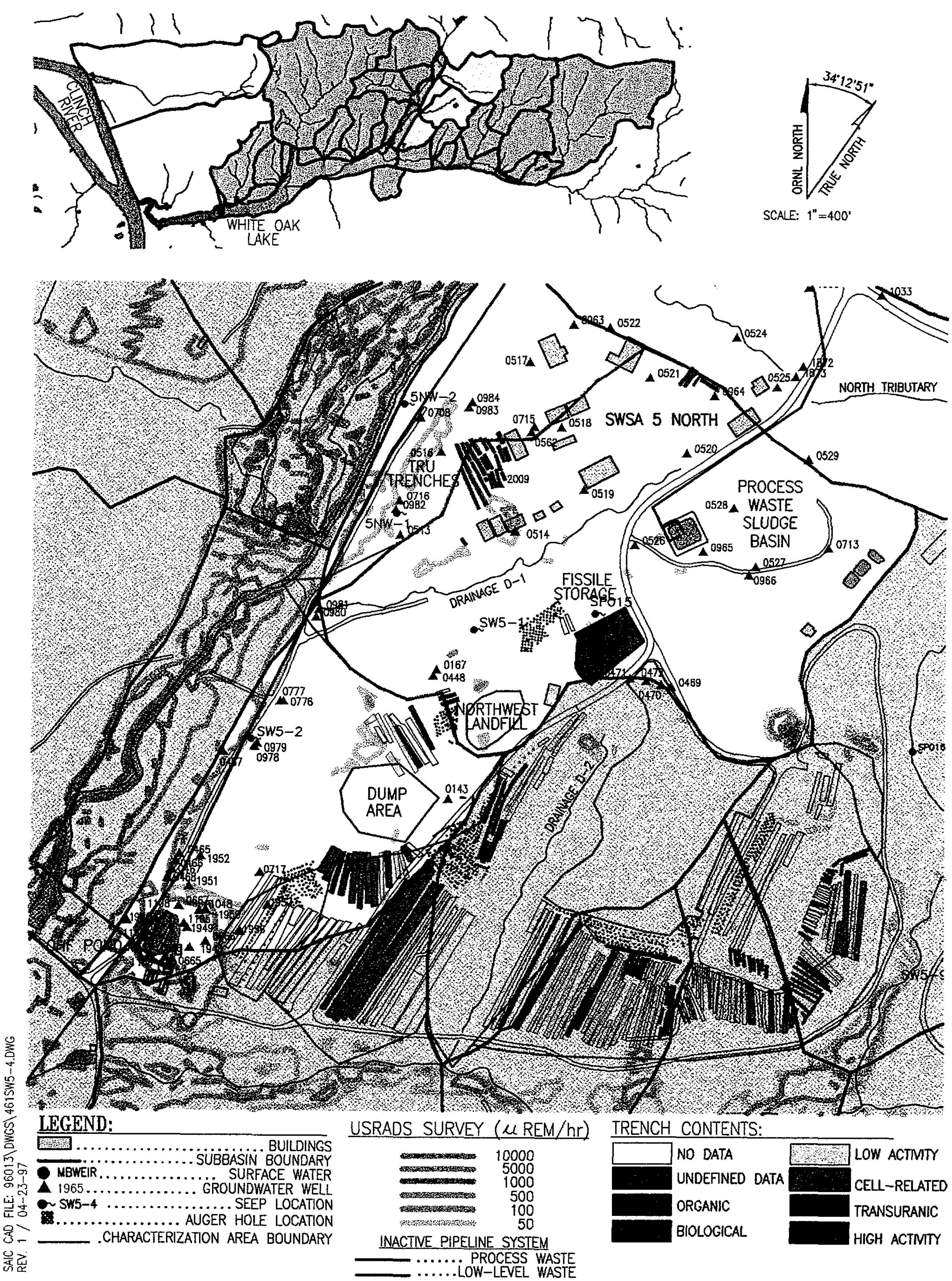

Fig. 3.34. Middle WOC subbasins east of White Oak Creek.

MV Drive Subbasin

The MV Drive subbasin contain portions of inactive waste transfer pipelines along which are leak sites known as the MV Drive leak sites. This subbasin receives drainage form the northern part of SWSA 5 North.

SWSA 5 North Subbasin

The principal operation of SWSA 5 North, both historically and current, has involved storage of alpha-contaminated waste, a small fraction of which appears to be TRU waste. TRU wastes are currently defined as those containing alpha-emitting transuranium radionuclides with half-lives >20 years and concentrations >100 nCi/g. Before 1970, there was no TRU waste classification and these wastes were classified as LLW and disposed of by shallow land burial (i.e., SWSA 5 South).

In 1970, the Atomic Energy Commission established a TRU waste classification that required solid waste contaminated with >10 nCi/g to be segregated and stored pending final determination of long-term disposal. In 1982, NRC changed the definition from >10 nCi/g to 100 nCi/g; this definition was adopted by DOE in 1984.

SWSA 5 North was designated as the TRU storage area in 1970 to abide by these new regulations and is currently used today. As noted above, from 1970 to 1984, TRU wastes were segregated based on a concentration of >10 nCi/g, which means that a large portion of the waste placed at this time may no longer be defined as TRU because its concentration is <100 nCi/g. This RI addresses the TRU waste placed in the 27 trenches and 8 stainless-steel auger holes identified in Fig. 3.34. These trenches were used for the retrievable storage of remotely handled alpha-contaminated LLW and remotely handled TRU waste in concrete casks and boxes (DOE 1995b). The other structures in this area are used for the retrievable storage of TRU waste awaiting final disposition at the Waste Isolation Pilot Plant.

Process Waste Sludge Basin

The PWSB is a PVC-lined basin constructed in 1975 and used since 1976 for the storage and decantation of sludge produced by water-softening processes at the Process Waste Treatment Plant. A subgrade pipeline was used to pump the process waste from the treatment plant to the basin and back, after adequate settling had occurred. The pipeline flow valves have been closed but the 2-in. PVC pipe remains (ORNL Drawing No. C-21246-EA-001 through -020). This basin contains surface water with low activities of ^{90}Sr, ^{60}Co, and ^{137}Cs and 960 m^3 of sludge/sediment with an inventory of ^{90}Sr (8 Ci), ^{137}Cs (4 Ci), and ^{60}Co (<1 Ci) (DOE 1995b).

Fissile Storage Area

The 4.7-acre fissile storage area is located in the northern portion of SWSA 5 South and was used primarily for storage of fissile waste, defined as wastes with >1 g of fissionable material, regardless of concentration, or with a concentration >1 g/ft^3, regardless of quantity. Historical information indicates this area is part of a larger area set aside for the disposal of high-activity wastes (DOE 1995b). This area contains one oversized trench (No. 36) that was used like a landfill for debris (and maybe sludge), two fissile waste trenches with ^{235}U, 151 fissile waste auger holes with ^{235}U (lesser amounts of ^{233}U), and a ravine landfill with debris thrown on the hillside (DOE 1995b).

SWSA 5–WOC Subbasin

The SWSA 5 WOC drainage area encompasses 22 acres in the westernmost portion of SWSA 5 South with approximately 5 acres being used for waste disposal in trenches, auger holes, and a small valley-fill dump area. The earliest trench (No. 37) excavated in the area was reportedly used in 1962 for the disposal of acid and sludge (ORNL Drawing No. E-52834, Rev.1). Waste disposal continued through the end of SWSA 5 operations in 1973 with various waste being placed there. This area contains 30 trenches with organics, transuranics, high- and low-activity radioactive waste, miscellaneous waste, and acid waste; 225 auger holes with organic and miscellaneous radioactive waste; and a dump area with debris, miscellaneous waste, and soil contaminated with ^{137}Cs and ^{90}Sr (DOE 1995b).

Old Hydrofracture Facility

The OHF site is in the southwest part of SWSA 5 South near the confluence of WOC and Melton Branch. The site was used from 1964 to 1979 for permanent disposal of liquid radioactive waste in shale formations at depths >780 ft. Various facilities were required to support the waste disposal operations, including five underground tanks used for storage of the LLLW before mixing it with grout; surface structures for storing, mixing, and handling the grout/LLLW mixture; and an impoundment and waste pit for emergency storage of LLW due to system failure. These facilities are shown in Fig. 3.34. The hydrofracture operations resulted in the contamination of these facilities and additional leak spill sites. The WAG 5 RI (and previous studies) identified three areas that warranted further consideration: (1) OHF Pond, (2) Waste Pit T-4, and (3) OHF waste storage tanks.

The OHF Pond is a rip-rap lined impoundment that received waste from the hydrofracture operation during emergencies (i.e., LLLW pipeline failure). The pond contains surface water contaminated with ^{90}Sr, ^{137}Cs, ^{60}Co, ^{99}Tc, and ^{233}U and 54 m^3 of sediments contaminated with ^{137}Cs (79 Ci), ^{90}Sr (12 Ci), and ^{244}Cm (5 Ci) (DOE 1995b). The OHF Waste Pit T-4 is a three cell concrete-lined pit that was used to receive radioactively contaminated grout when there was a system failure during hydrofracture operations. The pit was used once and now contains a 20 m^3 monolith of radioactive grout, contaminated water, and sediment. The OHF tanks were used for the storage of the LLLW before mixing with the grout constituents. The tanks are horizontal stainless steel tanks with capacities that range from 13,000 to 25,000 gal. The tanks currently contain approximately 20 m^3 of sludge with an inventory of 28,000 Ci of ^{90}Sr, ^{137}Cs, ^{60}Co, ^{244}Cm, ^{239}Pu, and ^{144}Ce. DOE has issued an action memorandum for removal of tanks contents in the OHF Tanks (DOE 1996a).

3.5.1.2 Pathway model of contaminant releases

MV Drive Subbasin. An unusual suite of contaminants detected in well 524 indicates that groundwater in this area may have been impacted by releases of contaminants from the miscellaneous trenches in the northeast part of SWSA 5 North and the drain field associated with Building 7831A (DOE 1995b). Limited data available from the WAG 2 RI (DOE 1995a and Borders et al. 1996) indicate that there are no significant levels of contaminant release from the SWSA 5 North Tributary to WOC.

SWSA 5 N WOC and SWSA 5 Trib 1 Subbasins. In SWSA 5 North, surface runoff, storm flow, and groundwater generally move radially from topographically higher areas, discharging into SWSA 5 Trib 1, North Tributary, and WOC (Fig. 3.34). The groundwater table usually is found at depths ranging from 5 to 40 ft below ground surface, at or near the bedrock/regolith interface during the dry season and at higher elevations in the regolith during the wet season.

Water level data collected in 1993 from in-trench standpipes and nearby monitoring wells show that most of the TRU trenches in the main group of trenches are at least partially inundated during the wet season (DOE 1995b). Water level data collected in 1993 from farther north indicate that a perched water table (bathtubbing) has occurred in the miscellaneous trenches in the northeast corner of SWSA 5 North. Therefore, trench inundation and/or bathtubbing are the most likely mechanisms accounting for the release of contamination in SWSA 5 North, particularly in the ten trenches containing wood or wood/metal boxes of TRU waste. Table 3.34 contains the available trench-specific information for trenches containing boxed TRU wastes. Contaminant transport from these trenches has the potential of discharging to WOC from the SWSA 5 N WOC subbasin and to Drainage D-1 in the SWSA 5 Trib 1 subbasin (Fig. 3.33).

Table 3.34. TRU waste trenches

Trench	No. of boxes	Date placed
T-2	5	1972
T-4	1	1974
T-21	1	1978
T-24	2	1979–1980
T-26	3	1980
T-27	1	1981

Sampling results from wells, seeps, and surface waters document a release of contaminants from the waste trenches in SWSA 5 North. Principal contaminants are ^{241}Am and ^{244}Cm, which have been detected at elevated levels in groundwater and surface water. Americium and/or curium have been detected in all of the samples from well 516 in the SWSA 5 N WOC subbasin, ranging up to 5940 pCi/L. Curium and americium have been detected in at least one sample from 18 of the 19 other wells in SWSA 5 North, but typically at much lower concentrations than in well 516 (<1–3 pCi/L) (DOE 1995b). In general, concentrations have risen during the wetter months of winter and spring and fallen during the drier months of summer and fall. Well 516 apparently intercepts a strike-parallel pathway with a source in the main trench area and a discharge point along WOC, as evidenced by the consistently elevated levels of TRU constituents detected in this well and in seeps which have been identified along strike to the west of this well along WOC (Morissey et al. 1994).

Samples collected by the Active Sites Environmental Monitoring Program from SWSA 5 Trib 1 have contained consistently elevated levels of gross alpha. Wastes buried in SWSA 5 North are possible sources for this alpha activity. Another possible source is waste buried in auger holes south of SWSA 5 Trib 1. According to the WAG 5 RI Report (DOE 1995b) both the SWSA 5 N WOC and the SWSA 5 Trib 1 subbasins are not significant contributors to the release of ^{90}Sr, ^{3}H, or ^{137}Cs in the watershed. Small quantities of alpha contamination are being released from both of these subbasins.

SWSA 5 WOC Subbasin. This subbasin consists of two WAG 5 RI study areas (DOE 1995b): the SWSA 5 WOC source area and the OHF Pond area. Most of the trenches and auger holes in this subbasin remain above the water table, even during the wet part of the year. The vadose zone beneath the upland trenches is as much as 25 ft thick during wet conditions, and even thicker during the dry season. Further to the west, toward WOC, the depth to groundwater decreases to about 10 ft

(DOE 1995b). Some of the westernmost trenches may become partially inundated during the wet season; however, trench inundation has not been directly observed in this area. Perched water tables (bathtubbing) may occur in upland trenches. Therefore, the primary release mechanism for contaminants in this area is the vertical percolation of rainwater through the wastes and then through the vadose zone to the groundwater table. Inundation of wastes with shallow groundwater may occur during intense storms in the westernmost trenches. Because hundreds of gallons of solvents have been disposed of in the "solvent auger holes," a release of dense non-aqueous phase liquids (DNAPLs) may have occurred. These DNAPLs may have migrated downward to below the water table and may be a source of dissolved VOCs in groundwater. Once in the saturated zone, contaminants then move to the west to discharge locations along WOC.

Seep SW5-2 and well 0978 had the highest VOC concentrations detected in SWSA 5 (DOE 1995b). A similar suite of compounds was detected in the seep and in the well, indicating that well 0978 intercepts a migration pathway for contaminants moving from source areas to discharge locations along the margin of the WOC floodplain. VOCs were detected from other wells in the area, including 0176, 0432, 0448, and 4116. The most likely source of the VOCs is the trenches and auger holes used for disposal of organic wastes (i.e., "solvent auger holes").

Elevated concentrations of ^{60}Co and ^{90}Sr were both detected (87 and 419 pCi/L, respectively) in samples from SP004 (SW5-2) (Fig. 3.34). Upgradient from the seep, ^{60}Co was detected at levels comparable to those detected in the seep at wells 0978 and 0979 (24 and 12 pCi/L, respectively). Strontium-90 was not detected in either of these wells, but it was detected at levels slightly higher than background in samples from wells farther upgradient (DOE 1995b). Therefore, it appears that these wells intercepted the ^{60}Co pathway, but did not intercept the ^{90}Sr pathway. This is evidence of the discrete nature of contaminant transport in the water table interval throughout SWSA 5.

The SWSA 5 WOC source area, consisting of the trenches, auger holes, and dump area, contributes approximately 2.9% and 3.6%, respectively, of the ^{90}Sr and ^{137}Cs release at WOD (DOE 1995b). There is no significant ^{3}H release from this area, and only small quantities of alpha contamination are released in surface water.

Sampling of groundwater in four wells installed around the OHF impoundment between 1985 and 1993 confirmed that groundwater in the area of the pond has been contaminated with ^{90}Sr, ^{137}Cs, ^{60}Co, ^{244}Cm, ^{238}Pu, and ^{233}U. The presence of ^{233}U and ^{244}Cm in the groundwater is a strong indicator that this contamination is derived from the pond and not from sources upgradient of the pond (DOE 1995b). The highest concentrations of contaminants have been found in well 1108, located downgradient of the northwestern corner of the impoundment (Fig. 3.34). In 1987, a tracer test was conducted during which ^{85}Sr was added to the pond water (Francis and Sealand 1987a). The tracer rapidly disappeared from the pond water and was detected in groundwater from well 1108. ^{85}Sr was not observed in the other three wells around the impoundment.

The presence of ^{90}Sr contamination in well 1108 and not in the other three wells around the impoundment indicates that groundwater flow and contaminant transport is occurring along discrete pathways in the soil and saprolite in the vicinity of the northwestern corner of the impoundment. The most likely mechanism of contaminant release from the pond is leakage around and/or into the standpipe that functions as an emergency overflow at the north end of the pond. The standpipe is connected to an 8-in. vitrified clay pipe that runs about 50 ft westward to an outlet near the margin of the WOC floodplain. The results of groundwater level measurements in the area indicate that groundwater flows to the west and discharges to WOC (DOE 1995b). A comparison of the elevation of the bottom of the pond and groundwater elevations around the pond indicates that during the wet season the water table intersects the pond bottom. Contaminant concentrations in well 1108 have been consistently higher during the wet season than during the dry season. Therefore, it appears that during the wet season groundwater may be acting as both a contaminant release and transport medium. A sample collected in May 1992, from seep SW2-4, located in the WOC floodplain about 200 ft west of the OHF impoundment, had an elevated ^{90}Sr activity of 316 pCi/L (DOE 1995a), the source of which may be the pond.

The OHF Pond area is not a significant contributor to ^{3}H releases in the watershed and accounts for an estimated 1.3% of the ^{90}Sr release at WOD (DOE 1995b). The total contributions from the SWSA 5 WOC subbasin to the releases at WOD are 4.2% for ^{90}Sr and 3.6% for ^{137}Cs.

3.5.1.3 Secondary contaminated media

Areas of radiologically contaminated surface soils in the Middle WOC are shown on Fig. 3.34. Gamma activity shine from the OHF Pond sediment and from the WOC and Intermediate Pond floodplain areas are prominent influences. Relatively small areas of radiologically contaminated surface soils are apparent near the Dump Area in SWSA 5 WOC, the Northwest Landfill, and the Fissile Storage Area. Elevated measurements near the building in SWSA 5 North probably originate from waste packages in temporary storage in that area. A prominent area of elevated surface gamma activity on the hilltop at the southeastern edge of the SWSA 5 Trib 1 subbasin is attributable to contaminated debris and containerized waste in the area.

SWSA 5 N WOC Subbasin

Secondary contaminated media in the SWSA 5 N WOC subbasin include contaminated soils and groundwater in the seepage pathway between the TRU trenches in SWSA 5 North and WOC. The approximate area of contaminated seepage pathway soils is 0.1 acre (0.04 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 30,000 ft^3 (900 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 3500 ft^3 (100 m^3).

SWSA 5 Trib 1 Subbasin

Secondary contaminated media in the SWSA 5 Trib 1 subbasin include contaminated soils and groundwater in seepage pathways between trenches to the south of SWSA 5 Trib 1 and the tributary and in seepage pathways between the TRU trenches in SWSA 5 North and SWSA 5 Trib 1. The approximate area of contaminated seepage pathway soils is 3 acres (1.2 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 900,000 ft^3 (26,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 110,000 ft^3 (3,000 m^3).

SWSA 5 WOC Subbasin

Secondary contaminated media in the SWSA 5 WOC subbasin include contaminated soils and groundwater in the seepage pathways in the northern part of the subbasin between the trenches and WOC and in the seepage pathway between the OHF Impoundment and WOC in the southern part of the subbasin. The approximate total area of contaminated seepage pathway soils is 3.8 acres (1.5 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is

1,100,000 ft^3 (32,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 130,000 ft^3 (3,700 m^3).

3.5.1.4 Human health risk, ecological risk, and criteria exceedances

The Middle WOC East subbasins that were analyzed in the human health risk assessment include: SWSA 5 Trib 1, Melton Valley Drive, SWSA 5 N WOC, and SWSA 5 WOC. The media evaluated are groundwater, sediment, soil, and two categories of surface water. The surface water categories for the human health and ecological risk assessments are surface water-seeps, consisting of samples taken at both seeps and small tributaries, and surface water-streams, consisting of samples collected in WOC, Melton Branch, and larger tributaries. COCs for each media are presented, based on recreational land use. Risk results are presented for recreational and industrial land uses. COCs and risk results for both land use scenarios evaluated can be found in the human health risk assessment (Appendix B). Figure 3.35 presents available carcinogenic risk results by sample location for each of the four media.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.35 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The subbasins within the Middle WOC East area have been comprehensively sampled as a part of the WAG 5 RI; therefore, the associated uncertainty in the risk results and the identified COCs is less than at other basins with a less comprehensive sampling history.

Middle WOC East Soil

Table 3.36 summarizes the carcinogenic risk, the noncarcinogenic HI, and the recreational COCs identified for the four subbasins that compose the Middle WOC subbasins east of the WOC floodplain. The MV Drive subbasin was analyzed for a select group of radionuclides only, while the other three subbasins were analyzed for a comprehensive list of inorganics, organics, and radionuclides.

Soil COCs for the Middle WOC East subbasins include all contaminants that were identified as COCs in any of the subbasins. Therefore, the total COC list for Middle WOC East includes ^{137}Cs, ^{60}Co, ^{226}Ra, ^{228}Ra, ^{228}Ac, ^{214}Bi, and ^{208}Tl for recreational land use. COCs for industrial and residential land uses are presented in Appendix B.

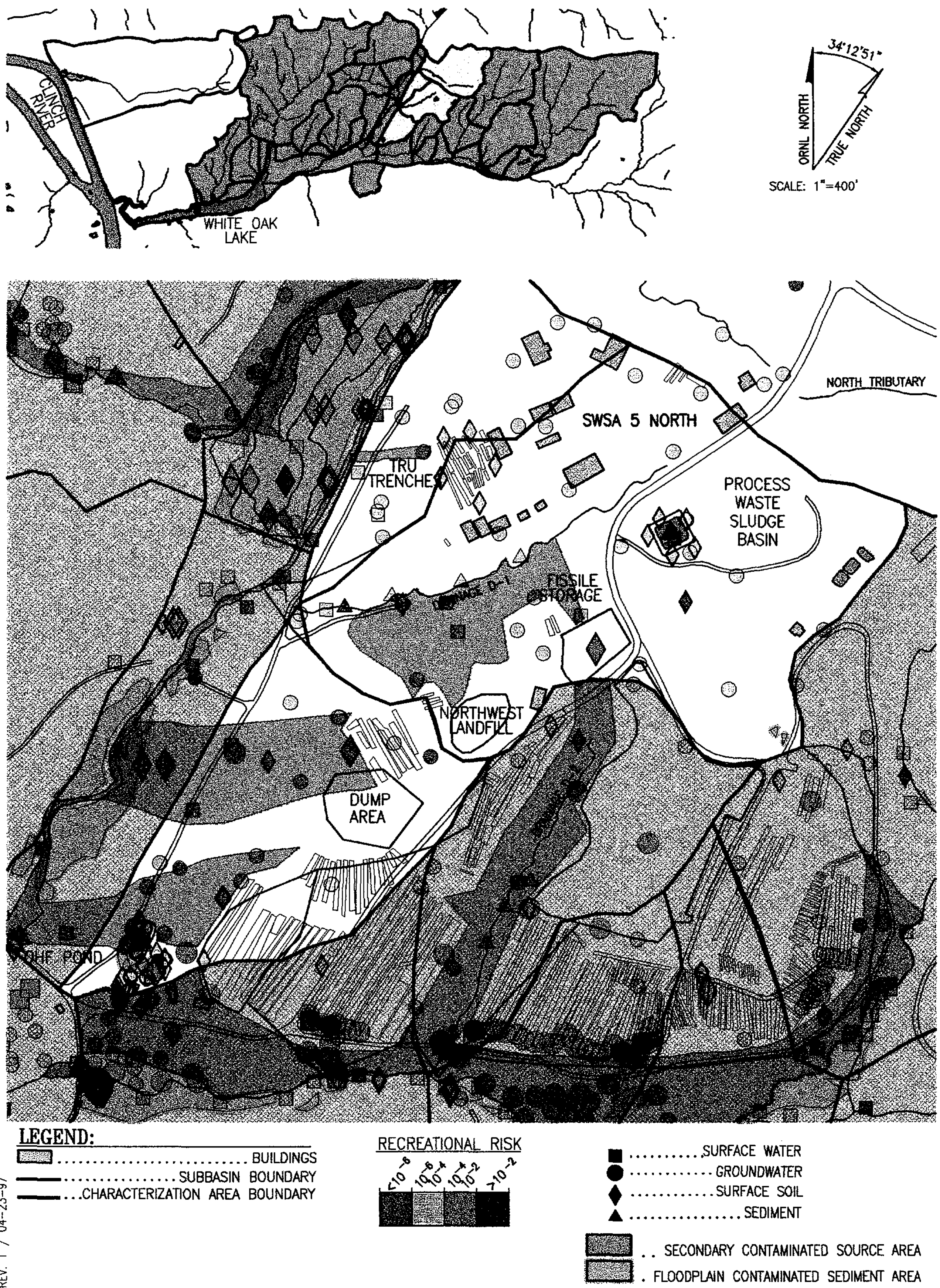

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Fig. 3.35. Risk estimates at sampling locations in the Middle WOC subbasins east of White Oak Creek.

Table 3.35. Media data summary for the Middle WOC East subbasins

Subbasin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
SWSA 5 Trib 1	Groundwater	17	1421	852	1261	769	2965	325
SWSA 5 Trib 1	Sediment	8	248	236	169	122	1112	141
SWSA 5 Trib 1	Soil	13	344	290	366	305	1619	203
SWSA 5 Trib 1	SW-seeps	4	891	640	868	545	1045	143
SWSA 5 Trib 1	SW-streams	1	56	36	76	40	165	15
MV Drive	Groundwater	7	457	278	732	455	1467	118
MV Drive	Soil	2	14	14	0	0	0	0
MV Drive	SW-seeps	1	13	5	148	89	112	9
SWSA 5 N WOC	Groundwater	10	1445	761	1336	789	2705	263
SWSA 5 N WOC	Soil	2	86	75	82	72	357	47
SWSA 5 N WOC	SW-seeps	3	123	68	285	154	377	34
SWSA 5 N WOC	SW-streams	1	20	20	0	0	0	0
SWSA 5 WOC	Groundwater	25	1768	1038	1690	997	3381	481
SWSA 5 WOC	Sediment	3	50	46	22	16	156	4
SWSA 5 WOC	Soil	18	663	528	467	376	2269	354
SWSA 5 WOC	SW-seeps	2	96	68	179	108	194	30
SWSA 5 WOC	SW-streams	1	129	107	93	59	163	13

Table 3.36. Summary of risk results for Middle WOC East soil

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
SWSA 5 Trib 1	1.1E-02	1.8E-02	4.9E-04	6.7E-03	^{137}Cs, ^{60}Co, ^{226}Ra, ^{228}Ra, ^{228}Ac, ^{214}Bi, ^{208}Tl
MV Drive	3.1E-03	–	1.4E-04	–	^{137}Cs, ^{60}Co
SWSA 5 WOC	8.5E-04	4.0E-02	3.9E-05	1.7E-02	None
SWSA 5 N WOC	3.1E-04	–	1.4E-05	–	None

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 5 Trib 1 subbasin. Overall dose rates from exposure to the 27 radionuclides detected marginally exceeded recommended dose limits for shrews and mice (HI = 1.9 and 1.9, respectively) but were below the recommended dose limits for all other receptors (Table 3.37). Plutonium-238 contributed >70% of the dose rate received by shrews and mice. Potential risks from nonradionuclides were identified for plants (HI = 20.6), soil invertebrates (HI = 43.1), short-tailed shrews (HI = 33.8), mouse (HI = 4.8), turkey (HI = 1.2), hawk (HI = 4.5), mink (HI = 7.4), and red fox (HI = 24.0). Inorganics contributed >84% of the HI for all receptors. HQs exceeding one were estimated for three inorganics (mercury, selenium, and silver) for plants, two (mercury and selenium) for shrews, and one (mercury) for soil invertebrates, mouse, turkey, hawk, mink, and red fox. Mercury was the primary risk driver for all receptors.

Table 3.37. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at Middle WOC East subbasins

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
MV Drive	All	na		<0.1	
SWSA 5 WOC	Plants	10.7	Hg (3.2), Zn, (2.36), Se (1.7), Ag (1.1)	<0.1	
SWSA 5 WOC	Invertebrates	10.3	Hg (9.6)	<0.1	
SWSA 5 WOC	Shrew	9.8	Hg (6.5), Se (1.3)	0.2	
SWSA 5 WOC	Mouse	1.4	Hg (0.9)	0.2	
SWSA 5 WOC	Fox	5.6	Hg (5.0)	0.1	
SWSA 5 WOC	Hawk	1.1	Hg (0.9)	<0.1	
SWSA 5 WOC	Mink	1.7	Hg (1.5)	<0.1	
SWSA 5 N WOC	Plants	2.5	Se (1.4), Ag (1.1)	<0.1	
SWSA 5 N WOC	Shrew	1.8	Se (1.8)	0.1	
SWSA 5 Trib 1	Plants	20.6	Hg (14.3), Se (3.3), Ag (1.6)	0.1	
SWSA 5 Trib 1	Invertebrates	43.1	Hg (43.0)	0.1	
SWSA 5 Trib 1	Shrew	33.8	Hg (30.3), Se (1.7)	1.9	^{238}Pu (1.5)
SWSA 5 Trib 1	Mouse	4.8	Hg (4.3)	1.9	^{238}Pu (1.5)
SWSA 5 Trib 1	Turkey	1.2	Hg (1.2)	0.6	
SWSA 5 Trib 1	Fox	24.0	Hg (23.4)	0.2	
SWSA 5 Trib 1	Hawk	4.5	Hg (4.4)	0.1	
SWSA 5 Trib 1	Mink	7.4	Hg (7.2)	0.2	

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

Risks to terrestrial biota were evaluated for radionuclides in soil in the MV Drive subbasin. Nonradionuclide data were unavailable. Only five radionuclides were detected in up to three samples from this subbasin, and no risks are anticipated for terrestrial biota (Table 3.37). Overall dose rates were well below recommended dose limits for all receptors.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 5 WOC subbasin. No risks were identified for exposure to radionuclides. Overall dose rates from exposure to the 27 radionuclides detected were well below the recommended dose limits for all receptors (Table 3.37). Potential risks were identified for plants (HI = 10.7), soil invertebrates (HI = 10.3), short-tailed shrews (HI = 9.8), white-footed mice (HI = 1.4), red-tailed hawk (HI = 1.1), mink (HI = 1.7), and red fox (HI = 5.6) from exposure to nonradionuclides. Inorganics contributed >86% of the HI for all receptors. HQs exceeding one were estimated for four inorganics (mercury, zinc, selenium, and silver) for plants, two (mercury and selenium) for shrews, and one (mercury) for soil invertebrates, mice, hawk, mink, and red fox. With the exception of mercury, exceedances of toxicological benchmarks were relatively low (less than a factor of 2.4), and the maximum HQ for mercury was 9.6 for soil invertebrates.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 5 N WOC subbasin. No risks were identified for exposure to radionuclides. Overall dose rates from exposure to the 18 radionuclides detected were well below the recommended dose limits for all receptors (Table 3.37). Potential risks were identified for plants (HI = 2.5) and short-tailed shrews (HI = 1.8) from exposure to nonradionuclides. Inorganics contributed >99% of the HI for both receptors. HQs exceeding one were estimated for two inorganics (selenium and silver) for plants and only one inorganic (selenium) for shrews. Exceedances of toxicological benchmarks were low (less than a factor of 1.8), but this subbasin was an important contributor to the estimated watershed-wide risks to shrews from exposure to selenium in soil.

Middle WOC East Sediment

Table 3.38 summarizes the carcinogenic risk, the noncarcinogenic HI, and the recreational COCs identified for the two subbasins that have sediment data. SWSA 5 Trib 1 and SWSA 5 WOC were analyzed for a comprehensive list of inorganics, organics, and radionuclides. SWSA 5 N WOC and Melton Valley Drive have not been sampled for sediment.

Table 3.38. Summary of risk results for Middle WOC East sediment

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	COCs
SWSA 5 Trib 1	3.2E-01	4.2E-01	1.7E-02	1.4E-01	^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{90}Sr, ^{238}U, ^{228}Th, ^{228}Ra, PCB-1248, PCB-1260, ^{241}Am, ^{244}Cm, ^{214}Bi, ^{226}Ra, ^{233}U
SWSA 5 WOC	1.0E+00	3.0E-01	1.0E+00	1.2E-01	^{137}Cs, ^{60}Co, ^{90}Sr, ^{228}Th, ^{228}Ra, PCB-1260, ^{241}Am, ^{244}Cm, $^{238/239/240}$Pu, ^{226}Ra

Sediment COCs for the Middle WOC East subbasins include all contaminants that were identified as COCs in any of the subbasins. Therefore, the total COC list for Middle WOC/East includes ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{90}Sr, ^{238}U, $^{238/239/240}$Pu, ^{228}Th, ^{228}Ra, PCB-1248, PCB-1260, ^{241}Am, ^{244}Cm, ^{214}Bi, ^{226}Ra, and ^{233}U.

Significant risks were identified for benthic invertebrates exposed to sediment in the SWSA 5 Trib1 subbasin, based on one line of evidence (sediment chemistry). Six inorganics and five organics, including PCB-1248 and PCB-1254, potentially present a significant risk and were identified as COECs (Table 3.39). Three inorganics and three organics, including PCB-1260, present a marginal risk, and seven organics exceeded only possible effects levels and were considered a negligible risk. No other analytes exceeded possible effects levels.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the SWSA 5 Trib 1 subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Significant risks were identified for benthic invertebrates exposed to nonradionuclides in sediment in the SWSA 5 WOC subbasin, based on one line of evidence (sediment chemistry). Four inorganics and three organics, including PCB-1254 and PCB-1260, potentially present a significant risk and were identified as COECs (Table 3.39). Zinc was considered to present a marginal risk, and no other analytes represented even a potential concern.

Table 3.39. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment in Middle WOC East subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
SWSA 5 Trib 1	Significant	Fe, Mn, Hg, Ni, Ag, Zn, 4-methylphenol, acetone, PCB-1248, PCB-1254, Phenol
	Marginal	Sb, Cu, Pb, BEHP, PCB-1260, 4-methyl-2-pentanone
	Negligible	2-butanone, 1,1-DCE, carbon tetrachloride, chloroform, dimethylbenzene, ethylbenzene, total PAHs
SWSA 5 WOC	Significant	Cu, Pb, Hg, Ag, acetone, PCB-1254, PCB-1260
	Marginal	Zn
	Negligible	None

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels are listed as contaminants of potential ecological concern.

Radionuclides in sediment in the SWSA 5 WOC subbasin result in the highest dose rates to aquatic organisms of all the subbasins in the watershed. The HI for large aquatic invertebrates was 202, and the HI for large fish was 91. Cesium-137 contributed 98.6% of the dose rate, and ^{60}Co accounted for 1.3%. While the risks are high, the data for this subbasin were collected from a single location, the OHF Pond, and do not represent a widespread ecological concern.

Middle WOC East Groundwater

Table 3.40 summarizes the carcinogenic recreational risk and the noncarcinogenic HI for the subbasins in Middle WOC East.

Table 3.40. Summary of risk results for Middle WOC East groundwater

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index
SWSA 5 Trib 1	1.1E-04	5.9E-01	4.9E-06	8.4E-02
Melton Valley Drive	9.6E-05	2.1E+00	4.3E-06	2.1E-01
SWSA 5 WOC	3.1E-02	2.6E+00	1.2E-03	1.9E-01
SWSA 5 N WOC	1.7E-04	3.9E-01	5.3E-06	4.8E-02

Recreational COCs were identified for the SWSA 5 WOC subbasin and include vinyl chloride, ^{90}Sr, ^{3}H, carbon tetrachloride, and tetrachloroethene. No other recreational COCs are identified for the Middle WOC East subbasins. Industrial and residential COCs are presented in Appendix B.

The groundwater data from the Middle WOC East subbasins were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. For the SWSA 5 Trib 1 subbasin, criteria exceedances were noted for benzene, carbon tetrachloride, and tetrachloroethene. In the Melton Valley Drive subbasin, exceedances were observed for ^{220}Ra, 1,1-dichloroethane, benzene, carbon tetrachloride, and tetrachloroethene. At SWSA 5 WOC, exceedances occurred for ^{90}Sr, ^{3}H, ^{137}Cs, ^{220}Ra, 1,1-dichloroethane, benzene, carbon tetrachloride, tetrachloroethene, trichloroethylene, cis-1,2-

dichloroethene, and vinyl chloride. At SWSA 5 N WOC, exceedances occurred for ^{244}Cm, 1,1-DCE, benzene, carbon tetrachloride, and vinyl chloride.

Middle WOC East Surface Water

Five samples have been analyzed for a comprehensive list of contaminants at SWSA 5 Trib 1. At SWSA 5 N WOC, four samples have been analyzed for ^{90}Sr and ^{3}H. One seep sample has been taken at the Melton Valley Drive subbasin and three samples from the SWSA 5 WOC subbasin. Table 3.41 summarizes the risk results and the recreational COCs for these samples.

Table 3.41. Summary of risk results for Middle WOC/East surface water

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
SWSA 5 Trib 1-seeps	8.7E-04	9.5E-01	1.5E-05	9.4E-02	None
SWSA 5 Trib 1-streams	2.3E-03	2.7E-01	2.9E-05	3.4E-02	None
MV Drive-seeps	2.8E-05	4.6E-01	6.7E-06	6.7E-02	None
SWSA 5 N WOC-seeps	5.2E-05	1.2E+00	6.3E-06	1.3E-01	None
SWSA 5 N WOC-streams	5.0E-05	–	5.4E-07	–	None
SWSA 5 WOC-seeps	2.1E-04	4.8E-01	1.1E-05	5.1E-02	None
SWSA 5 WOC-streams	3.9E-02	1.7E-01	4.3E-04	3.3E-02	^{90}Sr, ^{137}Cs, ^{14}C, 1,1-DCE, PCE

For subbasins analyzed for surface water contaminants, recreational risk and HI results were not high enough to warrant the identification of any recreational COCs, except for the SWSA 5 WOC stream sample. Residential and industrial COCs are presented in Appendix B.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the SWSA 5 Trib 1 subbasin based on the one available line of evidence (surface water chemistry). Nickel, the only analyte presenting a significant risk, was identified as a COEC (Table 3.42). Six organic analytes were considered negligible risk. Use of unfiltered water samples may result in overestimated risk for metals significantly associated with the particulate fraction (they may not be bioavailable).

Table 3.42. Summary of potential risks to aquatic organisms from contaminants in main stem surface water in the Middle WOC East subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
SWSA 5 WOC	Significant	Al, Cu
	Marginal	Li
	Negligible	Ni, Se, benzene, BEHP, carbon tetrachloride, ethylbenzene, naphthalene, toluene, xylene
SWSA 5 Trib 1	Significant	Ni
	Marginal	None
	Negligible	Benzene, carbon tetrachloride, ethylbenzene, naphthalene, toluene, xylene

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the SWSA 5 Trib1 subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Potential risks to white-tailed deer drinking surface water were identified based on comparison of the lower of the maximum or UCL95 water concentration to water concentration LOAELs. Risks were not identified for any other receptors, and thallium was the only analyte that exceeded the LOAEL for deer (HQ = 1.1). It is unlikely that thallium in drinking water poses a risk to deer. The thallium benchmark is conservative, based on a reduction in sperm motility, and was derived using a subchronic to chronic uncertainty factor of 10. In addition, the frequency of detection was low, only one of eight samples in the subbasin.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at stations 05.SP003, 05.SW001, and SW5-1, with HQs from 18.1 to 20.2. Thallium exceeded benchmarks at station SW5-1 (HQ = 21). The aluminum and thallium benchmarks appear to be conservative, as both analytes exceeded benchmarks at numerous seeps across the whole watershed, and the aluminum benchmark is below background. Other analytes marginally exceeding benchmarks at least one station in this subbasin included arsenic, cobalt, and manganese (HQs all <4.9). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. It is unlikely that aluminum is of ecological concern at seeps in this subbasin.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the MV Drive subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from the MV Drive subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution at the MV Drive subbasin (Table 3.11). Aluminum exceeded plant soil solution benchmarks at station 5NNT (HQ = 12). The aluminum benchmark appears to be conservative, as it is below the background concentration. Other analytes marginally exceeding benchmarks (HQs <3.3) at this station were arsenic and thallium. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. Aluminum is unlikely to be of ecological concern.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the SWSA 5 WOC subbasin, based on the one available line of evidence (surface water chemistry). Aluminum and copper were the only analytes presenting a significant risk and were identified as COECs (Table 3.42). However, aluminum is very insoluble in nearly neutral water and the bioavailable fraction is unlikely to be toxic to aquatic biota in the Melton Valley watershed. Lithium presented a marginal risk, and two inorganics and seven organic analytes were considered to present negligible risk. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, as they may not be bioavailable.

Radionuclides in surface water in the SWSA 5 WOC subbasin result in some of the highest dose rates to aquatic organisms of all the subbasins in the watershed. The HI for large aquatic invertebrates was 0.5, and the HI for large fish was 1.1. Cesium-137 contributed 98.6% of the dose rate, and ^{60}Co accounted for 1.3%. While the risks are high, the data for this subbasin were collected from a single location, the OHF Pond, and do not represent a widespread ecological concern.

Risks for piscivorous wildlife exposed to radionuclides were predicted to be likely for the SWSA 5 WOC subbasin, based on exposures modeled from surface water concentrations. Hazard indices ranged from 12.7 for the kingfisher, to 24.2 for the otter. Cesium-137 accounted for >94% of the dose, and ^{90}Sr accounted for 5.7%. As noted above, while the risks are high, the data for this subbasin were collected from a single location, the OHF Pond, and do not represent a widespread ecological concern.

No risks were identified for terrestrial wildlife drinking surface water from the SWSA 5 WOC subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at SWSA 5 WOC station 05.SP004 and SW5-2 (HQ = 6). The aluminum benchmark appears to be conservative, as it is below the background concentration. The only other analyte exceeding benchmarks at any station was arsenic (HQ = 2.3). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. Aluminum is unlikely to be of ecological concern at seeps in this subbasin.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the SWSA 5 N WOC subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water at SWSA 5 N WOC; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at SWSA 5 N WOC station 05.SP002, 5NW-1, and 5NW-2 (HQs from 2.2 to 4.9). The aluminum benchmark appears to be conservative, as it is below the background concentration. Manganese was the only other analyte that exceeded a benchmark (HQ = 1.3) at any station. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. Aluminum is unlikely to be of ecological concern at seeps in this subbasin.

The contaminant surface water concentrations for the Middle WOC East subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic, tetrachloroethylene, and 1,1-DCE were exceeded for the human health criteria at the SWSA 5 WOC and SWSA 5 Trib 1 subbasins. Copper showed an exceedance for the ecological criteria at SWSA 5 WOC.

3.5.1.5 Options for release mechanism intervention

Contaminant source units in the Middle WOC East basin include SWSA 5 North TRU Storage area, the PWSB, the Fissile Waste Storage Area, a portion of SWSA 5 South waste burial trenches and auger holes, and the Old Hydrofracture surface facilities and tanks. Contaminant release mechanisms vary for these sources and consequently they are discussed individually.

The contaminant release mechanism for the SWSA 5 North TRU Trenches is saturation of waste in the trenches by rainfall infiltration during the wet season, followed by seepage through discrete fracture pathways along geologic strike to WOC (DOE 1995b). The contaminant transport mechanism for the normally insoluble actinides observed is apparently complexation by dissolved naturally occurring organic compounds that allow the actinides to migrate. Opportunities to alter or interrupt this release mechanism include hydrologic isolation of the trenches to stop vertical and lateral groundwater infiltration into the waste units, source control of the waste in the trenches, and removal of the waste.

The PWSB is a PVC membrane-lined impoundment containing approximately 20 Ci or less of radiological contaminants contained primarily in ferric sulfate and ferric hydroxide water softening process sludges. There is no evidence of historic or ongoing release of contaminants from the unit (DOE 1995b). During the wet season the groundwater table may rise to intersect the base of the basin. While there is no release from the facility, options to prevent a release include treatment of the waste to immobilize contaminants, basin filling and hydrologic isolation, or sludge removal.

The Fissile Waste Storage area is a hilltop waste burial area including auger holes, two small trenches, and an area fill. Data published by DOE (1995b) indicate that the auger holes and small trenches are well above annual high water levels observed in local wells. Release mechanisms include infiltration of precipitation through waste with transport to the water table, and saturation of the lower part of the area fill. Options for release control or stabilization include hydrologic isolation of all areas to prevent vertical and lateral infiltration. Source treatment of these sources could provide long-term immobility; however, criticality analysis must be performed for any option that would alter the physical configuration of waste.

The WOC area contains waste burial trenches, auger holes, and a soil-covered dump area, which are SWSA 5 South waste disposal units. VOCs and ^{60}Co are detected in groundwater downgradient of the area, and soils along the groundwater seepage pathway are contaminated. Contaminant release mechanisms for the area include infiltration and percolation of contaminants to the water table, and saturation of the base of the dump area may occur during wet seasons. Release control options include hydrologic isolation of the source area to stop vertical and lateral infiltration, source treatment to immobilize contaminants in place, and source removal.

The OHF area includes pipelines and leak sites, contaminated soils at a spill site, surface facilities including the wellhead containment building, Waste Pit T-4 and other buildings, the OHF Pond, and the five OHF waste storage tanks. Of these, the only significant ongoing release is groundwater seepage from the OHF Pond, which releases significant concentrations of ^{90}Sr, ^{137}Cs, ^{60}Co, ^{3}H, and ^{14}C (DOE 1995b). The pond contains about 75 Ci of beta/gamma-emitting radionuclides and about 4 Ci of alpha-emitting radionuclides. The release mechanism for the pond is lateral groundwater seepage from SWSA 5 South into the pond, direct rainfall into the pond, and groundwater seepage out of the pond toward the WOC floodplain. Release control mechanisms include treatment and/or stabilization of the contaminated sediment, combined with hydrologic isolation or removal.

3.5.2 Middle White Oak Creek Floodplain Subbasins

The Middle WOC floodplain subbasins include the Intermediate Pond and the WOC subbasin, which lies between the Intermediate Pond and the WOC weir (Fig. 3.36). The Intermediate Pond contains a contaminated sediment terrace created by historic impoundment of contaminated liquid discharges from ORNL facilities in Bethel Valley. The WOC subbasin contains contaminated sediment, which originated from the Intermediate Pond and from Bethel Valley facilities, and also contains a portion of the abandoned liquid waste transfer pipeline connecting the OHF area facilities to the ORNL main plant area.

3.5.2.1 Contaminated sites

Middle White Oak Creek

The Middle WOC subbasin is the floodplain area between the WOC weir adjacent to the OHF area and the breached earth embankment that forms the downstream end of the Intermediate Pond (Fig. 3.36). Contaminated sediment was spread across the valley floor below flood level by high water levels that scoured contaminated sediment out of the Intermediate Pond after the earth embankment was breached. A utility corridor that includes liquid waste transfer pipelines lies along the eastern edge of this subbasin and may constitute a subsurface contaminant migration pathway. No leak sites have been documented along this segment of pipeline.

Intermediate Pond

The Intermediate Pond is located immediately east of SWSA 4 and encompasses about 8 acres of valley floor between the breached earth embankment and the northeastern tip of SWSA 4 (Fig. 3.36). Before ORNL's use of the Seepage Pits and Trenches, treated liquid radioactive waste was discharged to WOC in Bethel Valley and was retained in the Intermediate Pond to allow settling of particle-bound contaminants (predominantly ^{137}Cs and ^{60}Co). The area is covered by a 1- to 1.5-ft-thick blanket of contaminated sediment that was deposited on the floor of the former pond. This area is also in the discharge pathway for groundwater originating in the SWSA 4 East and the SWSA 4 Tributary subbasins. The surface water discharge from the SWSA 4 Tributary subbasin flows across the southern portion the Intermediate Holding Pond.

3.5.2.2 Pathway model of contaminant releases

WOC. Available information (mass balance of contaminants/radionuclides) indicates that this basin is not a source of ^{90}Sr or ^{3}H and not a significant source of ^{137}Cs.

Intermediate Pond. Available information (mass balance of contaminants/radionuclides) indicates that this basin is not a source of ^{90}Sr or ^{3}H. WAG 2 RI 1994 data (Hicks 1996, Borders et al. 1996) account for >100% and 98% of the ^{90}Sr and ^{3}H, respectively, in the middle WOC reach (combination of basins WOC and Intermediate Pond).

The Intermediate Pond is a potentially significant source of ^{137}Cs to downstream areas including the off-site environment (Clapp et al. 1996). However, very little ^{137}Cs appears to be eroded (and

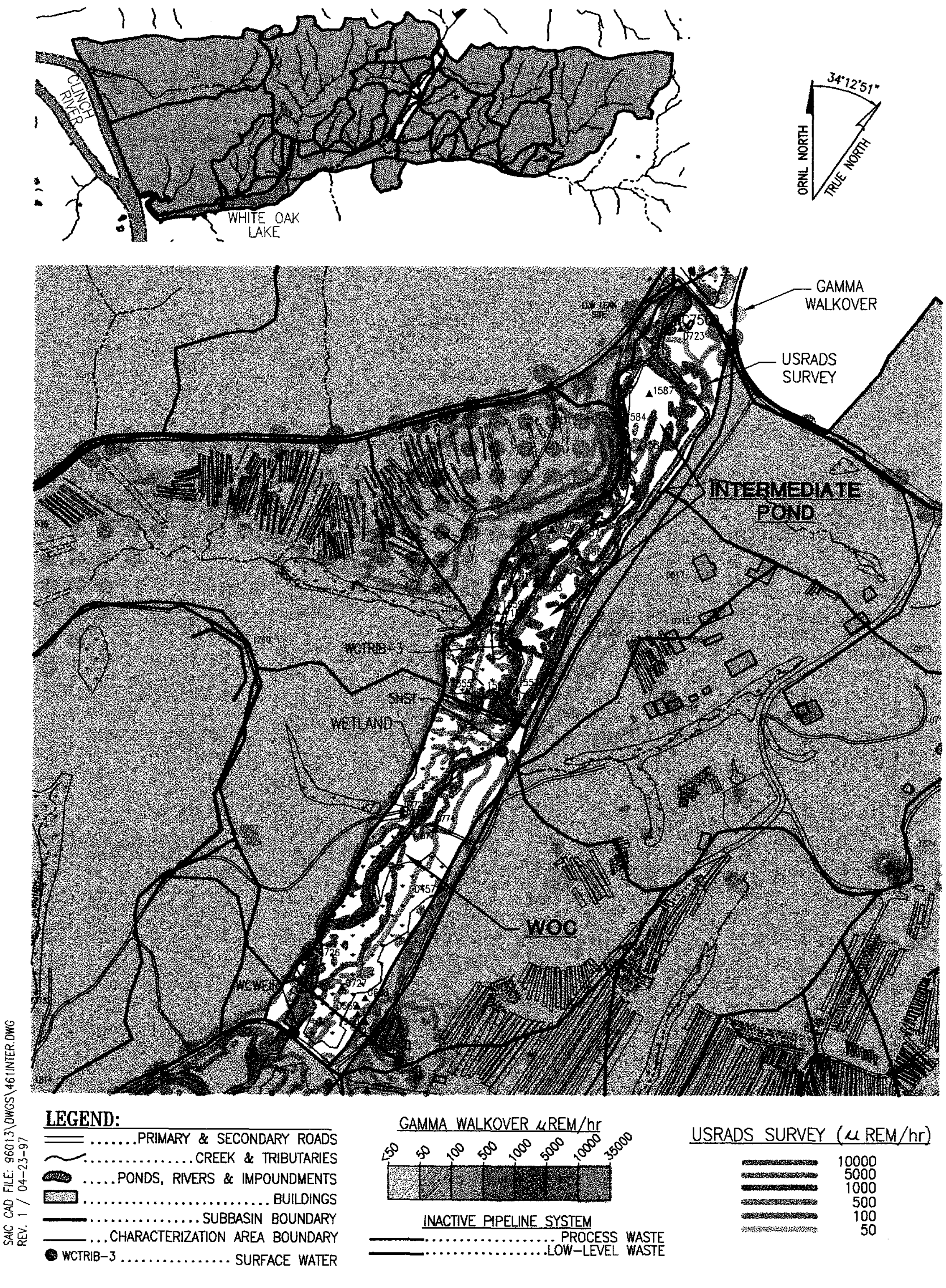

Fig. 3.36. Middle WOC floodplain subbasins.

hence released) from the Intermediate Pond Area on an annual basis, suggesting that the current vegetation and channel geometry result in a relatively stable condition. OECD radionuclide data and ORNL Environmental Restoration Program Surface Water Project surface water discharge data indicate the average ^{137}Cs contribution from the Intermediate Pond is approximately 10.9%.

Groundwater in the Intermediate Pond and WOC subbasins occurs in the alluvium that blankets the valley floor along WOC and in bedrock. Inflows to groundwater in these subbasins originates as direct rainfall infiltration and as water table and bedrock seepage from adjacent subbasins to the east and west of the floodplain. The contaminated surface soil layer that covers the Intermediate Pond subbasin contains ^{137}Cs, ^{60}Co, and small amounts of ^{90}Sr, Hg, PCBs, and other contaminants. The ^{137}Cs and ^{60}Co are strongly adsorbed to the soil particles and are not significant groundwater contaminants in the area. Direct infiltration of precipitation may dissolve ^{90}Sr in areas where the surface soil contains this contaminant. This local source may account for some of the ^{90}Sr detected in a shallow drive point located in the Intermediate Pond subbasin.

Along its western boundary, the Intermediate Pond subbasin receives most of its contaminated groundwater seepage from the SWSA 4 East subbasin and probably receives some from the SWSA 4 Main subbasin. Groundwater inflows from the SWSA 4 subbasins carry ^{90}Sr, ^{3}H, and VOCs into the Intermediate Pond. Along its eastern boundary, the Intermediate Pond subbasin receives inflows from the SWSA 5 N WOC and MV Drive subbasins, which carry groundwater and surface water discharges from SWSA 5 North. Groundwater inflows from the SWSA 5 N WOC subbasin carry actinide radionuclides leached from the TRU waste disposal trenches in SWSA 5 North to at least two seeps in the WOC stream bank. Actinides have not been confirmed in groundwater on the west side of WOC in the Intermediate Pond subbasin. Contaminant sources in the MV Drive subbasin include a liquid waste pipeline leak site and potential seepage from a small portion of SWSA 5 North. Bechtel (DOE 1995b) detected low concentrations of ^{241}Am, ^{244}Cm, $^{233/234}$U, $^{228/230/232}$Th, and $^{226/228}$Ra in well 0524 in the MV Drive subbasin suggesting that small fluxes of contaminants may be released into this area from SWSA 5 North facilities.

The hydrogeology of the WOC subbasin is similar to that of the Intermediate Pond—the major distinction being the much smaller inventory of contaminated surface soil present in the WOC subbasin. Little groundwater contamination has been detected in the WOC subbasin. The western boundary of the WOC subbasin is the WAG 7 WOC subbasin, which does not contain significant primary contaminant sources. Discharges of groundwater and surface water from the SWSA 5 WOC and SWSA 5 Trib 1 subbasins have the potential to carry dissolved radiological contaminants, VOCs, and metals originating in the numerous primary source sites in those subbasins.

3.5.2.3 Secondary contaminated media

Areas of radiologically contaminated surface soils in the Middle WOC floodplain subbasins are shown on Fig. 3.36. The most highly contaminated surface soils at ORNL lie in the Intermediate Pond area. Cesium-137 is the major gamma radiation-emitting radionuclide, although small quantities of ^{90}Sr and TRU isotopes are present. In addition to the radiological contaminants present in these areas, Hg, Ni, Ag, Zn, Mo, and PCB-1260 are present in the sediment and soil. The Intermediate Pond subbasin is estimated to contain 125 Ci of ^{137}Cs and less than 1 Ci of ^{60}Co in approximately 7.8E+05 ft^3 of sediment. The WOC subbasin is estimated to contain 1 Ci of ^{137}Cs and 0.01 Ci of ^{60}Co in approximately 6.1E+05 ft^3 of sediment.

Groundwater beneath the Intermediate Pond is contaminated with ^{90}Sr, ^{3}H, and VOCs including vinyl chloride, which are thought to originate from SWSA 4 East subbasin releases. The Intermediate Pond subbasin is estimated to contain approximately 1.2E+05 gal of contaminated groundwater.

3.5.2.4 Human health risk, ecological risk, and criteria exceedances

The Middle WOC floodplain subbasins include the Intermediate Pond and WOC subbasins, as shown on Fig. 3.36. COCs for each media are presented based on recreational land use. Risk results are presented for the recreational and industrial land uses. Figure 3.37 presents available carcinogenic risk results by sample location for each of the four media.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.43 summarizes data available for the Middle WOC floodplain subbasins by media type and analyte group type for both the Intermediate Pond and the WOC subbasins. Overall, the sample coverage in these subbasins is good, the exception being unavailability of groundwater organic constituent analyses in the WOC subbasin.

Table 3.43. Media data summary for the Middle WOC floodplain subbasins

Subbasin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
Intermediate Pond	Groundwater	3	62	49	237	133	459	8
Intermediate Pond	Sediment	4	13	13	138	115	193	57
Intermediate Pond	Soil	58	385	361	432	417	711	143
Intermediate Pond	SW-seeps	4	108	92	572	339	563	33
Intermediate Pond	SW-streams	4	422	330	561	328	132	12
WOC	Groundwater	4	32	12	77	48	0	0
WOC	Sediment	4	137	137	162	141	172	19
WOC	Soil	23	124	114	178	169	421	58
WOC	SW-seeps	3	49	33	325	157	516	31
WOC	SW-streams	7	602	504	3092	2227	326	82

Middle WOC Floodplain Soil

Table 3.44 summarizes the carcinogenic risks, the noncarcinogenic HI, and the recreational COCs identified for the Intermediate Pond and WOC subbasins soil. The Intermediate Pond and WOC subbasins were analyzed for a comprehensive list of inorganics, organics, and radionuclides from the WAG 2 RI sampling effort.

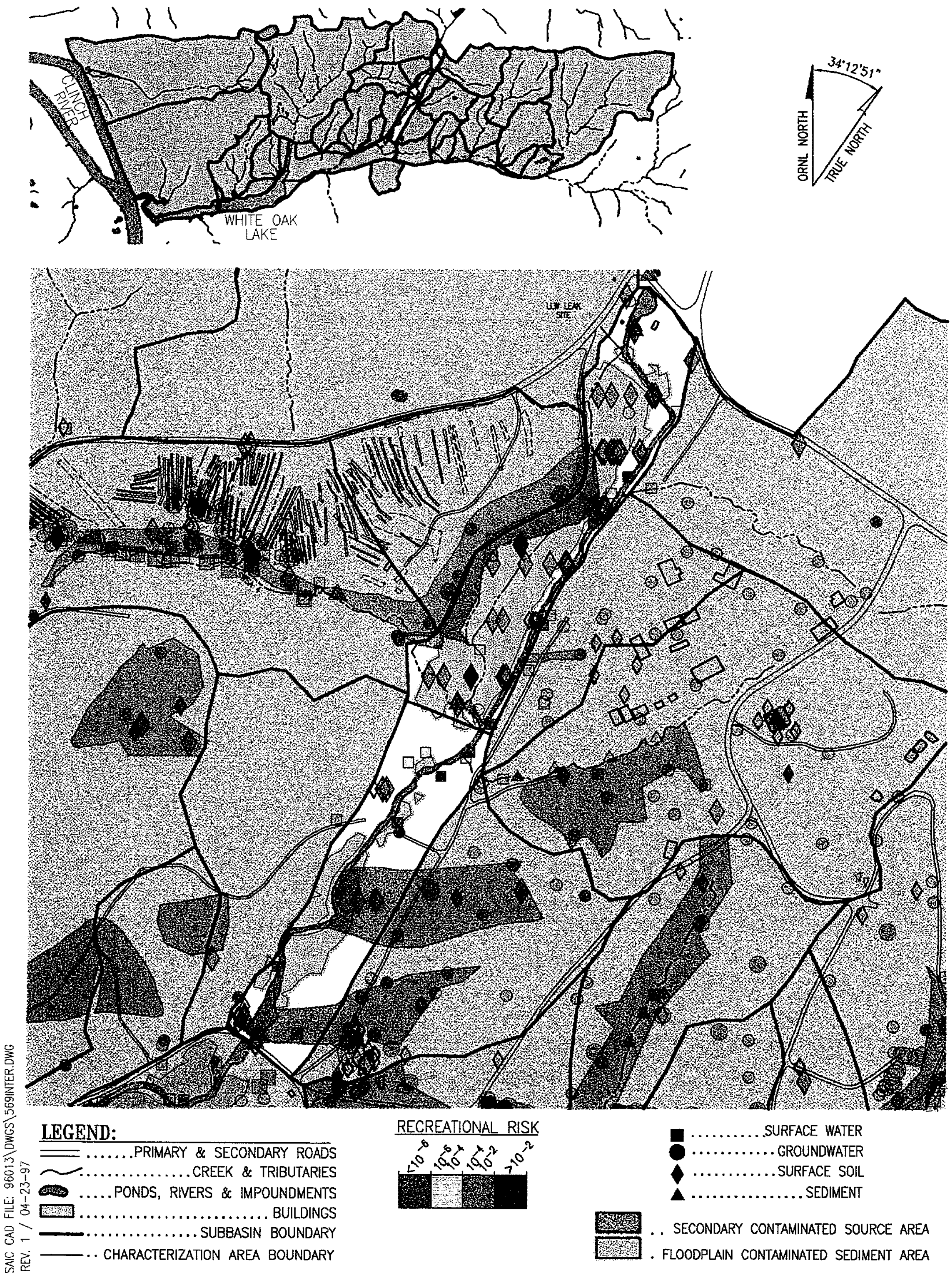

Fig. 3.37. Risk estimates for Middle WOC floodplain subbasins.

Table 3.44. Summary of risk results for Middle WOC floodplain soil

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
Intermediate Pond	6.0E-02	2.9E-01	2.8E-03	1.0E-01	^{137}Cs, ^{60}Co, PCB-1260, ^{228}Th
WOC	5.1E-03	6.5E-02	2.3E-04	2.8E-02	^{137}Cs, ^{60}Co, PCB-1260

Recreational COCs for the Middle WOC floodplain soil are ^{137}Cs, ^{60}Co, ^{228}Th, and PCB-1260. Residential and industrial COCs are presented in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the Intermediate Pond subbasin. Overall dose rates from exposure to the 14 radionuclides detected exceeded recommended dose limits for plants (HI = 3.8), soil invertebrates (HI = 2.4), shrews and mice (HI = 41.6 and 41.3), fox (HI = 1.0), and turkeys (HI = 4.7), but were below the recommended dose limits for all other receptors (Table 3.45). Plutonium-239/240 was the primary risk driver for plants, soil invertebrates, shrews, and mice, contributing 52–81% of the dose rate for these receptors while ^{241}Am contributed 11–26%. Cesium-137 accounted for virtually all of the dose rate to the fox, 15% for turkeys, and 3% for shrews and mice. The primary radionuclide risk driver for wild turkeys was $^{233/234}$U (contributing 53% of the overall dose rate).

Potential risks from nonradionuclides were identified for plants (HI = 286.6), soil invertebrates (HI = 767.3), short-tailed shrews (HI = 291.0), white-footed mice (HI = 41.0), red fox (HI = 216.5), white-tailed deer (HI = 3.0), red-tailed hawk (HI = 40.9), wild turkey (HI = 10.6), and mink (HI = 66.8).

HQs exceeding one were estimated for five inorganics (mercury, nickel, silver, zinc, and molybdenum) for plants, four inorganics (mercury, molybdenum, nickel, and zinc) for shrews, three inorganics (mercury, zinc, and nickel) for soil invertebrates, and one inorganic (mercury) for mice, fox, deer, hawk, turkey, and mink.

The organic PCB-1260 was an additional risk driver for shrews with an HQ of 4.6. The Intermediate Pond was the primary contributor to estimated watershed-wide risks to shrews and foxes from exposure to mercury. It is also an important contributor to estimated watershed-wide risks to shrews from exposure to PCB-1260 and molybdenum.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the WOC subbasin. Overall dose rates from exposure to the 14 radionuclides detected exceeded recommended dose limits for shrews and mice (HI = 4.2), but were below the recommended dose limits for all other receptors (Table 3.45). Plutonium-239/240 was the primary risk driver, contributing 67% of the dose rate for shrews and mice, while ^{244}Cm and ^{241}Am contributed 12% and 10%, respectively.

Potential risks from nonradionuclides were identified for plants (HI = 53.7), soil invertebrates (HI = 55.9), short-tailed shrews (HI = 37.6), white-footed mice (HI = 5.4), red fox (HI = 21.8), red-tailed hawk (HI = 4.9), wild turkey (HI = 1.2), and mink (HI = 6.9).

Table 3.45. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at Middle WOC West floodplain subbasins

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
Intermediate Pond	Plants	286.6	Hg (255.0), Ni (10.3), Ag (8.7), Zn (6.6), Mo (2.6)	3.8	$^{239/240}$Pu (2.6), ^{241}Am (0.6)
Intermediate Pond	Invertebrates	767.3	Hg (764.0), Zn (1.7), Ni (1.6)	2.4	$^{239/240}$Pu (1.2), ^{241}Am (0.8)
Intermediate Pond	Shrew	291.0	Hg (279.0), PCB-1260 (4.6), Mo (1.8), Ni (1.2), Zn (1.0)	41.6	$^{239/240}$Pu (32.4), ^{241}Am (6.1), ^{137}Cs (1.3)
Intermediate Pond	Mouse	41.0	Hg (39.4)	41.3	$^{239/240}$Pu (32.4), ^{241}Am (6.1), ^{137}Cs (1.1)
Intermediate Pond	Fox	216.5	Hg (215.0)	1.0	^{137}Cs (1.0)
Intermediate Pond	Deer	3.0	Hg (2.6)	0.6	
Intermediate Pond	Mink	66.8	Hg (66.4)	0.9	
Intermediate Pond	Hawk	40.9	Hg (40.4)	0.6	
Intermediate Pond	Turkey	10.6	Hg (10.5)	4.7	$^{233/234}$U (2.5), ^{238}U (0.7), ^{137}Cs (1.0)
WOC	Plants	53.7	Zn (18.2), Hg (16.0), Ag (12.6), Mo (2.0), Cu (1.6), Se (1.6)	0.4	
WOC	Invertebrates	55.9	Hg (48.0), Zn (4.5), Cu (3.3)	0.2	
WOC	Shrew	37.6	Hg (25.0), PCB-1260 (4.1), Zn (3.4), Mo (1.5), Cu (1.4), Se (1.5)	4.2	$^{239/240}$Pu (2.8), ^{244}Cm (0.5), ^{241}Am (0.4)
WOC	Mouse	5.4	Hg (3.5)	4.2	$^{239/240}$Pu (2.8), ^{244}Cm (0.5), ^{241}Am (0.4)
WOC	Fox	21.8	Hg (19.3)	0.1	
WOC	Deer	0.7		<0.1	
WOC	Mink	6.9	Hg (6.0)	<0.1	
WOC	Hawk	4.9	Hg (3.6), Zn (1.0)	<0.1	
WOC	Turkey	1.2	Hg (0.9)	0.5	

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

HQs exceeding one were estimated for six inorganics (zinc, mercury, silver, molybdenum, copper, and selenium) for plants, five inorganics (mercury, zinc, molybdenum, copper, and selenium) for shrews, three inorganics (mercury, zinc, and copper) for soil invertebrates, two inorganics (mercury and zinc) for red-tailed hawks, and one inorganic (mercury) for mice, fox, turkey, and mink. This subbasin was second to the Intermediate Pond in contribution to estimated watershed-wide risks to shrews and foxes from exposure to mercury. Mercury accounted for >65% of the HI for wildlife receptors and 86% for soil invertebrates. Zinc (34%), mercury (30%), and silver (23%) accounted for over 87% of the HI for plants. The organic PCB-1260 was an additional risk driver for shrews with an HQ of 4.1 and accounted for 11% of the shrew HI.

Middle WOC Floodplain Sediment

Table 3.46 summarizes the carcinogenic risk, the noncarcinogenic HI, and the recreational COCs identified for the Intermediate Pond and WOC subbasins sediment. The Intermediate Pond and the WOC areas were analyzed for a comprehensive list of inorganics, organics, and radionuclides from the WAG 2 RI sampling effort.

Table 3.46. Summary of risk results for Middle WOC floodplain sediment

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
Intermediate Pond	3.6E-02	6.6E-02	1.6E-03	2.5E-02	^{137}Cs, ^{60}Co, PCB-1260
WOC	1.3E-02	3.6E-02	6.0E-04	1.2E-02	^{137}Cs, benzo(a)pyrene, ^{60}Co, PCB-1260

Therefore, recreational COCs for sediment in Middle WOC floodplain include ^{137}Cs, ^{60}Co, PCB-1260, and benzo(a)pyrene. Benzo(a)pyrene was only detected in one sample.

Significant risks were identified for benthic invertebrates exposed to sediment in the Intermediate Pond subbasin, based on one line of evidence (sediment chemistry). Four inorganics (including mercury) and six organics (including PCB-1254 and PCB-1260) potentially present significant risks and were identified as COECs (Table 3.47). Copper, lead, and ten organics present marginal risks. No other analytes exceeded possible effects levels.

Table 3.47. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment in Middle WOC floodplain subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
WOC	Significant	Cu, Hg, Ag, Zn, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, PCB-1260, phenanthrene, pyrene
	Marginal	Pb, BEHP, dibenzofuran
	Negligible	Alpha-BHC, total PAH
Intermediate Pond	Significant	Hg, Ni, Ag, Zn, acenaphthene, anthracene, dibenz(a,h)anthracene, PCB-1254, PCB-1260, phenanthrene
	Marginal	Cu, Pb, 2-methylnaphthalene, benzo(a)anthracene, benzo(a)pyrene, BEHP, chrysene, fluoranthene, fluorene, naphthalene, pyrene, total PAH
	Negligible	None

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the Intermediate Pond subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Although the weight-of-evidence is not strong, it suggests that sediment in the WOC subbasin does not pose a significant risk to benthic invertebrates. Chironomid taxa richness was slightly lower than in the reference pools, but total taxonomic richness of the sediment community was similar to the reference sites. Hence, all of the 11 COECs (Table 3.47) appear to be credible contributors to toxicity, but the community does not appear to be degraded. Lead and two organics present marginal risks. Alpha-BHC exceeded at least one possible effects level but was considered a negligible risk. No other analytes exceeded possible effects levels.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the WOC subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Middle WOC Floodplain Groundwater

Table 3.48 summarize the carcinogenic recreational risk and the noncarcinogenic HI for the Intermediate Pond and WOC subbasin.

Table 3.48. Summary of risk results for Middle WOC floodplain groundwater

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
Intermediate Pond	6.8E-04	2.1E+00	7.3E-06	2.8E-01	None
WOC	1.5E-06	8.5E-01	1.6E-08	9.5E-02	None

No COCs were identified in groundwater for the recreational scenario at Middle WOC floodplain. Industrial and residential COCs are presented in Appendix B.

The groundwater data from the Intermediate Pond and WOC subbasins were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. In the Intermediate Pond subbasin, exceedances were observed for ^{90}Sr and ^{3}H. At WOC, no exceedances occurred for the contaminants screened.

Middle WOC Floodplain Surface Water

Table 3.49 summarizes the number of surface water samples collected (by analyte type), the carcinogenic risk, the noncarcinogenic HI, and the COCs identified for the Intermediate Pond and WOC subbasin.

No recreational COCs were identified for Middle WOC floodplain surface water. Industrial and residential COCs are presented in Appendix B.

Table 3.49. Summary of risk results for Middle WOC floodplain surface water

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
Intermediate Pond-seeps	7.9E-03	3.7E-01	8.9E-05	3.2E-02	None
Intermediate Pond-streams	6.7E-05	2.3E-01	3.9E-06	7.7E-03	None
WOC-seeps	6.9E-04	2.3E+00	1.1E-05	2.3E-01	None
WOC-streams	1.2E-04	1.1E+00	3.9E-05	1.4E-01	None

The weight-of-evidence suggests that water in the Intermediate Pond subbasin poses a significant risk to fish and benthic macroinvertebrates. The fish community is less species rich relative to the community observed here in the 1950s, and the water has been lethal to Medaka embryos and larvae. The total number of macroinvertebrate species and the number of sensitive species are significantly lower than the upstream and pooled reference communities. Copper, iron, silver, and thallium concentrations appear to present significant risks (Table 3.50). However, aluminum concentrations are probably not toxic in this system. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, as they may not be bioavailable.

Table 3.50. Summary of potential risks to aquatic organisms from contaminants in main stem surface water in the Middle WOC floodplain subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
Intermediate Pond	Significant	Al, Cu, Fe, Ag, Tl
	Marginal	B, carbon disulfide
	Negligible	Be
WOC	Significant	Ammonia, Al, Cu, Fe, Pb, Ni, Tl, PCBs
	Marginal	B, Hg, carbon disulfide
	Negligible	Be, Cd, Mn

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the Intermediate Pond subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

No risks were identified for terrestrial wildlife drinking surface water at the Intermediate Pond; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution at the Intermediate Pond subbasin (Table 3.11). Thallium exceeded plant soil solution benchmarks at station WC TRIB-4 (HQ = 13.6) and aluminum exceeded benchmarks at station WAG4T2A (HQ = 5). The aluminum and thallium benchmarks appear to be conservative, as both analytes exceeded benchmarks at numerous seeps across the whole watershed, and the aluminum benchmark is below background. No other analytes exceeded benchmarks at any stations in this subbasin. Use of unfiltered water samples may result in overestimates of risks for metals such as aluminum that are significantly associated with the particulate fraction, which is largely unavailable to plants. It is unlikely that aluminum is of ecological concern.

The weight-of-evidence suggests that water in this subbasin poses a significant risk to fish and benthic macroinvertebrates. The fish community is less species rich relative to the community observed here in the 1950s, redbreast sunfish have experienced reproductive failures, and the water has been lethal to Medaka embryos and larvae. The total number of macroinvertebrate species and the number of sensitive species are significantly lower than the upstream and pooled reference communities. Of the eight COECs (Table 3.50), copper, iron, and thallium concentrations appear to be the most likely contributors to toxicity. Ammonia concentrations exceeded only the lowest benchmark, suggesting that it may be toxic to sensitive species. Lead and nickel concentrations may be toxic, but these metals were detected in less than 5% of the samples. Total PCBs were detected in only 7% of the samples and are likely to be bound to particulate matter and not bioavailable. Aluminum concentrations are not expected to be toxic in this system. Also, use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, as they may not be bioavailable.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the WOC subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Risk estimates for piscivorous wildlife based on measured fish tissue data are available from one sampling location in the WOC subbasin (WCK 2.9). Adverse effects from mercury were predicted to be likely for river otter (LOAEL-based HQ = 1.6) and belted kingfisher (HQ = 1.6). No adverse effects from exposure to PCBs were predicted for any of the piscivorous receptors. No risks were predicted from exposure to radionuclides in surface water.

Potential risks to white-tailed deer drinking surface water from the WOC subbasin were identified based on comparison of the lower of the maximum or UCL95 water concentration to water concentration LOAELs. Risks were not identified for any other receptors, and thallium was the only analyte that exceeded the LOAEL for deer (HQ = 1.3). It is unlikely that thallium in drinking water poses a risk to deer. The thallium benchmark is conservative, based on a reduction in sperm motility, and was derived using a subchronic to chronic uncertainty factor of 10. In addition, the frequency of detection was low, only three of eight samples in the subbasin, and the concentration only exceeded the LOAEL at one station, SW2-4.

Potential risks were identified for WOC subbasin plants assumed to be exposed to seep water in soil solution (Table 3.11). Thallium exceeded plant soil solution benchmarks at stations 5NST and SW2-4 (HQs 13.6 and 20.9). The thallium benchmark appears to be conservative as thallium exceeded benchmarks at numerous seeps across the whole watershed. Other analytes marginally exceeding benchmarks (HQs <3) at least one station were arsenic and manganese. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

The contaminant surface water concentrations for the Middle WOC floodplain subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic, antimony, thallium, and PCBs were exceeded for the human health criteria at the WOC subbasin. PCBs, selenium, mercury, and chromium in WOC exceeded the ecological AWQC. For the Intermediate Pond, the only surface water exceedance recorded was for thallium against the human health AWQC.

3.5.2.5 Options for release mechanism intervention

Contaminants in the Middle WOC floodplain subbasins can be placed in one of two categories—contaminated soils, sediment, and pipeline; or contaminated groundwater. The contaminants associated with soils and sediment in these subbasins tend to be geochemically stable because of a tendency to adsorb strongly to soil particle surfaces. Contaminants sorbed to soils are predominantly transported by physical migration of the soil, such as by erosion and redeposition through surface water transport. Cesium-137, TRU isotopes, and PCB-1260 are contaminants in these subbasins that exemplify this behavior. Strontium-90 is an exception to this behavior and it has been detected at elevated concentrations in groundwater from a drive point located in the Intermediate Pond subbasin. Whether this ^{90}Sr originated in the Intermediate Pond or migrated in from SWSA 4 is unknown. Strontium-90, ^{3}H, and VOCs are soluble contaminants either present in the Intermediate Pond and WOC subbasins or present at elevated concentrations in adjacent upgradient subbasins.

Options for intervention in release or exposure mechanisms for these subbasins include removal of contaminants for redisposal elsewhere or containment of materials on-site. On-site containment would prevent erosional transport and limit direct exposure and uptake in the ecosystem. Collection and treatment of groundwater seepage to remove soluble contaminants before their movement into the surface water systems may be a requirement in the on-site containment scenario.

3.5.3 Middle White Oak Creek West Subbasins

Four subbasins compose the Middle WOC West subbasins, which are located west of the WOC floodplain (Fig. 3.38). The principal contaminant sources are those associated with the SWSA 4 Main and SWSA 4 East subbasins. Only the SWSA 4 Main and SWSA 4 East subbasins are included in the following sections because little to no contamination is present in the Haw Ridge and WAG 7 WOC subbasins.

The SWSA 4 Main subbasin drains surface water from an area of about 25 acres including the western two-thirds of SWSA 4 and the wooded hill slope south of the stream (Fig. 3.38). This subbasin was modified in 1983 by re-routing two tributaries that carry wet weather surface water runoff from Haw Ridge (Melroy et al. 1986). The purpose of re-routing the two streams was to reduce the water flow into the SWSA 4 burial grounds area; the project successfully reduced ^{90}Sr releases from that burial ground by approximately 45%.

In addition to the buried waste in SWSA 4, this subbasin contains sections of two abandoned liquid waste transfer lines that were formerly used to transport waste from the main plant area to the seepage pits and trenches in WAG 7.

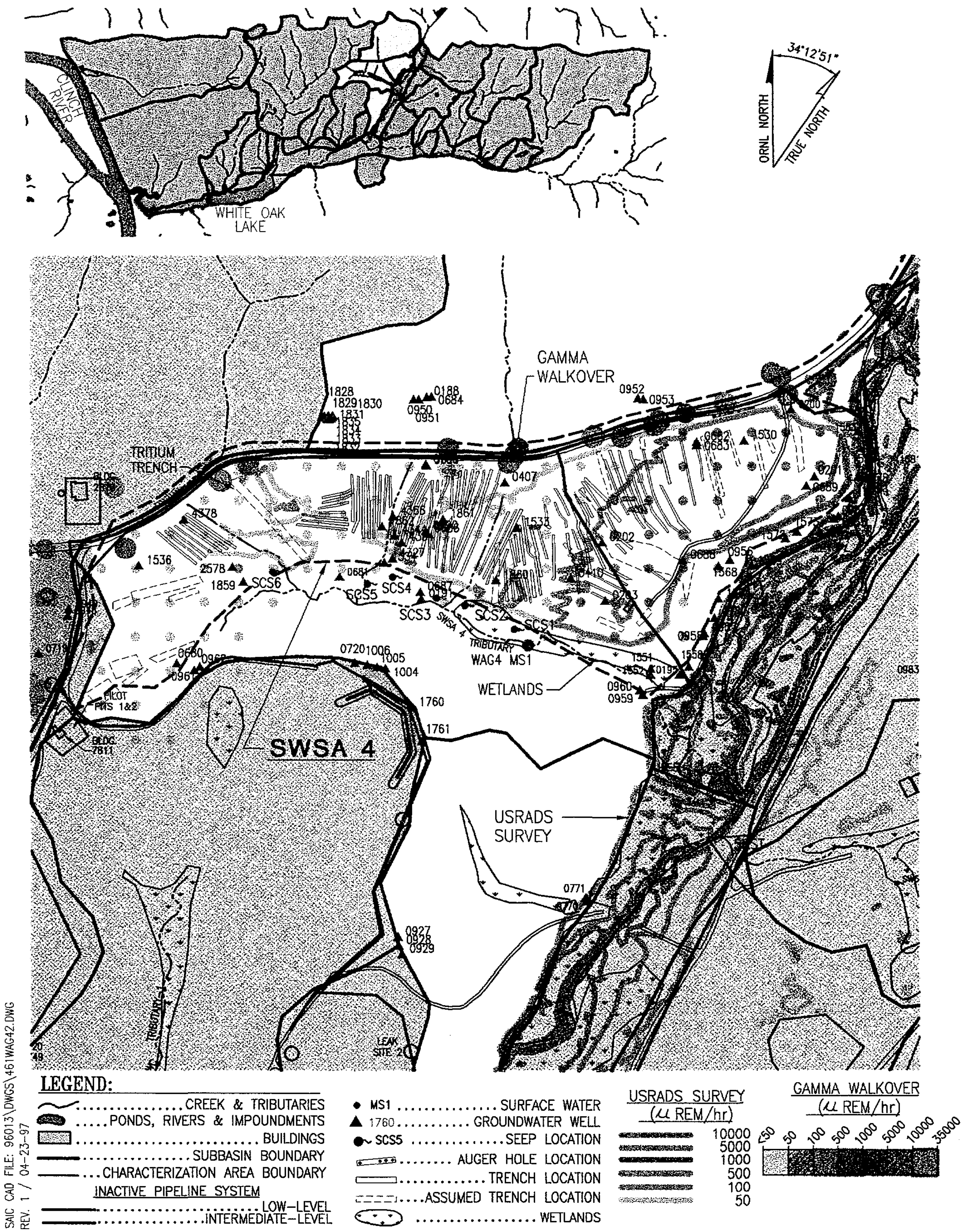

Fig. 3.38. Middle WOC subbasin west of WOC.

3.5.3.1 Contaminated sites

Because historic disposal records for SWSA 4 were destroyed, the following description of contaminant sources is applicable to both the SWSA 4 Main and the SWSA 4 East subbasins. The LLLW transfer pipelines at ORNL were an essential part of the liquid-radioactive-waste disposal system. The first transfer pipeline is located on the south side of Lagoon Road and was put into service in June 1954. In July 1961, when the second transfer pipeline was installed in this same location, the first transfer pipeline was capped at its ends. In November 1975, when use of the second transfer pipeline was discontinued, the pipeline was flushed with water, purged with air to remove as much of the remaining liquid as possible, and capped at its ends. No leaks have been reported for these pipelines in the vicinity of the SWSA 4 subbasins, although leaks have been reported along other sections (Energy Systems 1994b).

SWSA 4 was used for the disposal of various liquid and solid, radioactively contaminated wastes generated by defense- and research-related activities. SWSA 4 was opened in February 1951 for routine burial of radioactively contaminated wastes. In 1955, the U.S. Atomic Energy Commission designated ORNL as the Southeast Regional Burial Ground. The site was closed to those radioactive wastes in July 1959. As the Southeast Regional Burial Ground, it received a variety of poorly characterized wastes. Approximately 50% of the wastes buried from 1951 to 1959 originated from ORNL, and the remaining 50% originated from more than 50 off-site locations, including the Y-12 Plant, Argonne National Laboratory, Knolls Atomic Power Laboratory, Mound Laboratory, and the General Electric Company (Energy Systems 1994b).

Waste disposal records were destroyed in a 1957 fire. However, wastes reported to have been disposed include a variety of materials (Appendix A). Some waste materials were buried in metal, wood, plastic, fiber, or concrete containers, whereas others were simply dumped (Energy Systems 1988a). Radioactive wastes designated as TRU wastes also were stored at SWSA 4. These wastes required special handling and storage because of their long half-lives (2200 years), high linear energy transfer, and potential for criticality. Burial grounds active before 1970 were likely to receive TRU wastes in unlined earthen trenches and auger holes without regard to retrievability; after 1970, TRU wastes were required to be retrievably stored at designated locations (Energy Systems 1988a).

Approximately 50 auger holes are located just outside the SWSA 4 fence on the south side of Lagoon Road. The auger holes are 1 to 2 ft in diameter and approximately 15 ft deep. They were used for disposal of small packages of higher-level radioactive waste and for retrievable storage of TRU wastes. They are capped in concrete, and each contains a brass plaque at the concrete surface, stamped with the dimensions of the hole and the word "radioactive." In addition , some special high-level waste has been buried in individual, stainless steel containers. The tops of some of these containers are visible at land surface. They occur in a two-row array, embedded in concrete. The depth of the concrete and the dimensions of the stainless steel containers are unknown. Elevated levels of gamma radioactivity have been detected at the surface of these containers using field monitoring equipment (Energy Systems 1988a).

Trench sizes range from approximately 50 to 400 ft in length, 8 to 30 ft in width, and 8 to 15 ft in depth. The trench alignment direction varies throughout the burial ground. The typical method of disposal was to excavate a trench, dump waste into it, and then cover the trench with the excavated soil. Filled trenches known to contain alpha-contaminated waste were capped with approximately 18 in. of poured concrete (Energy Systems 1988a). The trenches reported to be capped with concrete are located in the southwest and east-southeast sections of SWSA 4, and compose approximately one-fourth to one-third of the total area of the disposal site. However, a survey found only two small trenches covered with concrete (Spalding et al. 1987). It was concluded that the use of concrete caps in SWSA 4 was neither as extensive nor as routine as published records indicate. The survey also found that the caps were not smooth or level, indicating that the concrete was dumped rather than formed or worked (Energy Systems 1988a).

3.5.3.2 Pathway model of contaminant releases

Doyle and Taylor (1986) conducted studies during the first half of 1986, in which seven of the older groundwater wells and three groundwater seeps were sampled. Analyses were performed for radionuclides, metals, and 118 organic compounds. None of the organics were detected. Strontium-90 was the predominant radionuclide present. Concentrations of ^{3}H, ^{60}Co, and ^{125}Sb were at or below their detection limits, and ^{137}Cs was measured above its detection limit in only one seep sample. Aluminum, beryllium, cadmium, iron, lead, manganese, and nickel were detected at concentrations above the MCLs in the seeps (Energy Systems 1995).

Results of radiological walkover surveys were used to map surficial "hot spots" to indicate locations of discharge points from leaking trenches (Energy Systems 1995). Results of the surveys indicate that in most of the seep areas there exists a region of higher activity in which contaminated seepage emerges from a source, and an apparent dispersion zone that indicates the flow pathway from the seep toward the stream. Surface soil analytical results confirmed that ^{90}Sr was present at all of the radiation "hot spots" identified during the walkover survey. The data suggested that Seep Areas 4 (SCS4) and 6 (SCS6) had the strongest sources feeding them, followed by Seep Areas 5 (SCS5) and 3 (SCS3). Seep Areas 2 (SCS2) and 1 (SCS1) were of much less apparent significance.

The SWSA 4 subbasins are a major source of contaminants, especially ^{90}Sr to WOC. There are six identified seeps (above) located on the southern end of SWSA 4 associated with bathtubbing trenches. These seeps discharge into an intermittent stream, which is a tributary of WOC. It has been estimated that these trenches contributed 25% of the ^{90}Sr release observed at WOD for the period 1987–1994 (Energy Systems 1995).

WAG 4 Site Investigation Project (Energy Systems 1995) results indicate no clear relationship between the concentrations of ^{90}Sr and stable strontium in trench water samples collected from trench drive points . This indicates that the ^{90}Sr from the wastes is not homogeneous or has not yet mixed well with the stable strontium. This is significant because it shows that the ^{90}Sr is still being actively leached from sources in the waste trenches, rather than moving from zones of secondary contamination. The ^{90}Sr also did not correlate with any of the chemical parameters measured, whereas the stable strontium did correlate with hardness, alkalinity, and conductivity. Concentrations of ^{90}Sr in trench drive point water samples are represented on Fig. 3.39. As seen from this figure, the highest ^{90}Sr concentrations in these samples were found in samples collected from trenches upgradient of the SCS4 and SCS6 areas.

Two distinct sources of water exist for the trenches: transient near-surface flows associated primarily with storm events, and the stable saturated-zone groundwater-flow pathway, of which an important component originates from the full catchment area, including the area upslope from Lagoon Road. Evidence for these two water sources is the response to precipitation of water levels in continuously monitored wells and trench drive points. One characteristic response is that some wells and drive points respond nearly immediately to infiltration of precipitation, with water levels peaking very soon after rainfall events. This type of water level response is frequently observed in

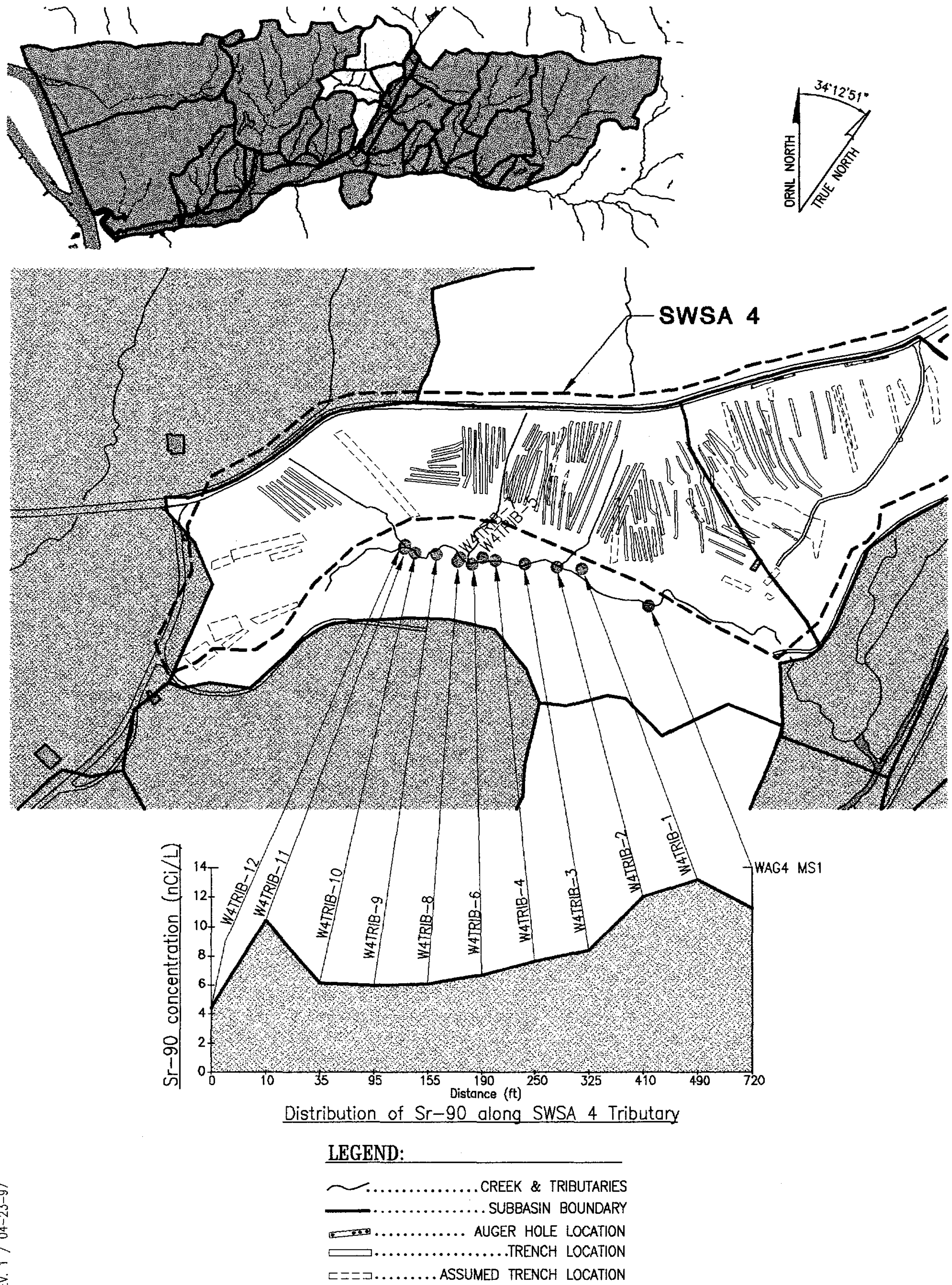

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Fig. 3.39. Surface sampling transect results in SWSA 4 tributary.

wells in the Oak Ridge area and is indicative of local recharge to the water table in native shales. The other water-level response observed at SWSA 4 was seen in some trench drive points where responses to rainfall during increases, it appears that the contributions from overflowing (i.e., "bathtubbing") trenches, as measured at the seep areas, also increase. For the month of March 1995, roughly half the mass flow appears to have followed this mechanism. The other major pathway appears to be along a subsurface route, and dominates transport in drier periods. For the full study period in 1995, nearly 65% of the total mass flow appears to have followed this route.

At present, it is not possible to differentiate the portions of the subsurface flow that originate from direct infiltration of rainfall at the site and the portion that comes from deeper groundwater that originates in the catchment to the north of the site. Hydrograph analysis suggests that about 70% of the ^{90}Sr mass flow during the year is associated with storms, where local infiltration would be the dominant factor. Thus, a rough estimate of relative importance of pathways would be about 35% via overflowing water from "bathtubbing" trenches that emerges at seeps, about 35% via shallow subsurface flow, and up to 30% from deep groundwater that discharges to the trenches and interacts with trench contents.

Contributions to surface water ^{90}Sr and ^{3}H contamination in the middle WOC reach (between WC7500 and the WOC monitoring station, WCWEIR) are generally attributed almost entirely to the SWSA 4 area (Fig. 3.33). Data collected by the WAG 2 RI have generally supported this assumption. Borders et al. (1996) indicate that approximately 86% and 94%, respectively, of the ^{90}Sr and ^{3}H released from SWSA 4 pass the surface water monitoring station at W4MS1 on the tributary to WOC (Fig. 3.38).

Figure 3.39 shows ^{90}Sr concentration as a function of distance along the SWSA 4 tributary. The stream transect data are referenced to sampling points along the tributary to allow easy association between SCS locations and changes in concentration along the tributary. The data shown here were derived from 1992 wet-season base-flow sampling, conducted as part of the WAG 2 ER Program (DOE 1995a). The data represented on Fig. 3.39 show that two major input regions exist along the tributary. The first one is in the headwaters area near SCS6. The highest concentration appears to be associated with the branch of the tributary that receives flow from the SCS6 surface flow discharge. It is also apparent that some contaminated seepage enters the westernmost portion of the headwaters. This seepage is probably a combination of surface overflow and subsurface seepage from the SCS6 area. The second reach of major input appears to be that along which discharges from SCS5, SCS4, and SCS3 are located. The figure suggests that SCS4 is a more important contributor than SCS5 or SCS3, based on relative rises in concentration in the adjacent stream. SCS2 and SCS1 do not appear to contribute significantly to contaminant transport away from SWSA 4. The results of the 1992 surface water sampling are generally consistent with the results of the 1995 seep investigation (Energy Systems 1995).

The WAG 4 Site Investigation Project (Energy Systems 1995) was conducted during the middle to latter portion of the 1995 wet season. Monitoring and sampling at the six seeps and at W4MS1 were conducted approximately from February 1 through April 30. The majority of total annual discharge recorded at W4MS1 occurs in a few months, during the wet season. Therefore, the majority of contaminants (e.g., ^{90}Sr) are transported from SWSA 4 sources to the receiving tributary and ultimately off-site in WOC during the few wettest months of the year. For each sampling event, concentration decreased with increases in discharge, but contaminant mass flow continued to increase with discharge. However, a given discharge corresponds to a higher concentration in the wet season than in the dry season. This is consistent with WAG 2 RI storm sampling results in 1993 and 1994 (Borders et al. 1996). Estimated ^{90}Sr mass flow (0.110 Ci) for the wet season period from February through April 1995 indicated a reduction of 71% from the estimated release (0.384 Ci) for the same period in 1994 (Energy Systems 1995). Flow-weighted average concentrations of ^{90}Sr for these two periods (6050 pCi/L in 1994 and 7860 pCi/L in 1995) indicate that the difference is attributable primarily to higher flows in 1994. The 1995 wet season was a significantly drier wet season than the 1994 wet season (9.51 in. of precipitation from February through April 1995 compared with 29.02 in. during the same period in 1994). Presumably, because substantially less precipitation infiltrated the surface soil layer during the 1995 wet season, and because the water table was depressed in comparison with wetter years, the surface pathway represented by active seeps discharge was diminished and total mass transport of ^{90}Sr was reduced.

Surface Water Project monitoring and sampling data from FY 1995 (Energy Systems 1995) and FY 1996 collected at the SWSA 4 tributary and seep monitoring stations indicate that approximately 91.5% of the ^{90}Sr that passes W4MS1 is released at or upstream from Seep area 4. Of this total, approximately 40.4% (17.5% storm flow and 23.0% base flow) is released from Seep Area 6 (SCS6) (the bathtubbing trench area), 43.4% (22.1% storm flow and 22.3% base flow) from Seep Area 4 (SCS4), and 7.6% from Seep Area 5 (SCS5). Seep area 6 dominates in dry weather and tends to be a greater source than Seep Area 4. The remainder (approximately 8.5%) is attributed to Seep Areas 1, 2, and 3 (SCS1, SCS2, and SCS3, respectively). For 1994, these totals (as a percentage of WOD ^{90}Sr) equate to: W4MS1–18.1%, SCS6–7.3%, SCS5–1.4%, and SCS4–7.9%.

The ^{3}H contamination released from the SWSA 4 area is almost entirely attributed to a single large trench between the bathtubbing trenches (Seep Area 6) and the Seep Area 5 Trenches. Tributary transect sampling (Hicks 1996) supports this supposition. For 1994, the total ^{3}H released at W4MS1 as a percentage of that released at WOD was 13.9.

In addition to the above, the bathtubbing trench area (Seep Area 6) is a source of ^{137}Cs and alpha contamination to WOC. However, most of the ^{137}Cs measured just downstream from the bathtubbing trench area settles out or adsorbs to stream sediments before it reaches WOC.

Limited WAG 2 RI data (Hicks 1996) indicate that the small tributary (WC TRIB-3) draining the SWSA 4 East subbasin (Fig. 3.36) contributes approximately 5% of the ^{90}Sr and 0.6% of the ^{3}H being released over WOD. WC TRIB-3 is also a small source of alpha to WOC.

Expected Reduction in ^{90}Sr Releases at WAG 4 from Interim Source Control Action

In October 1996, low-pressure permeation grouting was conducted in parts of four radioactive waste trenches in SWSA 4. These trenches, located in Seep Areas 4 (SCS4) and 6 (SCS6), were identified during a 1995 site investigation (Energy Systems 1995), but results indicated that the trenches that were actually grouted contributed approximately 90% of the ^{90}Sr release observed at the W4MS1 monitoring location. The report also noted that approximately 80% of all ^{90}Sr released from the entire SWSA 4 site was observed at the W4MS1 monitoring site.

The objective of the permeation grouting was to control the interaction between subsurface flow and wastes in the target trenches. If one assumes complete effectiveness of the source control action, it is possible to estimate the resulting time history of releases using a conceptual model for release processes and a numerical model (CRAFLUSH) (Sudicky and Frind 1982) with parameters derived from tracer studies in comparable geologic settings on the ORR (e.g., Sanford et al. 1996).

The conceptual model for ^{90}Sr release assumes that the waste trenches collect both shallow subsurface storm flow and deeper groundwater discharge along their length, that the water comes into contact with wastes that release ^{90}Sr into solution at a fixed concentration, and that the contaminated water then moves to the downslope end of the waste trench where it either moves into the fractured near-surface weathered shale or, during peak periods of runoff, partially surfaces at seeps and flows over the land surface. Both pathways discharge to the small tributary that drains the site. Evidence exists to confirm both pathways. The trench overflow, called "bathtubbing," is marked by surface contamination that originates at the point where seeps emerge and extends along flow pathways to the tributary. The subsurface pathway is indicated by the field measurements that showed that less than half of all ^{90}Sr observed in the tributary could be captured by seep collection systems that were established during the site investigation, which was conducted during the wet season.

To quantify expected future response to the interim source control grouting action, it was assumed that the pathways from the source trenches could be represented by a single large fracture in the weathered saprolite between the end of the trench and the tributary. The fracture aperture was set to 0.5 mm, which is larger than physical reality, but is hydraulically equivalent to several small fractures, which is the typical preferred flow pathway for transport that has been observed in controlled tracer tests at similar sites. The approach that was taken was to "turn on" ^{90}Sr sources at about the mid-point of burial ground operations (ca. 1955). Concentrations in trench water were set to approximate those actually observed at the site. The model was run for 40 years, using a specific discharge (i.e., volume of water per unit cross section) of 1.8 m/year. The simulation was continued for the next 60 years, but the source was turned off for that interval to represent the actual source control action taken. The concentration at the end of a 10-m flow pathway was taken as the indicator for expected future release. Because ^{90}Sr is sorbed by the material, a retardation factor of 30 was used to represent this interaction, based on typical distribution coefficient values and physical characteristics of the weathered shales. The half-life for radioactive decay that was used for ^{90}Sr was 28.6 years, and the physical diffusion process from the fracture into the rock matrix was considered. Figure 3.40 shows the model results for simulated concentration over the 100-year period. There is a ten-fold decrease in simulated concentration during the first 10 years, and after 50 years from source control, the concentration is roughly 100 times smaller. If one assumes that the rates and amounts of water moving through the site do not change, then similar fractional reductions in total ^{90}Sr released from the area would be expected. For purposes of comparison, scaled values of concentrations of representative cations (Ca, Sr, Mg, N, Na) observed in Bear Creek following the source control action at the S-3 Ponds (Moore and Toran 1992) are also shown on the graph. The observed "decay constant" for the decline was 0.16/year. The visual comparison strengthens the modeling results by showing that in a similar geologic setting, roughly comparable declines were observed for the first 10 years following source removal and control. Note, however, that the model overpredicts the decline when compared with the observations on the S-3 Ponds.

Currently, the average annual ^{90}Sr release at W4MS1 is about 470 mCi. Recognizing that about 90% of that release (423 mCi/year) has been estimated to come from the interim action target trenches, and using the fractional reduction in simulated concentration as equal to the reduction in the release from the grouted trenches, one can estimate that about 270, 340, and 380 mCi/year reductions in release from SWSA 4 will occur at 2.5, 5, and 10 years, respectively. These are only estimates, and should be confirmed by actual measurement, but they are in the same general range as the annual removals at Seeps C and D for 1995.

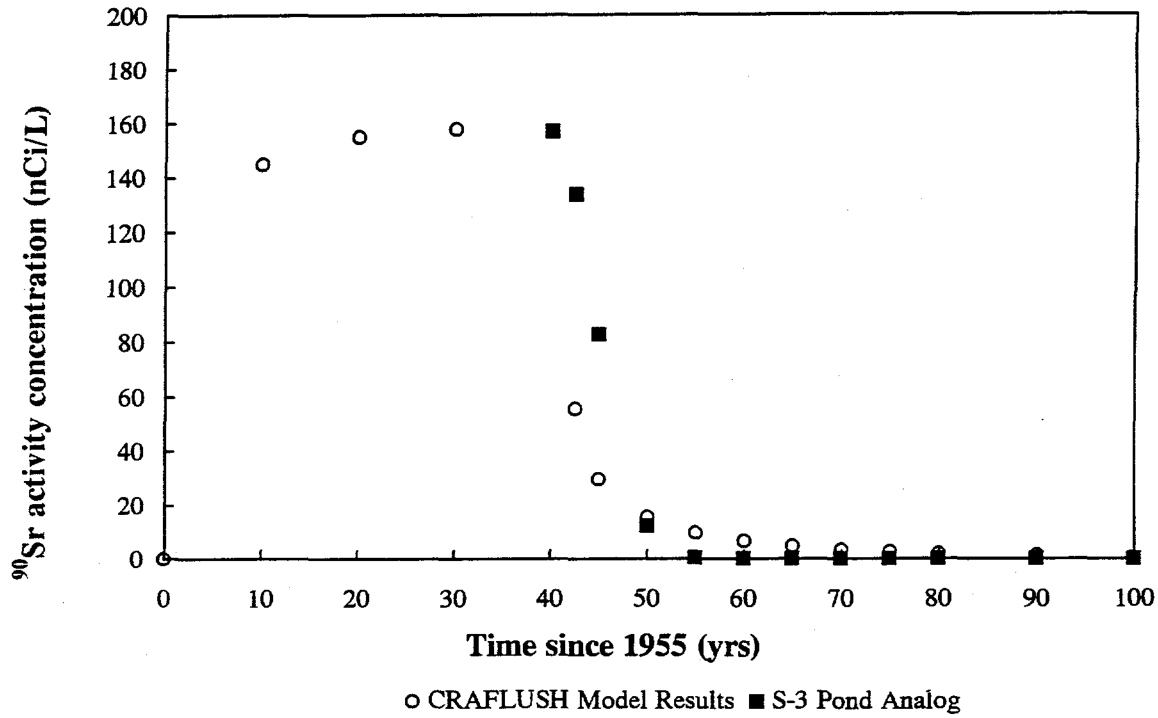

Fig. 3.40. Predicted release reduction for SWSA 4 seeps.

3.5.3.3 Secondary contaminated media

Areas of radiologically contaminated surface soils in the SWSA 4 subbasins are difficult to assess using the USRADS data because of gamma activity shine from the Intermediate Pond area and because USRADS survey has been performed in the SWSA 4 Trib channel area. There is radiological contamination in the vicinity of five seeps that discharge into the SWSA 4 tributary (Fig. 3.39). Two areas near SCS6 shown by the USRADS contour (Fig. 3.38) have been covered with gravel pads constructed for site activities associated with trench grouting to control ^{90}Sr releases.

SWSA 4 Main Subbasin

Secondary contaminated media in the SWSA 4 Main subbasin include contaminated soils and groundwater in the seepage pathways between the trenches in SWSA 4 and the SWSA 4 Tributary. The approximate area of contaminated seepage pathway soils is 2.3 acres (0.9 ha); average soil thickness is about 7 ft (2.1 m); and approximate soil volume is 700,000 ft^3 (20,000 m^3). Assuming a 2-ft (0.61-m) average saturated thickness and 40% average porosity, the volume of contaminated groundwater in seepage pathway soils is about 600,000 gal (2,000 m^3).

SWSA 4 East Subbasin

Secondary contaminated media in the SWSA 4 East subbasin include contaminated soils and groundwater in the seepage pathways between the trenches in SWSA 4 East and the WC TRIB-3 Tributary to WOC. The approximate area of contaminated seepage pathway soils is 1.5 acres (0.6 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 650,000 ft^3 (19,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 52,000 ft^3 (1,500 m^3).

3.5.3.4 Human health risk, ecological risk, and criteria exceedances

The Middle WOC West subbasin includes the following subbasins west of the WOC floodplain that are analyzed in the human health risk assessment: SWSA 4 Main, SWSA 4 East, WAG 7 WOC, and Haw Ridge. COCs for each media are presented based on recreational land use. Risk results are presented for the recreational and industrial land uses. Figure 3.41 presents available carcinogenic risk results by sample location for each of the four media.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.51 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The subbasins within the Middle WOC West area have been

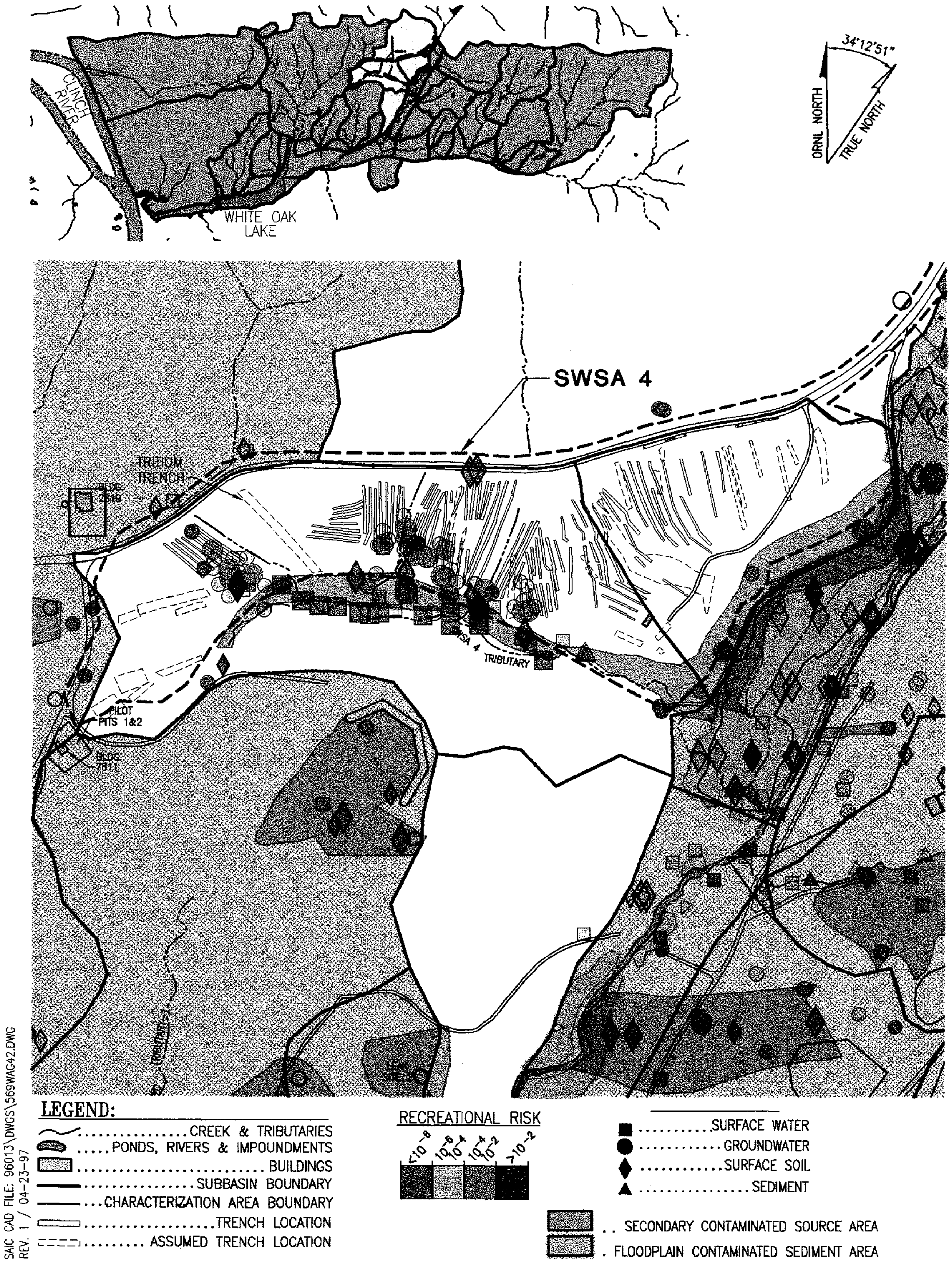

Fig. 3.41. Risk estimates at sampling locations in Middle WOC subbasins west of WOC.

reasonably well sampled as part of investigations at WAG 4. In particular, the seeps and groundwater have been sampled extensively. Therefore, the associated uncertainty in the risk results and the identified COCs is considered to be low to moderate, relative to the other subbasins.

Table 3.51. Media data summary for the Middle WOC West subbasins

Subbasin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
SWSA 4 Main	Groundwater	62	758	704	2242	1777	2486	45
SWSA 4 Main	Sediment	2	17	17	96	77	0	0
SWSA 4 Main	Soil	14	233	232	63	52	42	10
SWSA 4 Main	SW-seeps	26	782	746	2149	1337	983	118
SWSA 4 Main	SW-streams	1	550	363	1253	940	405	13
SWSA 4 East	Groundwater	6	291	243	1142	690	2759	155
WAG 7 WOC	Groundwater	1	22	18	108	52	252	2
WAG 7 WOC	Soil	1	29	18	21	17	7	6
WAG 7 WOC	SW-seeps	1	9	5	71	32	171	15
Haw Ridge	Groundwater	4	238	187	938	476	2334	51

Middle WOC/West Soil

Table 3.52 summarizes the carcinogenic risk, the noncarcinogenic HI, and the recreational COCs identified for one of the four subbasins that compose the Middle WOC West subbasins and that have soil data. SWSA 4 Main had 14 samples and WAG 7 WOC had 1 soil sample analyzed for a comprehensive list of contaminants. Haw Ridge and SWSA 4 East did not have any available soil analyses.

Table 3.52. Summary of risk results for Middle WOC West soil

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
SWSA 4 Main	5.7E-01	–	3.7E-02	–	Be, ^{137}Cs, ^{90}Sr
WAG 7 WOC	5.2E-02	–	2.4E-03	–	^{137}Cs

The only soil COCs for the entire Middle WOC/West basin are ^{137}Cs, beryllium, and ^{90}Sr. No noncarcinogenic COCs were identified. Residential and industrial COCs are presented in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 4 Main subbasin. Potential risks from exposure to the four radionuclides detected in soil were identified for all receptors except plants, with HIs ranging from 4.7 for soil invertebrates to 18.8 for shrews (Table 3.53). Cesium-137 was the primary risk driver, contributing >82% of the HI for all receptors. Strontium-90 was an additional risk driver for deer and turkey, accounting for 17% and 9% of the overall dose rate, respectively.

Table 3.53. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at Middle WOC West subbasins

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
Haw Ridge	All	NA		<0.4	
WAG 7 WOC	Shrew	<0.1		1.5	^{137}Cs (1.2)
WAG 7 WOC	Mouse	<0.1		1.3	^{137}Cs (1.0)
WAG 7 WOC	Turkey	<0.1		1.1	^{137}Cs (0.8)
SWSA 4 Main	Plants	267.6	Ni (262), Zn (2.4), Se(2.0)	0.8	
SWSA 4 Main	Invertebrates	39.9	Ni (39.3)	4.7	^{137}Cs (3.9)
SWSA 4 Main	Shrew	165.0	Ni (159), Se (2.5), Ba (1.8)	18.8	^{137}Cs (18.6)
SWSA 4 Main	Mouse	23.6	Ni (22.7)	15.6	^{137}Cs (15.4)
SWSA 4 Main	Fox	15.0	Ni (13.8)	14.0	^{137}Cs (13.6)
SWSA 4 Main	Deer	2.5	Ni (1.8)	7.6	^{137}Cs (6.3), ^{90}Sr (1.3)
SWSA 4 Main	Mink	2.2	Ni (1.8)	11.7	^{137}Cs (11.6)
SWSA 4 Main	Hawk	2.0	Ni (1.6)	7.7	^{137}Cs (7.6)
SWSA 4 Main	Turkey	2.0	Ni (1.8)	15.9	^{137}Cs (14.4), ^{90}Sr (1.4)

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

Potential risks from exposure to nonradionuclides in SWSA 4 Main soil were identified for all receptors with HIs ranging from 2.0 for hawks to 267.6 for plants (Table 3.53). Nickel was the primary risk driver in all cases, resulting in population level effects within the subbasin on shrews and mice and watershed-wide effects on shrews. However, the results are driven by the high nickel concentration (7860 mg/kg) at one sample location (WAG 4 Seep6). The highest concentration at two other locations in the subbasin was 49.6 mg/kg, suggesting that risks from nickel are spatially limited within the subbasin. This subbasin was a significant contributor to the watershed-wide risk to shrews from selenium.

Risks to terrestrial biota exposed to radionuclides and nonradionuclides in WAG 7 WOC soil were evaluated. Potential risks to shrews, mice, and turkeys from exposure to radionuclides were identified (Table 3.53), but dose rates were below dose limits for all other receptors. Cesium-137 was the primary risk driver in all cases. No risks were identified for terrestrial biota exposed to nonradionuclides; estimated exposures were below benchmarks for all receptors (Table 3.53).

Risks to terrestrial biota were evaluated for radionuclides in soil in the Haw Ridge subbasin. Nonradionuclide data were unavailable. Only three radionuclides were detected in the one sample from this subbasin, and no risks are anticipated for terrestrial biota (Table 3.53). Overall dose rates were below recommended dose limits for all receptors.

Middle WOC/West Sediment

Table 3.54 summarizes the carcinogenic risk, the noncarcinogenic HI, and the recreational COCs identified for one of the four subbasins that compose the Middle WOC subbasins west of the WOC floodplain and that have sediment data. SWSA 4 Main was analyzed for a select group of inorganics and two radionuclides (^{137}Cs and ^{60}Co). WAG 7 WOC, Haw Ridge, and SWSA 4 East did not have any available sediment analyses.

Table 3.54. Summary of risk results for Middle WOC West sediment

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
SWSA 4 Main	3.6E-03	4.0E-01	1.6E-04	1.1E-01	^{137}Cs

Cesium-137 was identified as a recreational COC for the Middle WOC West basin. Residential and industrial COCs are presented in Appendix B.

Significant risks were identified for benthic invertebrates exposed to nonradionuclides in sediment in the SWSA 4 Main subbasin, based on one line of evidence (sediment chemistry). Manganese and nickel were the only analytes potentially presenting significant risks and were identified as COECs (Table 3.55). No other analytes exceeded possible effects levels.

Table 3.55. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment in Middle WOC West subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
SWSA 4 Main	Significant	Mn, Ni
	Marginal	None
	Negligible	None

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels are listed as contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the SWSA 4 Main subbasin. Dose rates estimated for large invertebrates and large fish were well below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Middle WOC West Groundwater

Table 3.56 summarizes the carcinogenic recreational risk and the noncarcinogenic HI for the subbasins in Middle WOC West.

A number of recreational COCs in groundwater were identified in the two SWSA 4 subbasins of Middle WOC West. These COCs include ^{90}Sr, ^{3}H, ^{241}Am, ^{137}Cs, ^{14}C, ^{234}U, arsenic, vinyl chloride, and 1,1-DCE. Residential and industrial COCs were identified in Appendix B.

Table 3.56. Summary of risk results for Middle WOC West groundwater

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
SWSA 4 Main	2.3E-02	5.2E+00	2.6E-04	2.7E-01	^{90}Sr, Arsenic, ^{241}Am, ^{14}C, ^{137}Cs, ^{234}U
SWSA 4 East	1.6E-02	3.5E+00	5.5E-04	2.4E-01	Arsenic, 1,1,2-dichloroethene, ^{3}H, ^{90}Sr, vinyl chloride
WAG 7 WOC	1.9E-06	–	2.0E-08	–	None
Haw Ridge	1.4E-06	5.1E-01	3.7E-07	5.2E-02	None

The groundwater data from the Middle WOC West subbasins were screened against federal and state primary drinking water standards and against radionuclide specific proposed and promulgated primary drinking water standards. For the SWSA 4 Main subbasin, criteria exceedances were noted for ^{90}Sr, ^{3}H, ^{234}U, ^{241}Am, nickel, arsenic, antimony, and ^{14}C. At WAG 7 WOC and at Haw Ridge, no exceedances occurred for the contaminants screened. At SWSA 4 East, exceedances were observed for ^{90}Sr, ^{3}H, vinyl chloride, 1,1-DCE, trichloroethylene, nickel, and cis-1,2-dichloroethene.

Middle WOC/West Surface Water

Table 3.57 summarizes the carcinogenic risk, the noncarcinogenic HI, and the COCs identified for two of the four subbasins. SWSA 4 East and Haw Ridge did not have available surface water data.

Table 3.57. Summary of risk results for Middle WOC West surface water

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
SWSA 4 Main-seeps	7.6E-03	2.0E+00	8.7E-05	1.9E-01	None
SWSA 4 Main-streams	7.5E-04	1.1E+00	1.1E-05	8.8E-02	None
WAG 7 WOC-seeps	8.9E-06	3.6E-02	3.2E-06	1.3E-02	None

No recreational COCs were identified for Middle WOC West surface water. Industrial and residential COCs are presented in Appendix B.

Surface water in SWSA 4 Main appears to present significant risks to aquatic iota, based on the one available line of evidence (water chemistry). Seven metals are identified as COECs: Ag, Al, Cd, Cu, Fe, Ni, and Pb. Nine metals appear to present marginal risks (B, Ba, Co, Li, Mn, Tl, and zirconium) or negligible risks (Be and Sr) and are identified as COPECs.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the SWSA 4 Main subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

No risks were identified for terrestrial wildlife drinking surface water at SWSA 4 Main; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for plants assumed to be exposed to seep water in soil solution at SWSA 4 Main (Table 3.11). Arsenic exceeded plant soil solution benchmarks at stations SCS1B and SW4-1 (HQs 50 and 6.2, respectively). Thallium exceeded at stations SW4-1 and W4MS1 (HQs 16.6 and 16.7), but thallium was detected infrequently (in one of four and one of eight samples). Nickel exceeded benchmarks at SW4-2 (HQ = 18.9), and aluminum exceeded benchmarks at W4 TRIB-5 (HQ = 10.6). Other analytes marginally exceeding benchmarks at least one station were fluoride, iron, lead, and manganese (HQs all <3.1). The thallium and aluminum benchmarks appear to be conservative as they are exceeded at numerous seeps across the whole watershed, and the aluminum benchmark is below background. There is low confidence in the arsenic benchmark because it is based on limited data on root length reductions (Will and Suter 1995). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the WAG 7 WOC subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from WAG7 WOC; water concentrations were below wildlife LOAELs for all receptors and all analytes. No risks were identified for plants exposed to seep water in soil solution; water concentrations were below plant soil solution benchmarks for all analytes.

The contaminant surface water concentrations for the Middle WOC West subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic and thallium were exceeded for the human health criteria at the SWSA 4 Main subbasin. Nickel, lead, cadmium, and selenium showed exceedances for the ecological criteria at SWSA 4 Main. WAG 7 WOC did not show exceedances for either criteria.

3.5.3.5 Options for release mechanism intervention

The SWSA 4 Main subbasin contains portions of two abandoned liquid low-level waste transfer pipelines and low-level radioactive waste buried in shallow trenches and auger holes. The principal radionuclides being released from the SWSA 4 site are ^{90}Sr and ^{3}H. Trench water is contaminated, as is the soil along seepage pathways between the trenches and the SWSA 4 Tributary stream channel, as is sediment in the SWSA 4 Tributary channel. The release mechanism for the burial trenches is perennial inundation by the water table and bathtubbing and trench overflow during the wet season. Little is known about the construction details of the auger holes; however, they may be inundated by the water table at least during the wet season. Geophysical methods and remote sensing data interpretation have provided approximate trench locations; however, only trenches that have been located by installation of driven wells or pipes can be located with confidence. Evidence of releases from the abandoned transfer line north of Lagoon Road is the radiation zoned area of contaminated soil along the paved drainage swale.

During 1996, a CERCLA Removal Action was performed to contain contaminant sources in portions of four trenches that fed two seeps that contributed significant fluxes of ^{90}Sr to the surface water. Options to control releases from other trenches and the auger holes at SWSA 4 include additional trench grouting in areas where burial trenches are not deeply covered by the layer of D&D debris or hydrologic isolation of the burial area. Experience in driving the grout sleevepipes into trenches for the grout project suggest that excavation of the trench contents would be a very difficult task because of the apparent advanced deterioration of waste containers. Options to control the release from the abandoned pipelines include filling the pipes with a grout material and selectively excavating contaminated soils exposed at the surface or removing the entire pipeline along with contaminated soils.

The SWSA 4 East subbasin contains the eastern portion of SWSA 4, including waste burial trenches, a layer of D&D rubble that covers the waste burial trenches, auger holes, and portions of the two abandoned low-level liquid waste transfer pipelines. Among the waste burial trenches in this basin is one in which TRU waste was buried. This trench was grouted with polyacrylamide grout as a technology demonstration of chemical grout application for waste containment. Discharges from the basin include ^{90}Sr, ^{3}H, and VOC-contaminated groundwater seepage to the Middle WOC floodplain area and a small volume of contaminated surface water seepage. Uncertainty in locating the burial trenches, both horizontally and vertically, is extreme in this area due to the layer of D&D rubble and soil that blankets the site. Lack of data on trench depths makes defining the state of trench saturation impossible. Based on conditions observed in the SWSA 4 Main subbasin, the assumption is made here that trenches in the SWSA 4 East subbasin are perennially inundated. Given the assumption of trench inundation, the contaminant release mechanism is dissolution of contaminants from the waste and groundwater seepage toward the Middle WOC floodplain area. Options to control releases from this area appear more limited than those for other waste burial areas because of the rubble layer. Hydrologic isolation of the area is a viable option. Discrete source treatment or control is a limited option because of the uncertainty of locating trenches.

3.6 LOWER WHITE OAK CREEK TRIBUTARY BASINS

The lower WOC tributary basins compose 10 subbasins, including areas draining the Seepage Pits and Trenches and WAG 6. These subbasins encompass 226 acres in the area between Lagoon Road and the edge of the WOC floodplain (Fig. 3.42).

3.6.1 West Seep Subbasin

West Seep Tributary receives drainage from a large area including Haw Ridge, as shown in Fig. 3.43. In this drainage area there are several contaminated sites including: (1) SWSA 6–northeast auger holes, (2) SWSA 6–19 Trench area, (3) EWB, (4) Decontamination Facility–Building 7819, (5) HF-1 surface contamination site, (6) Experimental Pilot Pit Area 7811, (7) Contaminated Equipment Storage Area 7841, (8) Pit 1, (9) Pit 2, (10) Pit 3, (11) Pit 4, and (12) Pipeline Leak/Spill Site 7.4d and 7.4e. This drainage area is composed of a variety of waste units, including buried waste in SWSA 6, the impoundment at EWB, leak/spill sites at HF-1 and 7.4d, surface structures at Building 7819 and Area 7841, and LLLW disposal Pits 1 through 4. The following sections will discuss the sources, releases, contaminant transport pathways, media of concern, and human and ecological risk for these areas.

3.6.1.1 Contaminated sites

The EWB is just outside the northeast corner of WAG 6, and was designed as an emergency holding basin for LLLW and ORNL process waste, but has never been used for that purpose. Instead, it captures runoff and shallow groundwater flow from surrounding ridges. An earthen dam

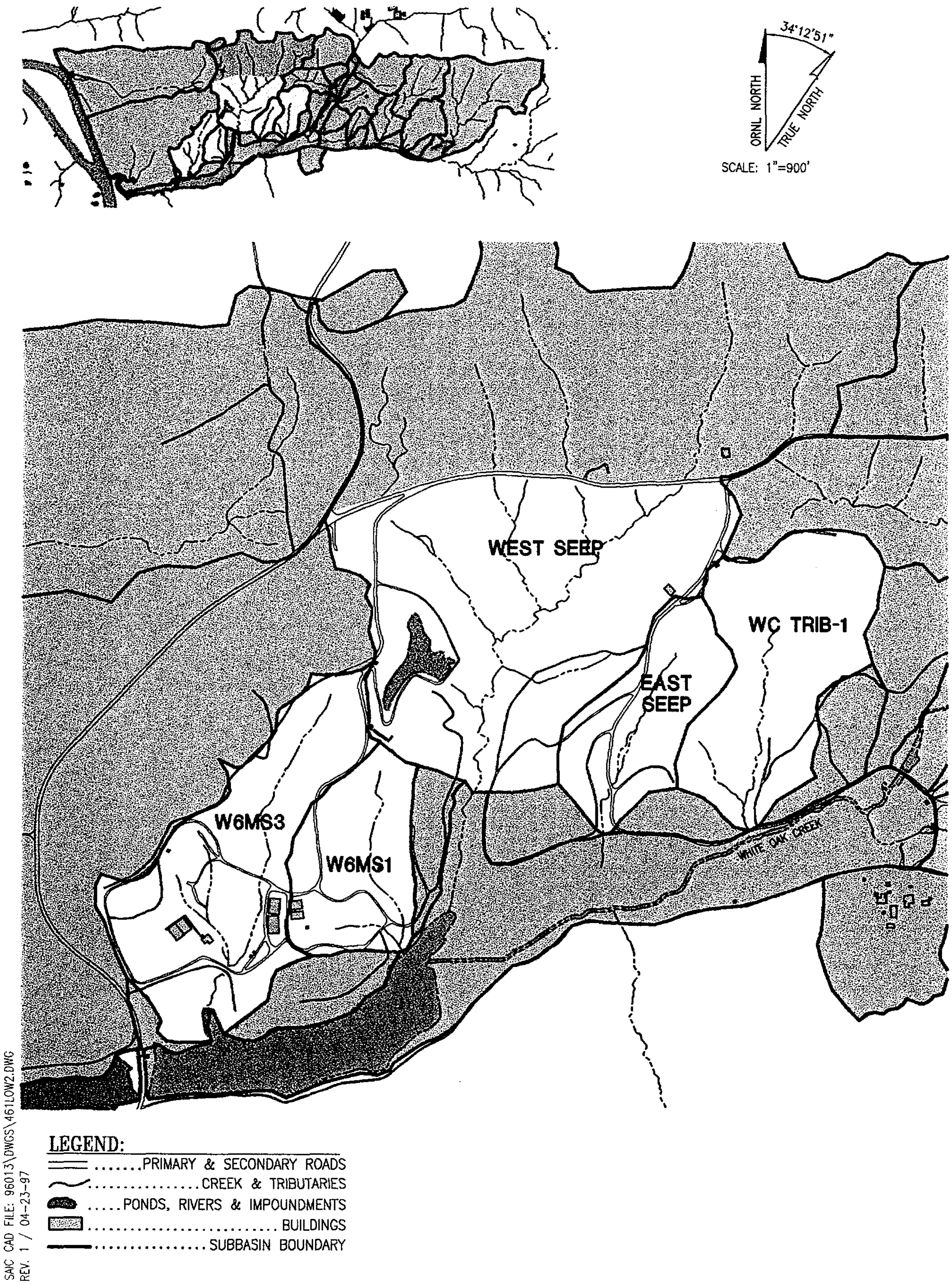

Fig. 3.42. Subbasins contained in Lower White Oak Creek tributaries area.

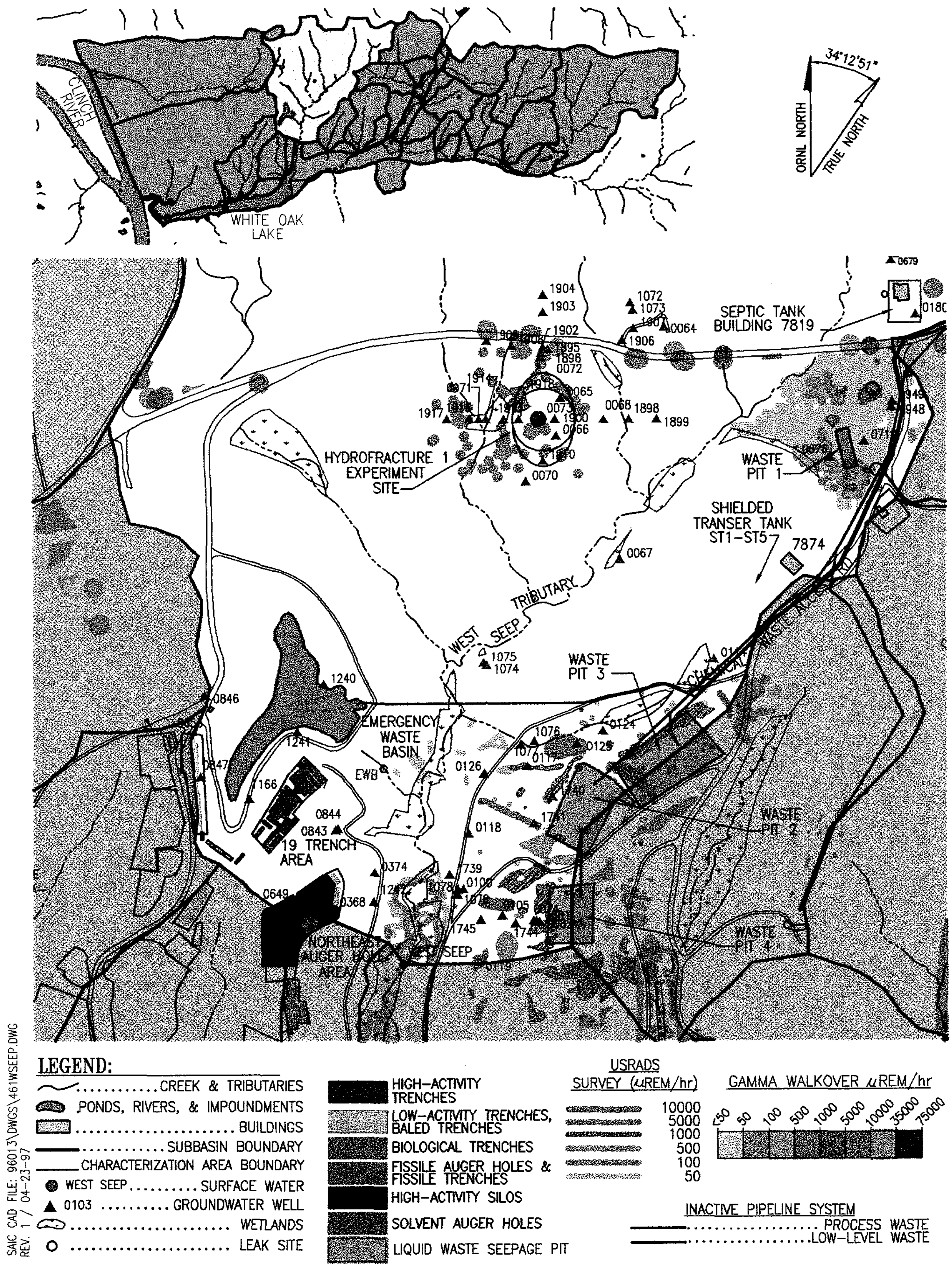

Fig. 3.43. West Seep subbasin, contaminant sources, and monitoring locations.

holds approximately 4.5 m gal of water in the basin. The basin is drained periodically (to West Seep Tributary) to maintain the integrity of the dam (DOE 1995f).

The sources that appear to be contributing the most to releases to the West seep subbasin are the 19 Trench Area (mainly via the EWB), the northeast auger holes, and the solvent auger holes underlying Cap 3. The Cap 3 area and northeast auger holes contain a combination of radioactive and RCRA-regulated wastes. An estimated 580,000 Ci is disposed in the auger holes; RCRA wastes disposed there include chlorinated solvents. These solvents have migrated away from the source toward the West Seep Tributary. The 19 Trench area contains an estimated 6000+ Ci of radioactive materials, including materials with activity >200 mrem/h at container surface. Strontium-90 activity concentrations in wells downgradient of the 19 Trench area indicated radioactive materials are migrating away from this source toward the EWB and West Seep Tributary.

A detailed summary of the waste units is presented in Appendix A.

Decontamination Facility–Building 7819

This facility was constructed in 1964 at the intersection of Lagoon Road and Chemical Waste Access Road (Fig. 3.43), and was used for decontamination of operating equipment and various other large equipment until the early 1970s. Decontamination of small equipment occurred in two open pits, using acid bath and sandblasting techniques, with larger equipment decontamination occurring on a concrete pad in the back of the building. All decontamination solutions were drained by means of gravity feed into Waste Pit 1 via a buried 6-in.-diam vitrified pipeline (SWMU 7.4d), as shown in Fig. 3.43. Runoff from the asphalt pad drained into a 6-in. corrugated metal pipe on the southeast corner of the building, which has since been plugged and abandoned.

In March 1964, a septic tank and drain field (Fig. 3.43) were added on the west side of the building to receive nonradiological discharges from the change room in the building. Five shielded transfer tanks (ST1–5) are stored on the west side of Building 7819 (Fig. 3.43) and are being managed as part of the surplus facility program. More detailed information on this unit is provided in Energy Systems 1988d.

Shielded Transfer Tanks ST1-ST5

These tanks were used during the 1960s to ship ^{137}Cs-loaded ion exchange resins to ORNL from Richland, Washington. There are four Model II tanks and one Model III tank. The Model II tanks consist of a 500-gal (1900-L) 0.4-in.-thick (1.0-cm-thick) stainless steel liner surrounded with 3.5 in. (9 cm) of lead shielding encased in a 0.75-in. (2-cm) steel outer shell. Three of these vessels contain approximately 395 gal (1500 L) of Decalso inorganic ion exchange medium, with one reported to be empty. The Model III tank consists of a 198-gal (750-L) stainless steel liner encased in 9 in. (23 cm) of steel. The vessel contains approximately 148 gal (560 L) of AW-500 inorganic ion-exchange medium. The total inventory for these tanks is estimated to be 2000 Ci of ^{137}Cs (Energy Systems 1987).

Hydrofracture Experimental Site 1 (HF-1) Surface Contamination Site

The HF-1 site is located 1200 ft west of Building 7819 as indicated on Fig. 3.43. On October 16, 1959, radioactive grout was added to well 73 to initiate the first hydrofracture experiment. After the grout had been injected, 400 gal of water were pumped down the injection well to flush it out. During this flushing activity, grout was observed slowly flowing out of a corehole located 199 ft north of the injection well. Flushing activities were halted and an estimated 200 gal of grout continued to flow out of the corehole for a few more hours. Also, an estimated 2000 gal of liquid continued to flow out of this corehole for the next 2 months.

An interceptor pit was excavated to intercept the grout and water flowing from the corehole. After the grout had set, the grout and soil around the corehole were excavated and disposed of in SWSA 5. An aerial radiological survey performed in 1987 and a radiological walkover survey performed soon after that indicates that residual soil contamination still existed at the HF-1 Site. More detailed information is provided in Energy Systems 1988d.

Experimental Pilot Pit Area 7811

The Experimental Pilot Pit Area is located on the southwestern boundary of SWSA 4 (Fig. 3.43) and was constructed in late 1955 for use in pilot-scale radioactive waste disposal studies on the sintering (or fixation) of high-level fuel reprocessing waste into stable solids. Two experiments were conducted during 1956–57. Only one experiment involved radioactivity and it was removed as part of the ceramic product produced. Currently, three large concrete cylinders imbedded vertically in the ground remain after the experiments were terminated. The only visible features above grade are a control building used for storage, and four large concrete cylinders that were used for municipal waste leaching experiments. Thus, there appears to be no known contamination at the site, just surplus equipment that needs to be properly disposed of.

Contaminated Equipment Storage Area 7841

The contaminated equipment storage area is located south of Pit 1 as indicated on Fig. 3.43. This area has been used for storage of contaminated equipment on a gravel pad with the area enclosed with a chain link fence. Presently, there is a considerable amount of potentially salvageable equipment at the site, including two large stainless steel tanks (20,000- and 40,000-gal capacity), many 55-gal drums of unknown contents, a large wind chamber, many smaller tanks (500-gal capacity), and various other equipment. A large portion of this equipment came from the aboveground storage yard at SWSA 3.

Building 7874, located adjacent to the north side of the storage area, was constructed in February 1987 for the storage of field equipment. For both storage area 7841 and Building 7874, there appears to be no released contamination at these sites. However, there is a large amount of surplus equipment that needs to be removed and properly disposed of.

Pit 1

Pit 1 was constructed in 1951 near the intersection of Lagoon Road and Chemical Waste Access Road (Fig. 3.43) to test the feasibility of the disposal of liquid waste into pits excavated in the natural clays in Melton Valley. The pit construction consisted of excavating a 100 ft × 20 ft wide × 15 ft deep pit, then covering it with wood to keep animals out. Pit 1 received LLLW from August 1951 to October 1951. This pit also received decontamination fluids from Building 7819 operations. In 1981, Pit 1 was backfilled and covered with an asphalt cap. More detailed information is provided in Energy Systems 1988d.

Pits 2, 3, and 4

Pit 2 was constructed in early 1952, approximately 1300 ft south of Pit 1 (Fig. 3.43), and began receiving waste in June of that year. Initially, liquid waste was transported to the site via dumpster, then by large capacity trailer, but this proved to be cumbersome. So in 1954, a waste transfer pipeline constructed of 2-in.-diam cast iron was installed, running from the Process Waste Treatment Plant located in Bethel Valley, to the waste disposal pit area. When this waste transfer pipeline became operational, use of the waste evaporator was discontinued because the volume of waste no longer needed to be reduced before transporting to Pit 2. Before December 1954, Pit 2 operated alone and received 1,294,000 gal of LLLW, containing 16,600 Ci of beta activity (Energy Systems 1988d).

Pit 3 was constructed and put into operation in January 1955 to help handle the increasing volume of LLLW. It was constructed just north of Pit 2 and was connected to it via a 4-in.-diam welded steel pipe (Fig. 3.43). Pit 4 was constructed in November 1955 but did not begin receiving waste until the next year. Pit 4 was constructed just south of Pit 2 and was also connected to it via a 6-in.-diam vitrified pipe.

Pits 2, 3, and 4 worked as a unit with LLLW initially entering Pit 3 with overflow to Pit 2 and finally, overflow to Pit 4. After excessive leakage from Pit 4 was detected, this pit was only used during the winter months, when evaporation rates were lower and precipitation contributions to the pits were higher (Energy Systems 1988d). Because of the overflow relationship of these pits, determination of volume and radionuclide concentration for waste disposed in individual pits is difficult to estimate.

In addition to the transfer of LLLW to these pits, sludge from the Process Waste Treatment Plant was disposed of in the pits. Initially, sludge was disposed of in Pit 3 until it was removed from service. The sludge was then disposed of in Pit 4 until 1976, at which time the new Process Waste Treatment Plant became operational. It is estimated that up to 80% of the volume of Pit 4 may be filled with sludge (Energy Systems 1988d).

During the operation of these pits, there were problems with high radiation levels around the sides of the pits and seepage into nearby streams and creeks. In late 1959, considerable seepage was detected on the east side of Pit 4, which had already released approximately 350 Ci to WOC. An interceptor trench was constructed down slope of the seepage face to capture this contaminated liquid and pump it pack to the pit. In 1961, a second interceptor trench was constructed near Pit 4 after two new seeps were detected on the west side of the first interceptor trench. Also in 1961, ^{106}Ru was detected seeping out of the west side of Pit 2. Another interceptor trench was constructed to capture the seepage and pump it back to Pit 2. In addition to construction of the interceptor trenches, several compounds were added to the waste pits in an attempt to increase the adsorptive capacity of the radionuclides. Both copper compounds and sodium sulfide were added to the pit.

In September 1961, Pit 3 was removed from service. In November 1962, after Trench 7 became operational, Pit 2 was removed from service, and a year later it was backfilled with shale and graded. Pit 3 was backfilled, graded, and covered with an asphalt cap in 1963. Pit 2 was covered with an asphalt cap in 1970. Pit 4 remained in service until 1976 to serve as a standby for sludge disposal from the PWTP. Pit 4 was backfilled in 1976 and an asphalt cap was added in 1980. More detailed information on this area is provided in Energy Systems 1988d.

Note that ORNL Drawing S-10830 for Pit 2 identifies 16 cased auger holes just north of this pit. On a tour of this area, the location of the auger holes was visually verified and they were determined to be constructed of 3-in.-diam steel casing (Energy Systems 1988d). The origin of these auger holes, or what they contain, or even if they were ever used, is unknown.

LLLW Line and Leak Site Near Pit 1

This leak site is associated with the 6-in.-diam vitrified pipe connecting the Decontamination Facility 7819 and Pit 1 (Fig. 3.43). The pipeline leak was identified in 1968 and 1969, when trees began dying in this area. This was thought to be due to the leakage of the liquid waste containing acids and/or alkalies used in the decontamination operations at Building 7819 that were transported to Pit 1 via this pipeline.

In 1983, approximately 200 ft^3 of contaminated soil and pipe section were removed from the site and disposed of in SWSA 6. The remaining pipe was plugged and capped to prevent future leakage of additional contaminants. A 1987 radiological walkover survey of this area revealed elevated concentrations of ^{137}Cs, ^{90}Sr, ^{60}Co, ^{152}Eu, and ^{154}Eu, which indicate that additional contaminated soil exists at the site. More detailed information is provided in Energy Systems 1988d.

LLLW Line and Leak Site–Line Between Pit 3 and Trench 6

This leak is located at the valve connection between the cast iron pipeline for Pit 3 and the cast iron pipe for Trench 6, as indicated on Fig. 3.43. The leak site was suspected to have occurred in 1973. In March 1974, the valve was removed and the pipeline going to Pit 1 was capped and replaced with a new valve and pipeline. Contaminated soil was removed and placed in SWSA 6. In 1982 and 1988 radiological walkover surveys of adjacent areas, it was determined that surface soil contamination and subsequent plant uptake at this leak site were present. No further corrective actions at the site have occurred. More detailed information on this area is provided in Energy Systems 1988d.

3.6.1.2 Pathway model of contaminant releases

According to WAG 2 RI results (Hicks 1996), the West Seep Tributary contributed approximately 1.7% of the total contribution of ^{90}Sr to WOD. In addition, FY 1995 Surface Water Project data indicate that the EWB (released in September 1995) contributed 4.4 Ci of ^{3}H, or approximately 0.3% of the total 1995 WOD release. This was a one-time release in calendar year 1995. The EWB contribution to ^{90}Sr contamination is also insignificant. West Seep is not a significant contributor of ^{137}Cs.

Potential sources of groundwater and surface water contamination within the West Seep Tributary subbasin include Pit 1; portions of Pits 2, 3, and 4; a low-level pipeline leak site; the hydrofracture experiment site; the 7819 Decontamination Facility; shielded transfer tanks; the 7841 Equipment Storage Area; the Northeast Auger Holes, the solvent auger holes underlying Cap 3; and the 19 Trench area in SWSA 6.

A ^{90}Sr activity of 128 pCi/L was detected in a sample collected on April 13, 1993, from seep RS-1, located to the west of Pit 3 (Fig. 3.43) (Hicks 1996). Pit 3 is a likely source for the ^{90}Sr found in this seep.

The bottom of Pit 3 is at about 795 ft above MSL, and the average groundwater elevation in the vicinity of the northern end of Pit 3 is 790 ft above MSL. Therefore, a possible release mechanism for the ^{90}Sr in this pit could be transient saturation of the sediments in the northern end of the pit and/or the weathered shale directly under the pit under high water table conditions during the wet part of the year and/or during storms, with the resulting contaminated groundwater moving along strike to the west and discharging to surface water at seep RS-1. In addition, because water levels were in excess of 30 ft higher during pit operation, transient subsurface flow above the current water table elevation could contribute to releases.

Radiochemical analyses of cores taken from Pits 2 and 3 in 1966 indicated that most of the ^{90}Sr activity was associated with the calcium carbonate fraction of the soft sludges and the first few inches of weathered shale comprising the bottoms and side walls of the pits. Leaching tests were performed on the sludges and weathered shale. Results of these tests indicated that less than 10% of the ^{90}Sr in the sludges existed in an easily exchangeable form and as much as 90% of the ^{90}Sr in the sludges was present as a slightly soluble coprecipitate of calcium carbonate. In the shales, at least 50% of the ^{90}Sr was present in an easily exchangeable form, with another 25–50% existing in the form of slightly soluble salts (Lomenick et al. 1967). Thus, it is likely that the release of ^{90}Sr from Pit 4 is occurring via leaching of the weathered shale around the pit.

During its operation, Pit 4 received overflow from Pit 2, which in turn received overflow from Pit 3. Being at the end of this overflow train, Pit 4 never received much waste volume or radioactivity. However, Pit 4 leaked much more rapidly than Pits 2 and 3. In 1959 and 1961, interceptor trenches were installed to the east and west, respectively, of Pit 4 to capture seepage from the pit. Samples from two seeps, RS-3A and SW7-2, located to the west of Pit 4 along West Seep Tributary (Fig. 3.43), had average ^{60}Co activities of 726 and 1081 pCi/L, respectively, during sampling for the WAG 2 RI Seeps Task in 1993 and 1994. In addition, samples collected in 1982 from two wells, W95 and W105, contained ^{60}Co activities of 5400 and 5130 pCi/L, respectively (Spalding 1987). Well W95 is located approximately 13 ft to the southwest of seep SW7-2 and well W105 is located about 200 ft to the west of Pit 4, between the pit and Seep RS-3A. However, the concentration of ^{60}Co in samples collected from the West Seep Tributary, located to the west of Pit 4 and downstream of seep RS-3A, was typically below detection.

The bottom of Pit 4 is at an elevation of 788 ft above MSL and the average groundwater elevation in the area is about 765 ft above MSL. Therefore, the sediments in the pit are not likely to be saturated, even during intense storms during the wet part of the year. A likely release mechanism for ^{60}Co from Pit 4 is percolation of infiltrating precipitation through relict seepage pathways and movement of the resulting contaminated water along strike via structurally controlled preferential flow pathways to discharge locations at seeps.

Three seeps containing ^{90}Sr (RS-1, SW7-1, and RS-3A) have been identified along West Seep Tributary. However, the total flux of ^{90}Sr from these seeps does not account for the total ^{90}Sr flux at the West Seep weir. Based on the presence of ^{90}Sr in streambed gravels from the drainage for the Pit 1 area (Cerling and Spalding 1981), the likely source of much of the ^{90}Sr in West Seep Tributary is Pit 1. Between 1964 and 1967, decontamination fluids from the 7819 decontamination facility were drained to Pit 1. Acids were used in some of the decontamination solutions employed at this facility and it is possible that ^{90}Sr in the sludges in Pit 1 was mobilized by these acids.

The bottom elevation of Pit 1 is about 810 feet above MSL, which corresponds with the average groundwater elevation in the area. Therefore, the ^{90}Sr mobilized out of the sludges could have directly entered the groundwater and moved westward along strike to the surface water drainage for the area. Another possible source for the ^{90}Sr in West Seep Tributary is the 19 Trench area in SWSA 6, located about 450 ft west of the creek. These unlined trenches contain a ^{90}Sr inventory of approximately 6,000 Ci and have not been capped, although a bentonite/shale compacted layer was placed over the 19 Trench area to control infiltration in the mid-1970s. The elevations of the trench bottoms range from approximately 820 to 825 ft above MSL and the average groundwater elevation ranges from 800 to 810 ft above MSL. Therefore, the trenches remain perennially unsaturated.

The probable release mechanism for ^{90}Sr from these trenches is leaching of trench wastes by infiltrating precipitation. The resulting contaminated water then moves downward through the vadose zone to the water table. In the saturated zone, the ^{90}Sr moves eastward with the groundwater along the hydraulic gradient, discharging at unidentified locations to West Seep Tributary.

3.6.1.3 Secondary contaminated media

Areas of radiological surface soil contamination in the West Seep subbasin are shown on Fig. 3.43. The most extensive surface-contaminated areas in the West Seep subbasin are associated with historic releases from Seepage Pits 2, 3, and 4. During operations, waste liquids from the pits permeated the vadose soils adjacent to the pits and surface seeps were noted. In some areas pumpback systems were used to recirculate contaminated seepage into the pits. Releases from the secondary contaminant mass derived from this pit seepage still feeds contaminant discharge at the West Seep.

Other areas of surface contamination in the West Seep subbasin include areas associated with LLW pipeline leaks near Pit 1, historic Pit 1 seepage contamination, soils at the HF-1 site, hot spots along Lagoon Road, hot spots around the 19 Trench disposal area in SWSA 6, and contamination surrounding and downstream of the West Seep.

Secondary contaminated media in the West Seep Tributary subbasin include soils and groundwater in seepage pathways between Pits 2, 3, and 4 and West Seep Tributary; soils and groundwater in Pit 1 seepage pathways and leak sites; soils and groundwater in seepage pathways along ravines from SWSA 6 sources; soils and groundwater in the contaminant discharge area along West Seep Tributary; and surface soils contaminated with ^{137}Cs in the vicinity of the Hydrofracture 1 experimental site. The approximate area of contaminated Pits 1, 2, 3, and 4 seepage pathway soils is 11.5 acres (0.6 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 5,000,000 ft^3 (140,000 m^3). Figure 3.44 is a cross section through Pit 4 showing current water table elevations, contaminant release mechanisms, and the extent of secondary soil contamination (i.e., seepage pathways). The approximate area of contaminated seepage pathway soils along ravines from SWSA 6 sources and contaminated soils in the contaminant discharge area along West Seep Tributary is 4.4 acres (1.8 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 1,300,000 ft^3 (38,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils and contaminant discharge area soils is about 4,100,000 gal (16,000 m^3). The approximate area of contaminated surface soils near the Hydrofracture 1 experimental site is 0.1 acre (0.04 ha), with an average thickness of 1 ft (0.31 m), and an approximate volume of 4,400 ft^3 (120 m^3).

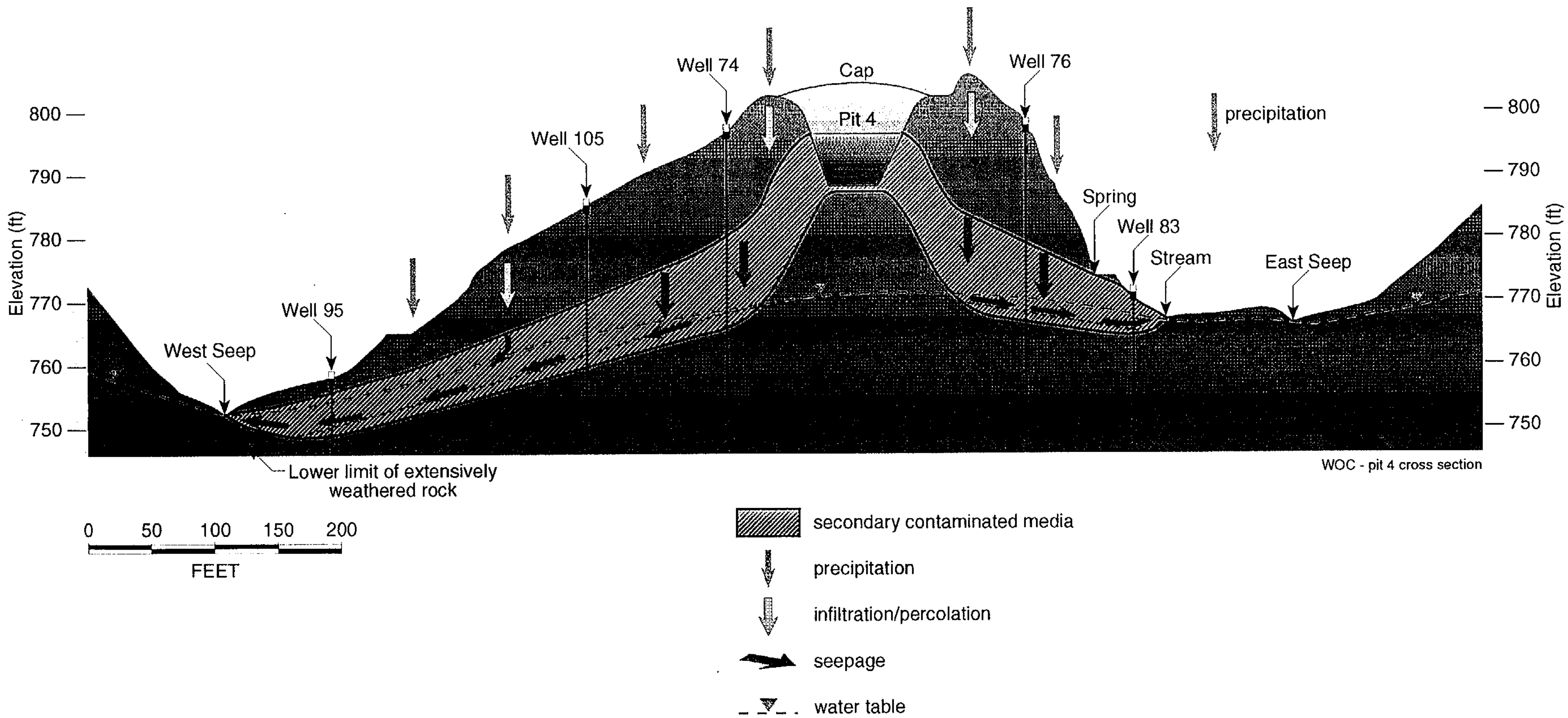

Fig. 3.44. Cross section through Pit 4 showing seepage pathways and secondary contaminant locations.

3.6.1.4 Human health risk, ecological risk, and criteria exceedances

The COCs for the West Seep Tributary subbasin for each of the media are presented based on recreational land use. Risk results are presented for the recreational and industrial land use scenarios. Figure 3.45 presents available carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.58 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The West Seep subbasin has been rather thoroughly sampled given that it has never been the subject of an RI. Therefore, the associated uncertainty in the risk results and the identified COCs is considered to be moderate.

Table 3.58. Media data summary for the West Seep subbasin

Basin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
West Seep	Groundwater	38	1251	848	4387	2545	12387	348
West Seep	Sediment	3	0	0	250	230	0	0
West Seep	Soil	43	561	416	684	569	2666	204
West Seep	SW-seeps	15	255	183	1356	937	1151	56
West Seep	SW-streams	3	45	9	108	71	248	15

West Seep Soil

Forty-three soil samples were analyzed for a comprehensive list of radionuclides, organics, and inorganics in the West Seep subbasin. The total recreational risk is 2.3E-01 and is due almost exclusively to ^{60}Co and ^{137}Cs. The industrial risk is 1.0. The recreational HI for this area is 4.0E-02 and the industrial HI is 8.0E-02. Since these values are less than one, no noncarcinogenic COCs are identified for the West Seep subbasin. Cesium-137 and ^{60}Co are identified as recreational COCs for West Seep soil. Industrial and residential COCs are identified in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the West Seep subbasin. Overall dose rates from exposure to the 29 radionuclides detected exceeded recommended dose limits for all receptors, with HIs ranging from 2.0 for plants to 53.0 for shrews (Table 3.59). Cobalt-60 was the primary risk driver for all receptors, contributing >96% of the dose rate for all receptors. Potential risks from nonradionuclides were identified for plants (HI = 9.6) and short-tailed shrews (HI = 2.1). Inorganics contributed >99% of the HI for all receptors. HQs exceeding one were estimated for five inorganics for plants (nickel, cobalt, tin, cadmium, and silver). HQs for nonradionuclide analytes were all low (<2.3), suggesting a low likelihood of adverse effects to plants.

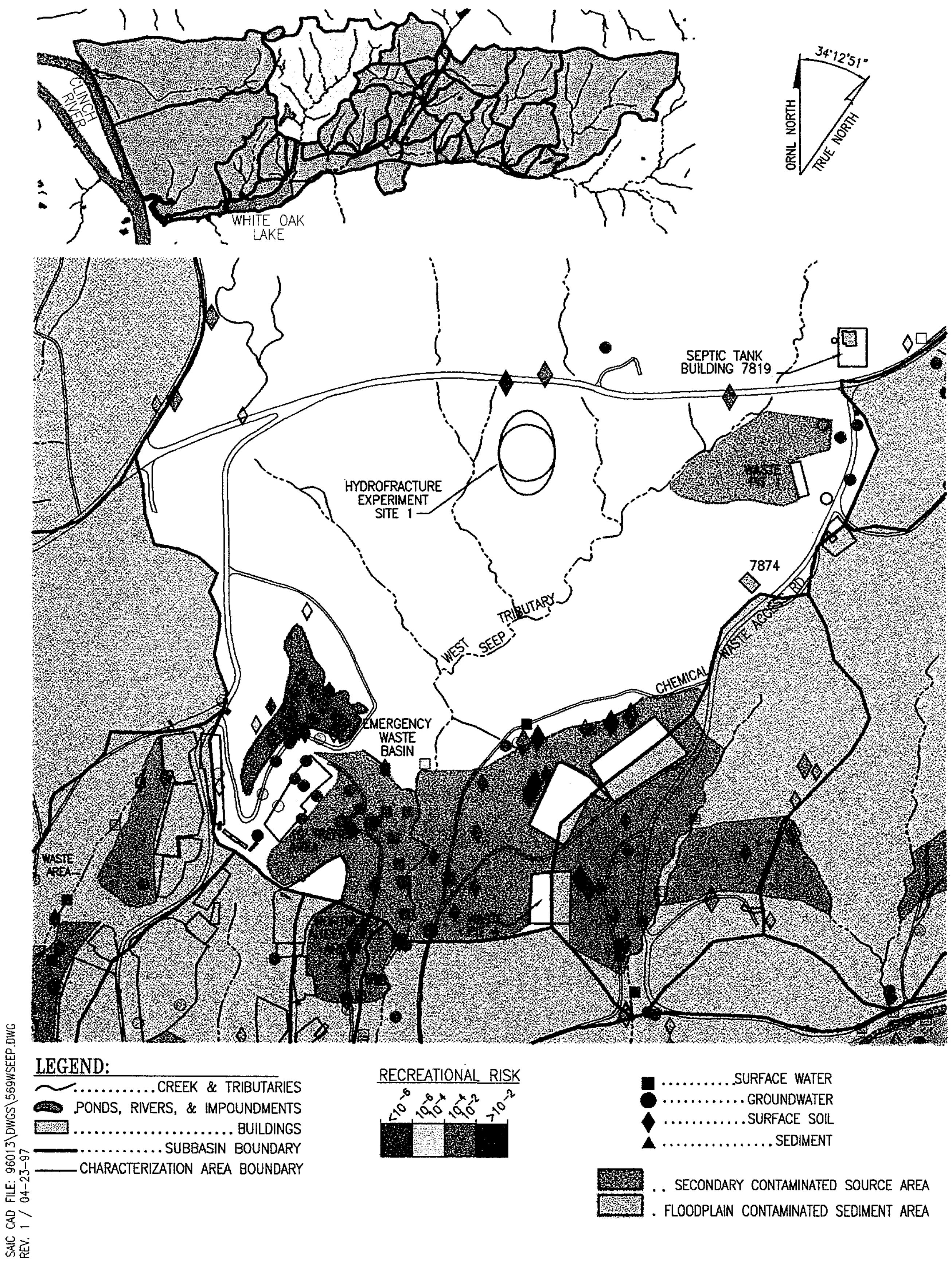

Fig. 3.45. Risk estimates for sampling locations in West Seep subbasins.

Table 3.59. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at West Seep subbasin

Basin/subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
West Seep	Plants	9.6	Ni (2.3), Co (2.0), Sn (1.7), Cd (1.7), Ag (1.5)	2.0	^{60}CO (1.9)
West Seep	Invertebrates	0.6		10.3	^{60}CO (10.2)
West Seep	Shrew	2.1	Ni (0.9)	53.0	^{60}CO (52.3)
West Seep	Mouse	0.4		53.0	^{60}CO (52.3)
West Seep	Fox	0.3		39.1	^{60}CO (40.0)
West Seep	Deer	0.4		19.5	^{60}CO (19.4)
West Seep	Mink	<0.1		38.2	^{60}CO (38.1)
West Seep	Hawk	<0.1		2.0	^{60}CO (2.0)
West Seep	Turkey	0.1		20.8	^{60}CO (20.0)

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

West Seep Sediment

Three sediment samples were analyzed for a limited list of inorganic contaminants. All of the inorganics that were detected were screened out through the reference and PRG screening steps so carcinogenic risk and the noncarcinogenic HI were not calculated. Therefore, no COCs are identified for the sediment in the West Seep subbasin based on recreational land use. However, no radionuclide or organic data are available for the sediment in this subbasin.

Potential risks were identified for benthic invertebrates exposed to sediment in the West Seep subbasin. However, no COECs were identified. Antimony was the only analyte presenting marginal risks, and no other analytes were of potential concern.

West Seep Groundwater

Radionuclide, organic, and inorganic contaminants have been sampled at 38 locations in the West Seep subbasin. The recreational carcinogenic risk sums to 1.2E-05 and the industrial risk is 3.7E-04. The recreational HI is 1.0E-01 and 1.4E+00 for an industrial receptor. Therefore, no recreational COCs are identified for West Seep groundwater. Industrial and residential COCs are presented in Appendix B.

The groundwater data from the West Seep subbasin were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. Criteria exceedances were noted for ^{3}H, ^{234}U, ^{238}U, and cadmium.

West Seep Surface Water

Seep and stream samples have been collected at 18 surface water locations within the West Seep subbasin. The recreational risk for seeps at West Seep is 2.4E-05 and 7.0E-06 for stream samples. These results are due to a number of radionuclides. For an industrial receptor, the risks are 1.6E-03 for seeps and 1.0E-04 for the stream samples. The only HI value greater than unity was for the industrial seeps receptor, with a value of 2.5. These values do not exceed the recreational target risk ranges and, therefore, no recreational surface water COCs are identified for West Seep surface water. COCs for industrial and residential use can be found in Appendix B.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the West Seep subbasin, based on the one available line of evidence (surface water chemistry). Four inorganics were the only analytes presenting a significant risk and were identified as COECs (Table 3.60). However, aluminum is very insoluble in nearly neutral water, and the bioavailable fraction is unlikely to be toxic to aquatic biota in the Melton Valley watershed. Carbon disulfide presented a marginal risk, and two analytes were considered a negligible risk. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction as they may not be bioavailable.

Table 3.60. Summary of potential risks to aquatic organisms from contaminants in main stem surface water in the West Seep subbasin

Subbasin	Risk category[a]	COECs/COPECs[b]
West Seep	Significant	Al, Cd, Cu, Fe
	Marginal	Carbon disulfide
	Negligible	Be, toluene

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the West Seep subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from the West Seep subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for West Seep plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum exceeded plant soil solution benchmarks at stations RS-3, RS-3A, RS-3B, SW7-2, and WSS-025 (HQs 7.9, 88.5, 7.1, and 485, respectively). Thallium exceeded benchmarks at stations RS-1 and SW6-2 (HQs 12.9 and 15.6). Arsenic exceeded benchmarks at RS-1, RS-3, RS-3A, SW6-2, and WSS-025 (HQs from 2 to 22.6). Iron and titanium exceeded benchmarks by 9.8 and 9.0, respectively, at station WSS-025. Other analytes marginally exceeding benchmarks at least one station were chromium, cobalt, copper, fluoride, iron, lead, and manganese (HQs all <2.6). The thallium and aluminum benchmarks appear to be conservative as they are exceeded at numerous seeps across the whole watershed, and the aluminum benchmark is below background. However, aluminum concentrations at RS-3A and WSS-025 may warrant concern. There is low confidence in the arsenic benchmark because it is based on limited data on root length reductions (Will and Suter 1995). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

The contaminant surface water concentrations for the West Seep subbasin were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic exceeded the human health criteria at the West Seep subbasin. Cadmium and chromium showed exceedances for the ecological criteria.

3.6.1.5 Options for release mechanism intervention

Contaminant sources in the West Seep Tributary subbasin include Pits 1, 2, 3, and 4; the 19 Trench area; and the Northeast Auger Holes. COCs being released from the area include ^{90}Sr. Primary contaminant sources are the sludges in Pits 1, 3, and 4 and the wastes in the trenches and auger holes; secondary contaminant sources are contaminated soils and groundwater along seepage pathways from Pits 1, 2, 3, and 4 to discharge locations along West Seep Tributary.

Based on water level measurements, the sludges in Pit 1 appear to be perennially saturated; the sludges in Pit 3 may be transiently saturated during high water table conditions; the sludges in Pits 2 and 4 appear to remain unsaturated; and the trenches in the 19 Trench area and the auger holes in the Northeast Auger Hole area are perennially unsaturated. Options to affect releases from Pits 1, 2, 3, and 4 in the West Seep Tributary area include: source treatment or removal, in situ stabilization of pit sludges and/or soils in seepage pathways, and hydrologic isolation of secondary sources in seepage pathways. Options to affect releases from the 19 Trench area and the Northeast Auger Holes area include: source removal, in situ stabilization, and hydrologic isolation with or without collection of a small groundwater seepage component likely to persist after the source area is capped.

Contaminated soil and sediment masses in and adjacent to the West Seep Tributary channel are potentially susceptible to scour and erosion during heavy precipitation runoff events. Sediment analyses show the presence of ^{60}Co, ^{90}Sr, and ^{155}Eu. Stabilization options for this sediment include removal and consolidation in a contaminated soil/sediment storage area, or covering/containment through the time duration of potential risk, based on contaminant decay.

3.6.2 East Seep Subbasin

The East Seep subbasin receives drainage from a 19.75-acre area that contains three contaminated sites: (1) Pits 2, 3, and 4, (2) Trench 5, and (3) HRE fuel wells (Fig. 3.46). These waste units served as LLLW disposal pits and trench and auger holes for disposal of HRE fuel as discussed in more detail below. The eastern half of Pits 2, 3, and 4 are in this drainage area but the source information on this area was presented earlier in Sect. 3.6.1.1 since the western half of the pits is in the West Seep basin.

3.6.2.1 Contaminated sites

Trench 5

Trench 5 was constructed in 1960, 700 ft east of Pit 4 (Fig. 3.46) with a modification to the original LLLW disposal pit design. These design modifications were needed to increase the

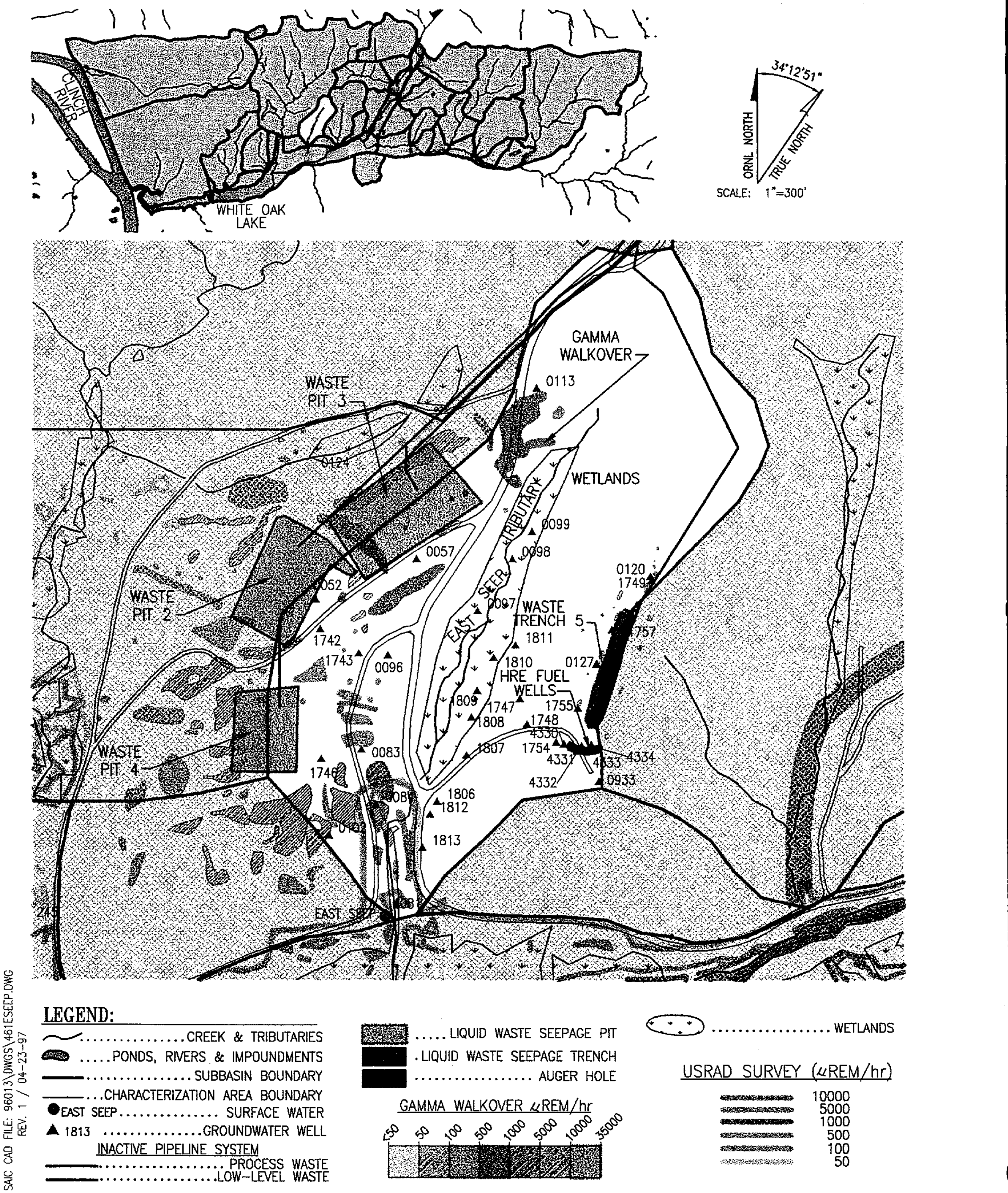

Fig. 3.46. East Seep subbasin, contaminant sources, and monitoring locations.

efficiency of the seepage pit and enhance worker safety. The first modification involved elongating the pit into a trench to maximize the exposure of the walls to a perpendicular orientation to bedding planes that would increase the seepage rate of the LLLW into the surrounding soil. Other design modifications included filling the trench with limestone to enhance strontium adsorption; adding an earthen cover to prevent human or animal intrusion into the waste, reduce direct radiation, reduce rainwater infiltration, and minimize waste evaporation in the trench; and incorporating steeper side walls to increase the vertical exposure to bedding planes (Energy Systems 1988d).

Before construction of Trench 5, it was determined, by collecting water level information from wells installed in the area, that the water table would be 25 ft below the bottom of the trench. Also, before waste placement in the trench, it was pretreated with copper sulfate and sodium sulfide to reduce the mobility of ^{106}Ru present in the LLLW. The first waste transfer into this trench was in May 1960 via a 2-in.-diam black iron pipeline connected to the waste transfer pipeline that serviced Pits 2, 3, and 4 (Fig. 3.46). Trench 5 was used until April 1966 when hydrofracture operations commenced. The mounded earthen cover over the trench was paved with asphalt in 1970.

During its operation, Trench 5 received 9.5 million gal of wastes containing gross beta activity of 311,824 Ci (Energy Systems 1988d). No leaks or seeps were reported during the operation of this trench. However, a 1962 study (Morgan et al. 1963) of the trees in this area and a 1986 study (Garten et al. 1986) of plants and trees west of the trench indicated elevated levels from the uptake of radionuclides. A more recent study by Goff (1991), involving a radiological walkover survey with additional soil and vegetation sampling, confirms the findings of the previous studies and indicates the presence of some isolated surface soil contamination and contaminated debris in the area. More detailed information on this area is provided in Energy Systems 1988d.

HRE Fuel Wells

The HRE fuel wells are located 50 ft south of Trench 5 (Fig. 3.46). The seven auger holes (S1–S7) were used in 1964 for the disposal of residual Homogeneous Reactor Test fuel. The auger holes are 1 ft diam by 17 ft deep, spaced 10 ft apart. These auger holes were used to dispose of 134.7 gal of a four molar sulfuric acid solution containing 10.3 lb of irradiated uranium sulfate (8.8 lb of ^{235}U) (Energy Systems 1988d). A radiological walkover survey performed by Goff in 1991 in this area detected no surface contamination at the well sites. More detailed information on this area is provided in Energy Systems 1988d.

3.6.2.2 Pathway model of contaminant release

According to WAG 2 RI results (Hicks 1996 and Borders et al. 1996), the East Seep subbasin contributes less than 0.1% each of ^{90}Sr and ^{3}H with no significant contribution of ^{137}Cs. The East Seep Tributary is also a ^{60}Co source to the Melton Valley watershed; however, ^{60}Co is no longer a significant risk contributor at WOD.

Portions of Pits 2, 3, and 4, a portion of Trench 5, and the HRE Fuel wells are potential sources of contamination in the East Seep subbasin. Elevated concentrations of ^{60}Co were detected in samples collected from the East Seep weir in 1993 and 1994 (Hicks 1996). The most significant source of groundwater and surface water contamination in this watershed appears to be the eastern one-third of Pit 4. Elevated ^{60}Co activities of 405 and 864 pCi/L were detected in samples collected in 1982 from wells W-83 and W-84, respectively (Spalding 1987). The average ^{60}Co activity in samples collected from seeps SW7-3 and SW7-4 during the WAG 2 RI Seeps Task in 1993 and 1994 were 450 and 106 pCi/L, respectively (Hicks 1996). Low levels of ^{90}Sr were also detected in the wells and in SW7-3. These wells and seeps are located along strike to the east of Pit 4 (Fig. 3.46). As discussed in Sect. 3.6.1.1, rapid seepage occurred on the eastern side of Pit 4 during its operation.

Since Pit 4 is currently perennially unsaturated (see above), a likely release mechanism for ^{60}Co and ^{90}Sr from the pit area is percolation of infiltrating precipitation through seepage pathways established during pit operations and movement of the resulting contaminated water along strike via structurally controlled preferential flow pathways to discharge locations at seeps along East Seep Tributary.

Elevated ^{60}Co concentrations of 197 and 297 pCi/L, respectively, were detected in samples collected from wells WT5-3 and WT5-5 in 1982 (Spalding 1987). Slightly elevated ^{90}Sr activities were also observed in these samples. The likely source of this contamination is Trench 5. The elevation of the bottom of Trench 5 is about 795 ft above MSL and the average groundwater elevation in the area of Trench 5 is approximately 775 ft above MSL. Therefore, Trench 5 is likely perennially unsaturated and the release mechanism from the trench is leaching of contaminants in relict seepage pathways by infiltrating precipitation and subsequent movement of the contaminated water along strike toward discharge locations along East Seep Tributary.

3.6.2.3 Secondary contaminated media

Areas of radiologically contaminated surface soils in the East Seep subbasin are shown on Fig. 3.46. Surface contaminants adjacent to Seepage Pits 2, 3, and 4 and near the mouth of East Seep Tributary originate from the waste liquids permeating the vadose soils during disposal operations. Small, hot spot contaminated areas exist around the Trench 5 site.

Secondary contaminated media in the East Seep subbasin include contaminated soils and groundwater in the seepage pathways between Pits 2, 3, and 4 and East Seep Tributary and contaminated soils and groundwater in the seepage pathways between Trench 5 and East Seep Tributary. Figure 3.44 shows a cross section through Pit 4 and the location of secondary contaminated soils and groundwater originating from Pits 2, 3, and 4. The approximate area of contaminated seepage pathway soils is 6.3 acres (2.5 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 2,700,000 ft^3 (77,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 220,000 ft^3 (6,200 m^3).

3.6.2.4 Human health risk, ecological risk, and criteria exceedances

The COCs for the East Seep subbasin for each of the media are presented based on recreational land use. Risk results are presented based on both recreational and industrial exposure scenarios. Figure 3.47 presents available carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human

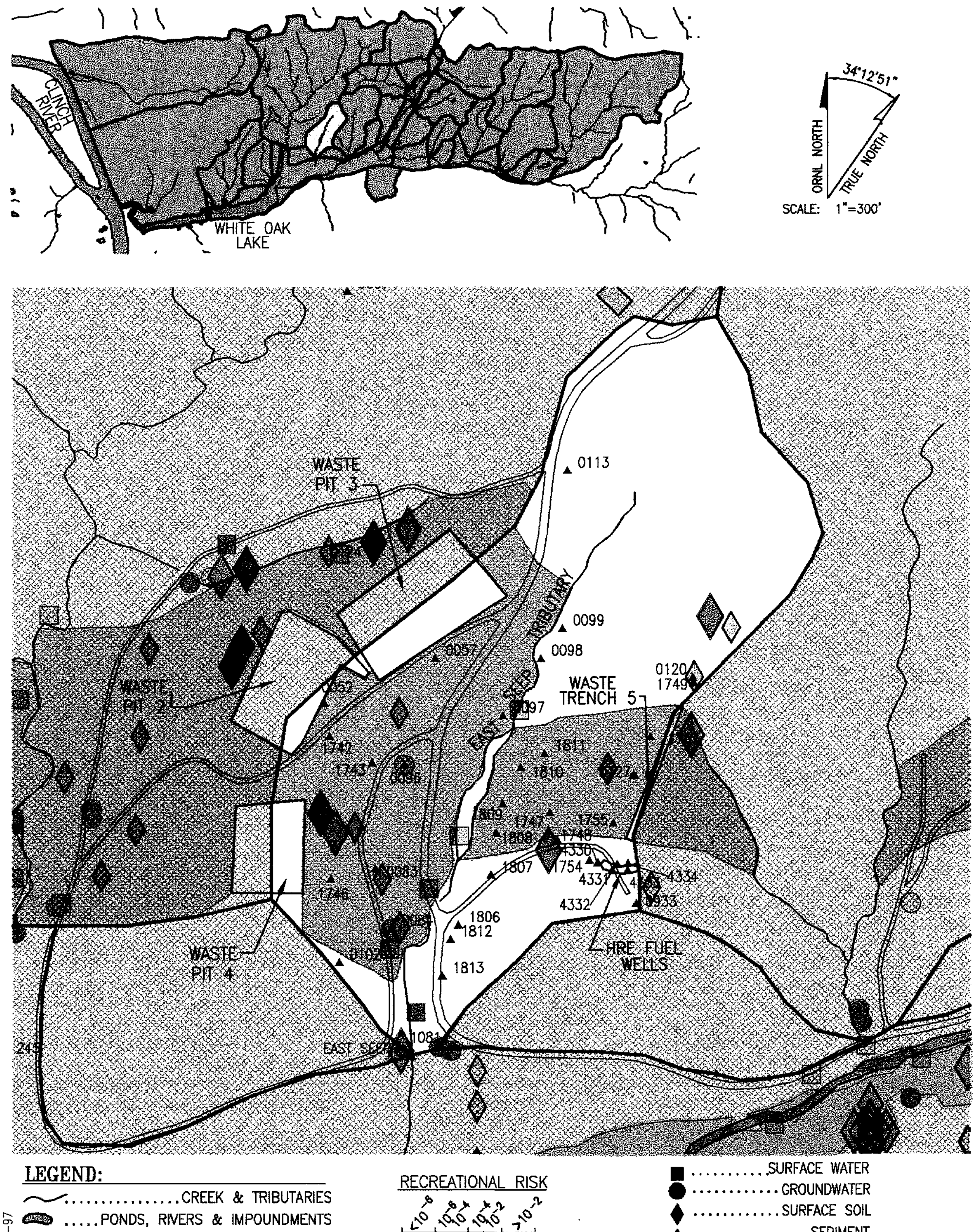

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Fig. 3.47. Risk estimates for sampling locations in East Seep subbasin.

health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.61 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The East Seep subbasin has not been as comprehensively sampled as a number of the other subbasins analyzed in this report; therefore, the associated uncertainty in the risk results and the identified COCs is considered to be high.

Table 3.61. Media data summary for the East Seep subbasin

Subbasin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
East Seep	Groundwater	4	13	8	77	54	152	0
East Seep	Soil	11	118	75	64	53	21	18
East Seep	SW-seeps	4	117	97	839	522	587	22

East Seep Soil

A comprehensive list of contaminants was evaluated in 11 samples of the East Seep soil. Detected radionuclides include ^{137}Cs, ^{228}Th, ^{208}Tl, and ^{60}Co. The total recreational risk based on these contaminants is 2.6E-01. The industrial risk is 1.0E+00. This risk is due almost exclusively to ^{137}Cs, but ^{60}Co, ^{228}Th, and ^{208}Tl were all detected at concentrations that correspond to recreational risk greater than 1E-06. Noncarcinogenic contaminants were analyzed for but none were detected, so an HI was not calculated. Therefore, the recreational COCs in soil for East Seep include ^{137}Cs, ^{60}Co, ^{228}Th, and ^{208}Tl. Residential and industrial COCs can be found in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the East Seep subbasin. Potential risks from exposure to the 19 radionuclides detected in soil were identified for all receptors with HIs ranging from 6.4 for plants to 148 for shrews (Table 3.62). Cesium-137 was the primary risk driver, contributing >99% of the HI for all receptors except turkey. Uranium-233/234 was an additional risk driver for turkeys. Cesium-137 in East Seep soil resulted in the highest soil-related radiological risks identified for terrestrial biota in the Melton Valley watershed. Potential risks from nonradionuclides were identified for plants and shrews (Table 3.62). Thallium and selenium marginally exceeded benchmarks for phytotoxicity. Selenium, barium, and thallium marginally exceeded LOAELs for shrews.

East Seep Sediment

No sediment samples have been collected in the East Seep subbasin; therefore, no carcinogenic or noncarcinogenic risk estimates have been generated and no COCs have been identified for any of the land use scenarios.

Table 3.62. Summary of risks to terrestrial biota from exposure to contaminants *in surface soil at the East Seep subbasin*

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
East Seep	Plants	4.3	Tl (2.5), Se (1.2)	6.4	^{137}Cs (4.2), $^{233/234}$U (2.0)
East Seep	Invertebrates	<0.1		30.9	^{137}Cs (30.8)
East Seep	Shrew	4.0	Se (1.5), Ba (1.2), Tl (1.2)	148.0	^{137}Cs (147.9)
East Seep	Mouse	0.5		122.2	^{137}Cs (122.1)
East Seep	Fox	0.8		108.6	^{137}Cs (108.5)
East Seep	Deer	0.6		50.5	^{137}Cs (50.0)
East Seep	Mink	0.1		92.6	^{137}Cs (92.6)
East Seep	Hawk	0.1		60.3	^{137}Cs (60.3)
East Seep	Turkey	0.1		129.9	^{137}Cs (114.8), $^{233/234}$U (13.5)

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

East Seep Groundwater

Radionuclide, organic, and inorganic contaminants have been sampled at four locations in the East Seep subbasin. The recreational risk is 1.5E-06 and the HI is 1.7E-02. The industrial risk is 1.4E-04 and the HI is 4.7E-02. Since the recreational results do not exceed the target risk range, no recreational COCs are identified for East Seep groundwater. Industrial and residential COCs are presented in Appendix B.

The groundwater data from the East Seep subbasin were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. The criteria exceedances included ^{60}Co and trichloroethylene.

East Seep Surface Water

Up to 26 radionuclide, 9 organic, and 16 inorganic samples have been collected at four surface water seep locations within the East Seep subbasin. The recreational risk at East Seep seeps is 1.8E-05 due to a number of radionuclides and beryllium. The HI for this area sums to 3.9E-02. These values do not exceed the target risk range; therefore, no recreational surface water COCs are identified for East Seep surface water. The industrial risk is 1.4E-03 and the HI is 7.9E-01.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the East Seep subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from the East Seep subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for East Seep plants assumed to be exposed to seep water in soil solution (Table 3.11). Thallium exceeded plant soil solution benchmarks at station SW7-4 (HQ = 14.5) and SW7-7 (HQ = 8.1). The thallium benchmark appears to be conservative as thallium exceeded benchmarks at numerous seeps across the whole watershed. Frequency of detection of thallium was generally low. Other analytes marginally exceeding benchmarks (HQs <5) at least one station were arsenic, aluminum, chromium, and manganese. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

The contaminant surface water concentrations for the East Seep subbasin were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. No exceedances were observed for the human health or ecological criteria.

3.6.2.5 Options for release mechanism intervention

The most significant source of groundwater and surface water contamination in the East Seep subbasin appears to be the eastern portion of Pits 2, 3, and 4. Trench 5 is also a significant source of contamination in this subbasin. COCs being released from the area include ^{90}Sr, ^{60}Co, and ^{155}Eu.

The Seepage Pits and Trenches are closed and asphalt capped. Portions of these source units may be subject to seasonal wetting. Contaminants are probably being released from these sources by infiltration of rainwater through relict seepage pathways (secondary sources). Therefore, stabilization/remediation options for this subbasin are source treatment or removal, in situ stabilization of soils in seepage pathways, and hydrologic isolation of secondary sources in seepage pathways.

3.6.3 WC TRIB-1 and ^{60}Co Seep Subbasins

The WC TRIB-1 subbasin encompasses 34.5 acres and receives surface water and groundwater contributions from the eastern edge of Trench 5 and the HRE fuel wells, the western sides of Trenches 6 and 7, and three waste transfer pipeline leak sites. The ^{60}Co Seep subbasin encompasses 7.1 acres and receives surface runoff and groundwater seepage from the eastern side of Trench 7 and from a waste transfer pipeline leak site. Figure 3.48 shows the WC TRIB-1 subbasin and the ^{60}Co Seep subbasin, contaminant sources, and monitoring locations.

3.6.3.1 Contaminated sites

The WC TRIB-1 contains eight contaminated sites: (1) Trench 6, (2) Trench 7, and (3) LLLW lines and leak sites and portions of Pilot Pits 1 and 2 and Building 7811. These waste units represent waste disposal trenches and pipeline leak/spill sites. The following sections will discuss the sources, releases, contaminant transport pathways, media of concern, and human and ecological risk for these areas.

Trench 6

Trench 6 was constructed in 1961 just south of SWSA 4 (Fig. 3.48) with a variation on the Trench 5 design; it was longer and had a pronounced curved shape that followed topography. The site was selected based on its proximity to the end of the LLLW transfer pipeline with no

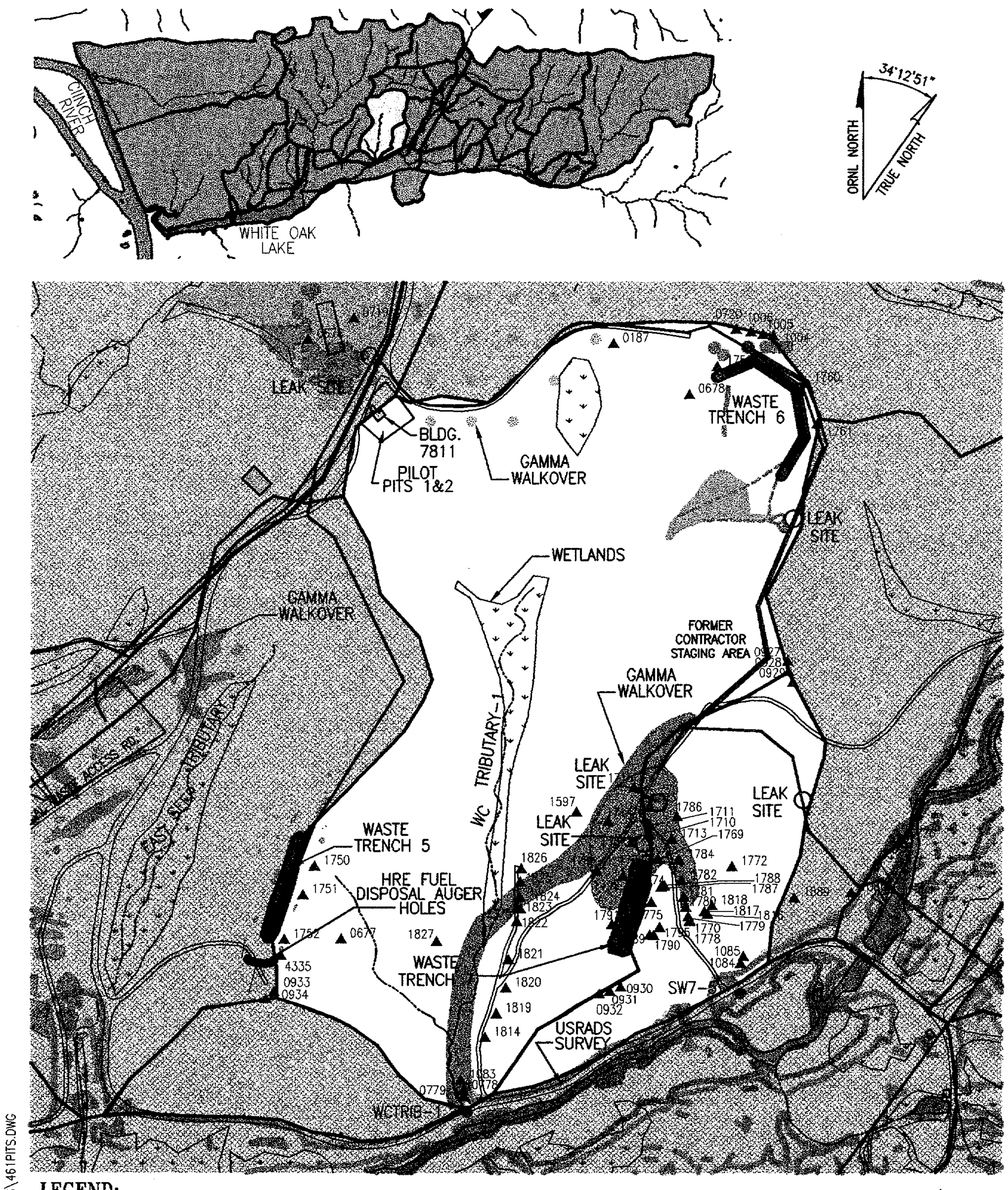

Fig. 3.48. WOC Tributary 1 and ^{60}Co Seep subbasins, contaminant sources, and monitoring locations.

preconstruction characterization of the site. The trench was pretreated with copper sulfate to reduce the mobility of ^{106}Ru present in the LLLW.

The first waste was transferred into Trench 6 in September 1961 via a 2-in.-diam cast iron pipeline connected to the waste transfer pipeline that serviced Pits 2, 3, and 4. The trench was removed from service on October 10, 1961, after a large seep (0.15 gpm) south of the trench was discovered. It was hypothesized that the seep was probably flowing through fissures in the rock. During the one month of operation of this trench it received 130,000 gal of waste containing 1,335 Ci of activity (Energy Systems 1988d). The trench was covered with an asphalt cap in 1981.

A 1989/1990 radiological walkover survey (Uziel et al. 1991) in this area identified trees at the south end of Trench 6 contaminated with ^{90}Sr, indicating that the tree roots are reaching the secondary soil contamination present due to the leaching of the LLLW from the trench. It was also noted that the beta activity present in the leaf litter and surface soil indicate that the decaying leaves are depositing measurable contamination on the ground surface. More detailed information on this area is provided in Energy Systems 1988d.

Trench 7

Trench 7 was constructed in 1962, 1000 ft south of Trench 6 (Fig. 3.48). Trench 7 was designed to consist of three separate cells to prevent loss of the entire disposal capacity of the trench if a geologic feature is encountered that causes excess seepage, as occurred with Trench 6. Only two of the cells were constructed after preconstruction monitoring established that the bottom of the third cell would be near the water table. The other design characteristics are similar to Trench 5 with each cell being 100 ft long, 10.5 ft wide with a depth of 16 ft. The trench was pretreated with sodium hydroxide to reduce the mobility of ^{106}Ru present in the LLLW.

The first waste was transferred into Trench 7 in October 1962 via a 2-in.-diam PVC pipeline connected to the waste transfer pipeline that serviced Trench 6 and OHF. Trench 7 was used until April 1966 when hydrofracture operation commenced. During its operation, it received 9,500,000 gal of waste with an activity level of 1,000,000 Ci. In 1970 the trench was covered with an asphalt cap. However, in 1985 and 1986 the asphalt cap was extended and a grout curtain was installed north of the trench to better control surface water runoff and reduce groundwater infiltration into the waste.

There is one known seep associated with Trench 7 that is located in an ephemeral stream on the eastern side of the trench that flows into WOC. More detailed information on this area is provided in Energy Systems 1988d.

LLLW Line and Leak Site–Gauging Station NW of Building 7852

This leak site is located on the cast iron pipeline extension between Trenches 6 and 7 and the OHF site, as shown on Fig. 3.48. The leak occurred July 9, 1970, at a pipe joint, which resulted in seepage of LLLW on a small surface area. Subsequently, the contaminated surface soils were transported into WOC via runoff in the area. Additional groundwater monitoring wells installed in this area also indicated that the leak had contributed to local groundwater contamination. Thus, in July and August 1973, contaminated soil was removed from the area and placed in SWSA 6 (Energy Systems 1988d).

During a 1979 survey of the pipeline, it was discovered that surface soil contamination still existed in this area. In May 1983 the leak site was covered with an asphalt cap to prevent further erosion and leaching from this surface soil contamination area. More detailed information on this area is provided in Energy Systems 1988d.

LLLW Line and Leak Site–Southeast of Trench 6

This leak site is located on the cast iron pipeline extension between Trench 6 and Trench 7, 150 ft south of Trench 6 (Fig. 3.48). This leak was identified during a survey of the area in July 1973—the exact date the leak occurred is unknown. Liquid waste had seeped out of a loose pipe joint and resulted in a small area of surface soil contamination. The joint was repaired, contaminated soil removed, and the area was backfilled with clean soil.

During a 1979 survey of the pipeline, it was discovered that surface soil contamination still existed in this area. In May 1983, the leak site was covered with an asphalt cap to prevent further erosion and leaching from this surface soil contamination area. More detailed information on this area is provided in Energy Systems 1988d.

LLLW Line and Leak Site–End of Trench 7 Access Road

The leak site is on the PVC pipeline extension from Trench 6 to Trench 7 located 100 ft north of Trench 7 (Fig. 3.48). The leak occurred on April 1966 during a routine waste transfer to Trench 7 when the pipeline ruptured, which resulted in a release of approximately 3000 gal of LLLW onto the ground surface. The surface contamination was covered with approximately 5 ft of soil and the area was contoured to reduce rainfall infiltration and leaching of contaminants into the surface water. A 1987 radiological walkover survey of the area (Williams et al. 1988) indicated that approximately 0.75 acre of contaminated surface area was still present at the site. No corrective actions have been undertaken. More detailed information on this area is provided in Energy Systems 1988d.

LLLW Line and Leak Site–Valve Pit North of Trench 7

The leak site is at a valve pit located on the cast iron pipeline extension from Trench 7 to OHF, just north of Trench 7 (Fig. 3.48). A 1987 radiological walkover survey of the area (Williams et al. 1988) indicated primarily low levels of gamma activity at the ground surface. Backfill soil was present at the site as a result of past excavation activities (i.e., pipeline repair and/or replacement). No corrective actions have been undertaken. More detailed information on this area is provided in Energy Systems 1988d.

3.6.3.2 Pathway model of contaminant release

WC TRIB-1. Limited WAG 2 RI data (Hicks 1996) indicate that before the Seeps C and D removal actions, ^{90}Sr and ^{3}H contributions were less than 0.5% each. There is no significant ^{137}Cs contribution from the WC TRIB-1 subbasin.

^{60}Co Seep. WAG 2 RI data (Hicks 1996 and Borders et al. 1996) indicate no significant contribution of ^{90}Sr, ^{3}H, or ^{137}Cs. However, this seep is a significant source of ^{60}Co (which is no longer a significant risk contributor at WOD). Trench 7 is the source of the ^{60}Co measured at this location.

Potential groundwater and surface water contamination sources in the WC TRIB-1 and ^{60}Co Seep subbasins include a portion of Trench 5, Trench 6, Trench 7, and three ILLW line leak sites. The most significant contaminant releases in these two subbasins are the ^{90}Sr release from Trench 6 and the ^{60}Co release from Trench 7.

A ^{60}Co activity of 999 pCi/L was found in a sample collected in 1985 from well T5-3, located about 50 ft to the east of Trench 5 (Spalding 1987). As discussed in Sect. 3.6.2.1, the probable release mechanism from Trench 5 is leaching of contaminants in relict seepage pathways by infiltrating precipitation and subsequent movement of the contaminated water eastward along strike.

The most significant release of ^{90}Sr from the pits and trenches area is occurring from Trench 6 into the WC TRIB-1 subbasin. A ^{90}Sr activity of 1458 pCi/L was measured in a sample collected in 1985 from well T6-7, located about 35 ft to the southwest of the northern portion of Trench 6. Furthermore, the highest ^{90}Sr concentrations in seeps in the pits and trenches area have been observed in seep SW7-6, located about 125 ft to the southwest of Trench 6. During the WAG 2 RI Seeps Task sampling in 1993 and 1994, the average ^{90}Sr concentration in samples from this seep was 1118 pCi/L (Hicks 1996).

The approximate elevation of the bottom of Trench 6 is 835 ft above MSL. The average groundwater elevation is about 835 ft above MSL in the vicinity of the northern part of Trench 6. Therefore, the most probable release mechanism for ^{90}Sr from Trench 6 is direct leaching of the sludges in the trench and/or the contaminated soil and weathered shale around the bottom and sides of the trench by groundwater, with subsequent movement along strike to the west and down the hydraulic gradient to the southwest to SW7-6, and possibly other unidentified discharge locations. However, ^{90}Sr activities observed at stream transect location WC TRIB-1, which is the surface water discharge location for this subbasin, were near detection levels (around 37pCi/L) during 1993 (Hicks 1996).

Some ^{60}Co is moving out of Trench 7 along strike to the west in the WC TRIB-1 subbasin, as evidenced by the detection of 6615 pCi/L of ^{60}Co in a sample collected in November 1982 from well T7-5, located about 45 ft west of Trench 7. An elevated ^{60}Co activity of 1080 pCi/L was also detected in 1982 in well WT7-3, located about 300 ft southwest of Trench 7 and 75 ft east of the WC TRIB-1 tributary. No discrete seeps with elevated ^{60}Co activities have been identified along this tributary, although part of the ^{60}Co detected in samples collected from the WC TRIB-1 stream location (see above) may be attributable to release from Trench 7. A much greater release of ^{60}Co is moving eastward from Trench 7 into the ^{60}Co Seep subbasin and is discharging at seep SW7-5 in the floodplain to the north of WOC (Fig. 3.48). The average ^{60}Co concentration in samples collected from this seep during 1993 and 1994 was 2475 pCi/L, the highest ^{60}Co activity detected in any seep in the Melton Valley watershed (Hicks 1996). The major radionuclides found in Trench 7 area groundwater are ^{60}Co, ^{3}H, and ^{99}Tc (Table 3.63).

Technetium-99 activities are strongly correlated with ^{60}Co activities in these groundwater samples; ^{3}H activities were less strongly correlated with ^{60}Co activities. Although ^{90}Sr and ^{137}Cs were the principal radionuclides disposed of in Trench 7, their activities in groundwater around the trench have remained extremely low. The relative immobility of ^{90}Sr may be attributed to chemical treatments of the sludge to maintain its alkalinity and promote the formation of strontium carbonates and phosphates. The lack of mobility of ^{137}Cs is probably due to its strong adsorption by illite, which is the dominant clay mineral in Conasauga soils and weathered bedrock in the area. Concentrations of nonradiological constituents of the waste liquids disposed of in Trench 7, including Na^{+}, Ca^{2+}, Cl^{-},

NO_3^- and SO_4^{2-}, correlate well with radionuclide activities in Trench 7 area groundwater. Elevated pH and total alkalinity were also observed in groundwater samples from wells to the east of the north end of the trench (T7-3, T7-24, T7-25, and T7-13), indicating that alkalinity is being reduced from trench sludges and/or from relict seepage pathways. This reduction of alkalinity could result in mobilization of ^{90}Sr in the future.

Table 3.63. Concentrations of radionuclides in Trench 7 area groundwater

Well	^{60}Co (pCi/L)	^{3}H (pCi/L)	^{99}Tc (pCi/L)
T7-3	21,600	197,100	24,530
T7-5	6,615	13,230	7,290
T7-13	35,910	251,100	17,820
T7-20	16,200	159,300	4,590
T7-21	50,220	810,000	99,900
T7-22	22,410	324,000	13,500
T7-23	0	351,000	0
T7-24	29,700	240,300	13,500
T7-25	8,370	56,700	6,750
T7-27	0	56,700	1,107

Vertical gamma activity profiles in the soil and weathered bedrock were measured in wells drilled to the east of Trench 7 in 1982. The gamma log for well T7-20, located about 30 ft east of Trench 7 (Fig. 3.48), showed three large gamma peaks occurring in discrete layers above the groundwater table. The largest of the peaks occurred at a depth of about 16 ft, which is coincident with the bottom of the trench. The largest gamma peak in well T7-24, located about 100 ft east of Trench 7, occurs at a depth of about 30 ft, which is just below the groundwater table. In general, the wells that show the greatest groundwater contamination are also those in which the greatest gamma peaks occurred below the groundwater table (Olsen et al. 1983). The gamma peaks probably represent relict seepage pathways that were active during trench operations. They may also serve as active contaminant migration pathways and secondary sources, especially during storms and high water table conditions. These pathways appear to be associated with strike-oriented (roughly east-west) structural features such as folds, fractures, and faults.

Radionuclide activities in wells to the east of the northern end of the trench rise during the spring and after periods of prolonged rain. The rise in nuclide activities in these wells is also associated with a rise in groundwater levels and pH. These observations suggest that contamination is being leached during high water table conditions during the spring and after prolonged rainfall when either (1) the groundwater level rises and intersects relict seepage pathways and/or trench sludges, or (2) infiltrating precipitation percolates through or along contaminated soil/weathered bedrock before recharging groundwater.

A groundwater sample collected in November 1982 from well T7-26, located approximately 115 ft to the north of Trench 7, contained an elevated ^{90}Sr activity of 1593 pCi/L. This well did not contain elevated concentrations of ^{60}Co, ^{99}Tc, Na^+, Ca^{2+}, NO_3^-, or SO_4^{2-}, which are typical of groundwater contaminated by trench seepage (see above). A possible source for the ^{90}Sr found in this well is a low-level line leak site located about 35 ft northeast of the well. However, this leak site and well T7-26 are both located in the ^{60}Co Seep subbasin and no surface water discharges of ^{90}Sr have been observed in this subbasin.

3.6.3.3 Secondary contaminated media

Areas of radiologically contaminated surface soil indicated by gamma exposure walkover surveys are shown on Fig. 3.48. The principal areas that exceed the recreational scenario exposure threshold are located near LLW pipeline leak sites near Trenches 6 and 7, at seepage breakout locations near Trenches 6 and 7, and near the cobalt seep.

Secondary contaminated media in the WC TRIB-1 and ^{60}Co Seep subbasins include soils and groundwater in the ^{90}Sr seepage pathway between Trench 6 and the WC TRIB-1 tributary; soils and groundwater in the seepage pathways between Trench 7 and the ^{60}Co seep to the east and between Trench 7 and the WC TRIB-1 tributary to the west; soils and groundwater in seepage pathways between Trench 5 and the WC TRIB-1 tributary; and contaminated soils at the spill site to the south of Trench 6 and at the leak site to the east of Trench 7. The approximate area of contaminated Trench 6 ^{90}Sr seepage pathway soils is 1.25 acres (0.5 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 540,000 ft^3 (15,000 m^3). The approximate area of contaminated seepage pathway soils between Trench 7 and the ^{60}Co seep and between Trench 7 and the WC TRIB-1 tributary is 4.4 acres (1.8 ha); the average thickness of these soils is about 8.5 ft (2.6 m); and their approximate volume is 1,600,000 ft^3 (46,000 m^3). The approximate area of contaminated seepage pathway soils between Trench 5 and the WC TRIB-1 tributary is 1.25 acres (0.5 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 540,000 ft^3 (15,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 1,800,000 gal (6,800 m^3). The approximate area of contaminated soils at the spill site south of Trench 6 and at the leak site east of Trench 7 is 2 acres (0.8 ha), with an average thickness of 3 ft (0.92 m), and an approximate volume of 260,000 ft^3 (7,400 m^3).

3.6.3.4 Human health risk, ecological risk, and criteria exceedances

The COCs for the WC TRIB-1 and ^{60}Co Seep subbasins for each media are presented based on recreational land use. Risk results are presented for recreational and industrial receptors. Figure 3.49 presents available carcinogenic risk results by sample location for each of the four media.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.64 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the five media discussed in this report. The subbasins within the WC TRIB-1 and ^{60}Co Seep subbasins have not been as comprehensively sampled as a number of the other subbasins analyzed in this report; therefore, the associated uncertainty in the risk results and the identified COCs is considered to be high.

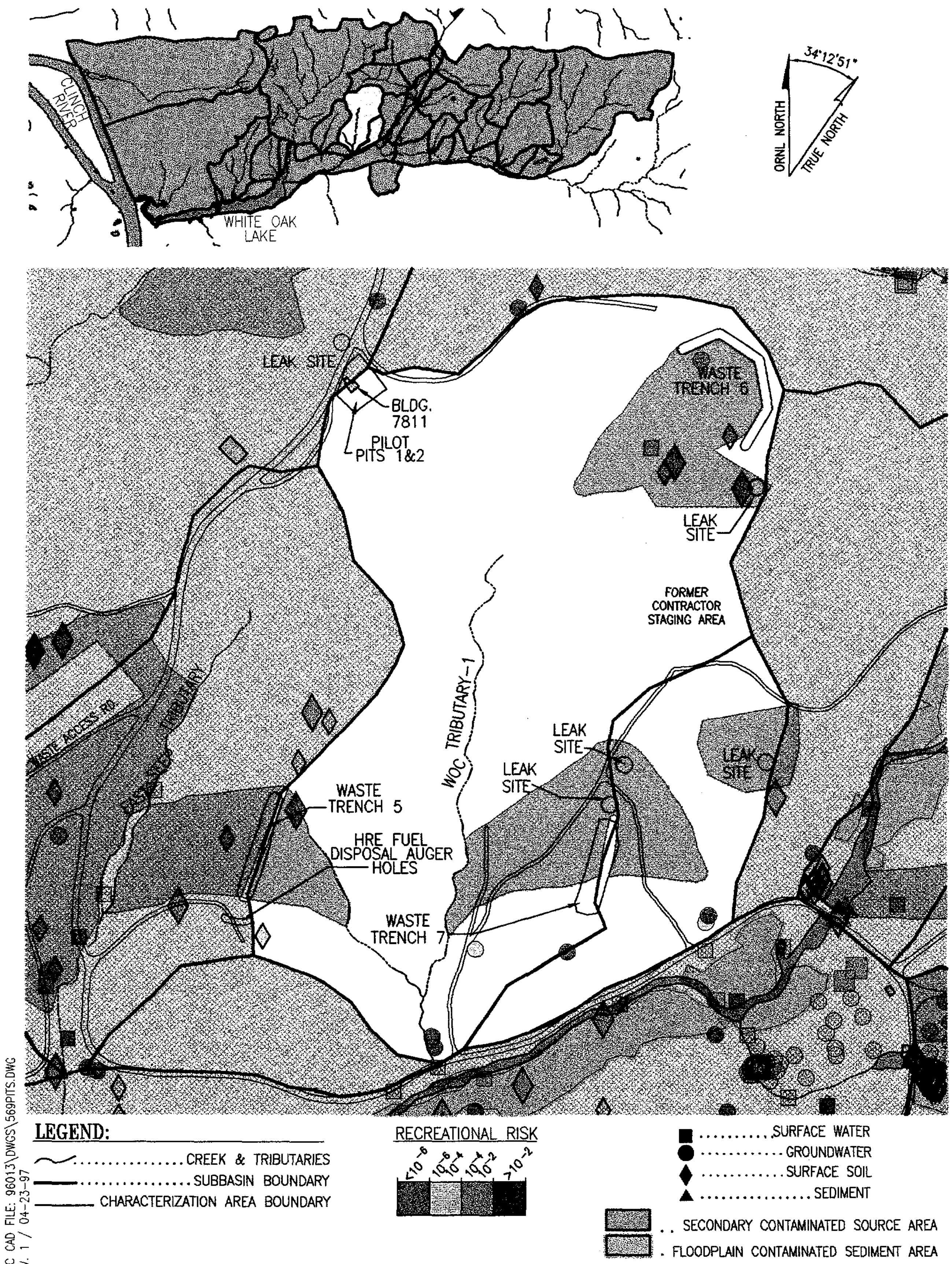

Fig. 3.49. Risk estimates for sampling locations in WOC Trib 1 and ^{60}Co Seep subbasins.

Table 3.64. Media data summary for the WC TRIB-1 and ^{60}Co Seep subbasins

Subbasin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
WC TRIB-1	Groundwater	8	89	66	355	195	789	11
WC TRIB-1	Sediment	2	0	0	53	43	0	0
WC TRIB-1	Soil	6	31	31	0	0	0	0
WC TRIB-1	SW-seeps	1	17	14	90	33	154	5
^{60}Co Seep	Groundwater	6	136	98	543	319	1345	32
^{60}Co Seep	Sediment	1	0	0	45	40	55	0

WC TRIB-1 and ^{60}Co Seep Soil

Six soil samples in WC TRIB-1 were analyzed for ^{137}Cs and ^{60}Co. These contaminants yield a recreational risk of 4.3E-03 and an industrial risk of 9.0E-02; both are identified as COCs for this subbasin. Noncarcinogenic contaminants were not analyzed in WC TRIB-1, and soil samples are not available for the ^{60}Co Seep subbasin. Therefore, the COC list for the WC TRIB-1 and ^{60}Co Seep subbasin is limited to ^{137}Cs and ^{60}Co.

Risks to terrestrial biota were evaluated for radionuclides in soil in the WC TRIB-1 subbasin. Nonradionuclide data were unavailable. Potential risks from exposure to the three radionuclides detected in soil were identified for shrews, mice, foxes, turkeys, and mink with HIs ranging from 1.3 for mink to 2.0 for shrews (Table 3.65). Cesium-137 was the primary risk driver, contributing >80% of the HI for all receptors.

Table 3.65. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at WC TRIB-1 and ^{60}Co subbasins

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
WC TRIB-1	Shrew	NA		1.8	^{137}Cs (1.8)
WC TRIB-1	Mouse	NA		1.5	^{137}Cs (1.5)
WC TRIB-1	Fox	NA		1.3	^{137}Cs (1.3)
WC TRIB-1	Mink	NA		1.1	^{137}Cs (1.1)
WC TRIB-1	Turkey	NA		1.5	^{137}Cs (1.4)

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

WC TRIB-1 and ^{60}Co Seep Sediment

Two samples in WC TRIB-1 were analyzed for a number of inorganic constituents, and one sample in the ^{60}Co Seep subbasin was analyzed for inorganic and organic contaminants. None of the samples in this subbasin have radionuclide results. None of the contaminants that were detected passed the risk assessment screening steps; therefore, there are no COCs identified for the sediments of this subbasin.

Potential risks were identified for benthic invertebrates exposed to contaminated sediment in the WC TRIB-1 and ^{60}Co Seep subbasins. However, no COECs were identified, and antimony was the only analyte presenting even a marginal risk. No other analytes were of potential concern.

WC TRIB-1 and ^{60}Co Seep Groundwater

Radionuclide, organic, and inorganic contaminants have been sampled at eight locations in the WC TRIB-1 subbasin and at six locations in the ^{60}Co Seep subbasin. The recreational risk for the WC TRIB-1 is 2.8E-06 and the HI is 3.5E-02. The industrial risk is 2.6E-04 and the HI is 1.7E-01. At the ^{60}Co Seep, the recreational risk is 1.7E-06 and the HI is 1.1E-02. The industrial risk is 1.1E-04 and the HI is 1.1E-01. Since no recreational results exceed the target risk range, no recreational COCs are identified for the groundwater in the WC TRIB-1 and ^{60}Co Seep subbasins. Industrial and residential COCs are presented in Appendix B.

The groundwater data from the WC TRIB-1 and ^{60}Co Seep subbasins were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. WC TRIB-1 exceedances were noted for ^{90}Sr and ^{137}Cs. Hydrogen-3 was the only contaminant with an exceedance for the ^{60}Co Seep subbasin.

WC TRIB-1 and ^{60}Co Seep Surface Water

A seep in the WC TRIB-1 subbasin was sampled for a comprehensive list of inorganics, organics, and radionuclides. No surface water locations were sampled in the ^{60}Co Seep subbasin. Strontium-90 detects were primarily responsible for the total recreational risk of 6.4E-06 in WC TRIB-1 and the HI summed to 1.6E-03. The industrial risk is 4.7E-04 and the HI is 1.1E-02. The recreational results do not exceed the target risk range; therefore, no recreational surface water COCs are identified for WC TRIB-1 or for the ^{60}Co Seep subbasins.

No risks were identified for terrestrial wildlife drinking surface water from the WC TRIB-1 subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for WC TRIB-1 plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum marginally exceeded plant soil solution benchmarks at station SW7-6 (HQ = 3.9). The aluminum benchmark appears to be conservative because it is below the background concentration, and average aluminum concentration at this station was below background. No other analytes exceeded benchmarks at this station. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. Aluminum is unlikely to be of ecological concern in plants at this station.

The contaminant surface water concentrations for the WC TRIB-1 and ^{60}Co Seep subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. No exceedances were observed for either the human health or the ecological criteria at these subbasins.

3.6.3.5 Options for release mechanism intervention

The most significant contaminant releases in these subbasins are the ^{90}Sr release from Trench 6 and the ^{60}Co release from Trench 7. COCs being released from the area include ^{90}Sr and ^{60}Co.

Comparison of groundwater level measurements and the elevation of the bottom of Trench 6 indicates that the northern part of Trench 6 may be saturated under high water table conditions. The northern part of Trench 7 may also be transiently saturated. Releases from these trenches are probably occurring when the groundwater level rises and intersects trench sludges and/or relict seepage pathways or when infiltrating rainwater percolates through contaminated soils in seepage pathways. Therefore, stabilization/remediation options for this subbasin are source removal, in situ stabilization of trench sludges and/or soils in seepage pathways, and hydrologic isolation of secondary sources in seepage pathways.

3.6.4 SWSA 6 Drainages

SWSA 6 is located in Melton Valley on the western portion of ORR. It is bordered on the south by WOL, on the east by West Seep Tributary, and on the west by Tennessee State Highway 95. SWSA 6 lies approximately 2 miles southwest of the ORNL main plant area. SWSA 6 covers a 68-acre area and composes the majority of WAG 6. Inactive waste units at the site include trenches, auger holes, and silos. Figure 3.50 shows the location of the various waste units within SWSA 6.

Mass balance calculations of the difference in ^{90}Sr and ^{3}H contributions between WOD and WOC plus MB are used to determine the total mass flux in the lower WOC/WOL reach (otherwise known as the source term for this reach). This is confirmed by the sum of the contributions of ^{3}H from the basins in SWSA 6 (primarily FB and DA). The total ^{3}H mass flux for this reach is generally attributed to SWSA 6.

3.6.4.1 Contaminated Sites

SWSA 6 contains more than 400 trenches, approximately 146 of which have been identified as containing RCRA wastes. Trenches were divided into the following categories, depending on the type of waste placed within: (1) high-activity, (2) low activity, (3) biological, (4) asbestos, (5) baled, (6) fissile, (7) high-activity concrete-lined, and (8) low-activity concrete-lined. Trenches were used for disposal of large waste packages and assorted bulky items. The trenches varied in size and dimensions, but most were approximately 50 ft × 10 ft × 13 to 20 ft deep and were spaced approximately 5 ft apart. When the waste level reached within 3 ft of the top of the trench, the trench was backfilled with soil and seeded to minimize erosion (DOE 1995f).

Unlined auger holes were used for disposal of small packages of high-activity, low-level waste—producing surface activities exceeding 200 mrem/h. Approximately 220 auger holes are believed to contain RCRA wastes. Auger holes are divided into the following three categories; (1) fissile, (2) high-activity, and (3) solvent. Auger holes generally measure from about 1 to 4 ft in diameter and 20 ft in depth, and are spaced about 3 ft apart (DOE 1995f).

The silos were concrete-lined waste disposal units used for disposal of low-level waste. The concrete provided greater confinement for radioactive waste than unlined auger holes and trenches. A typical concrete silo was constructed of two corrugated steel or iron pipes arranged concentrically. Concrete filled the annular space between the pipes. A 12- to 18- in.-thick, wire-reinforced, concrete pad forms the bottom of the silo. The majority are equipped with 3-in.-diam monitoring wells for detection and sampling of waste leachates.

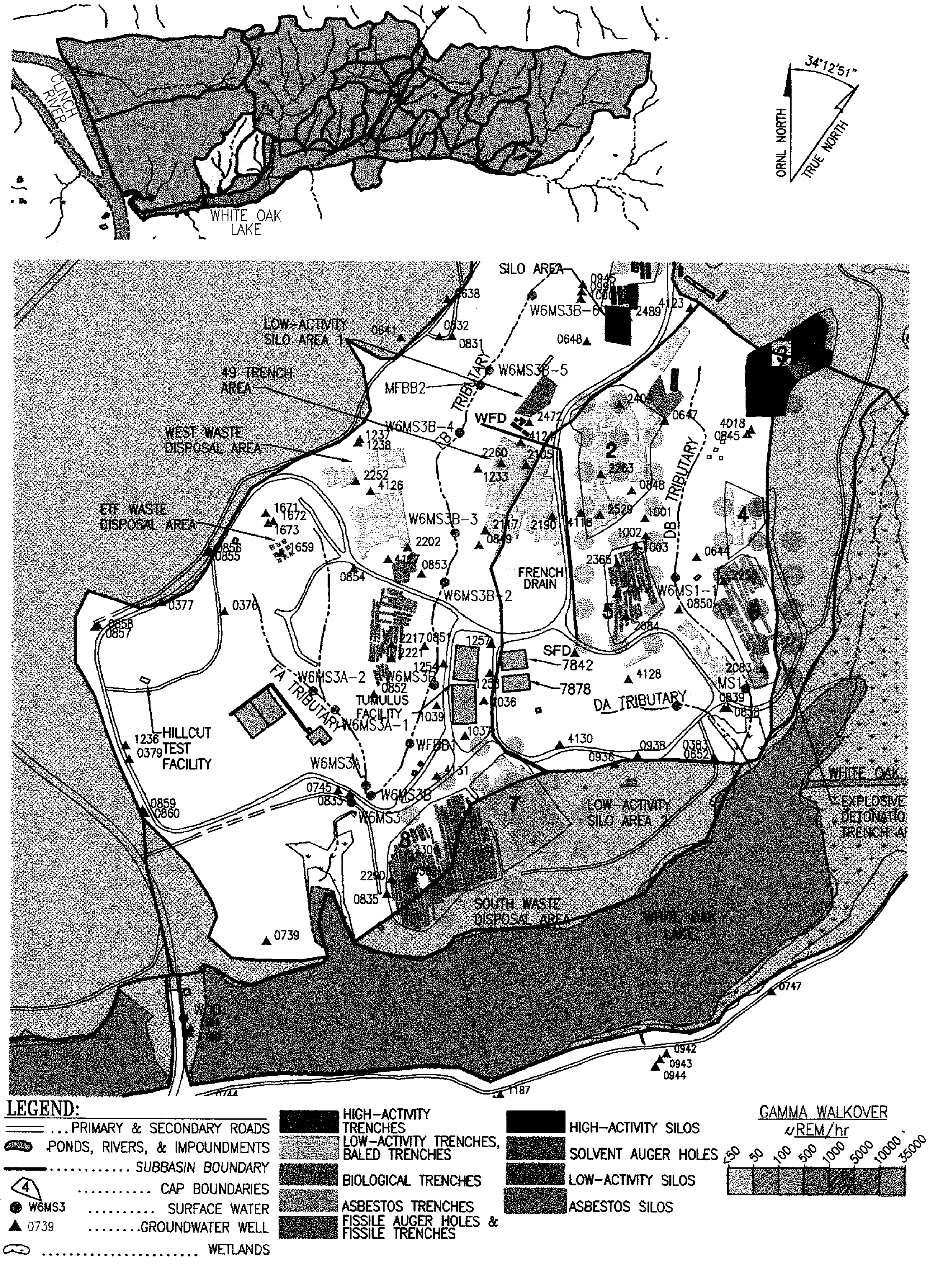

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Fig. 3.50. SWSA 6 subbasins, contaminant sources, and monitoring locations.

3.6.4.2 Pathway model of contaminant releases

W6MS1. Potential sources of groundwater and surface water contamination in this watershed include the Cap 2 low-activity trenches, the western part of the Cap 3 high-activity silos, the Cap 4 low-activity trenches, the eastern 49 Trench area, the Cap 5 biological trenches, the Cap 6 asbestos trenches, and the fissile auger holes and trenches adjacent to the Cap 2 area (Fig. 3.50).

The major ^{3}H sources in this watershed appear to be the Cap 2 low-activity trenches and the eastern 49 Trench area. A sample collected from well 848, located in the Cap 2 area directly downgradient from the trenches, contained a ^{3}H activity of 4,915,964 pCi/L, the highest ^{3}H activity of any well in the interior of SWSA 6 (DOE 1995e). In addition, a sample collected in 1994 from the FRENCH DRAIN S outfall at the southern end of the east leg of the French Drain had a ^{3}H activity of 8,739,300 pCi/L. The French Drain captures water from the 49 Trench area, from the Cap 2 area, and from the Cap 5 area. Significantly elevated tritium activities have been observed in groundwater from the 49 Trench area (wells 849 and 1233) and from the Cap 2 area (well 848), but not in groundwater from the Cap 5 area. Discharge from the east leg of the French Drain ultimately drains to the DA Drainage (Fig. 3.50). The average ^{3}H activity in three samples collected in 1993 from surface water sampling point WAG6MS2, located on the DA Drainage (Fig. 3.50), was 2,513,000 pCi/L. Therefore, it appears that ^{3}H is moving from the 49 Trench and Cap 2 areas to the French Drain, and thence to the DA Drainage and WOC.

The 49 Trench area, the Cap 2 area, and, possibly, the Cap 5 biological trenches also appear to be sources of VOCs in groundwater. As discussed above, the French Drain captures water from the 49 Trench area, the Cap 2 area, and the Cap 5 area. The VOCs 1,2-dichloroethylene (1,2-DCE), trichloroethylene (TCE), and PCE were detected at concentrations of 320, 770, and 81 μg/L in a sample collected from the FRENCH DRAIN S outfall in 1994 (DOE 1995e). These VOCs were observed at elevated concentrations in groundwater from the 49 Trench area (wells 849 and 1233) and from the Cap 2 area (well 848); however, elevated VOC concentrations were not found in groundwater from well 850, downgradient of the Cap 5 area. Slightly elevated concentrations of 1,2-DCE (1.57 μg/L) and TCE (1.47 μg/L) were detected in surface water samples collected in 1994 from the DA Drainage (DOE 1995e). Therefore, it appears that VOCs are moving from the 49 Trench area and the Cap 2 area to the east leg of the French Drain, and from the French Drain to the DA Drainage.

During the WAG 6 RFI (Energy Systems 1991), trench bottom elevations were compared with high water table elevations measured in February 1990 to characterize trench interactions with shallow groundwater. Based on this comparison, trenches were classified as unsaturated, intermittently saturated, or inundated. The mean maximum water table fluctuation in SWSA 6 is about 6.7 ft. If, during the wet season, the water table was greater than 6.7 ft above the bottom of the trench, the trench was assumed to remain inundated during the dry season; however, if the trench bottom was less than 6.7 ft below the water table during the wet season, the trench was assumed to be intermittently saturated. Trenches that were unsaturated during the wet season were assumed to remain so during the dry season.

Based on the analysis described above, trenches in the eastern portion of the 49 Trench area were determined to be predominantly unsaturated, with the trenches in the south-central portion of the area being intermittently saturated. Trenches in the central part of the Cap 2 area were determined to be unsaturated; trenches in the northeastern and southern parts of the area were found to be intermittently saturated; and a small number of trenches in the extreme northeastern part of the

Cap 2 area were found to be perennially saturated. Therefore, probable release mechanisms from unsaturated trenches in the eastern part of the 49 Trench area are leaching of trench contents by precipitation directly infiltrating into the trenches and/or water moving laterally into the trenches in the stormflow zone, with subsequent movement of contaminated water through the unsaturated zone to the water table. In the central part of the Cap 2 area, direct infiltration does not occur through the cap; therefore, the primary release mechanism in this area is probably leaching of trench contents by water entering the trenches via the stormflow zone from recharge areas outside of the cap. During saturated conditions, contaminants are likely leached from trench contents by direct interaction with groundwater.

The majority of groundwater flow in SWSA 6 occurs in the upper 50 to 100 ft of the saturated zone. Figure 3.51 is a north-south cross section of SWSA 6 showing primary and secondary contaminant sources and seepage pathways. Contaminant transport in the saturated regolith occurs in a combination of matrix porosity and secondary porosity features (i.e., fractures) and is expected to occur primarily along mapped hydraulic gradients; however, flow in the deeper, less weathered regolith and bedrock is expected to occur primarily along fractures and bedding planes and be strike-parallel. In general, groundwater follows short flow paths, flowing from recharge areas at higher elevations to discharge along surface water drainages. Therefore, contaminated water from trenches in the eastern 49 Trench area and the Cap 2 area should flow either to the east along strike or to the south along the hydraulic gradient to discharge locations along the DA and DB drainages.

W6MS1. Most surface water contamination (^{3}H) in this basin attributable to the DA (west) tributary and releases from the South French Drain (DOE 1995a). Potential sources include the 49 Trench area, Low-Activity Silo area, and SWMUs 6.01s and 6.01f. The W6MS1 basin contributes approximately 2.4% of the total ^{3}H at WOD. Contributions of ^{90}Sr and ^{137}Cs are insignificant.

W6MS3. Potential sources of groundwater and surface water contamination in this watershed include the high activity trenches under Cap 1 and north of Cap 1, the high activity silos south of Cap 1, the western half of the 49 Trench area, the western low-activity trenches, the western biological trenches, the tumulus facility, the Interim Waste Management Facility, and the northern portion of the Cap 8 biological trenches (Fig. 3.50).

The major source of ^{3}H in the watershed appears to be the western half of the 49 Trench area. The average ^{3}H activity from 1989 to 1994 in well 1233, located immediately to the west of the 49 Trench area, was 341,000 pCi/L and the average ^{3}H activity from 1988 to 1994 in well 849, located about 75 ft to the southwest of the 49 Trench area, was 2,215,028 pCi/L (Fig. 3.50). The results of stream transect sampling in the FB drainage in 1989 for the WAG 6 RFI (Energy Systems 1991) and in 1992 for the WAG 2 Phase I RI (DOE 1995a) showed that tritium concentrations ranged from 2,500 pCi/L to 175,500 pCi/L at locations upstream of the 49 Trench area and from 1,684,000 pCi/L to 8,112,000 pCi/L at locations downstream of the 49 Trench area (see Fig. 3.52).

The principal ^{90}Sr source in the watershed and in SWSA 6 appears to be the high activity trenches, both capped and uncapped, in the vicinity of Cap 1. The average ^{90}Sr activity from 1989 to 1994 in well 1225, located about 40 ft to the west of the uncapped high activity trenches in the northern portion of SWSA 6 (Fig. 3.50), was 3479 pCi/L. The ^{90}Sr activity in this well was at least two orders of magnitude higher than any other well in the interior of SWSA 6. This well is located between the trenches and a seep at the headwaters of the FB drainage that historically has contained elevated ^{90}Sr activities. The ^{90}Sr activity measured in 1989 in a sample collected from stream transect

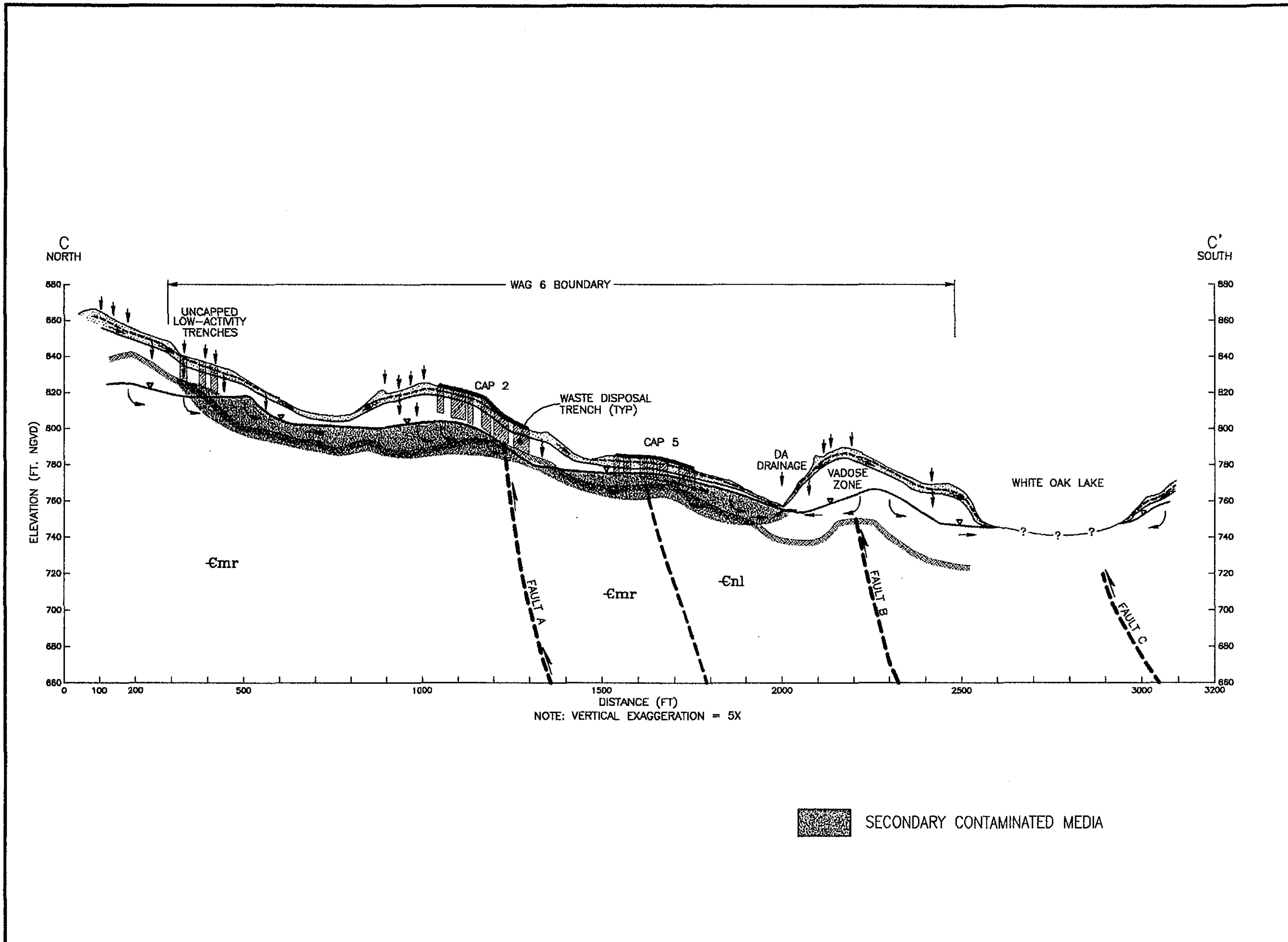


Fig. 3.51. North-south cross section of SWSA 6.

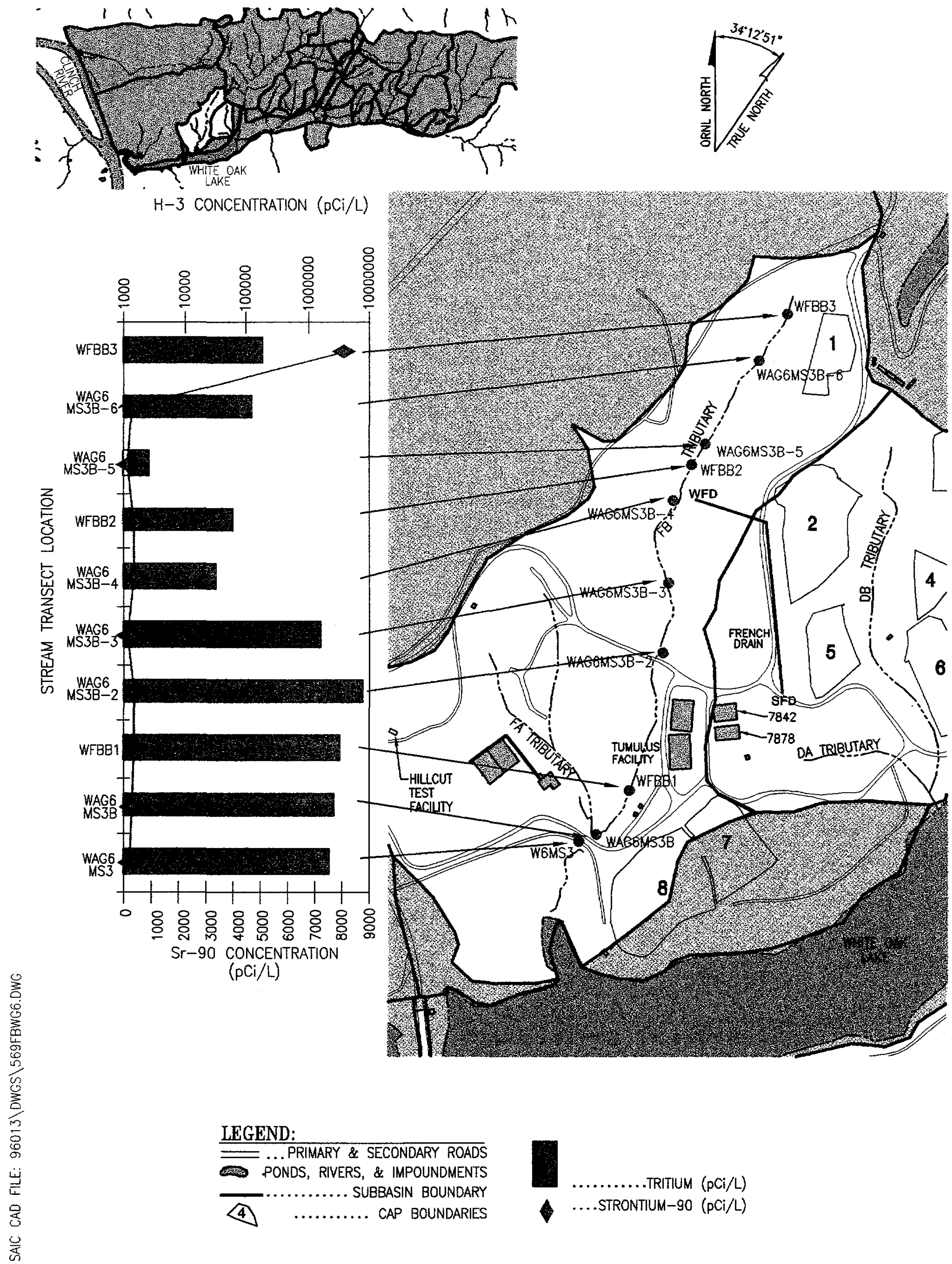


Fig. 3.52. FB drainage transect sample results.

location WFBB3 (Fig. 3.50), located about 90 ft to the west of well 1225 and close to the seep location, was 8061 pCi/L (Energy Systems 1991).

The western half of the 49 Trench area is also an apparent source of VOCs in groundwater in the W6MS3 watershed. Concentrations of 1,2-DCE, TCE, and PCE were 77, 300, and 16 μg/L, respectively, in well 849; and 910, 470, and 4500 μg/L in well 1233 (DOE 1995e). Well 849 is located immediately to the southwest of the 49 Trench area and well 1233 is located directly to the west of the northern portion of the 49 Trench area.

Another apparent source of VOCs in the W6MS3 subbasin is the Cap 1 area (Fig. 3.50). A sample collected in 1994 from well 648, located about 125 ft to the south-southwest of the Cap 1 area, contained 4.2 μg/L 1,2-DCE; 1700 μg/L TCE; and 200 μg/L PCE (SAIC 1995). These VOCs were also detected in three surface water samples collected in 1989 from stream transect location WFBB2, located about 340 ft southwest of well 648 along the FB drainage, at average concentrations of 110 μg/L 1,2-DCE, 19 μg/L TCE, and 1.3 μg/L PCE (Energy Systems 1991). Since significantly lower concentrations of these VOCs were detected at stream transect location WFBB3, located immediately upstream of the Cap 1 area, and since WFBB2 is located upstream of other source areas in the watershed, the Cap 1 area is a likely source of the VOCs detected at WFBB2.

Based on the trench hydrology analysis discussed above, trenches in the western part of the 49 Trench area are expected to be intermittently or perennially inundated. Therefore, the primary release mechanism from these trenches is leaching of trench contents by direct interaction with groundwater; a secondary release mechanism is leaching of trench contents by infiltrating precipitation and/or by water entering the trenches via the storm flow zone. Most of the trenches in the Cap 1 area should remain unsaturated, with some trenches in the northwestern and southwestern parts of the area being intermittently inundated. Therefore, the primary release mechanism from the Cap 1 area is expected to be leaching of trench contents by water entering the trenches via the storm flow zone from recharge areas outside the cap. Direct interaction of trench contents with groundwater could occur in the intermittently inundated areas during high water table conditions. The western half of the high activity trench area north of Cap 1 is intermittently inundated and the eastern half of the area is unsaturated. Therefore, the primary release mechanism from this area should be leaching of trench contents by directly infiltrating precipitation or by water entering the trenches via the storm flow zone. Under high water table conditions, releases may occur from the western part of the area by direct interaction with groundwater.

Contaminated water from the 49 Trench area should flow in the saturated zone to the west along strike and/or to the southwest along the hydraulic gradient to discharge locations along the FB drainage. There is also a component of groundwater flow from the 49 Trench area that is captured by the French Drain that was installed to suppress water table elevations in the 49 Trench area. Contaminated water from the Cap 1 area and from the high level trenches north of Cap 1 should also flow to the west/southwest to discharge locations along the FB drainage. Contaminated water from the western low activity trenches should flow to the east/southeast toward the FB drainage or to the west/southwest toward the FA drainage.

W6MS3. Most surface water contamination (^{3}H and ^{90}Sr) in this basin is attributable to the FB (east) tributary. Transect sampling in 1992 (DOE 1995a) indicated that most of the ^{3}H comes into the tributary in the vicinity of the 49 Trench area and/or the West Waste Disposal area. Transect sampling also indicated that most of the ^{90}Sr comes into the tributary at or above (upstream from) the same location. The W6MS3 subbasin contributes approximately 6.6% of the ^{3}H and 0.7% of the ^{90}Sr at WOD.

3.6.4.3 Secondary contaminated media

Areas of radiologically contaminated surface soils in the SWSA 6 subbasins are shown on Fig. 3.50. Gamma walkover data for the SWSA 6 subbasins were collected on a regular grid. Areas in which gamma exposure levels exceed the recreational scenario limit of 50 μR/h are located in the W6MS1 subbasin in proximity to waste burial trenches associated with Cap 5 and near auger holes associated with Cap 3.

W6MS1

Secondary contaminated media in the W6MS1 subbasin include contaminated soils and groundwater in seepage pathways between the eastern 49 Trench area, the Cap 2 area, and the Cap 5 area and the DA drainage. The approximate area of contaminated seepage pathway soils is 3.9 acres (1.6 ha); the average thickness of these soils is about 7 ft (2.1 m); and their approximate volume is 1,200,000 ft^3 (34,000 m^3). Assuming an average saturated thickness of 2 ft (0.6 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is approximately 80,000 ft^3 (2,300 m^3).

W6MS3

Secondary contaminated media in the W6MS3 subbasin include contaminated soils and groundwater in the ^{90}Sr seepage pathway between the high activity trenches, both capped and uncapped, in the vicinity of Cap 1 and the FB drainage and contaminated soils and groundwater in the seepage pathway between the 49 Trench area and the FB drainage. The approximate area of contaminated seepage pathway soils is 3.9 acres (1.6 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 1,700,000 ft^3 (48,000 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 140,000 ft^3 (3,900 m^3).

SWSA 6 East

Secondary contaminated media in the SWSA 6 East subbasin include contaminated soils and groundwater in the seepage pathways between the trenches in SWSA 6 East and West Seep Tributary. The approximate area of contaminated seepage pathway soils is 2.5 acres (1.0 ha); the average thickness of these soils is about 10 ft (3.1 m); and their approximate volume is 1,089,000 ft^3 (30,881 m^3). Assuming an average saturated thickness of 2 ft (0.61 m) and an average porosity of 40%, the volume of contaminated groundwater in seepage pathway soils is about 651,658 gal (2,471 m^3).

3.6.4.4 Human health risk, ecological risk, and criteria exceedances

The SWSA 6 Drainages subbasins include the W6MS3 and W6MS1 subbasins that are analyzed in the human health risk assessment. COCs for each media are presented based on recreational land use. Risk results are presented based on recreational and industrial land use. Figure 3.53 presents available carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

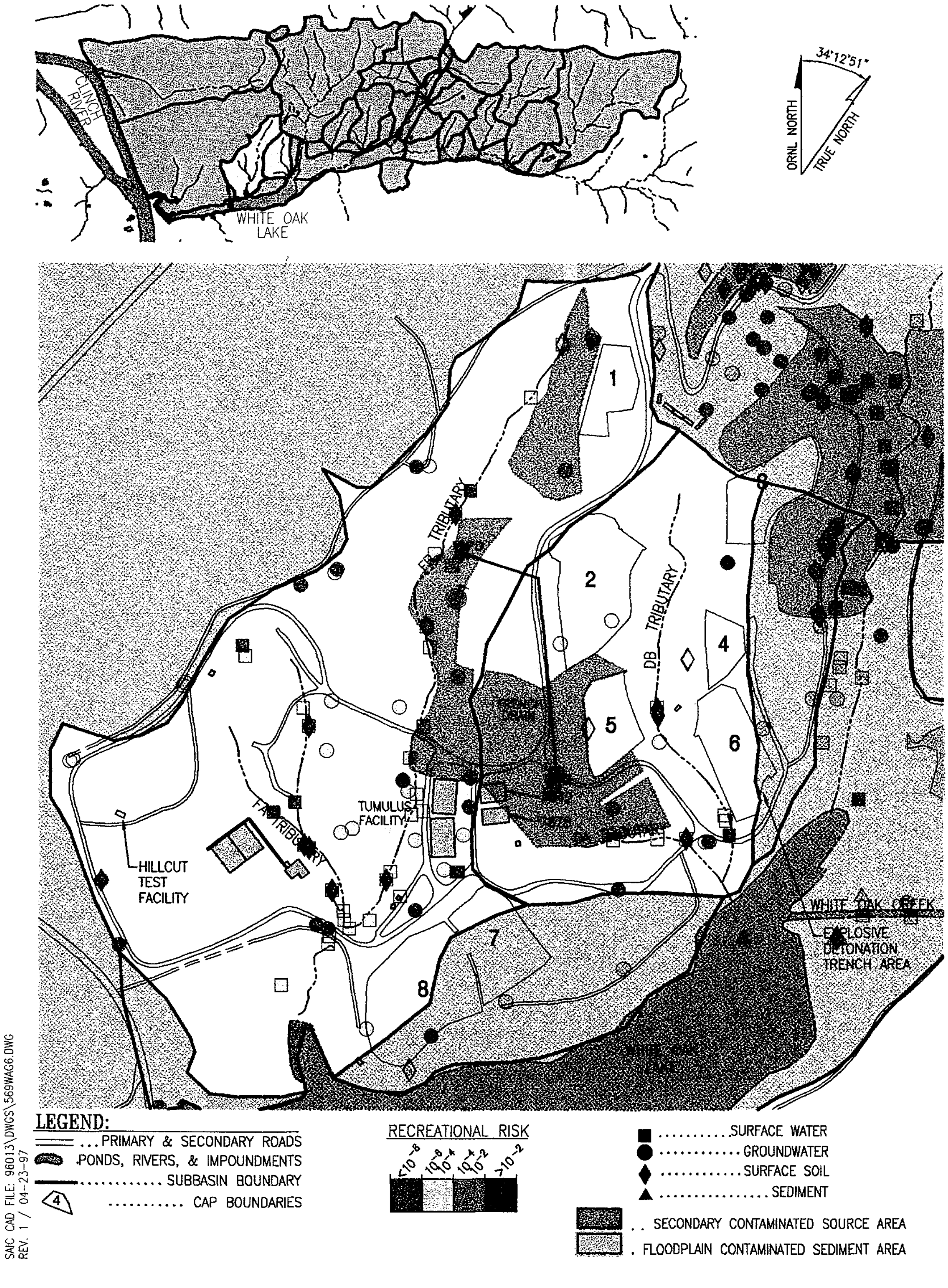


Fig. 3.53. Risk estimates for SWSA 6 subbasin sampling locations.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.66 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the media discussed in this report. The SWSA 6 Drainages subbasins have been comprehensively sampled as part of the WAG 6 RI and subsequent activities. Therefore, the associated uncertainty in the risk results and the identified COCs is considered to be low relative to the other subbasins.

Table 3.66. Media data summary for the SWSA 6 Drainages subbasins

Basin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
W6MS1	Groundwater	9	581	207	1633	975	3587	245
W6MS1	Sediment	2	0	0	47	39	0	0
W6MS1	Soil	6	78	58	124	104	558	29
W6MS1	SW-seeps	5	60	36	342	182	493	74
W6MS1	SW-streams	4	252	136	679	514	730	84
W6MS3	Groundwater	42	1888	630	5320	3154	13156	694
W6MS3	Sediment	2	0	0	92	71	55	0
W6MS3	Soil	11	112	89	236	191	1147	87
W6MS3	SW-seeps	13	85	59	388	226	264	16
W6MS3	SW-streams	11	660	361	1346	1011	1996	260

SWSA 6 Drainages Soil

Six soil samples in the W6MS1 subbasin and eleven samples in the W6MS3 subbasin were analyzed for a comprehensive list of inorganics, organics, and radionuclides as part of the WAG 6 RI. Table 3.67 summarizes the carcinogenic and noncarcinogenic risk for a recreational use scenario and the identified recreational COCs.

Table 3.67. Summary of risk results for SWSA 6 Drainages soil

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index
W6MS1	1.2E-04	1.7E-01	1.1E-05	7.3E-02
W6MS3	9.4E-05	1.0E-01	4.4E-06	4.8E-02

The carcinogenic and noncarcinogenic risk results are not high enough for the recreational scenario to warrant the identification of recreational COCs for the SWSA 6 Drainages soil. Industrial and residential COCs are presented in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the W6MS3 subbasin. No risks were identified for exposure to radionuclides. Overall dose rates from exposure to the 13 radionuclides detected were below the recommended dose limits for all receptors (Table 3.68). Potential risks from exposure to nonradionuclides were identified for plants (HI = 5.4) and short-tailed shrews (HI = 2.5). Inorganics contributed >99% of the HI for both receptors. HQs exceeding one were estimated for three inorganics (silver, arsenic, and cadmium) for plants and only one (arsenic) for shrews. Exceedances of toxicological benchmarks were low (less than a factor of 1.8), suggesting a low likelihood of adverse effects to plants within this subbasin.

Table 3.68. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at the SWSA 6 subbasins

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
W6MS1	Plants	5.4	Ni (2.2), Cd (1.6), As (1.3)	<0.1	
W6MS1	Shrew	6.4	As (4.3), Ni (1.2)	<0.1	
W6MS3	Plants	5.4	Ag (1.8), As (1.5), Cd (1.4)	<0.1	
W6MS3	Shrew	2.5	As (1.8)	<0.1	

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the W6MS1 subbasin. No risks were identified for exposure to radionuclides. Overall dose rates from exposure to the 12 radionuclides detected were below the recommended dose limits for all receptors (Table 3.68). Potential risks from exposure to nonradionuclides were identified for plants (HI =5.4) and short-tailed shrews HI = (6.4). Inorganics contributed >99% of the HI for both receptors. HQs exceeding one were estimated for three inorganics (nickel, cadmium, and arsenic) for plants and only two (arsenic and nickel) for shrews. Exceedances of toxicological benchmarks were low (less than a factor of 2.2) for all analytes except arsenic, which had an HQ of 4.3 for the shrew. This suggest a minor risk of adverse effects on terrestrial plants in this subbasin.

SWSA 6 Drainages Sediment

Table 3.69 summarizes the carcinogenic and noncarcinogenic risk for a recreational use scenario. The W6MS1 subbasin sediment was analyzed for a limited set of inorganics only. The W6MS3 sediment was analyzed for a longer list of inorganics and organics. Radionuclide results for the sediment samples in the SWSA 6 Drainages are not available.

Table 3.69. Summary of risk results for SWSA 6 Drainages sediment

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index
W6MS1	–	–	–	–
W6MS3	–	1.8E-01	–	5.2E-02

The carcinogenic and noncarcinogenic risk results are not high enough for the recreational scenario to warrant the identification of recreational or industrial COCs for the SWSA 6 Drainages *sediment. Residential COCs are presented in Appendix B.*

Significant risks were identified for benthic invertebrates exposed to sediment in the W6MS3 subbasin, based on one line of evidence (sediment chemistry). Manganese was the only analyte potentially presenting a significant risk and was identified as a COEC. No other analytes represented even a potential concern.

SWSA 6 Drainages Groundwater

Radionuclide, organic, and inorganic contaminants have been sampled at nine locations within the W6MS1 subbasin and at 42 locations in the W6MS3 subbasin. The recreational groundwater risk in the W6MS1 subbasin is 1.4E-05 and in the W6MS3 subbasin it is 8.8E-05. The HIs for these sites are 9.2E-02 and 1.5E+00, respectively. The industrial risks are 1.2E-03 and 6.2E-04 for W6MS1 and W6MS3. The HIs are 8.8E-01 and 1.4E+00. The noncarcinogenic recreational results for W6MS3 exceed the target risk range. The recreational COCs for this subbasin are PCB-1254 and tetrachloroethylene.

The groundwater data from the W6MS1 and W6MS3 subbasins were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. W6MS1 exceedances were noted for ^{3}H and thallium. The contaminants with exceedances for the W6MS3 subbasin were ^{3}H, ^{90}Sr, ^{244}Cm, thallium, and vinyl chloride.

SWSA 6 Drainages Surface Water

Surface water samples were collected at nine surface water locations in the W6MS1 subbasin and at 24 locations within the W6MS3 subbasin. Table 3.70 summarizes the carcinogenic and noncarcinogenic risk for a recreational and industrial use scenario.

Table 3.70. Summary of risk results for SWSA 6 Drainages surface water

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index
W6MS1-seeps	2.7E-03	1.2E+00	4.5E-05	1.6E-01
W6MS1-streams	2.1E-03	4.0E-01	5.4E-05	7.0E-02
W6MS3-seeps	3.7E-03	1.5E+00	4.4E-05	1.4E-01
W6MS3-streams	1.5E-01	4.9E-01	2.7E-05	8.6E-02

The carcinogenic and noncarcinogenic risk results are not high enough for the recreational scenario to warrant the identification of COCs for the SWSA 6 Drainages surface water. Industrial and residential COCs are identified in Appendix B.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the W6MS3 subbasin, based on one line of evidence (surface water chemistry). Eleven inorganics and BEHP were the risk drivers (Table 3.71). Two other inorganic analytes and one organic present marginal risks, and three analytes were considered a negligible risk. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction as they may not be bioavailable. Aluminum is very insoluble in nearly neutral water, and the bioavailable fraction is unlikely to be toxic to aquatic biota in the Melton Valley watershed.

Table 3.71. Summary of potential risks to aquatic organisms from contaminants in main stem surface water in the SWSA 6 subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
W6MS3	Significant	Al, Cd, Co, Cu, Fe, Pb, Mn, Hg, Ni, Ag, Sn, BEHP
	Marginal	Ba, B, carbon disulfide
	Negligible	Be, benzene, toluene
W6MS1	Significant	Al, Cd, Co, Cu, Fe, Pb, Hg, Ni, BEHP
	Marginal	Ba, B, Mn, carbon disulfide
	Negligible	Se, naphthalene, toluene

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the W6MS3 subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from W6MS3; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for W6MS3 plants assumed to be exposed to seep water in soil solution (Table 3.11). Thallium exceeded plant soil solution benchmarks at station W6MS3A, W6MS3A-1, and W6MS3B (HQs from 8.7 to 15.6). The thallium benchmark appears to be conservative as thallium exceeded benchmarks at numerous seeps across the whole watershed. Frequency of detection of thallium was generally low. Other analytes marginally exceeding benchmarks (HQs <5) at least one station were arsenic, chromium, and manganese. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the W6MS1 subbasin, based on one line of evidence (surface water chemistry). Eight inorganics and BEHP present significant risks and were identified as COECs (Table 3.71). Three other inorganic analytes and one organic present marginal risks, and three analytes were considered a negligible risk. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction as they may not be bioavailable. Aluminum is insoluble in nearly neutral water, and the bioavailable fraction is unlikely to be toxic to aquatic biota in the Melton Valley watershed.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the W6MS1 subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from W6MS1; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for W6MS1 plants assumed to be exposed to seep water in soil solution (Table 3.11). Thallium exceeded plant soil solution benchmarks at stations French Drain S, French Drain, W6MS1, W6MS1-1, and W6MS2 (HQs from 8.1 to 19.2). The thallium benchmark appears to be conservative as thallium exceeded benchmarks at numerous seeps across the whole watershed. Frequency of detection of thallium was generally low. Other analytes marginally exceeding benchmarks (HQs <4) at least one station were arsenic and manganese. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

The contaminant surface water concentrations for the SWSA 6 Drainages subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic and mercury exceeded the human health criteria at both subbasins. In addition, 1,1-DCE exceeded the human health criteria at W6MS3. Cadmium, lead, copper, chromium, and mercury showed exceedances for the ecological criteria at both subbasins.

3.6.4.5 Options for release mechanism intervention

SWSA 6 contains hazardous waste and low-level radioactive waste disposed of in trenches, auger holes, and below-grade silos; and waste packaged in boxes placed on concrete tumulus pads and covered with an engineered cap. Secondary contaminated media include soils along the seepage pathways form contaminant sources to seep areas along streams, some surface-contaminated "hot spots," and contaminated sediment in and adjacent to stream channels. VOCs and ^{3}H are the principal contaminants being released from SWSA 6. Contaminant release mechanisms include infiltration of precipitation, lateral storm flow seepage into trenches and auger holes, and seasonal and perennial inundation of trenches. Interim synthetic caps were constructed in portions of SWSA 6 to stop direct infiltration of the rainfall into the waste trenches. VOC releases downgradient of the northeast auger holes were reduced severalfold within two or three years after capping of the source area. Options to interrupt the release mechanisms at SWSA 6 include hydraulic isolation of trench groups to stop water entry into waste, source treatment or control to stop releases and/or stop water contact with waste, or removal of the sources.

3.7 WHITE OAK LAKE, WHITE OAK CREEK EMBAYMENT, AND LOWER WHITE OAK CREEK FLOODPLAIN

The locations of subbasins included in the assessment of contaminant sources, releases, and pathways in the WOL, WOCE, and Lower WOC are shown on Fig. 3.54 along with contaminant source areas in adjacent subbasins, sample locations, and radiological walkover survey results. Much of the floodplain is classified as wetland. Subbasins included in this area for purposes of this RI include:

- WOCE,
- WOL,
- SWSA 6 South,
- SWSA 6 East,

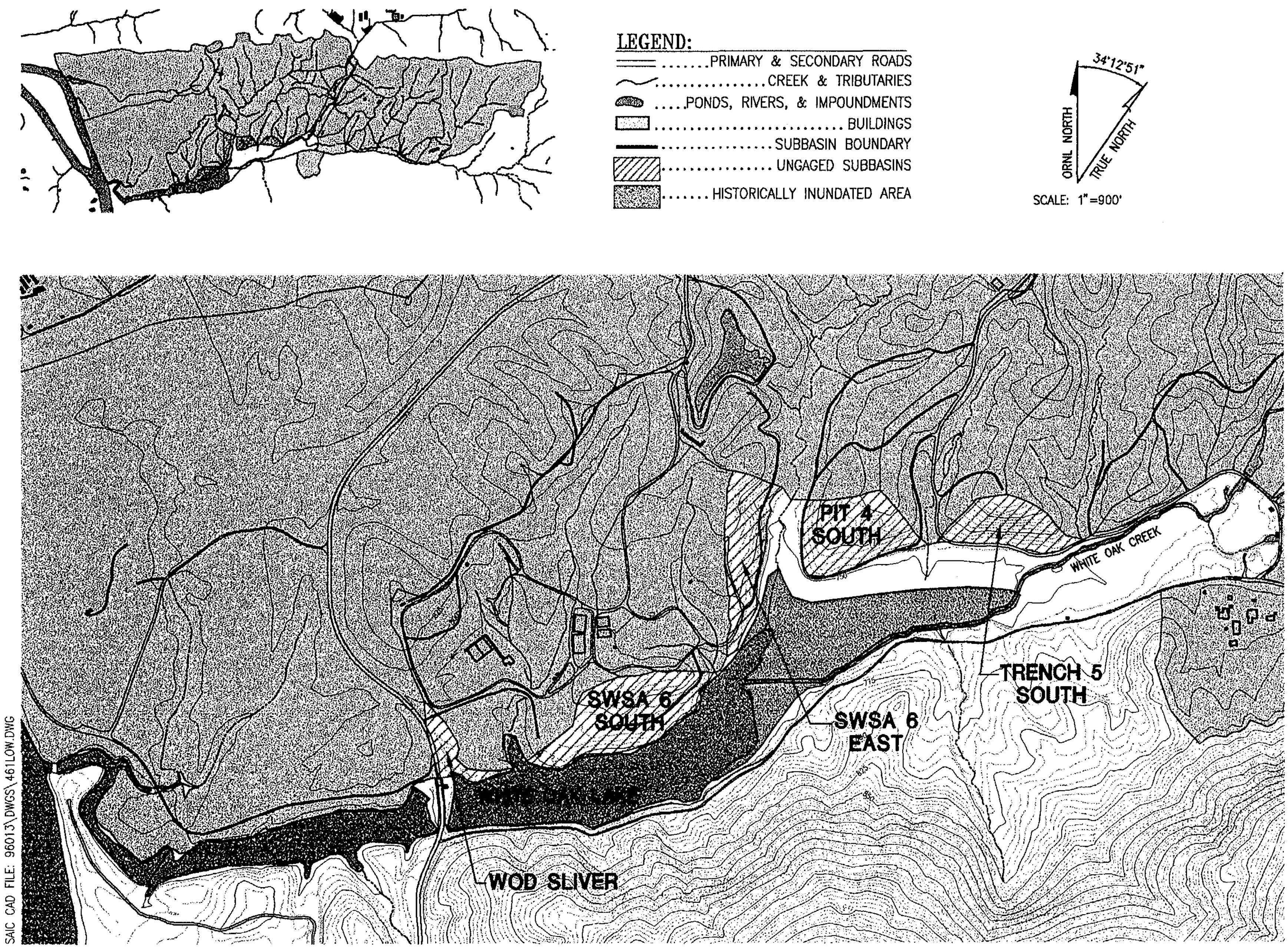


Fig. 3.54. Subbasins included in Lower WOC, WOL, and WOCE.

- Lower WOC,
- Pit 4 South, and
- Trench 5 South.

The four subbasins adjacent to the floodplain area that are associated with the floodplain area all drain directly to the floodplain area and may contribute groundwater seepage directly to the floodplain. The WOCE and WOL include about 29 acres of impounded surface water with a contaminated bottom sediment layer. The Lower WOC (including WOL and WOCE) subbasins encompass about 94 acres of which about 26.5 are designated wetland areas and 29.1 are within WOL and WOCE.

3.7.1 Contaminated Sites

Of the seven subbasins included in this area, only the SWSA 6 South subbasin and the Pit 4 South subbasin contain primary contaminant sources. The SWSA 6 South subbasin contains buried waste and the Pit 4 South subbasin contains a small portion of Seepage Pit 4. The remaining five subbasins contain secondary contaminated soil, sediment, surface water, groundwater, and vegetation.

White Oak Creek Embayment

The WOCE is the segment of WOC that lies between the spillway at WOD and the creek mouth at the Clinch River where a sediment retention structure was constructed in 1992 to contain contaminated sediment. The estimated cure inventory in sediment of the embayment is approximately 12 Ci with the predominant radionuclide being ^{137}Cs. This sediment has accumulated in the bed of the embayment since contaminant discharges began at ORNL. In 1992 the sediment retention weir was constructed at the mouth of WOC to hold contaminated sediment within the embayment and prevent movement of channel bed sediment out into the Clinch River.

White Oak Lake

Since the inception of ORNL operations in 1943, laboratory-related process releases to WOC have resulted in the accumulation of approximately 300–450 Ci of radioactively contaminated sediment in WOL. During the history of operation of ORNL, the management of WOL has varied by changes in the maintained water level in the lake and temporary draining of the lake at one time.

SWSA 6 South

Potential sources of groundwater and surface water contamination in the SWSA 6 South subbasin include the southern portion of the low activity trenches under Cap 7, the biological trenches under the southern two-thirds of Cap 8, and the low activity silos to the east of Cap 7 (Fig. 3.54).

SWSA 6 East

Several waste units in the WAG 6 area also drain to Lower WOC (Fig. 3.54). Two waste units in this subbasin are designated as SWMUs: the Explosives Detonation Trench and the EWB. The Explosives Detonation Trench is located in the eastern section of SWSA 6; however, its precise location is unknown. The trench is approximately 15 ft long × 5 ft wide × 4 ft deep, and was used for detonation of explosives and shock-sensitive chemicals such as acids and oxidizers (e.g., picric acid, phosphorous, ammonium nitrate). Wastes were placed in the bottom of the trench and detonated using plastic charges; debris (fragments of containers) from the explosions generally remained in the trench (DOE 1995f).

Lower White Oak Creek

The Lower WOC subbasin is the floodplain area between the head of WOL and the weirs above the confluence of Melton Branch and WOC. In this area, 24.8 acres are designated as wetland. During the 1940s and 1950s, the controlled water level in WOL was maintained at the 849 ft elevation and sediment bound contaminants were deposited in the upper end of the historic high lake level. In 1955, the controlled lake level was reduced to the current 844 ft elevation, leaving the earlier sediment deposits stranded. The approximate location of the historic lake level is shown on Fig. 3.54. In addition to the stranded old lake bed sediment, overhand flooding spread a thin layer of contaminated sediment across the valley floor below the flood level. Radiological walkover measurements and sampling and analysis of soil cores provides a basis for contaminant inventory estimates, which is provided under the discussion of secondary contaminated media.

A contaminated groundwater discharge point known as "Seep D" is located in the Lower WOC subbasin in the Melton Branch streambed, just upstream of the Melton Branch–WOC confluence. This seep contains high concentrations of ^{90}Sr and ^{3}H (Table 3.1) and was part of the seeps removal project performed at SWSA 5 to collect and treat ^{90}Sr-contaminated seeps. The contaminant source for Seep D is suspected to be groundwater seepage originating in SWSA 5 South because ^{3}H content is higher than would be expected from other local sources such as hydrofracture grout sheets.

Pit 4 South

The Pit 4 South subbasin is the southern end of the knoll adjacent to the southern end of Seepage Pit 4. The area slopes steeply southward toward WOC. The southern end of Pit 4 lies within the subbasin; however, no surface water drainage features lie within the area. The principal contaminated media are soils within the seepage plume area of Pit 4.

Trench 5 South

The Trench 5 South subbasin is the southern end of the knoll adjacent to the southern end of Seepage Trench 5 and the HRE Fuel Wells. This subbasin contains no primary contaminant sources. Results of subsurface investigation of soil and groundwater contaminants related to the HRE Fuel Wells suggest that there is little potential for secondary contaminated soil within the area.

3.7.2 Pathway Model of Contaminant Release

Surface Water

Pit 4 South. No direct surface water monitoring or sampling information is available. This subbasin is a potential contributor to the diffuse/unidentified ^{90}Sr source in the lower WOC/WOL reach (the source would likely be Pit 4).

Trench 5 South. No direct surface water monitoring or sampling information is available. This subbasin is a potential contributor to the diffuse/unidentified ^{90}Sr source in the lower WOC/WOL reach (the source would likely be Trench 5).

Lower WOC

Big No-Name. No direct surface water monitoring or sampling information is available; however, there are no known sources of contamination in this subbasin. Therefore, surface water contamination is not expected.

Little No-Name. Limited data available from the WAG 2 RI indicate no significant levels of contamination in the lower (western) tributary to the WOCE.

WOCE

Before the construction of a sediment retention structure at the mouth of WOC in 1992, the WOCE, below WOD, was an active source of ^{137}Cs contamination to the Clinch River (Blaylock et al. 1993). However, since the construction of the sediment retention structure, the WOCE is believed to act primarily as a conduit from WOD to the Clinch River. Due to its inventory of ^{137}Cs (relatively small relative to WOL, the Intermediate Pond Area, and the WOC floodplains) it remains a potential source to the off-site environment. According to WAG 2 RI results (Clapp et al. 1996), the embayment can be a passive conduit or a slight source of ^{137}Cs (i.e., a maximum of a few 1/100ths Ci of ^{137}Cs were mobilized during one storm).

SWSA 6 South and SWSA 6 East

These subbasins have no surface water discharge measurement points. Any discharges from these areas is via groundwater seepage directly to the Lower WOC subbasin.

Lower WOC/WOL. This basin (reach) is the integrator for all source areas in the Melton Valley watershed above WOD. It acts as a source or sink (potential) of contaminants and is represented by the difference between WOD and the sum of WOC and Melton Branch monitoring stations above their confluence. Mass balance calculations indicate that contributions of ^{90}Sr, ^{3}H, and ^{137}Cs are 20%, 4.2%, and -59.1%, respectively, from this reach. Therefore, the lower WOC and WOL reach is a sink for ^{137}Cs. However, because of the significant inventory of ^{137}Cs in WOL and the surrounding floodplains, this basin has the potential to become a significant source to the off-site environment under extreme to catastrophic flooding conditions.

The major source area physically located within this basin is Seep D, which contributed approximately 6.7% of the ^{90}Sr at WOD (Hicks 1996) before a removal action began operation in November 1994. Seep D has elevated levels of ^{3}H; however, it is not a significant source of ^{3}H, ^{137}Cs, or any other radionuclide.

Groundwater

SWSA 6 South. Based on analyses of groundwater samples collected from three downgradient wells [0835, 0836, and 0837 (Fig. 3.54)], significant contaminant releases do not appear to be occurring in this subbasin. A slightly elevated ^{3}H activity of 25,679 pCi/L was detected in a sample collected from well 835 in 1994 (DOE 1995e); this result was consistent with ^{3}H activities detected in previous samples collected from this well (18,651 to 32,436 pCi/L). Strontium-90 or other radionuclides were not detected at elevated levels in samples from these wells.

Scintillation fluids were disposed of in some of the trenches in this subbasin. Some components of these scintillation fluids and other VOCs have been detected in groundwater samples from well 835 (TCE, benzene, 1,4-dioxane, and ethyl ether) and well 836 (TCE and chloroform). However, these VOCs were present at low concentrations; no primary MCLs have been exceeded (Energy Systems 1991).

An analysis of groundwater elevations in SWSA 6 South compared to trench bottom elevations indicates that the trenches under Cap 8 are intermittently inundated to perennially unsaturated and the trenches under Cap 7 and the low activity silos remain unsaturated year-round. Therefore, the primary release mechanism from this area should be leaching of trench contents by directly infiltrating precipitation or by water entering the trenches via the storm flow zone. Under high water table conditions, releases may occur from the inundated trenches under Cap 8 by direct interaction with groundwater.

SWSA 6 East. Based on results of analyses of groundwater samples from wells in this subbasin, there is no significant release of contaminants occurring from SWSA 6 East. An analysis of water table elevations compared to trench and auger hole bottom elevations (Energy Systems 1991) indicates that the trenches and auger holes in SWSA 6 East remain perennially unsaturated. Therefore, the primary release mechanism from this subbasin should be leaching of wastes by directly infiltrating precipitation or by water entering the wastes via the storm flow zone.

3.7.3 Secondary Contaminated Media

Secondary contaminated media estimates for the subbasins associated with Lower WOC, WOL, and WOCE are summarized in Table 3.72.

Table 3.72. Estimated secondary contaminant inventory, Lower WOC, WOL, and WOCE

Subbasin	^{137}Cs inventory (Ci)	^{60}Co inventory (Ci)	Sediment volume (ft^3)	Estimated groundwater volume (gal)
WOCE[a]	11	–	670,388	–
WOL[a]	300–450	–	1,474,070	–
Lower WOC[b]	70.6	1.8	963,066	501,163

[a] Sediment curie estimates from Loar 1992; volume estimate based on 1.5 ft thickness over impounded area floor.
[b] Groundwater volume estimated based on assumption of 5-ft saturated sediment thickness with 40% porosity beneath subbasin area.

3.7.4 Human Health Risk, Ecological Risk, and Criteria Exceedances

The Lower WOC, WOL, and WOCE includes the Lower WOC/WOL, the WOCE, SWSA 6 South, SWSA 6 East, Pit 4 South, and Trench 5 South subbasins analyzed in the human health risk assessment. COCs for each media are presented based on recreational land use. Risk results are presented for the recreational and industrial land use scenarios. Figure 3.55 presents available carcinogenic risk results by sample location for groundwater, sediment, soil, and surface water.

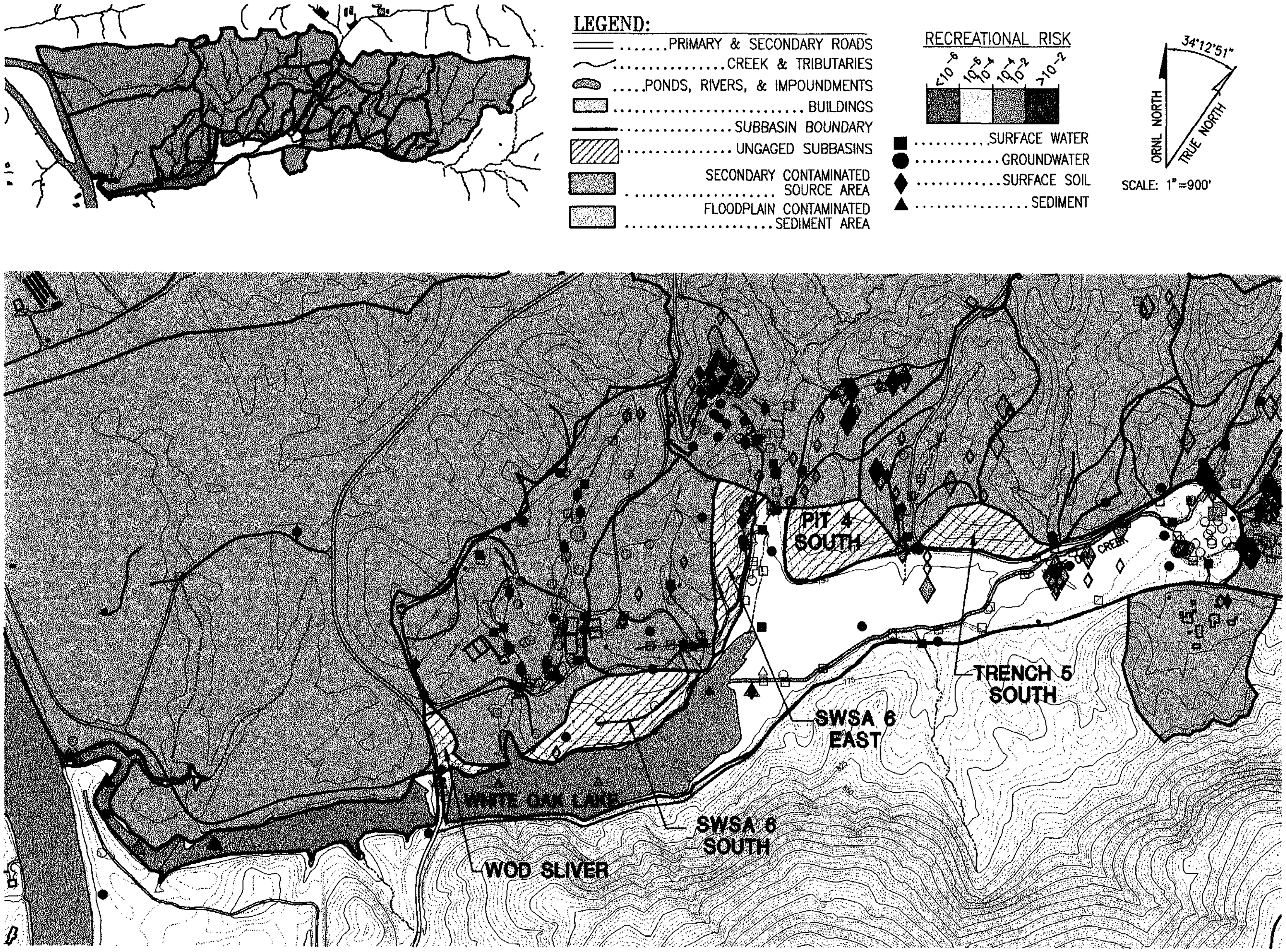


Fig. 3.55. Risk estimates for sampling locations in Lower WOC, WOL, and WOCE.

Subbasin groundwater and surface water concentrations have been compared to federal and state criteria to determine areas in the watershed where criteria exceedances exist. Subbasin groundwater concentrations were screened against MCLs for chemicals (40 CFR 141, TDEC 1200-5-1) and proposed MCLs for certain radionuclide isotopes (56 FR 33050). Subbasin surface water concentrations represent an aggregate of analytical data for seep, tributary, and stream samples. These data were screened against TDEC AWQC (TDEC 1200-4-3) for the protection of human health during recreational use (ingestion of aquatic organisms only) and for the protection of aquatic life (criterion continuous concentration).

Table 3.73 provides a summary by subbasin of the analytical data that were used to generate the human health risk results, ecological risk results, and criteria exceedances for each of the media discussed in this report. The subbasins around the WOL area have been comprehensively sampled as a part of the WAG 2 program and a number of historical studies; therefore, the uncertainty in the risk results and the identified COCs is considered to be low.

Table 3.73. Media data summary for the Lower WOC, WOL, and WOCE subbasins

Subbasin	Media	No. of stations	No. of radionuclide analytical results	No. of radionuclides detected	No. of metal analytical results	No. of metals detected	No. of organic analytical results	No. of organics detected
Lower WOC/WOL	Groundwater	54	1431	1235	3162	1908	7181	569
Lower WOC/WOL	Sediment	24	223	221	1439	1182	760	87
Lower WOC/WOL	Soil	46	311	268	352	335	815	63
Lower WOC/WOL	SW-seeps	12	797	620	2513	1467	1393	125
Lower WOC/WOL	SW-streams	20	2688	2357	4560	3046	1075	87
WOCE	Sediment	6	1294	1087	938	813	2533	90
WOCE	SW-streams	3	97	85	23	15	53	0
SWSA 6 South	Groundwater	6	237	92	537	298	1610	39
SWSA 6 South	Soil	1	16	12	22	17	82	3
SWSA 6 East	Groundwater	9	427	248	1269	713	5386	399
SWSA 6 East	Soil	3	37	31	83	68	399	18
SWSA 6 East	SW-streams	1	15	5	32	22	62	1
Pit 4 South	Groundwater	1	55	46	240	112	676	13
Pit 4 South	Sediment	2	4	4	56	43	139	22
Pit 4 South	Soil	2	28	27	58	58	140	22
Pit 4 South	SW-seeps	1	52	48	1503	1130	132	5
Trench 5 South	Groundwater	1	53	38	244	112	676	15

WOC, WOL, and WOCE Floodplain Soil

Table 3.74 summarizes the carcinogenic risk, the noncarcinogenic HI, and the recreational COCs identified for the six subbasins that compose the Lower WOC, WOL, and WOCE subbasins. No soil samples are available for the WOCE and Trench 5 South. Lower WOC/WOL, SWSA 6 South, SWSA 6 East, and Pit 4 South were analyzed for a comprehensive list of inorganics, organics, and radionuclides as part of the WAG 2 RI, the WAG 6 RI, and other studies.

Table 3.74. Summary of risk results for Lower WOC, WOL, and WOCE subbasin soil

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
Lower WOC/WOL	6.1E-03	4.5E-02	2.8E-04	1.6E-02	^{137}Cs, ^{60}Co
SWSA 6 South	2.9E-05	1.4E-01	2.0E-06	5.3E-02	None
SWSA 6 East	2.5E-03	1.7E-01	1.1E-04	8.6E-02	^{60}Co
Pit 4 South	1.1E-02	–	4.8E-04	–	^{60}Co, ^{137}Cs, ^{228}Th

Recreational soil COCs for the WOC, WOL, and WOC floodplain subbasins include all contaminants that were identified as COCs in any of the subbasins. Therefore, the total COC list includes ^{137}Cs, ^{60}Co, and ^{228}Th for the recreational scenario. Industrial and residential COCs are presented in Appendix B.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the Lower WOC/WOL subbasin. Overall dose rates from exposure to the 14 radionuclides detected exceeded recommended dose limits for plants (HI = 1.4), shrews (HI = 17.4), and mice (HI = 17.3), but were below the recommended dose limits for all other receptors (Table 3.75). Plutonium-239/240 was the primary risk driver for all receptors, contributing >86% of the dose rate. Americium-241 accounted for 6% of the HI for shrews and mice. Potential risks from nonradionuclides were identified for plants (HI = 150), soil invertebrates (HI = 343), short-tailed shrews (HI = 46.4), white-footed mice (HI = 6.6), red fox (HI = 20.3), red-tailed hawk (HI = 3.9), wild turkey (HI = 1.0), and mink (HI = 6.0). Inorganics contributed >95% of the HI for all receptors. HQs exceeding one were estimated for six inorganics (chromium, mercury, zinc, silver, molybdenum, and selenium) for plants, five inorganics (mercury, chromium, zinc, molybdenum, and selenium) for shrews, three inorganics (chromium, mercury, and zinc) for soil invertebrates, two inorganics (mercury and chromium) for mice and foxes, and one inorganic (mercury) for hawks, turkeys, and mink. The organic PCB-1260 was an additional risk driver for shrews with an HQ of 2.3. This subbasin was third behind Intermediate Pond and WOC subbasins in contribution to watershed-wide risks to shrews and foxes exposed to mercury. HQs for mercury were as high as 51.0 for soil invertebrates and 23.2 for shrews. Chromium was a significant risk driver for plants, invertebrates, shrews, mice, and foxes, but the UCL95 of the chromium concentration only exceeded background by 1.1×. The analytical data did not specify the valence state of the chromium. Chromium (VI) is more toxic and bioavailable than chromium (III), but in most soils chromium (VI) is likely to be reduced to chromium (III) (Will and Suter 1995). However, the toxicological benchmark used to estimate effects of chromium is based on chromium (VI) studies. The use of the benchmark for the more toxic and available chromium (VI) when exposures may be predominantly from chromium (III) may lead to overestimation of the risks of adverse effects. Terrestrial wildlife exposures to chromium were below the NOAEL for chromium (III) for all receptors.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the SWSA 6 South subbasin. No risks were identified for exposure to radionuclides. Overall dose rates from exposure to the 9 radionuclides detected were below the recommended dose limits for all receptors (Table 3.75). Potential risks from exposure to nonradionuclides were identified for plants (HI = 4.2), short-tailed shrews (HI = 9.2), and white-footed mice (HI = 1.2). Inorganics contributed 100% of the HI for all receptors, as benchmarks were unavailable for the three organics detected in the single sample from the subbasin. HQs exceeding one were estimated for two inorganics (arsenic and cadmium) for plants and only one (arsenic) for shrews and mice. Exceedances of toxicological benchmarks were low (less than a factor of 2.2) for all analytes except arsenic, which had a HQ of 8.1 for the shrew. This suggests a minor risk of adverse effects on terrestrial plants in this subbasin.

Table 3.75. Summary of risks to terrestrial biota from exposure to contaminants in surface soil at Lower WOC, WOL, and WOCE subbasins

Subbasin	Receptor[a]	HI[b]	Nonradionuclide risk drivers[c]	HI: rads	Radionuclide risk drivers
Lower WOC/WOL	Plants	150.2	CrVI (116.0), Hg (17.0), Zn (8.2), Ag (3.4), Mo (2.0), Se (1.3)	1.4	$^{239/240}$Pu (1.2)
Lower WOC/WOL	Invertebrates	343.2	CrVI (290.0), Hg (51.0), Zn (2.1)	0.8	
Lower WOC/WOL	Shrew	46.4	Hg (23.2), CrVI (15.4), PCB-1260 (2.3), Zn (1.6), Mo (1.5), Se (1.2)	17.4	$^{239/240}$Pu (15.4), ^{241}Am (1.0)
Lower WOC/WOL	Mouse	6.6	Hg (3.3), CrVI (2.2)	17.3	$^{239/240}$Pu (15.4), ^{241}Am (1.0)
Lower WOC/WOL	Fox	20.3	Hg (17.9), CrVI (1.2)	0.2	
Lower WOC/WOL	Mink	6.0	Hg (5.5)	0.1	
Lower WOC/WOL	Hawk	3.9	Hg (3.4)	0.1	
Lower WOC/WOL	Turkey	1.0	Hg (0.9)	0.7	
Pit 4 South	Plants	5.8	Mo (2.1), Se (1.2), Tl (1.2)	0.1	
Pit 4 South	Shrew	5.1	Mo (1.8), Se (1.5), Ba (1.1)	0.2	
SWSA 6 East	Plants	6.9	Zn (2.6), Ni (2.0), Cd (1.8)	<0.1	
SWSA 6 East	Invertebrates	1.2		<0.1	
SWSA 6 East	Shrew	3.8	Ni (1.2), Cd (1.0)	0.1	
SWSA 6 South	Plants	4.2	As (2.2), Cd (1.1)	<0.1	
SWSA 6 South	Shrew	9.2	As (8.1)	<0.1	
SWSA 6 South	Mouse	1.2	As (1.1)	<0.1	

[a] Risks were evaluated for plants, soil invertebrates, short-tailed shrews, white-footed mice, red fox, white-tailed deer, mink, red-tailed hawk, and wild turkey. Only receptors with HIs exceeding 1.0 are included here.
[b] HIs are the sum of HQs for individual analytes for a given receptor within each subbasin.
[c] Risk drivers were generally identified as radionuclides or nonradionuclides with HQs >1.0. HQs are included in parentheses.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in SWSA 6 East subbasin. No risks were identified for exposure to radionuclides. Overall dose rates from exposure to the 13 radionuclides detected were below the recommended dose limits for all receptors (Table 3.75). Potential risks from exposure to nonradionuclides were identified for plants (HI = 6.9), soil invertebrates (HI = 1.2), and short-tailed shrews (HI = 3.8). Inorganics contributed >99% of the HI for all receptors. HQs exceeding one were estimated for three inorganics (zinc, nickel, and cadmium) for plants and only two (nickel and cadmium) for shrews. Exceedances of toxicological benchmarks were low (less than a factor of 2.6) for all analytes. This suggests a minor risk of adverse effects on terrestrial plants in this subbasin.

Risks to terrestrial biota were evaluated for radionuclides and nonradionuclides in soil in the Pit 4 South subbasin. No risks were identified for exposure to radionuclides. Overall dose rates from exposure to the 12 radionuclides detected were below the recommended dose limits for all receptors

(Table 3.75). Potential risks from exposure to nonradionuclides were identified for plants (HI = 5.8) and short-tailed shrews (HI = 5.1). Inorganics contributed >99% of the HI for all receptors. HQs exceeding one were estimated for three inorganics for plants (molybdenum, selenium, and thallium) and shrews (molybdenum, selenium, and barium). Exceedances of toxicological benchmarks were low (less than a factor of 2.1) for all analytes. This suggests a minor risk of adverse effects on terrestrial plants in this subbasin.

Lower WOC, WOL, and WOCE Sediment

Table 3.76 summarizes the carcinogenic risk, the noncarcinogenic HI, and the recreational COCs identified for the subbasins with sediment data that compose the WOC, WOL, and WOC floodplain basin. The WOCE and Pit 4 South were analyzed for a limited amount of radionuclides, inorganics, and organics. Lower WOC/WOL was analyzed for a comprehensive list of inorganics, organics, and radionuclides in a number of studies. No sediment samples are available for SWSA 6 South, SWSA 6 East, and Trench 5 South. None of the detected noncarcinogenic contaminants passed the reference and PRG screening steps; therefore, the noncarcinogenic HIs are not calculated for any of the subbasins.

Table 3.76. Summary of risk results for Lower WOC, WOL, and WOCE subbasin sediment

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	COCs
WOCE	3.1E-02		1.4E-03	–	Beryllium, ^{60}Co, ^{137}Cs, $^{239/240}$Pu
Lower WOC/WOL	5.4E-02	6.9E-01	2.5E-03	2.7E-01	Beryllium, ^{60}Co, ^{137}Cs, PCB-1260
Pit 4 South	8.4E-03	–	3.8E-04	–	^{60}Co

Sediment COCs for the Lower WOC, WOL, and WOCE subbasins include all contaminants that were identified as COCs in any of the subbasins. Therefore, the total recreational COC list includes ^{137}Cs, ^{60}Co, beryllium, PCB-1260, and $^{239/240}$Pu.

The weight-of-evidence suggests that sediment in Lower WOC/WOL poses a significant risk to benthic invertebrates. Seven sediment COECs were identified in this subbasin (Table 3.77); and the sediment community surveys were inconclusive. The relative importance of habitat and contamination could not be determined because a good reference was not available. However, the very low taxonomic richness observed in WOL provides no evidence to refute the risks indicated by the sediment chemical concentrations.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the Lower WOC/WOL subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Significant risks were identified for benthic invertebrates exposed to sediment in the Pit 4 South subbasin, based on one line of evidence (sediment chemistry). Anthracene was the only analyte potentially presenting a significant risk and was identified as a COEC (Table 3.77). Copper, mercury, and five organics, including PCB-1254, present a marginal risk, and five other analytes exceeded only possible effects levels and were considered a negligible risk. No other analytes exceeded possible effects levels.

Table 3.77. Summary of potential risks to benthic invertebrates from exposure to contaminants in sediment in Lower WOC, WOL, and WOCE subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
WOCE	Significant	Hg, Ag, 4,4'-DDT, PCB-1254, PCB-1260
	Marginal	Cd, Cr, Pb, Zn, benzo(a)pyrene, BEHP, chrysene, endosulfan sulfate, fluoranthene, phenanthrene, pyrene, total PAH
	Negligible	Sb, As, Cu
Lower WOC/WOL	Significant	Ag, Sb, Cr, Ni, Zn, PCB-1254, PCB-1260
	Marginal	As, Cd, Cu, Pb, alpha-BHC, diethylphthalate
	Negligible	Hg, di-n-butylphthalate, methylene chloride, toluene
Pit 4 South	Significant	Anthracene
	Marginal	Cu, Hg, acenaphthene, fluorene, naphthalene, PCB-1254, phenanthrene
	Negligible	Benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, total PAH

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels are listed as contaminants of potential ecological concern.

Significant risks were identified for benthic invertebrates exposed to sediment in the WOCE subbasin, based on one line of evidence (sediment chemistry). Mercury, silver, 4,4'-DDT, PCB-1254, and PCB-1260 potentially present significant risks and were identified as COECs (Table 3.77). Four inorganics and eight organics present a marginal risk, and three inorganics exceeded only possible effects levels and were considered a negligible risk. No other analytes exceeded possible effects levels.

No risks were identified for aquatic organisms exposed to radionuclides in sediment in the WOCE or Rt. 4 South subbasins. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Lower WOC, WOL, and WOCE Groundwater

Table 3.78 summarizes the carcinogenic recreational risk and the noncarcinogenic HI for the subbasins in the Lower WOC, WOL, and WOCE that have groundwater data.

Recreational COCs were identified for Lower WOC, WOL, and WOCE groundwater based on carcinogenic risk in the Lower WOC/WOL subbasin. COCs included ^{90}Sr, ^{3}H, arsenic, 1,1-DCE, and tetrachloroethene. Residential and industrial COCs are presented in Appendix B.

Table 3.78. Summary of risk results for Lower WOC, WOL, and WOCE groundwater

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index
Lower WOC/WOL	9.5E-03	1.1E-01	1.1E-04	8.0E-02
SWSA 6 South	6.8E-05	8.3E-01	9.6E-06	4.6E-01
SWSA 6 East	2.8E-04	7.5E-01	1.6E-05	3.6E-01
Trench 5 South	1.3E-06	–	1.5E-08	–

The groundwater data from the subbasins within the Lower WOC, WOL, and WOCE were screened against federal and state primary drinking water standards and against radionuclide-specific proposed and promulgated primary drinking water standards. Lower WOC/WOL exceedances were noted for ^{90}Sr, ^{3}H, ^{14}C, ^{234}U, benzene, thallium, and 1,1-DCE. SWSA 6 South showed exceedances for thallium. SWSA 6 East had exceedances for ^{3}H, carbon tetrachloride, thallium, and 1,2-DCE. Pit 4 South, WOCE, and Trench 5 South did not have any criteria exceedances for groundwater contaminants.

Lower WOC, WOL, and WOCE Surface Water

No surface water samples are available for the SWSA 6 South and Trench 5 South subbasins. A large number of samples were available for Lower WOC/WOL and were analyzed for inorganics (up to 77), organics (up to 21), and radionuclides (up to 258) as part of the WAG 2 RI, OECD monitoring, and some earlier studies. Table 3.79 summarizes the carcinogenic recreational risk and the noncarcinogenic HI for the subbasins in the Lower WOC, WOL, and WOCE that have groundwater data.

Table 3.79. Summary of risk results for Lower WOC, WOL, and WOCE surface water

Subbasin	Industrial risk	Industrial hazard index	Recreational risk	Recreational hazard index	Recreational COCs
Lower WOC/WOL-seeps	1.8E-01	5.4E-01	2.1E-03	6.7E-02	^{90}Sr, ^{3}H, tetrachloroethylene, beryllium
Lower WOC/WOL-streams	5.2E-04	6.6E-01	4.7E-05	7.3E-02	None
WOCE-streams	5.6E-05	4.7E-02	6.1E-07	1.7E-02	None
SWSA 6 East-streams	1.8E-04	1.6E-01	2.2E-06	2.8E-03	None
Pit 4 South-seeps	1.1E-04	1.2E+00	4.5E-06	9.6E-02	None

Recreational COCs for Lower WOC, WOL, and WOCE surface water are limited to ^{90}Sr, ^{3}H, tetrachloroethylene, and beryllium in the seeps of the Lower WOC/WOL subbasin. Industrial and residential COCs are presented in Appendix B.

The recreational ingestion of fish was also evaluated for fish data collected from WOL. These data were collected for five species of fish (gizzard shad, bluegill sunfish, largemouth bass, common carp, and redbreast sunfish) and evaluated for six contaminants (^{90}Sr, ^{137}Cs, ^{60}Co, mercury, Aroclor-1260, and Aroclor-1254. The carcinogenic risk was 2.74E-4 primarily to Aroclor-1260, with ^{137}Cs and ^{90}Sr also contributing. The noncarcinogenic HI was 2.5E+0 due solely to Aroclor-1254. Therefore, Aroclor-1254, Aroclor-1260, ^{137}Cs, and ^{90}Sr are identified as COCs for the fish ingestion pathway.

The weight-of-evidence suggests that water in these subbasins pose a significant risk to fish and benthic macroinvertebrates. The fish community is less species rich relative to the community observed here in the 1950s, redbreast sunfish have experienced reproductive failures, and the water has been lethal to Medaka embryos and larvae. The total number of macroinvertebrate species and the number of sensitive species are significantly lower than the upstream and pooled reference communities. Of the 11 COECs (Table 3.80), cobalt, copper, iron, nickel, thallium, and zinc concentrations appear to be the most likely contributors to toxicity. Ammonia concentrations exceeded only the lowest benchmark, suggesting that it may be toxic to sensitive species. Cadmium, silver, and total PCB concentrations may be toxic, but these chemicals were detected in less than 5% of the samples. Aluminum concentrations are not expected to be toxic in this system. Also, use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, as they may not be bioavailable.

Table 3.80. Summary of potential risks to aquatic organisms from contaminants in main stem surface water in the Lower WOC, WOL, and WOCE subbasins

Subbasin	Risk category[a]	COECs/COPECs[b]
SWSA 6 East	Significant	Al, Fe, Hg
	Marginal	None
	Negligible	None
Lower WOC/WOL	Significant	Ammonia, Al, Cd, Co, Cu, Fe, Ni, Ag, Tl, Zn, PCBs
	Marginal	Ba, B, Mn, Hg, carbon disulfide
	Negligible	Be, Li, Se
WOCE	Significant	Cd
	Marginal	None
	Negligible	None

[a] Risks were estimated by subbasin by comparing the distribution of observed concentrations to aquatic benchmarks. See the ecological risk assessment (Appendix C) for details.

[b] Contaminants of ecological concern were identified as analytes for which the 80th percentile concentration exceeded at least one probable effects level benchmark. Other analytes that exceeded possible or probable effects levels were considered contaminants of potential ecological concern.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the Lower WOC/WOL subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Risk estimates for piscivorous wildlife based on measured fish tissue data are available from two fish sampling locations in the Lower WOC/WOL subbasin (WCK 1.5 and WCK 2.3). Adverse effects from mercury were predicted to be likely for river otter (LOAEL-based HQ = 1.4) and belted kingfisher (HQ=1.5). Adverse effects from exposure to PCBs were predicted for river otter (HQ=2.6), but not for any of the other piscivorous receptors. No risks were predicted from exposure to radionuclides in surface water.

No risks were identified for terrestrial wildlife drinking surface water from the Lower WOC/WOL subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for Lower WOC/WOL plants assumed to be exposed to seep water in soil solution (Table 3.11). Thallium exceeded plant soil solution benchmarks at stations MBTrib 3, SW2-5, SW6-1, and WC TRIB-1 with HQs ranging from 3.0 to 25.6. Aluminum exceeded benchmarks at stations 05.SW006, SW7-5, and WC TRIB-1 with HQs from 4.8 to 19. The aluminum and thallium benchmarks appear to be conservative as both analytes exceeded benchmarks at numerous seeps across the whole watershed, and the aluminum benchmark is below background. Other analytes marginally exceeding benchmarks at least one station in this subbasin included arsenic, copper, iron, and lead (HQs all <1.7). Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants. It is unlikely that aluminum is of ecological concern.

Significant risks were identified for aquatic organisms exposed to main stem surface water in the SWSA 6 East subbasin, based on one line of evidence (surface water chemistry). Aluminum, iron, and mercury were the only COECs (Table 3.80). No other analytes were of potential concern. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, as they may not be bioavailable. Aluminum is insoluble in nearly neutral water, and the bioavailable fraction is unlikely to be toxic to aquatic biota in the Melton Valley watershed.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the SWSA 6 East subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water from the SWSA 6 East subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the Pit 4 South subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits.

No risks were identified for terrestrial wildlife drinking surface water at the Pit 4 South subbasin; water concentrations were below wildlife LOAELs for all receptors and all analytes.

Potential risks were identified for Pit 4 South plants assumed to be exposed to seep water in soil solution (Table 3.11). Aluminum, arsenic, and thallium exceeded plant soil solution benchmarks at station East Seep (HQs = 150, 28.2, and 7.8, respectively). The aluminum benchmark appears to be conservative as it is below the background concentration. However, the aluminum concentration at this station was well above background and substantially higher than concentrations at other seeps across the watershed. The arsenic benchmark is based on limited data on root length reduction. Other analytes marginally exceeding benchmarks (HQs <3.6) at this station were boron, fluoride, and iron. Use of unfiltered water samples may result in overestimates of risks for metals that are significantly associated with the particulate fraction, which is largely unavailable to plants.

Although the weight-of-evidence is not strong, it suggests that water in this subbasin poses a significant risk to fish and macroinvertebrates. Cadmium is the only COEC (Table 3.80), and the concentrations measured may overestimate the fraction that is bioavailable. Although water from within the embayment was not tested, water entering the embayment reduced Medaka embryo and larvae survival by 90%. Hence, there is no strong evidence to indicate that cadmium does not pose a risk in this subbasin.

No risks were identified for aquatic organisms exposed to radionuclides in surface water in the WOCE subbasin. Dose rates estimated for large invertebrates and large fish were below recommended dose rate limits, and the combination of surface water and sediment exposures also resulted in dose rates below the limit.

Risk estimates for piscivorous wildlife based on measured fish tissue data are available from two fish sampling locations in the WOCE subbasin (WCK 0.3 and WCK 0.9). Adverse effects from PCBs were predicted to be likely for river otter (LOAEL-based HQ = 1.9) and belted kingfisher (HQ = 1.9). No adverse effects from exposure to mercury were predicted for any of the piscivorous receptors. No risks were predicted from exposure to radionuclides in surface water.

No risks were identified for terrestrial wildlife drinking surface water from the WOCE; water concentrations were below wildlife LOAELs for all receptors and all analytes.

The contaminant surface water concentrations for the Lower WOC, WOL, and WOCE subbasins were screened against state of Tennessee AWQC for human health recreational exposures and for ecological criteria based on continuous fish and aquatic life exposures. Arsenic, PCBs, and thallium exceeded the human health criteria at the Lower WOC/WOL subbasin. Arsenic and mercury exceeded the human health criteria at SWSA 6 East. Chromium, mercury, and PCBs showed exceedances for the ecological criteria at the Lower WOC/WOL subbasin. Cadmium also exceeded the ecological criterion at WOCE and mercury exceeded the criterion at SWSA 6 East.

Although WOC is not designated for domestic water supply, it flows into the Clinch River, which is designated as such. Therefore, in addition to the criteria exceedance conducted for the surface water data in this subbasin, the data from WOD, an exit point for the watershed, was screened against promulgated and proposed MCLs. Exceedances were observed for ^{90}Sr, ^{3}H, and thallium. For the screening against AWQC, arsenic, thallium, and PCBs were exceeded for human health AWQC and chromium, mercury, and copper was exceeded for the aquatic life AWQC.

3.7.5 Requirements for Site Stabilization/Remediation

Three broad categories of conditions exist in the subbasins included with Lower WOC, WOL, and WOCE. The area contains upland subbasins with primary and/or secondary contaminant sources, floodplain areas containing secondary contaminated soils and sediments, and areas of impounded water with a blanket of contaminated bed sediment.

Upland subbasins containing sources in this area have minimal current releases to the surface water system. Some sources have been capped while others have not. Inasmuch as these areas are not current issues with respect to release, the management options focus on long-term stability of primary and any secondary contaminant masses and direct exposure considerations in areas of elevated surface contamination. Long-term stabilization of these areas may be achieved either by planning and construction of source control measures or hydrologic isolation measures. Direct exposure may be handled by removal and replacement of contaminated surface soils or by covering and containment of such areas.

In areas of floodplain containing secondary contaminated soils and sediment, the greatest problem is direct exposure by gamma radiation from ^{137}Cs and ^{60}Co in the surficial deposits. A secondary consideration is transport of contaminated surface material by extreme flood events and a much lower exposure or release problem is posed by re-dissolution of contaminants from the sediment. The exposure pathway of greatest concern in these areas may be handled by institutional control or by improved physical containment for the purpose of shielding humans and/or terrestrial biota.

In areas of impounded water with a blanket of contaminated bed sediment, the potential problems are (1) adverse effects of contaminants on aquatic organisms, (2) re-dissolution of contaminants from the sediment, and (3) the potential for transport of contaminated sediment by extreme flood events. Approaches to handling these problems include removal of contaminated sediment and disposing of again elsewhere or containment in place with improved routing of the stream to prevent sediment transport. A major issue with regard to handling the submerged sediment is control of surface water inflow and outflow.

3.8 HYDROFRACTURE SITES

The hydrofracture facilities consist of surface facilities (buildings, dry material storage tanks, waste storage tanks, and mixing and pumping equipment) at two formerly operational sites, four wells used for injection of grout slurry, and more than 100 additional wells ranging in depth from about 200 ft to more than 1000 ft. Figure 3.56 shows the locations of hydrofracture facilities and related wells. Near-surface contaminants associated with hydrofracture sites are described in subbasin discussions for subbasins containing the sites.

3.8.1 Contaminated Sites

The hydrofracture waste emplacement process involved mixing intermediate level liquid and tank sludge solid radioactive wastes with cement-based grout and additives and injecting the mixture under high pressure through deep wells. The geologic formation used for deep injection was the low permeability Pumpkin Valley Shale, a thin-bedded, maroon silty shale approximately 300 ft thick. The two wells used as operational injection points were constructed to total depths of 900 to 1100 ft. The hydrofracture injection process used discrete slots cut through the casing wall to isolate the depth at which grout slurry was emplaced in each well. The injected slurry spread along induced fractures (primarily bedding plane fractures) for several hundred feet from the injection wells, forming multiple, thin grout sheets (e.g., often less that 1/8 in. thick). The hydrofracture waste disposal process resulted in emplacement of approximately 50,000 yd^3 (10.1 million gal) of radioactive wastes and grout containing an aggregate of approximately 1.4 million Ci of radioactivity in the 43 grout injections performed between 1959 and 1984.

Four different sites at ORNL were used in the experimental/developmental and full-scale application of hydrofracture operations:

- Hydrofracture Experiment Site 1 (HF-1, also known as the 4-acre site),
- Hydrofracture Experiment Site 2 (HF-2),
- Old Hydrofracture Facility (OHF or HF-3), and
- New Hydrofracture Facility (NHF or HF-4).

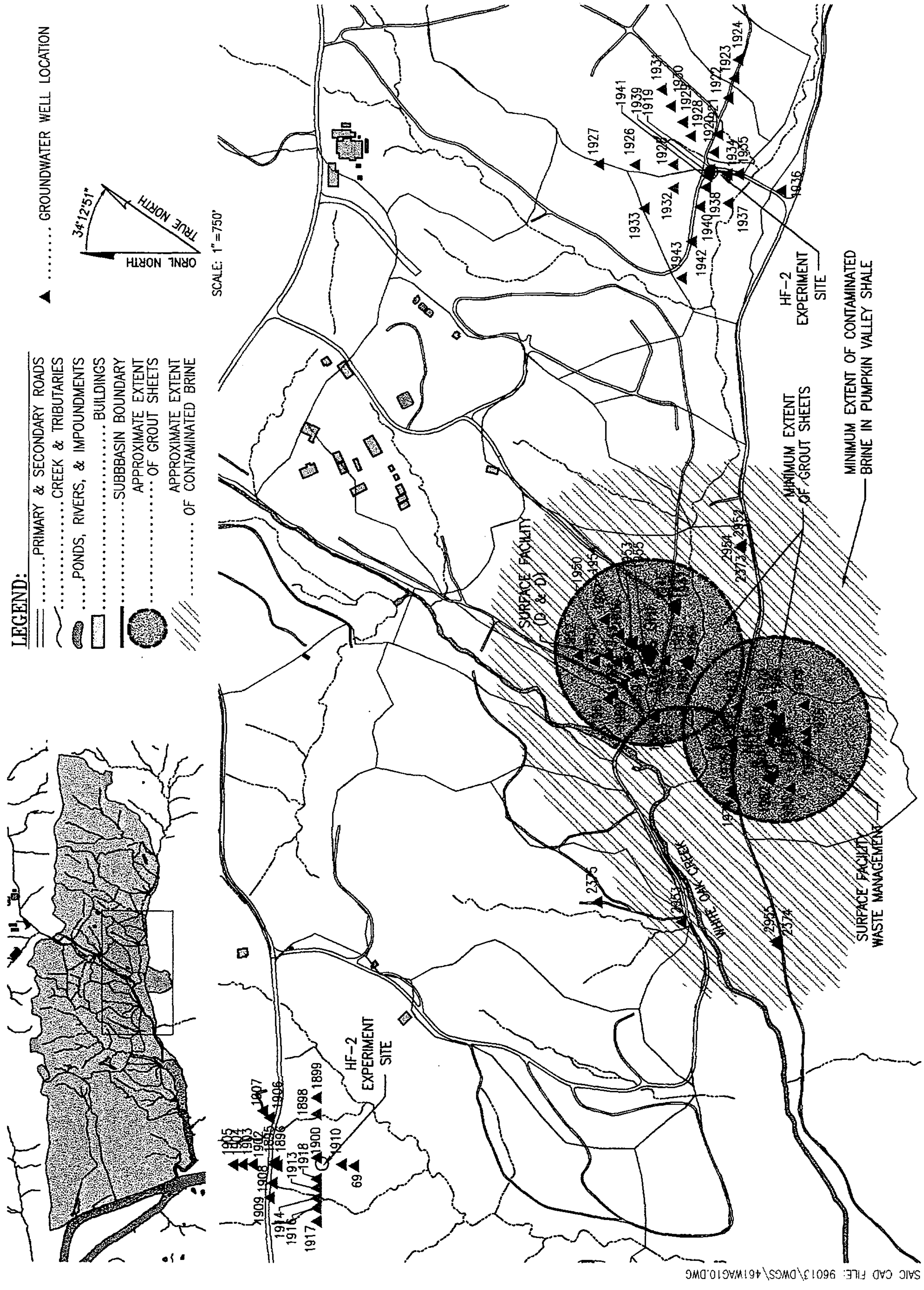


Fig. 3.56. Locations of hydrofracture sites, contaminated area, and wells.

Three test injections, one at HF-1 and two at HF-2, introduced less that 100 Ci of ^{137}Cs and short-half-life radionuclides into the upper Pumpkin Valley Shale. OHF (HF-3) was a developmental operation that was later converted into an operational facility, and NHF (HF-4) was designed as an operational facility. The OHF and NHF were operational for over a 20 year period. The last hydrofracture waste injection was conducted at NHF in January 1984. Water was injected before waste/grout slurry to open a fracture and also after the waste to push grout out of the well.

Grout used as the carrier to entrain the liquid and solid radioactive wastes consisted of a mixture of Portland cement, fly ash, clays, and a small amount of a set-retarding material. The Portland cement acted as a binder in the grout matrix. Fly ash was added to reduce the amount of Portland cement needed and thus reduce the cost of the mix; and additional benefit of using fly ash was a potential reduction in the strontium leach rate, the major radionuclide in the NHF waste. Clays (attapulgite, grundite, and illite) retarded and decreased the amount of phase separation water (grout filtrate) released by the mix and reduced the leaching potential of cesium (held by ion exchange). The set retardant (glucono delta lactose) increased the time the grout remained liquid and pumpable. The set retardant was used at OHF but was deleted from the mix used at NHF.

3.8.2 Pathway Model of Contaminant Release

There is no known contribution from the hydrofracture waste to the surface water ^{90}Sr or ^{3}H release in the Melton Valley watershed. The driving mechanism for possible migration of aqueous contaminants during the initial stages of injection and shortly after the total slug of contaminated grout injection was the waste injection pressure. The induced pressure regime would, for a time, dominate the ambient head distribution and alter the normal flow system. Contaminated grout would be expected to remain within the induced fracture(s) or within boreholes or wells penetrated by grout during the injection process.

Open and effective joints and fractures provide the most efficient natural flow path within the clastic and carbonate geologic formations underlying the hydrofracture facilities. Healed joints and fractures, while basically impermeable under undisturbed subsurface conditions, provide planes of weakness within the clastic section. When disturbed (such as by hydrofracturing) these planes of weakness could be opened to increase the effective fracture porosity/permeability, thereby increasing flow within the deep system.

As the leading edge of an artificially induced fracture develops and moves out from the point source into the formation, a network of leading-edge microfractures is also created in association with the major fracture. The induced microfracture system(s) would increase the total effective fracture porosity/permeability of the rock section.

The contaminated liquids could, under induced pressure, migrate along those planes of weakness (bedding planes and/or open fractures/joints) into formations overlying or underlying the injection horizon (Pumpkin Valley Shale). After dissipation of the induced pressure, the regional hydrogeologic flow regime would again dominate. The flow regime near NHF, however, was altered by the opening of fresh pathways (induced fractures, microfractures, and boreholes) and emplacement of grout.

Data obtained recently and analyzed as part of the hydrofracture well evaluation task (DOE 1996b), shows the approximate extents of the injected grout masses and the dissolved phase contaminants that separated from the grout after injection (referred to as grout filtrate). Figure 3.57 shows the subsurface distribution of grout and filtrate in the vicinity of the OHF and NHF sites.

Characterization data obtained through hydrofracture-related well evaluations and through deep groundwater investigations in Melton Valley have revealed the presence of artesian pressure in portions of the bedrock beneath the hydrofracture injection zone (Dreier in DOE 1995d). A conceptual model of the deep hydrogeology of Melton Valley has been developed using the combined information from area geology (structural and stratigraphic), geochemistry of groundwater, and hydraulic head data. This conceptual model suggests that pressures at depths beneath the hydrofracture injection zone are influenced by groundwater recharge in the Rome Formation and in the fault rock of the Copper Creek Fault (Fig. 3.58). A concern that arises from this conceptual model is the possibility that the grout filtrate (dissolved phase contamination) may slowly migrate through the deep bedrock fracture system to mix with the shallower fresh groundwater system or to mix with groundwater or surface water beyond DOE's controlled area boundary. Strontium-90 seeps, SW2-6, and SW2-7 were found in the floodplain area between WOC and Melton Branch, where inorganic water chemistry data suggest that the seeps may have a deeper groundwater component than typical seeps in the Melton Valley watershed (Hicks 1996).

Contaminants could also move vertically in wellbores through annular or intrawell flow. Results from the recent hydrofracture well evaluation project (DOE 1996b) identified numerous anomalies and poor casing integrity in many of the wells. Many wells were interpreted to have poor construction grout bonding (voids and channeling) between the casing and the borehole wall. Considering the combined factors of local hydrogeology, effects of hydrofracture injections on the local rock mass and on well bores, and deterioration of wells, it appears that the well bores (particularly those that penetrate the grout injection zone) represent the most probable pathway for unattenuated migration of contaminants out of the hydrofracture system. During migration through geologic pathways, contaminants are subjected to the natural attenuation mechanisms of ion exchange and geochemical interactions with the rock mass, while during seepage within a faulty or badly deteriorated well, much less attenuation would occur.

3.8.3 Secondary Contaminated Media

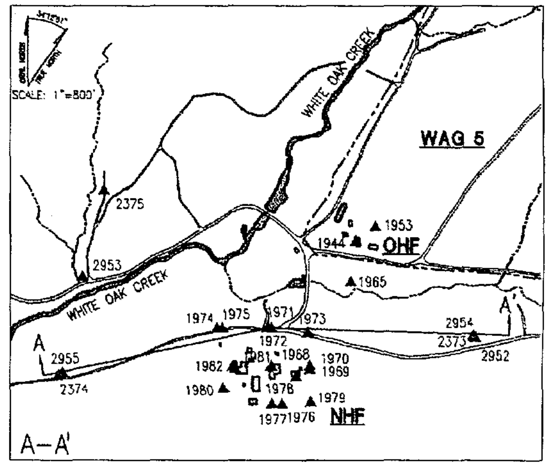
Secondary contaminated media associated with the hydrofracture system include contaminated deep groundwater, bedrock, and well bores. Near-surface contaminants such as soil and shallow groundwater near hydrofracture surface facilities are discussed in the appropriate subbasin sections (i.e., SWSA 5 Seep C and SWSA 5 WOC).

3.8.4 Human Health Risk, Ecological Risk, and ARAR Exceedances

No surface water, sediment, or surface soil are associated with WAG 10, so no COCs are identified for this media. Currently, no groundwater data are associated with this area, so groundwater COCs are also not identified.

3.8.5 Requirements for Site Stabilization/Remediation

Stabilization or remediation of the hydrofracture facilities involves closure and removal of surface facilities and waste storage tanks and control of well bores associated with the hydrofracture sites. Surface facilities are part of CERCLA deactivation and decommissioning activities and a project is currently active to remove the residual liquids and sludges from the storage tanks at the



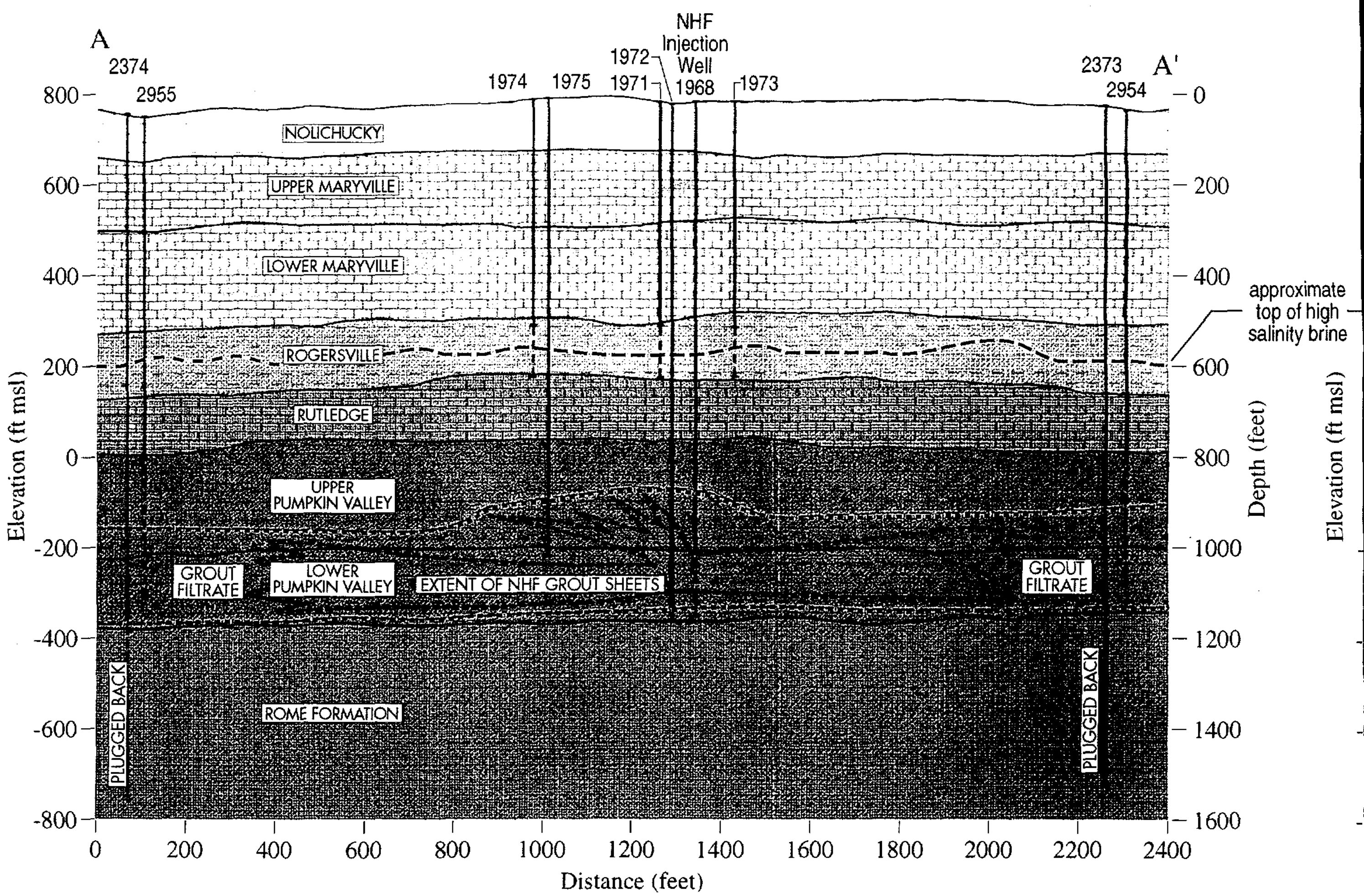
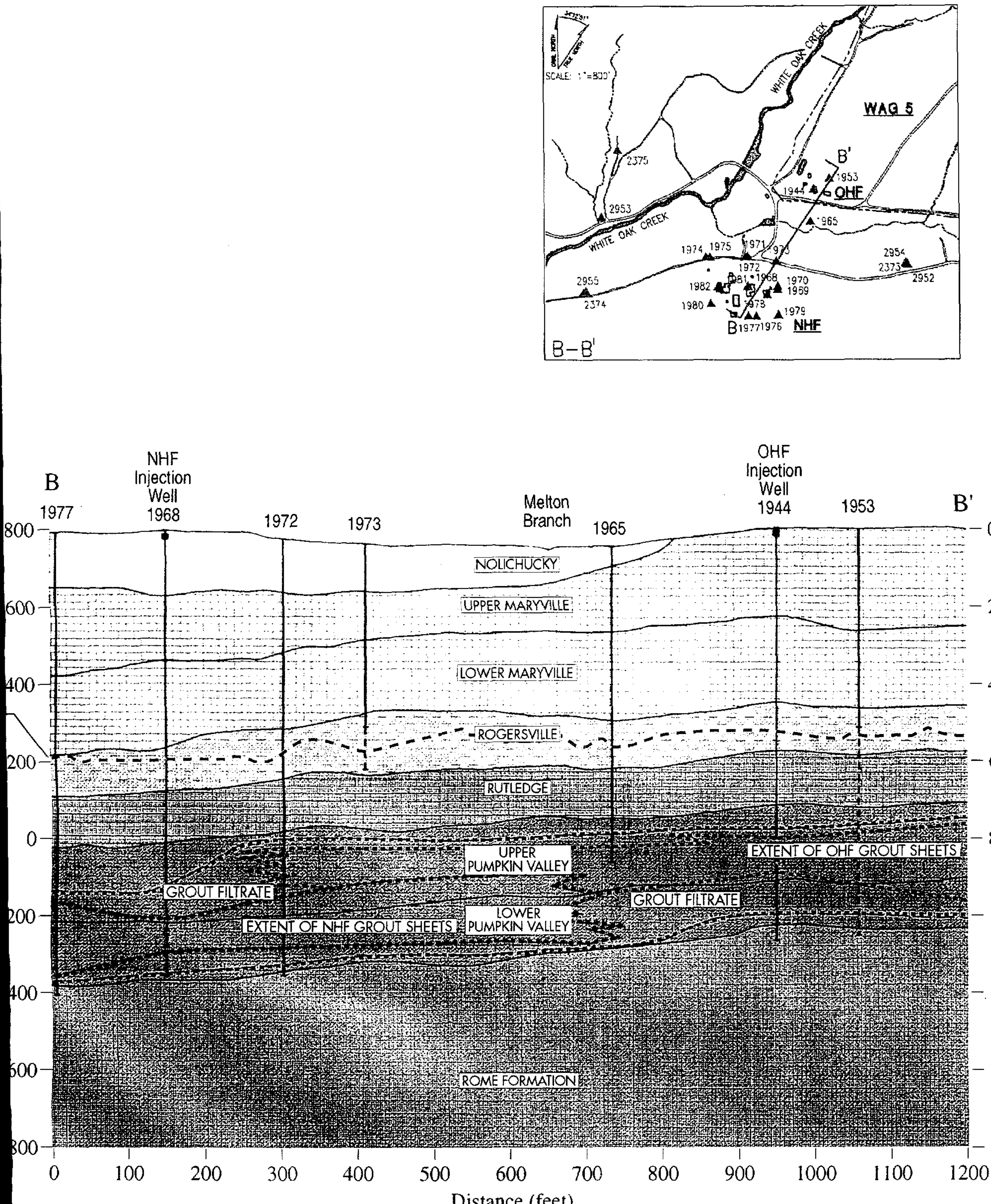


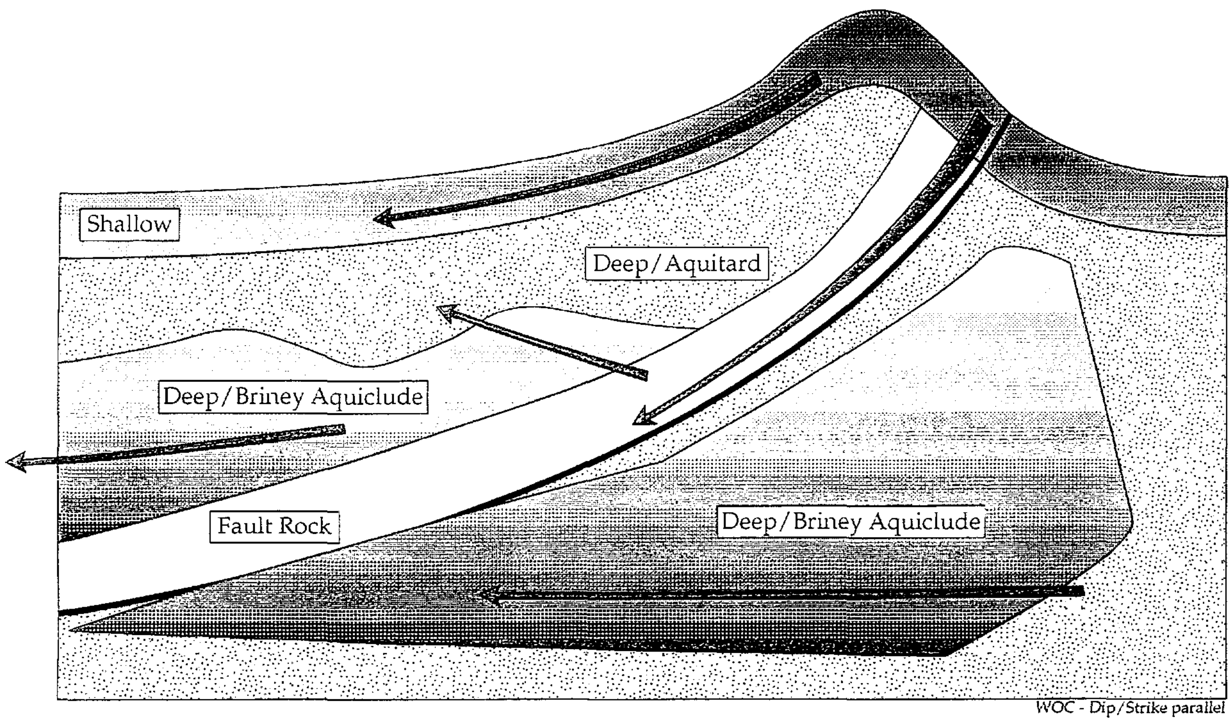
Fig. 3.57. Cross section showing subsurface distri
contaminated filtra



WOC - A&B cross sections

ution of hydrofracture grout and
te.

Dip-Parallel Conceptual Model



Strike-Parallel Conceptual Model

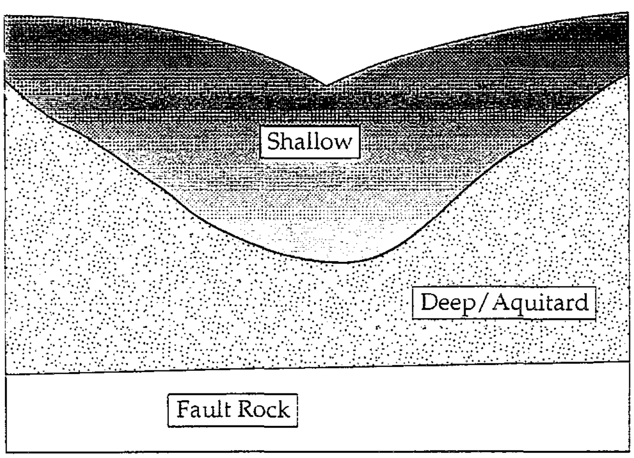


Fig. 3.58. Conceptual model hydrostratigraphy of Haw Ridge and Melton Valley.

OHF site. Removal of the deep injected contaminants associated with the grout is impractical. A plan has been prepared for conversion of selected hydrofracture related wells to monitoring devices to enable assessment of contaminant migration above the injection zone. Plans have also been prepared for plugging and abandonment of wells associated with OHF and NHF. Until direct evidence of contaminant releases through geologic pathways exists, the most cost-effective actions for management of the hydrofracture system are to complete surface facility removal, complete well modifications and plugging, and monitor appropriate locations to detect migration of contaminants.

4. CONCLUSIONS

This report presents a compilation of relevant data and information descriptive of the legacy waste disposal units and contaminated sites in the Melton Valley watershed, contaminant releases from those sites, mechanisms that cause the releases, exceedances of AWQCs, and assessments of risk to human health and ecological populations. The conceptual model of processes active in the watershed is presented in Sect. 2 along with brief discussions of exposure scenarios used in the assessment of risk, ARARs, and data sources used extensively in preparation of the report. Section 3.3 presents an overview of the Melton Valley watershed with respect to site physical conditions of key importance in decision-making and remedial action planning for the area. Sections 3.4 through 3.8 present detailed descriptions of each subbasin in the Melton Valley watershed, including descriptions of contaminant source characteristics, identification of contaminant release mechanisms, a physical pathway description, and identification of potential points at which intervention into the releases may be possible.

In overview, there are three separate aspects of the Melton Valley watershed that comprise the major problems identified in this RI—current contaminant releases to surface water, the presence of high activity and long-half-life radiological wastes, and widespread distribution of radiological contamination in secondary media.

These three factors are interrelated in the watershed but constitute separate individual problems from the standpoint of site and risk management. The importance of these parameters varies in the decision-making process and varies spatially throughout the Melton Valley watershed.

A subbasin ranking table has been prepared that provides an overview of the importance of each subbasin in the Melton Valley watershed based on several criteria including importance of the area to current ^{3}H and ^{90}Sr releases from the watershed, estimated radiological waste inventory, secondary contaminated media volumes, and recreational and ecological risk. Table 4.1 shows the subbasin ranking for the key evaluation criteria developed through the subbasin analyses presented in Sect. 3. The basis for assigning scores for each criterion is discussed in Sect. 3.3 along with discussion of assumptions that provide the basis for the overall ranking system.

Subbasin rankings in Table 4.1 show the relative importance of individual subbasins with respect to the criterion column. No weighting of the importance or comparability of ranking criteria within individual subbasins or between subbasins is implied. The Release Group column ranks subbasins based on the sum of current ^{3}H and ^{90}Sr releases to surface water. The inventory, column ranks subbasins based on estimated current inventory account for radioactive decay applied to the best estimate of disposed radionuclide inventory. Subbasins are also ranked according to recreational and industrial scenario risk estimates with an indication of environmental media that dominate the risk in each subbasin. Subbasins are ranked for both radiological and nonradiological ecological risk assessment results and dominant affected receptors in aquatic and terrestrial exposure scenarios are identified.

Review of Table 4.1 shows that application of different criteria provides different ranking orders for the subbasins.

Table 4.1 Melton Valley Watershed Subbasin Summary Table

Basin ID	Release group	Inventory group	Sec. med. group	Recreational risk group	Industrial risk group	Terr. rad. ecorisk group	Terr. non-nad. ecorisk group	Aquatic rad. ecorisk group	Aquatic non-rad. ecorisk group
SWSA 4 Main	●	◒	⊙	● [1]	● [2]	◒ [5]	● [3,5]	○ [6,7,8]	● [6]
SWSA 5 Seep B West	●	⊙	⊙	◒ [1]	● [1]	⊙ [4,5]	◒ [3,4,5]	○ [7,8]	⊙ [6]
SWSA 5 Seep C	●	●	◒	◒ [1]	● [1]	⊙ [5]	◒ [3]	⊙ [6,8]	◒ [7]
SWSA 4 East	◒	⊙	⊙	⊙ [1]	● [1]	ND	ND	○ [7]	ND
SWSA 5 Seep B East	◒	⊙	◒	◒ [1]	● [1]	⊙ [5]	⊙ [3,5]	○ [7,8]	● [6]
HRE	◒	○	⊙	◒ [1]	● [1]	⊙ [5]	● [3,4]	○ [7,8]	◒ [6]
W6MS1	⊙	●	◒	○ [2]	◒ [2]	○ [3,4,5]	⊙ [3,5]	○ [7,8]	● [7]
West Seep	⊙	●	●	● [1]	● [1]	◒ [4,5]	⊙ [3,5]	○ [7,8]	◒ [7]
WCTRIB-1	⊙	●	◒	◒ [1]	● [1]	⊙ [5]	ND	○ [7]	○ [6]
SWSA 5 Drainage D-2	⊙	◒	◒	◒ [1]	● [1]	○ [3,4,5]	◒ [5]	○ [6,7]	● [6]
W6MS3	⊙	⊙	◒	○ [2]	◒ [2]	○ [3,4,5]	○ [3,5]	○ [7,8]	● [7]
SWSA 5 Seep A	⊙	⊙	⊙	◒ [1]	● [1]	⊙ [5]	◒ [3]	○ [6,7,8]	◒ [7]
SWSA 5 WOC	⊙	⊙	◒	● [2]	● [2]	○ [3,4,5]	◒ [3,4]	● [6]	● [6,7]
SWSA 6 East	○	●	⊙	⊙ [1]	◒ [1]	○ [3,4,5]	⊙ [3,4,5]	○ [8]	● [7]
East Seep	○	●	◒	● [1]	● [1]	● [5]	⊙ [3,5]	○ [7]	ND
^{60}Co Seep	○	◒	⊙	○ [1]	⊙ [1]	ND	ND	ND	○ [6]
Intermediate Pond	○	⊙	○	◒ [1]	● [1]	◒ [5]	● [3,4,5]	○ [6,7,8]	◒ [6,7]
SWSA 5 Trib 1	○	⊙	⊙	● [2]	● [2]	⊙ [5]	◒ [3,4,5]	○ [6,7]	● [6]
SWSA 6 South	○	⊙	○	○ [1]	○ [1]	○ [3,4,5]	⊙ [3,5]	ND	ND
Pit 4 South	○	⊙	○	⊙ [1]	● [1]	○ [3,4,5]	⊙ [3,5]	○ [6,7]	⊙ [6]
SWSA 5 N WOC	○	○	○	○ [1]	⊙ [1]	○ [3,4,5]	⊙ [3,5]	○ [7,8]	ND
Lower WOC	○	⊙	○	◒ [2]	● [2]	◒ [5]	● [3,4]	○ [6,7,8]	● [6,7]
WOC	○	○	○	⊙ [2]	● [2]	⊙ [5]	◒ [3,4,5]	○ [6,7,8]	● [6]
MB-15	○	○	○	● [2]	● [1]	◒ [5]	ND	○ [7,8]	◒ [6]
Haw Ridge	○	○	○	⊙ [1]	● [1]	○ [3,4,5]	[4]	ND	ND
HF-2	○	○	○	⊙ [1]	◒ [1]	○ [3,4,5]	● [3,4]	○ [7,8]	● [7]
HFIR	○	○	○	○ [1]	◒ [1]	⊙ [4,5]	ND	ND	ND
HFIR East	○	○	○	○ [1]	○ [1]	○ [3,4,5]	ND	○ [7]	⊙ [6]
HFIR South	○	○	○	○ [2]	○ [2]	ND	ND	○ [7,8]	◒ [7]
MV Drive	○	○	○	⊙ [1]	◒ [1]	○ [3,4,5]	ND	ND	ND
NHF	○	●	○	○ [1]	⊙ [1]	○ [3,4,5]	○ [3,4,5]	ND	ND
Trench 5 South	○	○	○	○ [1]	○ [1]	ND	ND	ND	ND
WAG 7 WOC	○	○	○	◒ [1]	● [1]	⊙ [5]	○ [3,4,5]	○ [7]	ND
WOCE	○	○	○	◒ [2]	● [2]	ND	ND	○ [6,7,8]	◒ [7]
Explanation	○ Low			⊙		◒		●	High

[1] Human health risk from groundwater + soil

[2] Human health risk from main stem surface water

[3] Terrestrial ecological risk - plants dominant

[4] Terrestrial ecological risk - soil invertebrates dominant

[5] Terrestrial ecological risk - wildlife species dominant

[6] Aquatic ecological risk - benthic invertebrates dominant

[7] Aquatic ecological risk - fish dominant

[8] Aquatic ecological risk - piscivores dominant

[ND] No data were available for appropriate media

- Ranking of ^{3}H and ^{90}Sr releases provides a ranking of subbasins on the basis of current releases to surface water from the source areas. The most important sources of current radionuclide release to surface water are associated with SWSAs 4 and 5 and the HRE area.

- Ranking according to total estimated current radionuclide inventory in the subbasin provides a somewhat different perspective because not all waste inventory is directly associated with the current releases. Other than the deep-injected hydrofracture waste, the highest inventory of disposed radioactive waste lies in the West Seep Tributary subbasin and is associated with the combination of high activity waste disposed in auger holes in SWSA 6 and with the residual waste contained in the inactive Seepage Pits 2, 3, and 4. Subbasins in the SWSA 5 South area also contain high inventories of radiological waste. Some similarity in the overall ranking for radionuclide inventory and secondary contaminated media is observed and is attributed largely to the estimates of large volumes of contaminated soil in the seepage areas surrounding the Seepage Pits and Trenches.

- In general, both the human health risk assessment for potential recreational risk and the ecological risk assessment highlight subbasins other than those that are prominent for inventory and current release. This difference occurs because the risk assessment is highly sensitive to potential exposures of humans and wildlife to contaminants contained in surface soils and sediment. Only the single-chemical toxicity line of evidence for impacts to benthic invertebrates is reflected in Table 4.1, which may result in conservative estimates. The areas where the risk assessments identified on the most significant problems were in the Intermediate Pond subbasin, the East Seep subbasin, the Lower WOC subbasin upstream of WOL, SWSA 5 drainages, and the sediment and contaminated soil areas associated with the HFIR Ponds. Radiological contaminants dominated in the human health risk assessment; however, nonradiological contaminants contribute to risk in several areas. Nonradiological contaminants, metals in particular, dominated in the ecological risk assessment.

Several general conclusions may be drawn from the assessments performed throughout the Melton Valley watershed. These conclusions focus on the conditions that are fundamental to scoping remedial actions that can meet remedial action goals and are key points for decision-makers in selecting a realistically achievable endpoint for the site.

1. *Thirteen of 35 subbasins in the WOC Melton Valley RI Area contribute approximately 71% of the ^{90}Sr and 97% of the ^{3}H currently released to surface water* (Fig. 4.1).

Releases of contaminants to surface water, though diminished by several significant control actions taken between 1994 and 1996, continue to produce concentrations of ^{90}Sr and ^{3}H that exceed MCLs and recreational risk scenario action levels (1E-04) at the watershed exit point in the main stems of streams in the Melton Valley RI area. Portions of some tributaries are also affected. Early actions taken at SWSA 5 Seep C and Seep D combined have reduced the ^{90}Sr flux measured at WOD by 25%.

The distribution of estimated current ^{90}Sr releases indicates that the SWSA 4 Main, SWSA 5 Seep C, HRE, Seep B East, SWSA 4 East, and SWSA 5 WOC subbasins are the six most important sources of continuing release in the Melton Valley area. SWSA 5 Drainage D-2, West Seep Tributary, and W6MS3 are significant but secondary in importance for ^{90}Sr releases measured at the watershed exit point. Remedial actions recently completed in the SWSA 4 Main subbasin are expected to further reduce ^{90}Sr releases.

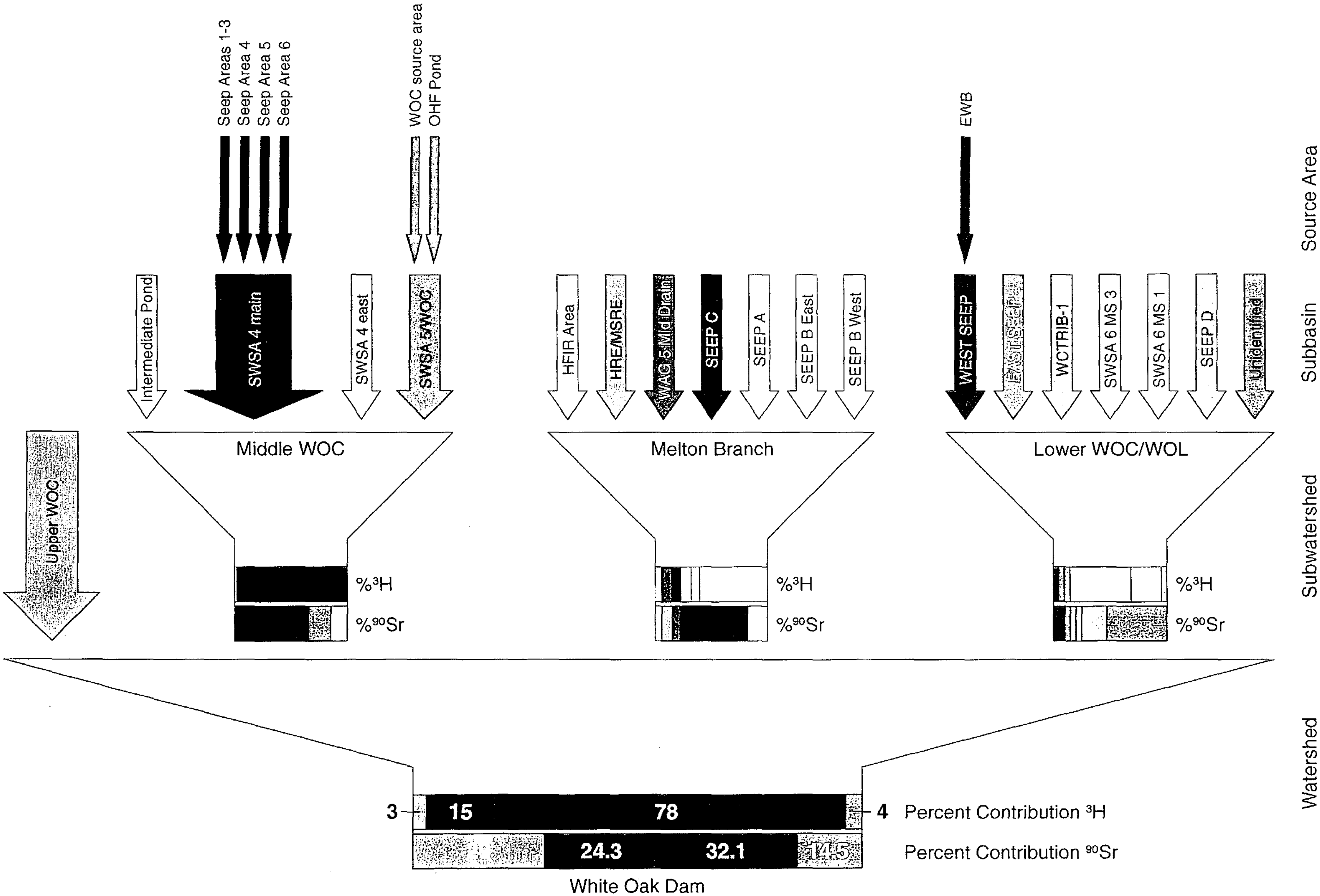


Fig. 4.1. Schematic diagram of ^{3}H and ^{90}Sr releases to surface water in Melton Valley watershed.

WOC - flux at WOD

Tritium releases have not been affected significantly by the control actions taken to reduce ^{90}Sr releases because locations treated were not major ^{3}H sources and because the treatment methods selected have no effect on ^{3}H. The Seep B subbasin is the major source area for watershed releases of ^{3}H (56.3%) followed by SWSA 4 Main (13.9%), Seep A, WAG 5 Drainage D-2, Seep B East, and W6MS3.

2. *Radioactive decay, changes in site operations, and remedial actions completed to date account for decreasing trends in ^{90}Sr and ^{3}H releases.*

Historic surface water monitoring data show that annual releases of ^{90}Sr and ^{3}H have decreased significantly since monitoring started. Changes in waste management account for much of the reduction in ^{90}Sr release. Radioactive decay has reduced radionuclide inventories by approximately 50% in most areas.

Projection of the current release trend for ^{3}H incorporating the radioactive decay process suggests that within about 20 years ^{3}H contributions from Melton Valley sources may produce concentrations at the exit point of the Melton Valley watershed less than the proposed MCL (56 FR 33050 July 18, 1991). Tritium concentrations could still exceed the proposed MCL in Melton Branch and in some tributaries and seeps. A similar projection for ^{90}Sr shows the impact of seep collection and treatment projects completed between 1994 and 1996. This analysis shows timespans of 10 to 70 years to reach ^{90}Sr contributions to streams producing concentrations less than the proposed MCL (56 FR 33050 July 18, 1991) at the watershed exit point, depending upon the aggressiveness and effectiveness of remedial actions.

Groundwater contaminant trend analysis shows most wells monitored have steady contaminant levels. Of those with significant trends in Melton Valley, more are decreasing than increasing.

3. *Most areas currently releasing significant quantities of contamination to surface water appear to be associated with perennially inundated shallow land burial trenches* (Fig. 4.2).

Release mechanisms for the contaminated sites in the Melton Valley watershed are associated with waste or contaminated material in direct contact with water. Five of the six most important contaminant-releasing subbasins in Melton Valley have a large percentage of their contaminant inventory in perennially inundated trenches. The highest ranked subbasins where source inundation is the predominant release mechanism include SWSA 4 Main, SWSA 5 Seep B East and West, SWSA 4 East, and HRE. Contaminant sources in SWSA 5 Seep C, which is also a major contaminant release area, are known to be seasonally inundated. Seasonal inundation and direct infiltration affect most other contaminated sites to some extent.

In the Melton Valley watershed, most contaminants derived from near-surface contaminant sources follow shallow, fracture-controlled seepage pathways that discharge to the local streams. Tritium is detected in some wells as deep as 400 ft beneath SWSA 6, although at concentrations much lower than those detected in the shallow groundwater zone. Geochemical attenuation mechanisms retard the migration of most other contaminants, such as ^{90}Sr and metals, in the same flow systems.

VOCs are detected in groundwater in some wells beneath and adjacent to several waste disposal areas including SWSAs 4, 5, and 6. Concentrations are typically less than about 100 μg/L although concentrations as high as about 3 mg/L have been detected near solvent auger hole groups at

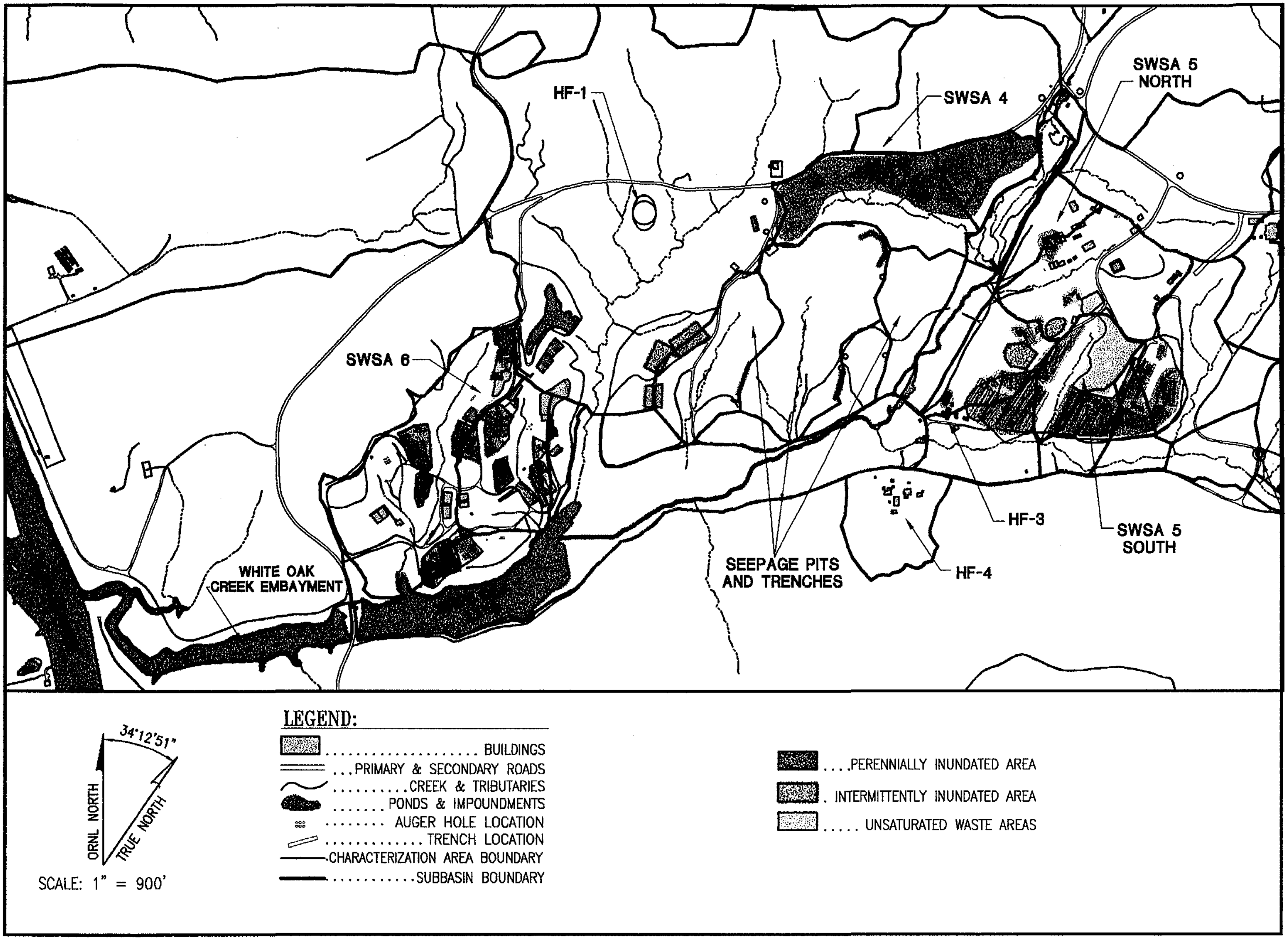


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Fig. 4.2. Hydrologic characteristics of contaminant source areas.

SWSA 5. The local "hot spot" distribution of VOC detection suggests that sources of these contaminants may be localized and that the migration is controlled by the fracture-dominated groundwater flow patterns.

Uncertainty remains regarding the potential for long-term migration of contaminated deep groundwater in the hydrofracture waste disposal zone. Contaminated fluids have been detected more than 1000 ft from the two injection wells. The lateral extent of deep fluid migration in the hydrofracture zone is not well defined with existing data. Deep wells and boreholes in the vicinity of the injected grout and waste are the most likely pathways vertical from the deep disposal zone upward to the potentially potable groundwater zone, which lies between about 20 and 300 ft.

4. *Contaminants in the Melton Valley watershed are present in surface water, groundwater, and soil.*

Contaminants in the Melton Valley watershed surface water that exceed the AWQC for protection of human health include:

- arsenic, which was detected in a large number of samples from many subbasins downgradient of contaminated sites, but overall was detected in less than about half of the surface water samples in which it was analyzed;
- antimony, which was detected in two subbasins (SWSA 5 Seep A and Middle WOC);
- mercury, which was detected near the HFIR area and in the West Seep Tributary;
- PCBs, which were detected in the Lower WOC and WOC subbasins; and
- VOCs, including carbon tetrachloride, 1,1-DCE, and PCE.

Contaminants in the Melton Valley watershed surface water that exceed the AWQC for protection of aquatic life include: cadmium, copper, chromium, selenium, lead, mercury, nickel, and PCBs, which were detected in unfiltered WOC floodplain surface water samples. Subbasins most affected include those at SWSAs 4, 5, and 6 and Lower WOC/WOL.

While AWQC were exceeded in several subbasins for Cd, Se, and Ni, the more detailed analyses presented in Sect. 3 suggest that these analytes may not always be a concern.

Radionuclides that exceed MCLs in groundwater include: ^{3}H and ^{90}Sr, which are widespread in Melton Valley; ^{137}Cs; ^{60}Co; ^{228}Ra; isotopes of uranium; ^{241}Am; and isotopes of Pu. Areas most affected by radiological groundwater contamination include SWSAs 4 and 5.

Metals that exceed MCLs in groundwater include: antimony, nickel, and thallium Areas most affected by metals in groundwater include SWSAs 4 and 5 and HRE.

VOCs that exceed MCLs in groundwater include: benzene, carbon tetrachloride, 1,1-DCE, PCE, TCE, and vinyl chloride. Areas most affected by VOC contamination in groundwater include SWSAs 4, 5, and 6.

Nonradiological COCs detected in soil and sediment and potentially significant in the human health recreational risk assessment or in the ecological risk assessment include:

- mercury, PCBs, and several PAHs detected predominantly in WOC floodplain soils;
- silver and zinc, potentially present within several subbasins;
- chromium, which was detected at high concentrations in soils in the HF-2 subbasin and in Lower WOC and WOL; however, the ecological risk assumption was that the chromium was Cr^{+6} rather than the more probable Cr^{+3}; and
- aluminum and manganese, which are present in high concentrations in some soil samples; however, these two elements are naturally abundant, and the risk estimate assumptions are very conservative with respect to potential adverse effects on plants and soil invertebrates.

5. *Contaminated surface soils are a significant problem in the Melton Valley watershed as shown by both the human health recreational risk assessment and the ecological risk assessment* (Fig. 4.3).

Radiological contamination present at the ground surface in soil or sediment exceeds recreational risk levels for gamma radiation exposure in contaminant source area hot spots, in secondarily contaminated areas along seepage discharge routes, and in broad floodplain areas. The exposure limit of 50 μR/h, which corresponds to the upper end of EPA's target risk range (1.0E-04), is exceeded in significant fraction of the WOC Melton Valley RI Area. The most common radionuclide present in the hot spots is ^{137}Cs, although ^{60}Co is detected along with ^{137}Cs in some areas. The largest areas affected by contaminated surface soils lie within the WOC floodplain. Most of the contamination in these areas originated from historic releases from the ORNL main plant area. The relatively low geochemical mobility of cobalt and the extremely low geochemical mobility of cesium when it is particle-bound in Melton Valley soils account for the very low dissolved concentrations of these radionuclides within the WOC Melton Valley RI Area. In subbasins containing main stem streams in Lower WOC, Middle WOC, and Melton Branch, much of the mapped wetland area contains contaminated soil and sediment. In areas designated wetlands, the ARAR for wetland protection applies to any proposed remediation activities.

6. *Long-half-life radionuclides pose a future potential risk for several areas.*

Although short-half-life fission products such as ^{3}H, ^{60}Co, ^{90}Sr, and ^{137}Cs will decay to levels below concern in most disposal areas within about 100 to 300 years, the presence of long-half-life (>100 years) radionuclides in some of the contaminated sites in Melton Valley poses a future risk on-site. Before the mid-1960s, long-half-life wastes, including uranium, thorium, and TRU isotopes, were disposed in shallow land burial trenches. These wastes were usually placed in special containers such as concrete casks or had concrete poured over the waste after emplacement in a trench. Locations of such wastes in SWSA 4 are not well known because disposal records for SWSA 4 and a portion of SWSA 5 were lost. Remaining disposal records for SWSA 5 suggest that casks containing high activity, alpha-emitting waste were disposed of in six known shallow land burial trenches in SWSA 5 South including areas in SWSA 5 Seep B West, Drainage D-2, Seep C, and SWSA 5 WOC subbasins. Isotopic inventories for other shallow land burial trenches in SWSA 5 and SWSA 6 suggest that undesignated but presumably small quantities of transuranic isotopes are widely distributed throughout the buried waste. The greatest concern lies with the larger curie

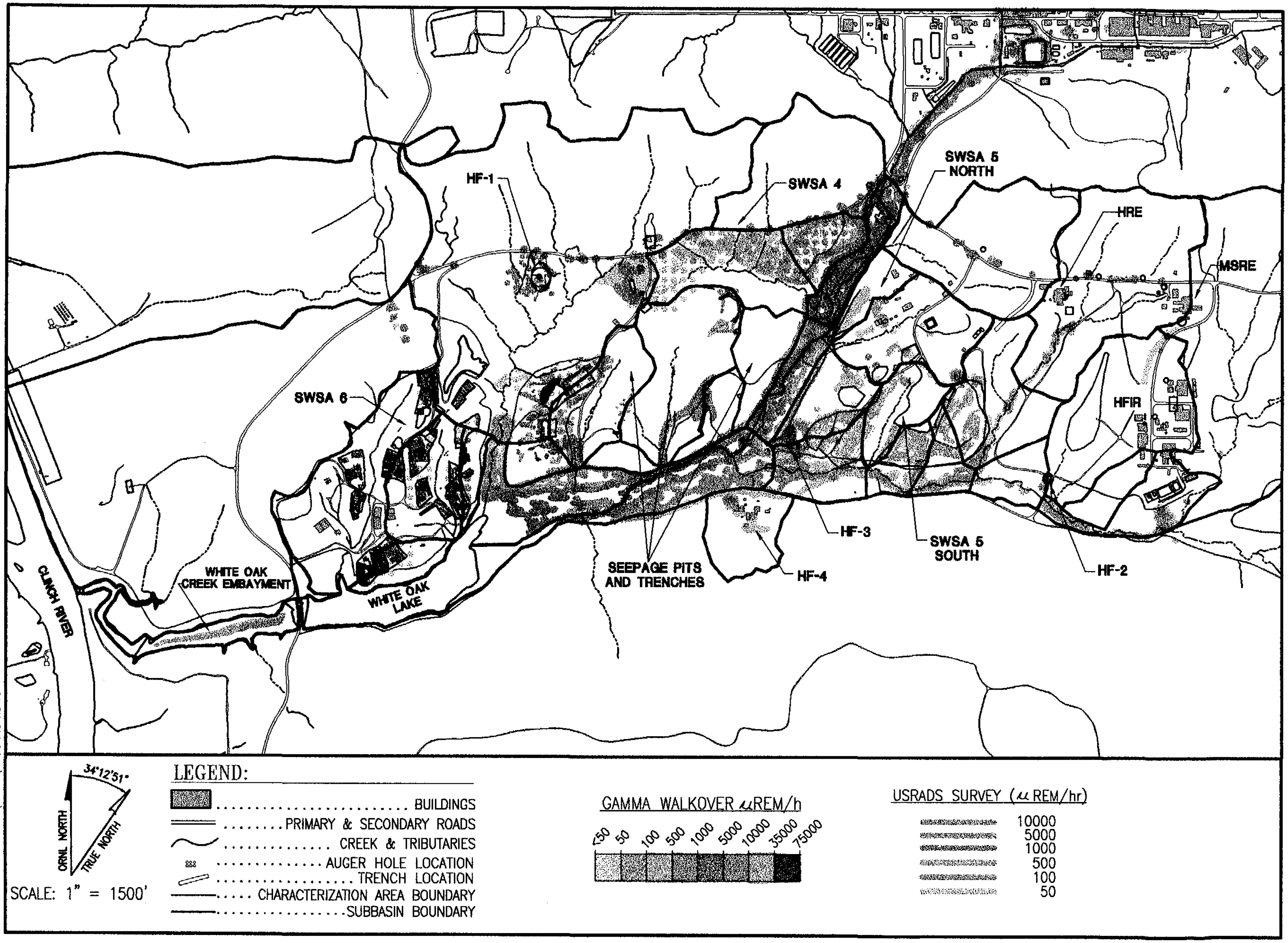

Fig. 4.3. Distribution of contaminated surface soil in the Melton Valley watershed.

inventory associated with the high alpha activity special disposals. A management strategy for these wastes must be included in long-term site remediation and management planning.

7. *Hydrofracture wastes and wells are a long-term site management challenge.*

The deeply injected wastes associated with the hydrofracture waste disposal process and the deep wells associated with these wastes present a potential long-term site management requirement. The grouted waste and associated highly contaminated fluids have permeated fractures in the shale bedrock to distances in excess of 1000 ft (horizontally) from the two injection wells. While the bedrock permeability is very low at depths of 800 to 1000 ft below ground where the grout was injected, and fluid migration rates are slow in the deep briney zone, artesian pressure is evident in some wells penetrating the grout injection interval. This artesian pressure combined with the high salinity of the deep groundwater is capable of causing contaminant migration upward into shallow groundwater or to the ground surface through deteriorated deep wells. The majority of radiological contaminants disposed in hydrofractures are ^{90}Sr or ^{137}Cs, and radioactive decay has already reduced the inventory in the OHF injections by about one-half since disposal.

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