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Remedial Investigation Report on Waste Area Grouping 5 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

Volume 1
Technical Summary

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Energy Systems Environmental Restoration Program
ORNL Environmental Restoration Program

Remedial Investigation Report on Waste Area Grouping 5 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

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Technical Summary

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PREFACE

This Remedial Investigation Report on Waste Area Grouping (WAG) 5 at Oak Ridge National Laboratory (DOE/OR/01-1326&D1/V1, DOE/OR/01-1326&D1/V2, DOE/OR/01-1326&D1/V3, and DOE/OR/01-1326&D1/V4) was prepared in accordance with requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for reporting the results of a site chacterization for public review. This work was performed under Work Breakdown Structure 1.4.12.6.1.05.40.02 (Activity Data Sheet 3305, "WAG 5"). Publication of this document meets a Federal Facility Agreement milestone of March 31, 1995. This document provides the Environmental Restoration Program with information about the results of investigations performed at WAG 5. 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 decisions regarding the need for subsequent remediation work at WAG 5.

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ACRONYMS

ADS	activity data sheet
AEC	Atomic Energy Commission
ARAR	applicable or relevant and appropriate
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	Department of Energy
DQO	data quality objective
EE/CA	engineering evaluation/cost analysis
EPA	Environmental Protection Agency
ER	Environmental Restoration
ERBAM	environmental risk/benefit assessment matrix
ESD	Environmental Sciences Division
FFA	federal facility agreement
FSP	field sampling plan
GWOU	groundwater operable unit
HSPF	Hydrologic Simulation Program—FORTRAN
IDW	investigation-derived waste
ILLW	intermediate-level liquid waste
LLW	low-level waste
NHF	New Hydrofracture Facility
NPDES	National Pollutant Discharge Elimination System
OHF	Old Hydrofracture Facility
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PVC	polyvinyl chloride
PWSB	Process Waste Sludge Basin
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RH	remote handled
RI	remedial investigation
SC	special case
SWMU	solid waste management unit
SWSA	solid waste storage area
TDEC	Tennessee Department of Environment and Conservation
TRU	transuranic
TVA	Tennessee Valley Authority
WAG	waste area grouping

EXECUTIVE SUMMARY

A remedial investigation (RI) was performed to support environmental restoration activities for Waste Area Grouping (WAG) 5 at the Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. The WAG 5 RI made use of the *observational approach*, which concentrates on collecting only information needed to assess site risks and support future cleanup work. This information was interpreted and is presented using the framework of the *site conceptual model*, which relates contaminant sources and release mechanisms to migration pathways and exposure points that are keyed to current and future environmental risks for both human and ecological receptors. The site conceptual model forms the basis of the WAG 5 remedial action strategy and remedial action objectives. The RI provided the data necessary to verify this model and allows recommendations to be made to accomplish those objectives.

SITE DESCRIPTION AND BACKGROUND

WAG 5 is a 70-acre site consisting of a burial ground [Solid Waste Storage Area (SWSA) 5], a transuranic waste storage area (SWSA 5 North), waste storage tanks and other components in the Old and New Hydrofracture Facilities (OHF and NHF), two small surface impoundments, and several areas used for landfilling. The disposal areas are primarily open fields (due to excavation activities) with forested areas along drainages and creeks.

Waste disposal activities occurred primarily between 1959 and 1973, during which time over 220 unlined trenches and nearly 1000 unlined auger holes were used for disposal of approximately 3,000,000 ft^3 of solid waste and 210,000 Ci of radioactivity. Most of the wastes contained only low levels of radioactivity. Radionuclides include tritium, fission products, fissile materials, uranium-thorium elements, and transuranics. Waste types include lab equipment, paper, scrap metal, lumber, machinery, filters, animal carcasses, and miscellaneous trash. Between 1970 and 1981, alpha-contaminated and transuranic wastes were buried in trenches in SWSA 5 North.

ENVIRONMENTAL SETTING

WAG 5 is within the Oak Ridge Reservation (ORR) and classified as a controlled area; entry is strictly controlled through administrative and security procedures and physical barriers that prevent unrestricted access to contaminated areas. The surrounding area is primarily rural with the City of Oak Ridge (pop. 27,310) the closest population center (4 miles to the northeast). The climate includes warm, humid summers and mild, wet winters. Average annual rainfall is 54.2 in., and the greatest accumulations are during winter months.

WAG 5 is underlain by fractured shale and limestone bedrock; depth to bedrock varies from a few feet to 40 ft, depending on topographic elevation. Soil thickness varies from 1 to 6 ft, and the saprolite (weathered rock) thickness generally varies from a few feet to several tens of feet. Relict bedrock features (bedding planes, fractures, etc.) in the saprolite greatly influence the movement of water (and contamination) in the subsurface. Soils are generally classified as silty and clayey sands, but because of the extent of excavation and regrading in SWSA 5 South, the area contains a significant quantity of fill material and soil types can vary greatly.

Surface water features include White Oak Creek to the west and Melton Branch to the south. Surface water drainage from WAG 5 is divided about equally between the White Oak Creek and Melton Branch drainage basins. Principal on-site drainages are D-1, discharging to White Oak Creek; D-2, discharging to Melton Branch; and D-3, discharging to a tributary of Melton Branch. D-1 and D-3 are typically dry during summer and fall while D-2 flows year-round, albeit at a very low volume during the summer. White Oak Creek and Melton Branch converge opposite the southwest corner of the site, and White Oak Creek then flows westward toward eventual discharge into the Clinch River.

Development along the Clinch River downstream of the mouth of White Oak Creek has been limited; most of this area remains rural with scattered, low-density residential areas. Farther downstream, the Clinch joins with the Tennessee River in the Watts Bar Reservoir embayment. The Clinch River and Watts Bar supports significant levels of water-based recreation, including fishing, swimming, water skiing, and waterfowl hunting.

CONTAMINATION SUMMARY

Contamination of environmental media at WAG 5 is mostly related to hydrologic processes: water is the key release and transport medium, responsible for mobilizing the radionuclide (and chemical) contaminants in the wastes, moving them through the subsurface or across the land surface to the perennial streams that border the site and, finally, transporting them away from the site. Along the way, some of the contamination in the water is being transferred to other media—to surface soils along drainage paths and in seep areas, onto subsurface soils (and saprolite) in the vadose zone and water table interval, and to the sediment in the streams.

The distribution of contamination is thus a function of these hydrologic processes, and the presence or absence of contamination in a given area can be explained in strictly hydrologic terms (e.g., the area is hydraulically downgradient of the source as described by groundwater flowpaths, or is downstream of a contaminated seep discharge point). Any attempts to explain the distribution of contamination at WAG 5 must be based on a clear understanding of hydrologic processes at the site. For example, the trenches in SWSA 5 South exert considerable influence on the movement of water in the subsurface, and thus the release and migration of contaminants. The hydrologic role of the trenches—in addition to their status as a contaminant source—is a fundamental part of the hydrologic model of the site.

Contamination in WAG 5 can therefore be summarized almost entirely in the context of site hydrology: the trenches inundated by groundwater are the most active sources and greatest contributors of contamination; groundwater is the principal release mechanism and contaminant migration pathway and as a result is the most widely spread contaminated medium at the site; the discharge of this groundwater and the resulting contamination of surface water creates on-site exposure points and leads to the off-site (and, for some of the contamination, off-ORR) transport of WAG 5 contaminants. Contaminant- and media-specific highlights from the evaluation of WAG 5 contamination include the following.

- Most of the contaminant source material consists of low-level radioactive solid wastes in unlined trenches and auger holes of SWSA 5 South. Disposal of these wastes has resulted in a significant ongoing release of contamination to soils, groundwater, and surface water.

- From an on-site risk perspective, the most significant contaminants detected are ^{90}Sr, ^{3}H, ^{137}Cs, ^{60}Co, $^{243/244}Cm$, $^{238/239}Pu$, ^{241}Am, $^{233/234}U$, ^{226}Ra, and ^{228}Ra. Contaminants most responsible for off-site risk are ^{90}Sr, ^{3}H, and, to a lesser extent, ^{137}Cs.

- Significant levels of groundwater contamination were detected in SWSA 5 South; the principal contaminants are ^{3}H and ^{90}Sr. High concentrations of ^{3}H are ubiquitous in SWSA 5 South; high concentrations of ^{90}Sr are less widespread, typically occurring along migration pathways between source trenches and contaminated seep discharge areas.

- Cesium-137 has a strong affinity for adsorption onto clay soil particles and was shown to be much less mobile than ^{90}Sr in the surface and subsurface waters of WAG 5.

- Results from the inundated trench water sampling in SWSA 5 South show levels of contamination at the microcurie and millicurie level.

- Contaminated seep discharges along the southern perimeter of SWSA 5 South are significant components of the overall flux of ^{3}H and ^{90}Sr measured at White Oak Dam.

- Soil contamination at WAG 5 is mostly due to ^{137}Cs, ^{90}Sr, and ^{60}Co and is limited to areas contaminated by seep discharges, overflowing (bathtubbing) trenches, or surface debris.

- Transuranic radionuclides are currently being released from WAG 5 at negligible levels, but they are migrating through the subsurface and being discharged at seeps along the site perimeter and interior drainages.

Off-site fluxes of contamination from WAG 5 to Melton Branch and White Oak Creek were calculated and compared to the total flux measured at White Oak Dam (see table below). Tritium and ^{90}Sr are the primary WAG 5 contributions to the contaminant flux measured at the dam. The primary sources of ^{3}H and ^{90}Sr were identified as inundated trenches in SWSA 5 South.

Analyte	Flux from WAG 5 (mCi/year)	Contribution from WAG 5 to White Oak Dam (%)
Gross alpha	29.8	15
^{3}H	2,450,000	81
^{60}Co	8.75	4.5
^{90}Sr	1390	49
^{137}Cs	50.1	2.5

CONCEPTUAL SITE MODEL AND RISK SUMMARY

Baseline risks for current residential and industrial scenarios were assessed for nine designated areas on site. Calculations were also performed for residential scenarios downstream at the Melton Branch and White Oak Creek weirs (opposite the southwest corner of WAG 5) and for drinking water risks farther downstream at White Oak Dam and the Clinch River. The site conceptual model was used to integrate these risk results with site hydrology and contaminant dynamics.

Under current conditions, residential or industrial use of the site would result in an increased risk of developing cancer that exceeds 1×10^{-4} in all nine areas. In most of the areas, direct external radiation exposure to contaminated soils was primarily responsible for the calculated risks; ingestion of groundwater and produce represented a secondary, but important, exposure pathway for the residential scenario. Groundwater inundation of sources and bathtubbing in trenches are primarily responsible for the release of contaminants.

Hypothetical off-site residents at the weirs would also be subject to an increased cancer risk. The risk associated with the Melton Branch location is primarily attributable to ingestion of drinking water (from the creek) contaminated with ^{3}H and ^{90}Sr released from trenches in the southern portion of the site. Risk at the White Oak Creek location is also due primarily to contaminated surface water ingestion; however, the ^{90}Sr and ^{137}Cs driving the risks originate from other ORNL sources upstream of WAG 5.

Drinking water risks calculated for White Oak Dam are lower, due to dilution, but still exceed the threshold of 1×10^{-4}. Strontium-90, ^{3}H, and ^{137}Cs flux from the inundated trenches in the southern portion of WAG 5 are responsible for approximately 50% of this risk. Based on dilution factors, the calculated drinking water risk for the Clinch River downstream of the mouth of White Oak Creek is approximately 2×10^{-6} due to ^{90}Sr and ^{3}H. WAG 5 contributions are again responsible for about half of this risk (i.e., 1×10^{-6}).

Current and future ecological risks to terrestrial and aquatic endpoints were evaluated for six habitat-based areas on site, and the contaminant contributions from these areas to off-site terrestrial and aquatic receptors were assessed. Ranked on four categories ranging from *no impact* to *likely impact*, none of the areas received a ranking exceeding *possible impact* for current or future cases on site or for contributions to off-site receptors. Possible impacts were due primarily to concentrations of metals in soil.

REMEDIAL ACTION STRATEGY

Future remediation work at WAG 5 will be constrained by a number of factors—technical feasibility, resource (funding) availability, and the overall risk management strategy for the ORR. A remedial action strategy for WAG 5 must recognize these constraints and at the same time ensure that significant problems are addressed in a timely fashion. Dividing the site into smaller "remedial project areas" allowing for phased cleanup actions is an approach that has been used elsewhere at ORNL and is particularly well suited for WAG 5; this approach also is consistent with the operable unit concept described in Section XII of the Federal Facility Agreement (FFA) (DOE 1992).

The environmental problems and concerns associated with each project area were identified to support identification of response actions necessary to achieve a given remediation target, determination of the benefits that would result from implementing various actions, and prioritization of potential actions. The discussion of problems and concerns for the WAG 5 remedial project areas is based on the following considerations.

- *Source term*: inventory, waste volumes, contaminant types and distribution, source dimensions

- *Releases and impacts*: types of release mechanisms, extent of current releases, potential for future releases, flux (type and magnitude), affected area

- *Relative significance*: based on source term, type, extent, and magnitude of releases, resulting impacts (exposures and risks) on and off site

Remediation targets, essentially land use and/or restoration goals, were developed to cover a full spectrum of potential remediation scenarios for WAG 5. Evaluating a range of alternatives is consistent with EPA guidance on the conduct of CERCLA feasibility studies and provides a stronger foundation to support risk management decisions and ensure that realistic restoration goals are identified. The list of targets includes the following:

- *Monitoring*: Continued monitoring and maintenance to detect changes in site exposures, releases, or other conditions so that appropriate future actions would be taken if needed.

- *Stabilization*: Action would be taken as needed to prevent an increase in contaminant flux of fission products and transuranics and minimize impacts to surveillance and monitoring activities.

- *Recreational use*: Expanded actions would be taken to make the site (or at least most of the site) safe for recreational use and as wildlife habitat.

- *Water quality*: Relatively aggressive remediation steps would be taken so that discharges from the site attained ARARs such as Tennessee water quality standards in Melton Branch and White Oak Creek.

- *Remove wastes*: Relocate high-activity and long-half-life wastes to a more secure industrial facility, and in the process potentially render the site suitable for limited industrial use.

The remediation targets were used to develop a remediation strategy matrix that is intended to function as the primary tool for guiding the pre-feasibility study strategy for WAG 5. The matrix presents general response actions, cost, and a feasibility rating (index) based on the objectives associated with each remediation target. The matrix shows that both cost and technology limitations increase with the increasing scope and complexity of the remediation targets. Actions necessary to attain the objectives for the monitoring and stabilization targets could be readily implemented with a relatively high degree of confidence that the overall goals would be achieved. The feasibility index is lower for the expanded actions associated with the recreational use scenario, due primarily to uncertainty regarding the ability to identify and effectively mitigate all on-site exposures potentially impacting recreational users of the site.

A much higher level of uncertainty is associated with the ability of the actions identified to attain the objectives of the water quality and waste removal targets. For the water quality target, complexities in the hydrogeologic system at the site, the absence of source control actions, and the potentially insurmountable difficulties in treating all of the discharges render the primary components of the action—isolation of SWSA 5 South and interception of discharges along Melton Branch—as technically impracticable. A similar conclusion applies to the waste removal target due to the health and safety concerns associated with excavating the buried wastes and problems in trying to dispose of the excavated materials. Future technology developments or changes in the site contaminant dynamics may offer opportunities to implement final actions involving source control and/or isolation technologies; consequently, a comprehensive solution should be the long-term goal for the buried LLW.

The absence of a clear path for near-term resolution of the most significant site problems at the site does not preclude the identification of near-term actions that can effectively mitigate some of the more manageable problems at the site. A principal consideration in the identification of these near-term actions is whether it makes sense to remediate portions of WAG 5 when other problems at the site are not addressed (at least in the near term). The benefit from any actions toward cleanup of WAG 5 must therefore be weighed against the impact of not remediating the entire site—for example, it may not make sense to remediate a relatively small area adjacent to or surrounded by a much larger and more highly contaminated area. Additionally, it may not be prudent to undertake certain types of actions when the site conceptual model has shown that the area will be recontaminated in the future. An effective way to conduct this evaluation is to establish the benefits associated with the various response actions identified in the remediation strategy matrix.

Evaluation of cost, feasibility, and potential benefits indicates that the most appropriate near-term goals for WAG 5 should be based on the stabilization or recreational use targets. Near-term actions would thus be limited to smaller and more manageable tasks such as pond closure or hot spot capping. In the longer term, more aggressive (and costly) remedial actions can be considered if new technologies become available or conditions change such that more aggressive actions are both warranted and technically feasible. All near-term actions would constitute definite progress toward a final remediation of the site and could be designed and implemented to be consistent with future actions and land uses.

Further refinement of the WAG 5 remedial action strategy will be accomplished through a series of DOE-led workshops with TDEC and EPA to better define the issues affecting remediation decisions and integrate the WAG 5 remedial projects into the FFA prioritization system.

1. INTRODUCTION

A remedial investigation (RI) was performed at Waste Area Grouping (WAG) 5 to support environmental restoration (ER) activities at Oak Ridge National Laboratory (ORNL) (Fig. 1.1). WAG 5 is one of several sites on the Department of Energy's (DOE) Oak Ridge Reservation (ORR) in Roane and Anderson counties, Tennessee, that was identified by DOE for possible cleanup (*remediation*) under the regulatory and administrative framework established by the Federal Facility Agreement (FFA) for the ORR. The FFA represents a cooperative effort under the Comprehensive Environmental Response, Liability, and Compensation Act (CERCLA) that defines the interactions and responsibilities of DOE, the Tennessee Department of Environment and Conservation (TDEC), and the U.S. Environmental Protection Agency (EPA) for cleanup actions on the ORR.

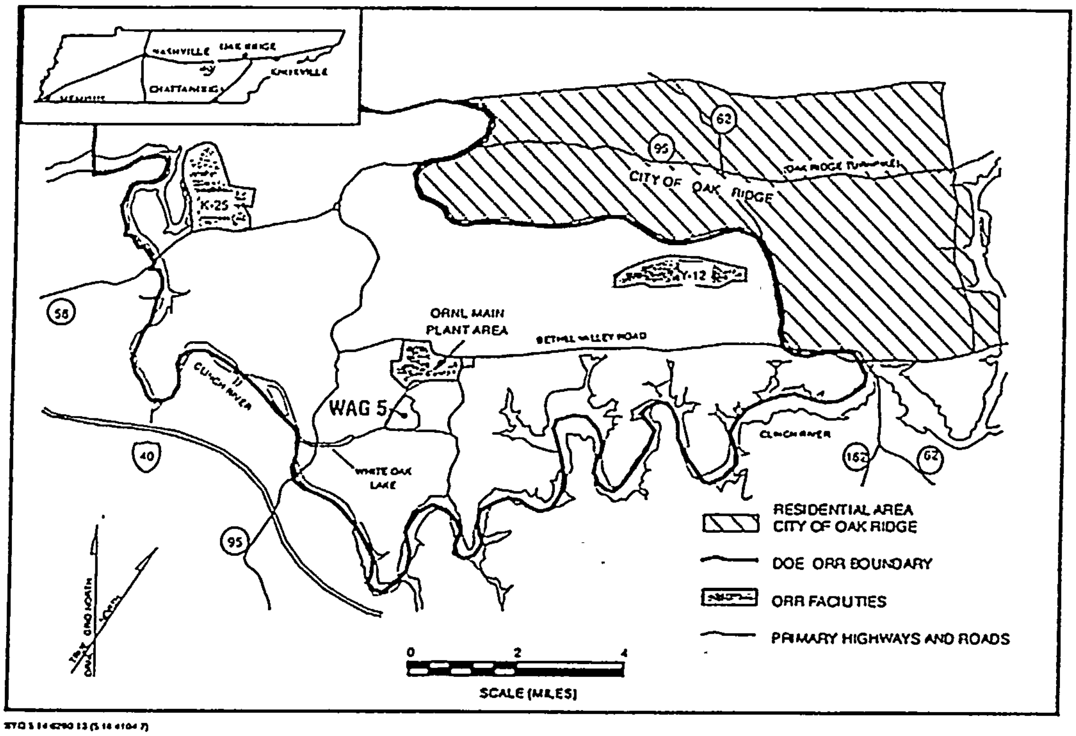

Fig. 1.1. Site location.

WAG 5 consists of several contaminant source areas, the most important of which is a solid waste burial ground used from 1959 to 1973 for disposal of low-level radioactive, transuranic (TRU), and fissile wastes as well as inorganic and organic chemical wastes and biological wastes. Wastes were buried in hillside trenches and auger holes, and radionuclides from the buried wastes are being transported by shallow groundwater to Melton Branch and White Oak Creek, two streams that border WAG 5. White Oak Creek is the principal conduit for the release of contamination from ORNL to areas outside the ORR, and WAG 5 contributes a significant proportion of that contamination.

The two major elements of the RI were to evaluate the nature and extent of contamination at the site; and assess the risks to human health, both on and off site, and to the ecological system on or near the site. This RI report documents the results of the contamination and risk assessments to create a comprehensive summary of current (*baseline*) conditions that will support decisions regarding the need for and scope of future remediation at WAG 5. This report includes a remedial action strategy that presents potential remediation targets and possible ways to divide the site into remedial project areas, discusses prioritization of those areas (based on concerns), and suggests some possible near-term actions and further investigations needed to support these actions. The proposed strategy is considered a starting point for future discussions to be held through a series of DOE-led workshops involving TDEC and EPA. These workshops will be used to better define the issues affecting remediation decisions for WAG 5 and integrate the WAG 5 remedial projects into the ORR-wide prioritization system.

The focus of the WAG 5 RI and format of the RI report are both departures from tradition. Rather than a complete site characterization, the RI was tailored to fit unique site conditions (see Sect. 1.3) and used the *observational approach*, which concentrates on collecting only that information needed to assess site risks and support future cleanup work. This information was interpreted and presented using the framework of the *site conceptual model*. This model relates contaminant sources and release mechanisms to migration pathways and exposure points, which are keyed to current and future environmental risks for both human and ecological receptors (Fig. 1.2). The RI provided the data to verify the site conceptual model, which in turn supported the development of the WAG 5 remedial action strategy.

The WAG 5 RI report includes this technical summary (Volume 1) and three separate volumes of appendices (Appendix A/Volume 2, Appendix B/Volume 3, and Appendix C/Volume 4). The purpose of the technical summary is to bring focus to the critical information presented in Volumes 2 through 4 and lead to an understanding of the site's physical (environmental) setting, the site conceptual model, and the basis for any further ER work at WAG 5.

Volume 2 (Characterization Methods and Data Summary) describes background/historical data sources and applicable or relevant and appropriate requirements (ARARs) (Appendix A1), summarizes the RI field investigation (A2), presents the analytical data quality assessment (A3), and summarizes the analytical data (A4). Volume 3 (Technical Findings and Conclusions) presents the results of the investigation as they relate to the environmental setting (Appendix B1), the nature and extent of contamination (B2), and contaminant fate and transport (B3); Appendix B4 presents historical photographs, and Appendix B5 summarizes the hydrologic modeling conducted to support the RI. Volume 4 (Risk Assessment) reports the findings of the human health (Appendix C1) and ecological risk assessments (Appendix C2).

Figure 1.3 shows the relationship between the technical summary and the appendices. It also shows which appendices comprise each volume and is a useful "roadmap" for finding information within the four-volume set.

1.1 SITE DESCRIPTION AND HISTORY

WAG 5 is approximately 0.5 mile south of the ORNL main plant area; Fig. 1.4 illustrates its location relative to the other ORNL WAGs. The site includes a burial ground [Solid Waste Storage Area (SWSA) 5], the TRU waste storage area, waste storage tanks and other components in the Old Hydrofracture and New Hydrofracture Facilities (OHF and NHF), two small surface impoundments, and several areas used for landfilling. Figure 1.5 is an aerial photograph of the site; Fig. 1.6 provides

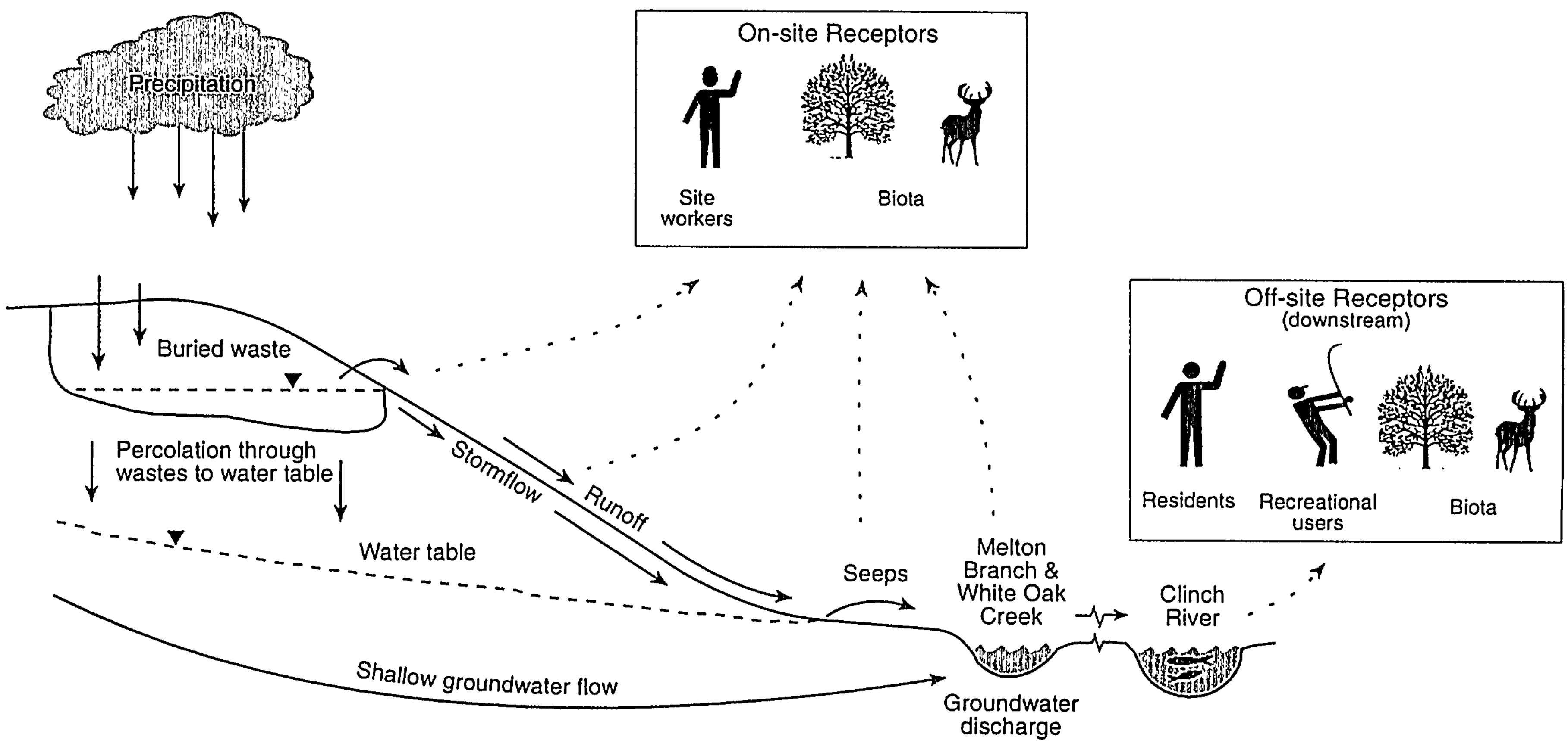

Fig. 1.2. Site conceptual model.

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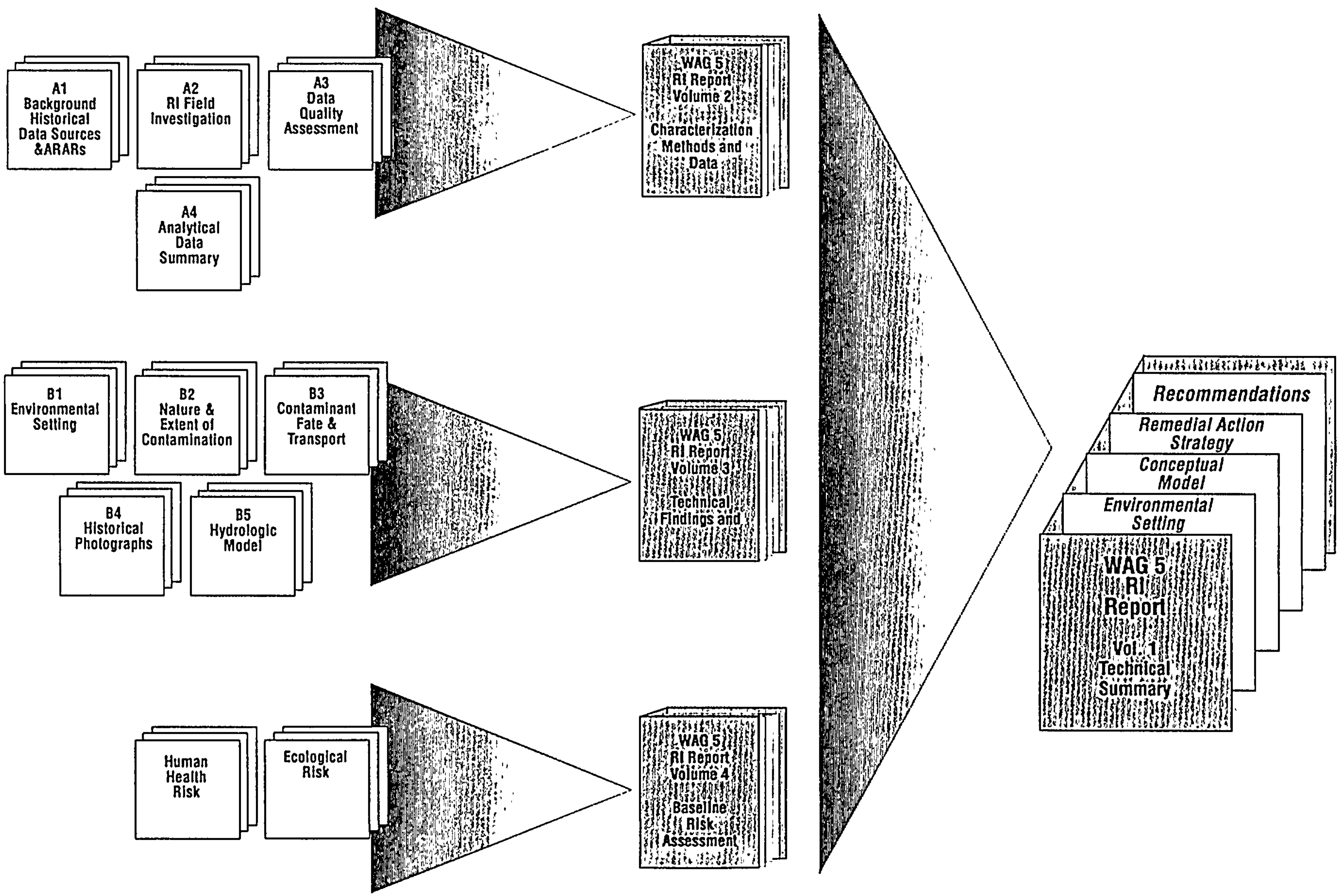

Fig. 1.3. WAG 5 RI report.

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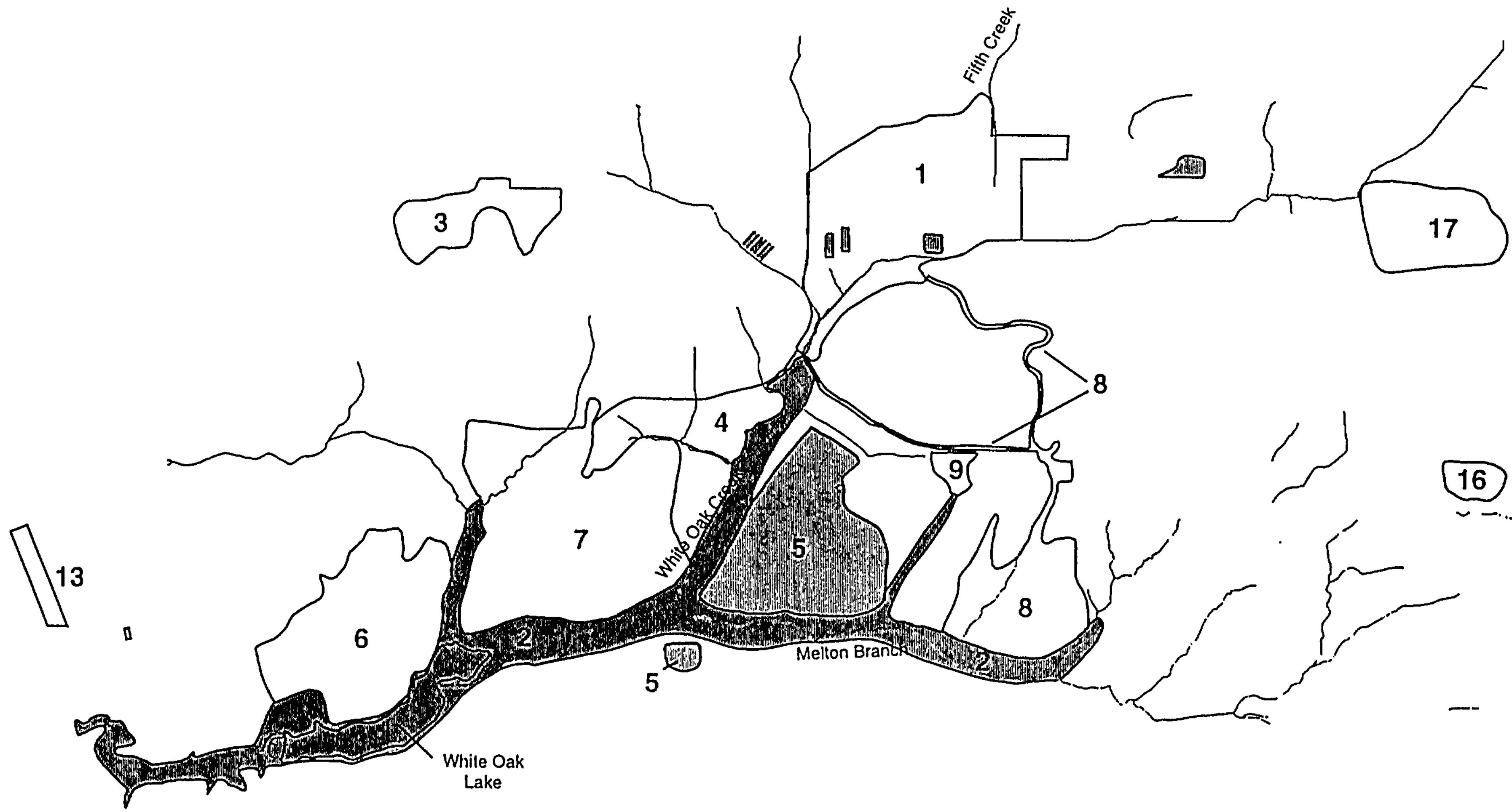

Fig. 1.4. Waste area groupings at Oak Ridge National Laboratory.

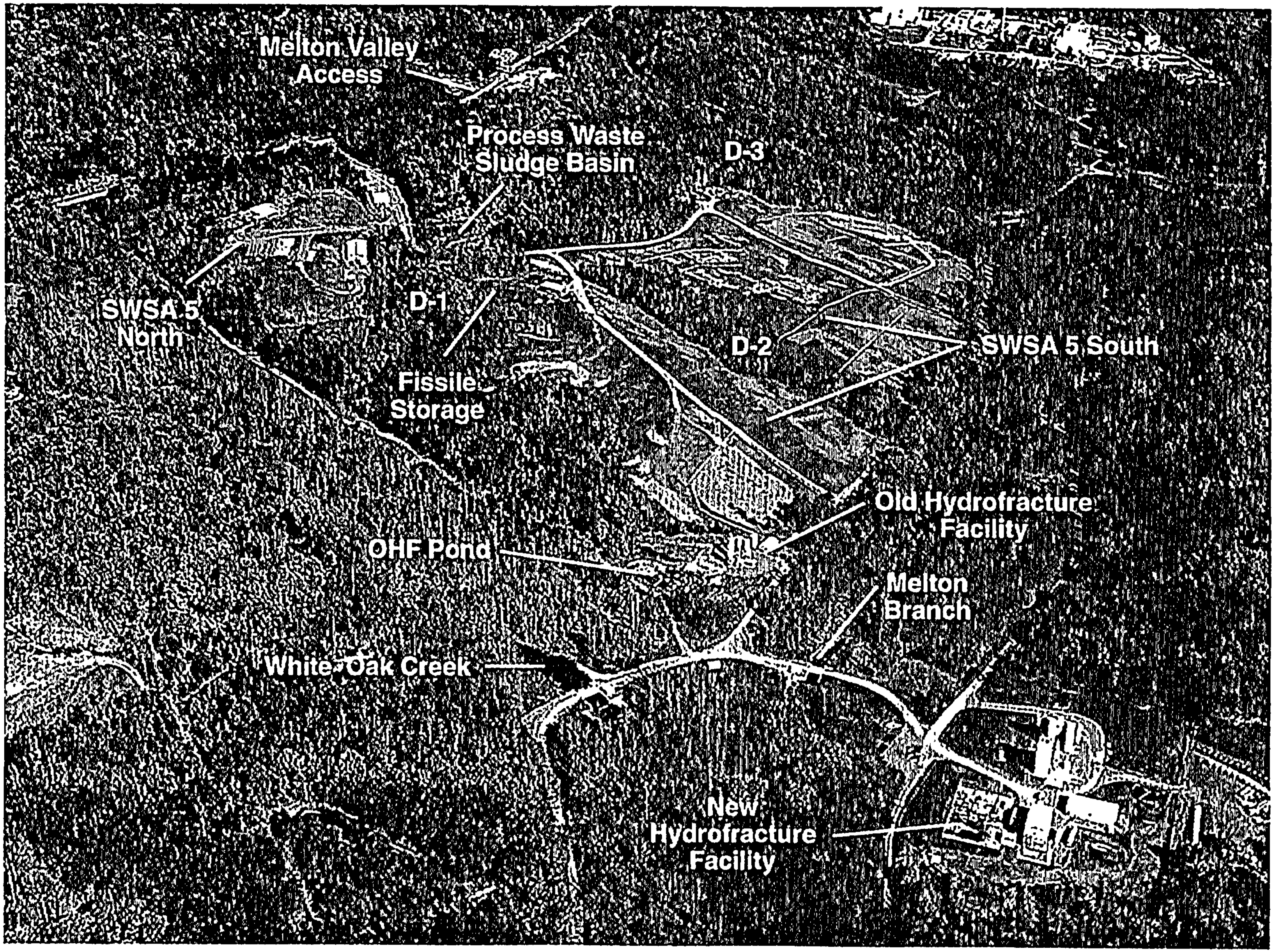

Fig. 1.5. WAG 5 surface features (1988).

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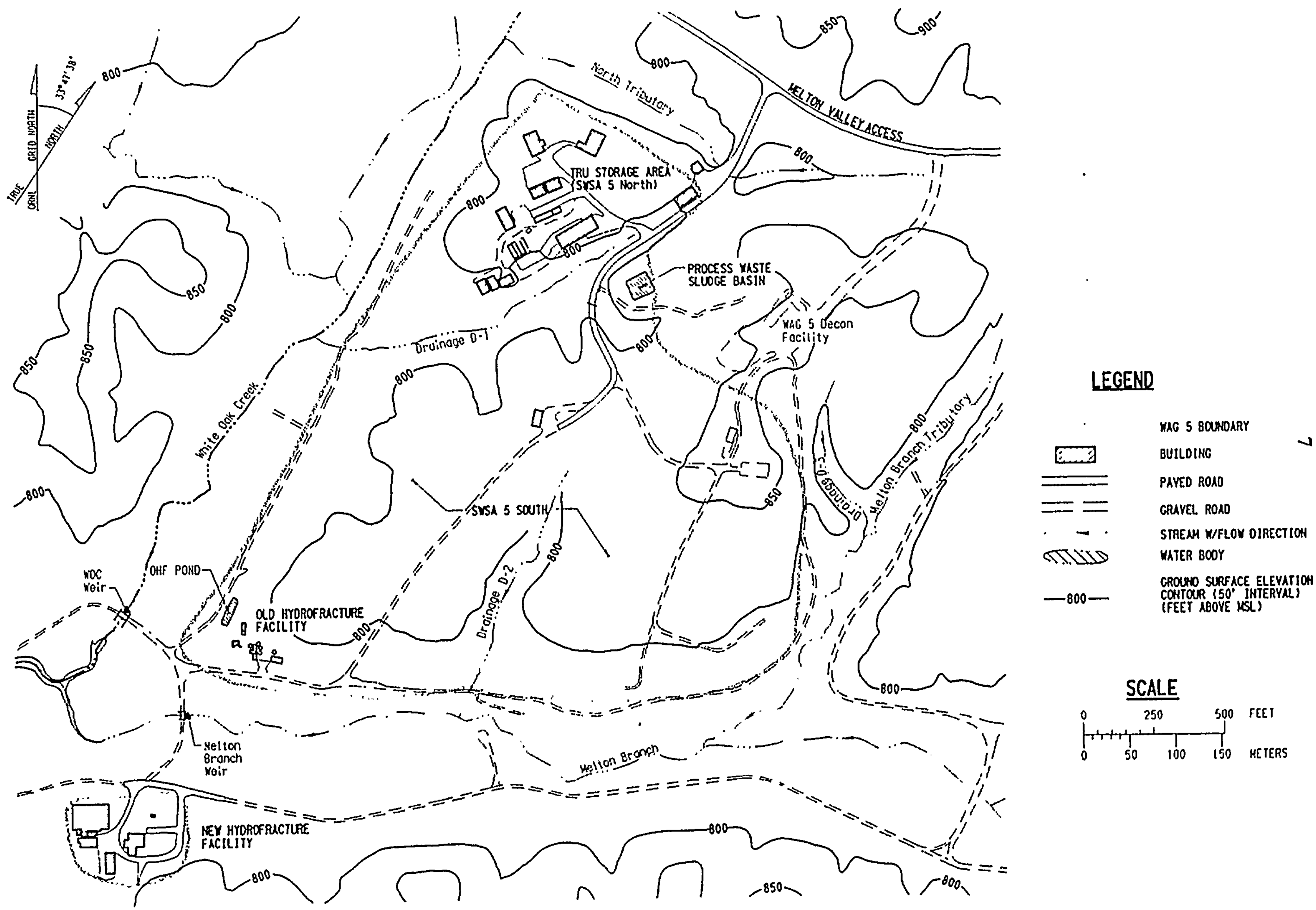

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Fig. 1. 6. WAG 5 base map.

further definition of site features. WAG 5, one of several areas in Melton Valley used for waste disposal operations, comprises an area of approximately 70 acres, about 30 of which are wooded and the remainder are grass-covered and are kept mowed. Ground surface elevations range from a low of 756 ft along White Oak Creek and Melton Branch to a topographic high of 865 ft in the northeast corner of SWSA 5 South.

The western and southern boundaries of WAG 5 are contiguous with the WAG 2 area that includes White Oak Creek and Melton Branch and associated floodplains. The administrative boundary between WAGs 5 and 2 was drawn at the eastern and northern edges of the White Oak Creek and Melton Branch floodplains, respectively. Two principal WAG 5 drainages transport surface water from the site: D-1 extends from the WAG interior to White Oak Creek, and D-2 empties into Melton Branch. Drainage D-3 is a small side tributary along the east-central WAG perimeter that discharges into a larger tributary of Melton Branch. Although D-3 is outside the WAG 5 administrative boundary, it receives runoff from portions of the site and was therefore included in the scope of the RI.

Man-made surface features (e.g., buildings, paved areas, roads) are concentrated in three areas: OHF, NHF, and the TRU storage area (also known as SWSA 5 North.) In addition to the two small surface impoundments [OHF pond and process waste sludge basin (PWSB)], the site has a system of interconnecting gravel roads, a perimeter boundary fence and electrified deer fence, numerous groundwater monitoring wells, and remnants of concrete diversion ditches constructed for erosion control. Several ravines at the site contain surface debris from past disposal activities. Construction of surface facilities (tanks, piping, treatment units) associated with a removal action for collection and treatment of contaminated seeps was completed at two locations along the southern (Melton Branch) perimeter of WAG 5 in November 1994.

1.1.1 Historical Operations

Waste disposal operations in WAG 5 began in 1959 with the opening of SWSA 5. When the TRU storage facilities were opened in 1970, the original SWSA 5 areas became known as SWSA 5 South and the TRU storage area was designated SWSA 5 North. Waste disposal operations continued through 1973, during which time over 220 unlined trenches and nearly 1000 unlined auger holes were used for the disposal of approximately 3 million cubic feet of solid waste containing an estimated 210,000 curies of radioactivity.

Between 1959 and 1964, ORNL was the Southern Regional Burial Ground for the Atomic Energy Commission (AEC) (a precursor agency to DOE). During this time, much of the radioactive waste disposed of in SWSA 5 came from more than 50 off-site facilities (Fig. 1.7). Waste types sent to ORNL included chemical, radioactive, and biological (e.g., animal carcasses contaminated with radionuclides); most was reportedly composed of various radioactive solid wastes containing tritium, beta-gamma radionuclides, uranium-thorium decay series isotopes, and fissile (^{235}U) materials (see Appendix B2 for additional information).

After 1964, most of the wastes were from ORNL sources, although wastes from other ORR sources such as the Y-12 Plant continued to be disposed of in SWSA 5. Most of the ORNL wastes were associated with radioisotope production facilities, reactors, hot cells, pilot plants, and research

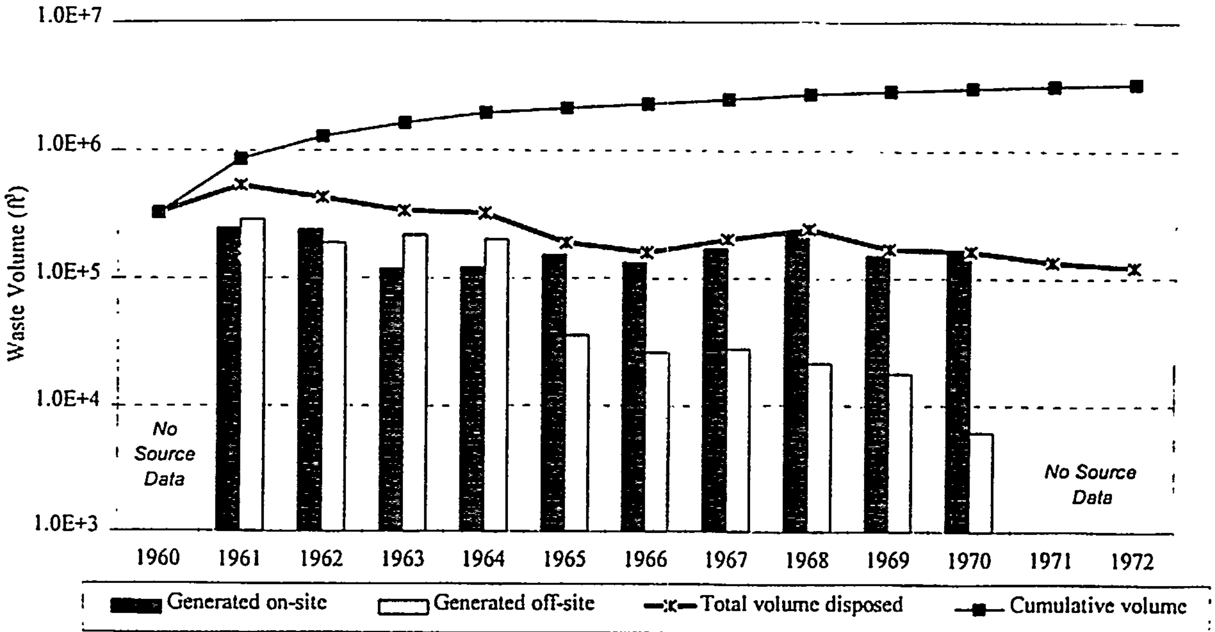
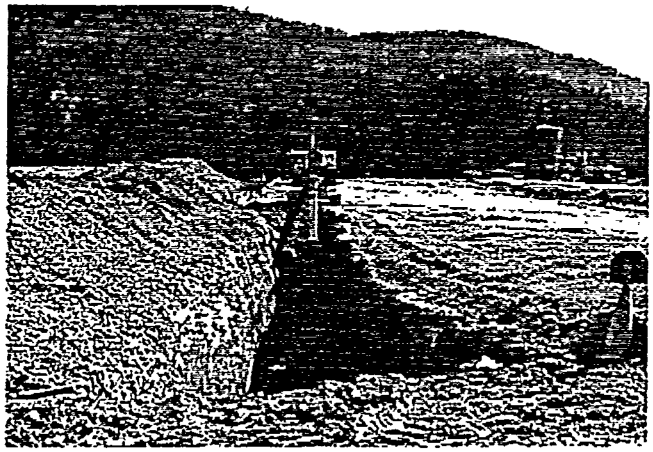


Fig. 1.7. Waste disposal rate and sources for SWSA 5 South.

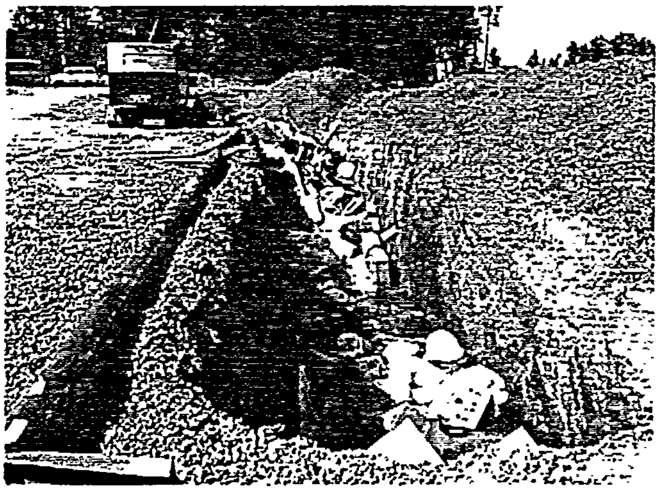
laboratories; they included fission products, elements of the uranium-thorium decay series, neutron activation products, tritium, and transuranic isotopes. Because much of the original radioactivity was associated with radionuclides having relatively short half-lives (<1 year), the activity of the wastes is currently dominated by the longer-lived fission products, uranium-thorium elements, and transuranics. Most of the radioactive wastes were low-level waste (LLW) variously described as lab equipment, rags, paper, valves and piping, scrap metal, lumber, machinery, filters, soil, and miscellaneous trash. It is important to note that not all of the wastes disposed of in WAG 5 were contaminated and that most of the contaminated wastes contained only low levels of radioactivity.

Low-level and transuranic wastes generally were disposed of in trenches (Fig. 1.8). In some cases, construction debris and other bulky items were dumped into small landfills in ravines on the edge of SWSA 5 South. Higher-activity beta-gamma and fissile wastes were placed in auger holes that typically were capped with concrete (Fig. 1.8d). SWSA 5 also received wastes from both ORNL and off-site sources with inorganic and organic chemical contaminants such as mercury, beryllium, and trichloroethene. A potentially significant quantity of classified wastes from the Oak Ridge Y-12 Plant and other off-site facilities was also disposed of in SWSA 5 South. This information is currently under evaluation by the ORNL ER Program to ensure that relevant data will be factored into the decision-making process for cleanup actions at WAG 5.

The 7802N area of SWSA 5 North was used from 1971 to 1981 for retrievable storage of remote-handled (RH) TRU and alpha-contaminated LLW wastes in 23 unlined trenches. An area in the northeast corner of SWSA 5 North contains four unlined trenches used between 1970 and 1976 for disposal of specia .ase (SC) TRU and alpha-contaminated waste. Wastes in the 7802N storage trenches were packaged in concrete casks, wooden and metal boxes, and 55-gal drums, although most were disposed of in concrete casks. Wastes in the disposal trenches were primarily in wooden boxes that were encased in concrete after being placed in the trenches. Stewart et al. (1989) reported



(a) Trench excavation (ORNL photo 60818).



(b) Miscellaneous solid waste in trench (ORNL photo 60822).

(c) Concrete and metal boxes and miscellaneous containers in trench (ORNL photo 61846).

(d) Placement of wastes in auger hole (ORNL photo 60817).

Note: Additional photographs of operations in SWSA 5 South and SWSA 5 North are presented in Volume 3, Appendix B4.

Fig. 1.8. Historical photographs showing waste disposal operations at SWSA 5 South.

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a total of 274 waste containers in the 27 trenches in SWSA 5 North. SC wastes, including SC-TRU and nuclear fuel materials, were placed in eight stainless-steel-lined storage vaults in SWSA 5 North between 1970 and 1975.

From 1964 to 1979, OHF was used for permanent disposal of liquid radioactive waste in shale formations at depths between 780 and 950 ft. More than 8 million liters of an intermediate-level liquid waste (ILLW) and grout mixture containing several hundred thousand curies of beta-gamma radionuclides—mostly ^{137}Cs, ^{90}Sr, and ^{60}Co with lesser amounts of ^{233}U, ^{23x}Pu, ^{244}Cm, and ^{241}Am—were injected. Five underground storage tanks stored the ILLW prior to injection.

Injection operations began in 1982 at NHF, which was also used to dispose of ILLW through deep well injection; the ILLW was stored prior to injection in a series of doubly contained stainless steel tanks. Thirteen injections were conducted before operations were permanently terminated in 1984.

1.1.2 Current Operations

Current operations at WAG 5 are being conducted by the ORNL Waste Management Division (TRU waste handling and storage in SWSA 5 North and liquid waste solidification in NHF), the ORNL ER Division (mowing, road and utility repairs, etc.), and the ORNL Environmental Compliance Division (sampling of monitoring wells). The ORNL ER Division is also responsible for operation and maintenance of the collection and treatment systems recently installed at two contaminated seep areas in WAG 5. A number of research projects are also under way, most of which focus on characterizing secondary sources (e.g., highly contaminated soil) and/or understanding the processes related to the fate and transport of contaminants in the subsurface.

1.1.3 Regulatory Background

Cleanup activities at ORNL were originally tied to a listing of solid waste management units (SWMUs) identified in 1987 to satisfy ORNL's Resource Conservation and Recovery Act (RCRA) corrective action requirements (ORNL 1987). As part of the FFA (which became effective on January 1, 1992), DOE agreed to coordinate the RCRA and CERCLA response actions at ORNL to minimize duplication of investigative and analytical work (DOE 1992a). The FFA identifies specific sites (designated "remediation sites" or "areas") to be evaluated as part of the ORNL ER Program and tracks their status through yearly updates of Appendix C of the FFA.

The scope of the WAG 5 RI was based on the FFA list of remediation sites (presented in Table 1.1). Table 1.1 also shows several areas not on the FFA list but included in the scope of the RI because they represented potential contaminant sources or exposure points. Evaluation of all potential source areas was necessary for accurate refinement of the site conceptual model and reduction of the uncertainties associated with decision-making for cleanup work.

A draft work plan and field sampling plan (FSP) were prepared in 1988 (Bechtel 1988), but work on the site was not resumed until 1991, at which time a revised FSP was prepared and submitted to EPA and TDEC for review and approval (DOE 1992b). In 1993, planning began for a removal action to address contaminated seep discharges along the Melton Branch perimeter of WAG 5. These efforts culminated in the source areas investigation plan submitted to EPA and

Table 1.1. WAG 5 remediation sites and other areas of concern

Site No.[a]	Designation	Description
5.1a	LLW Lines and Leak Sites: OHF Observation Wells S-100 and S-220 Leak Sites	1968 release of approximately 2 Ci of ^{90}Sr from observation well S-220 drilled into a fracture containing contaminated grout from an earlier grout injection at OHF; drilling of well S-100 in 1964 also encountered contaminated groundwater but no documentation regarding release; SWMU 5.1a includes potentially contaminated soil in vicinity of both wells.
5.1b	LLW Lines and Leak Sites: Hydrofracture Injection Area	Release of 2300 gal of radioactive (LLW) grout to waste pit T-4 due to valve failure during a 1977 injection (later disposed of through injection with no release to the OHF soil).
5.2	OHF Impoundment (7852a)	Unlined 100,000-gal impoundment designed for emergency grout overflow storage during OHF injections; releases of radioactive grout to pond occurred in 1965 and 1977; contaminated drilling fluids were placed in the pond in 1984-1985.
5.3	OHF Surface Facilities	Surface facilities associated with storage, mixing, and deep well injection of LLW grout mixtures used from 1964-1979; includes waste pit T-4, the valve pit associated with SWMU 5.1b, and underground piping.
5.4	NHF Surface Facilities	Replacement facility for OHF; in operation from June 1982 through January 1984.
5.5a-e	OHF Waste Storage Tanks T-1, T-2, T-3, T-4, T-9	Carbon steel underground storage tanks at OHF used from 1964-1979 to store liquid LLW prior to blending with grout for deep well injection; capacities range from 13,000–25,000 gal.
5.6	Process Waste Sludge Basin (7835)	PVC-lined basin used from 1976–1981 for the storage and decantation of sludge produced by ORNL Process Waste Treatment Plant.
5.7	SWSA 5 South (7802)	Burial ground for disposal of ORNL wastes from 1959-1973; also AEC Southern Regional Burial Ground from 1959-1964 for wastes from 50 off-site sources. Trenches were used for low-level radioactive solid waste and TRU wastes; higher activity beta-gamma wastes and fissile wastes were placed in auger holes.
5.9	Waste Oil Storage Tank (7860a)	Underground storage tank in NHF area used from 1981-1985 to store radioactively contaminated waste oil from NHF pumps and equipment.

Table 1.1 (continued)

Site No.[a]	Designation	Description
5.10h	TRU Storage Vaults	Eight stainless steel, concrete-lined auger holes northwest of Building 7823 received RH-TRU waste with high external gamma exposure rates from 1970-1977.
5.10i	RH-TRU Direct Burial Trenches	22 trenches in SWSA 5 North used for retrievable storage of remote-handled (RH) TRU wastes (>200 mR/h surface exposures) from 1972-1979; waste containers were primarily concrete casks.
5.10i	Miscellaneous TRU Trenches	Five trenches in SWSA 5 North used for disposal of RH-TRU wastes in boxes and other containers from 1972-1979.
5.14	Old Landfill	Area in northeast corner of SWSA 5 used for disposal of reportedly noncontaminated rubbish from ORNL operations; visible surface debris includes aircraft engine and ammunition boxes.
5.15	Active LLLW Slotting Tank T-13	Stainless steel 4000-gal tank to collect potential hot cell leakage during NHF operations (1982-1984).
5.16	Inactive LLLW Tank T-14	Concrete 48,500-gal tank used as an emergency waste tank to collect drainage from the injection well cell during NHF operations (1982-1985).
NA	Building 7831A	Structure at the entrance to SWSA 5 used for decontamination operations during the late 1950s to the early 1960s; decon fluids drained west from the structure into buried trench filled with crushed stone.
NA	Classified Burial Area	0.75-acre area adjoining RH-TRU direct burial trenches in SWSA 5 North used for disposal of classified waste material; area is surrounded by secondary security fence.

[a]Remediation site numbers correspond to SWMU numbers presented in earlier WAG 5 documentation.

TDEC in May 1993 (ORNL 1993). An engineering evaluation/cost analysis (DOE 1993) was prepared for removal actions in seep areas C and D and approved by EPA and TDEC in January 1994. Systems to collect and treat the contaminated seep discharges in areas C and D became operational in November 1994.

1.1.4 Rationale

WAG 5 contains a large quantity of radiologically contaminated waste that in turn has contaminated much of the site soil, surface water, and groundwater. The WAG is classified as a controlled area, and access is strictly controlled through administrative and security procedures and physical barriers that limit on-site exposures. Access to downstream areas within the ORR (e.g., White Oak Creek and White Oak Lake) is also restricted through security measures such as fencing, gates, and posting. These controls do not, however, prevent the eventual release of contamination from WAG 5 to areas outside the ORR.

Monitoring at White Oak Dam, approximately 1 mile upstream of the Clinch River, indicates that ^{3}H and ^{90}Sr discharged from WAG 5 into Melton Branch and, to a lesser extent, White Oak Creek, contribute significant proportions of the total contaminant flux associated with the release of contamination from ORNL and the ORR. The buried wastes at WAG 5 also represent a significant long-term source of contamination to both surface water and groundwater in Melton Valley and other areas downstream and/or downgradient. Because of WAG 5's status as one of the principal contaminant sources at ORNL, the RI was given a relatively high priority in the ORNL ER Program.

Off-site populations potentially affected by release of contaminants via White Oak Creek include residents along (and recreational users of) the lower Clinch River and the Tennessee Valley Authority's (TVA) Watts Bar Reservoir in Roane, Rhea, and Meigs counties. Both the Clinch River and Watts Bar are popular areas for water-based recreation including fishing, swimming, and water skiing. Domestic (potable) water supplies are also drawn from surface water downstream of WAG 5, including that for the K-25 Site (part of the ORR); TVA's Kingston Steam Plant on the Clinch River; and the communities of Kingston, Rockwood, and Spring City, which obtain water from Watts Bar Reservoir.

Another consideration in scheduling and scoping of the RI concerned future land use both within the WAG 5 administrative boundary and in adjacent, mostly downgradient, areas affected by release or migration of contaminants. Determination of viable land use options—based in part on the nature and extent of site contamination and the availability of cost-effective cleanup methods—is a major step toward the ORNL ER Program goal of comprehensive remediation of releases and threatened releases of contamination at or from ORNL. DOE recently began a formal evaluation of land use alternatives for the ORR with its stakeholders (area citizens, regulatory agencies, environmental organizations, industry representatives, and others) through what has been designated the "common ground process."

1.2 APPROACH AND OBJECTIVES OF THE WAG 5 RI

The WAG 5 FSP (DOE 1992b) established the scope of the RI by identifying the information needed to refine the site conceptual model, complete a baseline risk assessment, and support development and evaluation of remedial alternatives for any feasibility-type studies. The RI did not attempt to completely characterize all of the physical, chemical, and radiological aspects of the site. Data needs were identified in the context of the observational approach, which recognized the inherent uncertainty associated with characterizing a complex site such as WAG 5.

The FSP also identified the specific objectives for characterizing the site. Development of these objectives was consistent with EPA's data quality objective (DQO) process, which has since become the norm for environmental investigation and remediation activities at ORNL. The RI objectives were considered the DQOs for the WAG 5 field investigation, based as they were on identifying the type, quality, and quantity of data sufficient to support environmental decision-making. Broadly stated, the WAG 5 RI objectives included the following.

- To support a baseline risk assessment conducted in accordance with EPA risk assessment guidance, representative data were needed to identify the type, distribution, and magnitude of radiological and chemical contaminants not considered in previous studies.

- To support evaluation of on-site risks (industrial and residential exposure scenarios) and remediation options, collection and analysis of representative samples from shallow soils and groundwater from interior locations were required.

- To support refinement of the conceptual site model, a more detailed definition of the groundwater-surface water relationships, the areal extent of contamination in shallow groundwater, and the WAG 5 contribution to contamination in deeper groundwater (i.e., Melton Valley groundwater operable unit) were needed.

- To support evaluation of remedial alternatives, delineation of the disposal areas, the extent of contamination outside the major sources areas, and the geotechnical properties of selected soil and wastes was required.

Quantitative information concerning the type and number of samples, analytical parameters, and quality assurance/quality control (QA/QC) protocol were specified in the FSP on a media and area-specific basis. This information is also summarized in Appendix A2 of this report.

Several additional objectives identified for the source areas investigation were also important considerations for the WAG 5 RI. The scope of the source areas investigation was focused on the four seep areas along the southern perimeter of SWSA 5 South; area-specific objectives included

- identifying trenches that are probable sources of contamination in seep areas A, B, and C; determining trench saturation levels and contaminant concentrations in trench water; assessing the hydrologic relationship between trench water and groundwater;

- delineating, where possible, contaminant migration pathways from the source trenches (or other source terms) to the contaminated seeps in all four seep areas;

- defining contaminant transport properties affecting the release, migration, and discharge of contaminants in all four seep areas, particularly ^{3}H from trenches in areas A and B; and

- determining the type, magnitude, and seasonal trends of contamination in seep discharges; quantifying contaminant flux and discharge volumes to support removal action (areas C and D).

The primary objective of the RI report (as opposed to the RI field investigation) was to integrate the results of the contamination and risk assessments into a comprehensive summary of baseline conditions to support identification and selection of appropriate cleanup actions. To enhance the value of the WAG 5 RI as a management tool for ER decision-making, an additional objective was to use the results of the contamination and risk assessments to formulate a remedial action strategy and preliminary set of remedial action objectives. This RI document will provide much of the rationale needed to support decisions for follow-on ER work at WAG 5. These decisions will likely include whether to proceed with WAG-wide or area-specific response actions, determination of need for interim or early actions, selection of final remediation objectives and cleanup goals, and the role of technology development in the cleanup of the site.

1.3 SPECIAL PROBLEMS

Since the WAG 5 RI began in 1992, the strategy of the ORNL ER Program has evolved considerably. For example, it was assumed at the time of the initial scoping of the RI that an interim action (such as placement of a large cap for hydrologic isolation) was likely to be selected for the site, with the intent of implementing some sort of final remediation in the future. The current ER strategy requires that a much broader range of remedial actions be considered, thus placing greater demands on the results of the WAG 5 characterization and risk assessment efforts than was originally anticipated during the RI planning phase. Consequently, the results from the WAG 5 RI and baseline risk assessment may be somewhat limited in resolving all of the questions or issues likely to arise during evaluation of potential remedial actions. While the RI and risk data will be appropriate for guiding decision-making and supporting the overall remediation process, it is possible that the ultimate remediation scheme selected will entail one or more actions for which additional data will be needed.

Anticipating these data needs is problematic because the site has a number of unusual and in some cases unique attributes that complicate environmental decision-making. These attributes mostly are related to site physical conditions or the nature of wastes and contaminants; in some cases, however, they are based on the uncertainties associated with the baseline risk assessment and/or limitations regarding the understanding of the WAG 5 source term. Because these attributes potentially affect the type, scope, and priority of remedial actions, they are considered "special problems" or issues that need to be factored into the decision-making process. Table 1.2 identifies the specific issues that have been identified to date and summarizes background information and potential impacts on site cleanup.

Table 1.2. Special problems and considerations for remediation of WAG 5

Issue	Background	Potential Impact
Transuranic (TRU) wastes in SWSA 5 South	• TRU wastes in 11 trenches; additional locations likely • TRU constituents detected in groundwater, surface water, seeps • Source term not defined	• Long half-lives complicate evaluation and selection of remedial alternatives • Future risks cannot be predicted
Limited understanding of major source term (SWSA 5 South)	• Trench or auger hole wastes were not sampled directly • Incomplete disposal records with poor records of composition and inventory	• Limits ability to model long-term risks • Insufficient data to develop or evaluate source control alternatives
WAG 5 risks in the context of overall risks both on and off the ORR	• Percent contribution to off-site risk as measured by WAG 5 contribution to flux at White Oak Dam has been documented • The point at which off-site releases are measured and assessed may change	• Remediation of WAG 5 will need to be justified on the basis of tangible risk reduction benefits as measured by releases at multiple points, including the Clinch River, White Oak Dam, and as-yet-undetermined points upstream
Risk reduction obtained from planned seep removal action	• Systems to intercept and treat groundwater discharge in seep areas C and D reduce WAG 5 contribution to off-ORR release by up to 25% • Additional removal actions may be feasible and accomplish greater reductions	• Cost-effective measures to manage off-WAG releases do not address long-term problems on site • Collect-and-treat actions may require eternal operation and maintenance unless combined with source control actions
Determination of cleanup criteria for WAG 5	• Future land uses have not been specified; potential uses include exclusion zone, restricted industrial, unrestricted industrial, agricultural, and residential • Ecological impacts likely to be related to nonradiological contamination	• Risk-driven remedial actions will be based on realistic assumptions of future land use • Land use issue currently being evaluated jointly by DOE and stakeholders • Ecologically driven cleanup criteria must be consistent with ORNL-wide approach
Division of WAG 5 into remediation project areas or operable units	• WAG 5 RI includes a strategy for identifying and prioritizing project areas	• Future monitoring data, risk management decisions, and resource availability ($$) may invalidate current approach
Phase II RI work	• Scope of the WAG 5 RI was based on supporting a feasibility study and ER decisions for selection of appropriate cleanup actions	• Site is highly complex and has significant uncertainty (e.g., source term definition)

2. ENVIRONMENTAL SETTING

Section 2 presents an overview of the environmental setting of WAG 5. Site-specific details (e.g., surrounding population and land uses, ecology, topography, geology, and hydrology) are presented in Appendix B1 (Volume 3). The WAG 5 RI did not entail an exhaustive characterization of all physical attributes of the site; the information presented in the appendix (and summarized here) focuses on those physical characteristics most relevant to the development and verification of the site conceptual model.

2.1 SURROUNDING POPULATIONS AND LAND USE

WAG 5 is within the ORR, and access is limited through security measures such as fencing, gates, and posting. The area surrounding the ORR is predominantly rural with the exception of the City of Oak Ridge, which is adjacent to the northern perimeter of the ORR (see Fig. 2.1). Census data from 1990 indicate that the population of Oak Ridge is 27,310. A number of small towns (population <10,000) are located in the vicinity of the ORR, including Oliver Springs (7 miles northwest), Kingston (7 miles southwest), Harriman (8 miles west), and Clinton (10 miles northeast). The nearest metropolitan area, Knoxville, is 25 miles to the east; 1990 census data indicate that Knoxville has a population of approximately 200,000. Local and regional population distributions are provided in Appendix B1.

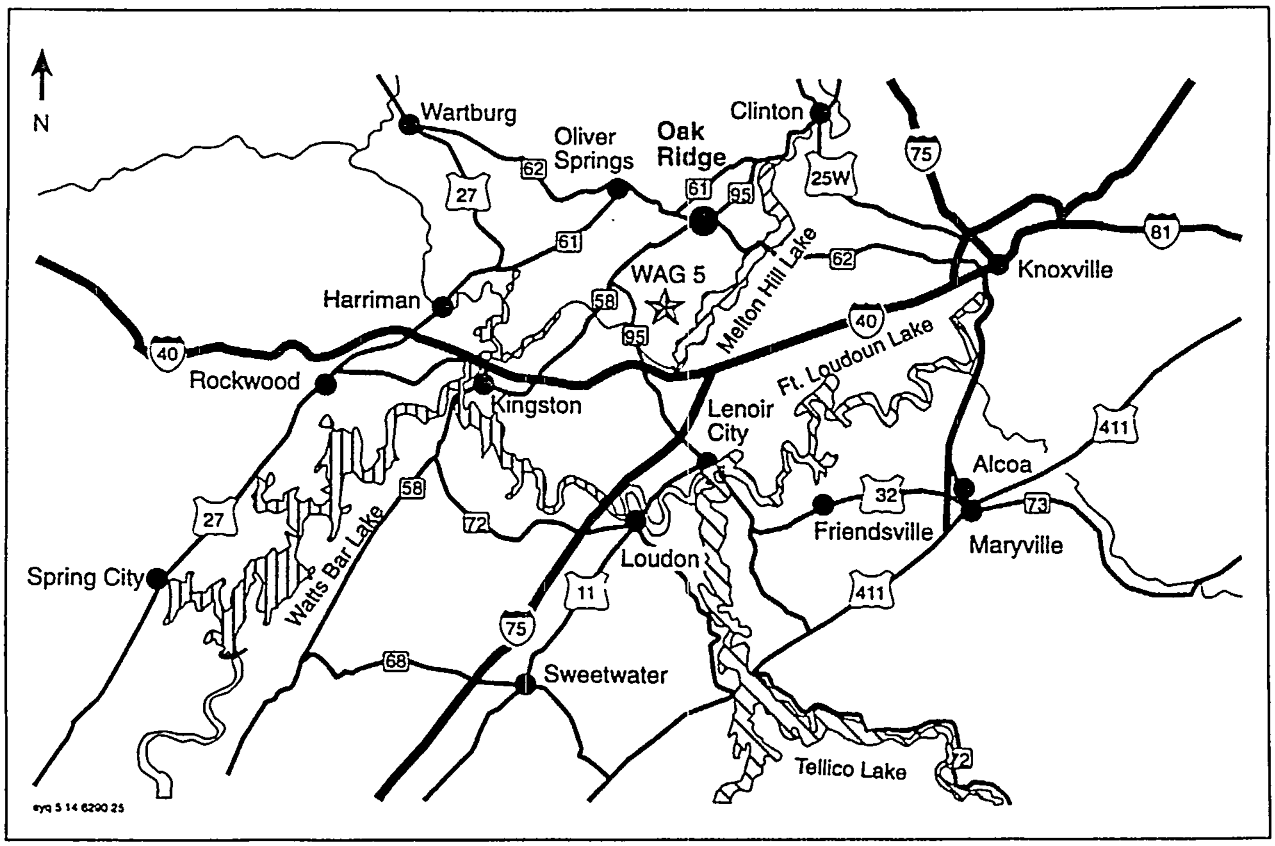

Fig. 2.1. Population centers in the vicinity of WAG 5 and the ORR.

WAG 5 is bordered by Melton Branch and White Oak Creek, which are tributaries of the Clinch River. Downstream of the ORR, the Clinch River and Tennessee River join within the embayment of Watts Bar Reservoir. Residential development along the lower Clinch River and upstream (Clinch River) arm of Watts Bar has been limited; most of this area remains rural with scattered, low-density residential areas. Both the Clinch River and Watts Bar support fishing, swimming, water skiing, and waterfowl hunting. Sport fishing for game fish (striped bass, largemouth bass, etc.) constitutes a major use of the reservoir, which also has a significant economic impact on the surrounding communities (marinas, bait shops, convenience stores, etc.).

2.2 ECOLOGY

The ecology of the ORR is typical of the Appalachian region. WAG 5-specific ecological data were collected during a wetlands delineation and preliminary (scoping) ecological survey in the spring of 1992, and ecological risk was assessed to determine the impact of site-related contamination on selected biological receptors and the ecosystem as a whole. The results of this risk assessment are included as Appendix C2 (Volume 4).

The Melton Valley burial grounds include grassed fields, deciduous forest, wetlands, and developed areas associated with waste management and ER activities (e.g., SWSA 5 North, NHF). Grass-covered areas were originally forested slopes that were cleared prior to trenching and waste disposal operations; regular mowing during the growing season prevents deep-rooted plants from being reestablished. The forested portions of the valley are associated with both upland slopes and wetland/floodplain areas of Melton Branch, White Oak Creek, and the ephemeral tributaries at the site. Field surveys for rare plant species in Melton Valley were conducted for the WAG 6 RCRA facility investigation (RFI) report (Cunningham 1990) and WAG 5 (Ashwood et al. 1992; Rosensteel 1992); no rare species were found.

The great variety of wooded and open areas and extensive edge communities provide favorable habitats for a broad range of species, and approximately 60 species of reptiles and amphibians, 150 species of birds, and 40 species of mammals have been recorded on the ORR. The fauna at WAG 5 would be typical of those associated with other areas of Melton Valley and the ORR; most animals on the ORR can adapt to a variety of habitats. No threatened or endangered bird or mammal species (as listed by the U.S. Fish and Wildlife Service) and no critical habitats are known to be present on the ORR, and, therefore, none should be present on WAG 5. Some species listed by the State of Tennessee as threatened or endangered, such as the Cooper's hawk (*Accipiter cooperii*) and sharp-shinned hawk (*Accipiter striatus*), may occasionally hunt for prey on the site but are not confined to it.

Aquatic communities on the ORR are typical of lake and stream systems in East Tennessee. Flow and habitat in both Melton Branch and White Oak Creek are adequate to support populations of fish and macroinvertebrates. The three WAG 5 drainages are ephemeral tributaries that usually dry up during the late summer and fall, and the aquatic habitat in these drainages is not likely to be suitable for the support of fish species.

2.3 GEOLOGY AND SOILS

The geology and soils of WAG 5 are key components of the site conceptual model and exert considerable influence over hydrologic processes, including those associated with the release, transport, and environmental fate of site-specific contamination. An understanding of the relevant geologic and soil characteristics is therefore a prerequisite for verifying this conceptual model, interpreting the current distribution of contamination, and developing viable predictions regarding future contaminant migration.

WAG 5 is situated in the Valley and Ridge Province, part of the Appalachian fold and thrust belt characterized by a succession of northeast-trending thrust faults that duplicate the Paleozoic-age sedimentary rock sequences. Differential erosion resulted in a series of alternating valleys and ridges that parallel the surface traces of the thrust faults. Rocks resistant to weathering (sandstones and dolomite or chert units) generally form the ridges, whereas rocks that are more readily weathered (shales and shaley carbonates) typically underlie the valley floors.

2.3.1 Bedrock Geology

WAG 5 is underlain by sedimentary shales and limestones of the Conasauga Group. The Conasauga includes several different formations, all of which are exposed in a series of linear, northeast-southwest-trending belts that are the result of folding and thrust fault motion along the Copper Creek thrust fault. This fault is exposed on the northwest side of Haw Ridge, dips to the southeast under Melton Valley, and quickly attains a depth of several hundred feet below the ground surface at WAG 5. Figure 2.2 is a generalized geologic map of the site.

Most of WAG 5 is underlain by the Maryville Limestone, and drilling and coring activities typically encountered a variable sequence of thinly interbedded shales, siltstones, and limestones. The limestones, protected by the more prevalent shaley beds, generally form more resistant horizons. The Maryville has been divided into upper and lower units. The upper unit, present in the southern portion of the site, typically has a greater proportion of shale and is likely to have greater numbers of fractures and hydrologically active zones. The Nolichucky Shale, present in the southern portions of the site and Melton Branch, is predominantly a shale with minor amounts of limestone. The Rogersville and Pumpkin Valley shales in the northern part of WAG 5 are mostly shale with interbedded lenses of siltstone and limestone.

2.3.2 Regolith

WAG 5 contaminant sources lie on the ground surface or are buried within the regolith (i.e., the zone between the surface and the bedrock), and most contaminants moving within or being released from the site do so via pathways in, through, or over the soil, saprolite (weathered or decomposed bedrock), and fill materials that make up the regolith. The thickness of the regolith varies from a few feet at the southern boundary near Melton Branch to 40 ft in the interior and higher topographic locations. Within the regolith, soil thickness varies from less than 1 to as much as 6 ft; in most undisturbed areas, the soils are less than 2 ft thick. Saprolite thickness varies from a few feet to several tens of feet. The vertical transition from soils to saprolite is generally sharp, and the transition from saprolite to unweathered ("fresh") rock is highly gradational in most areas.

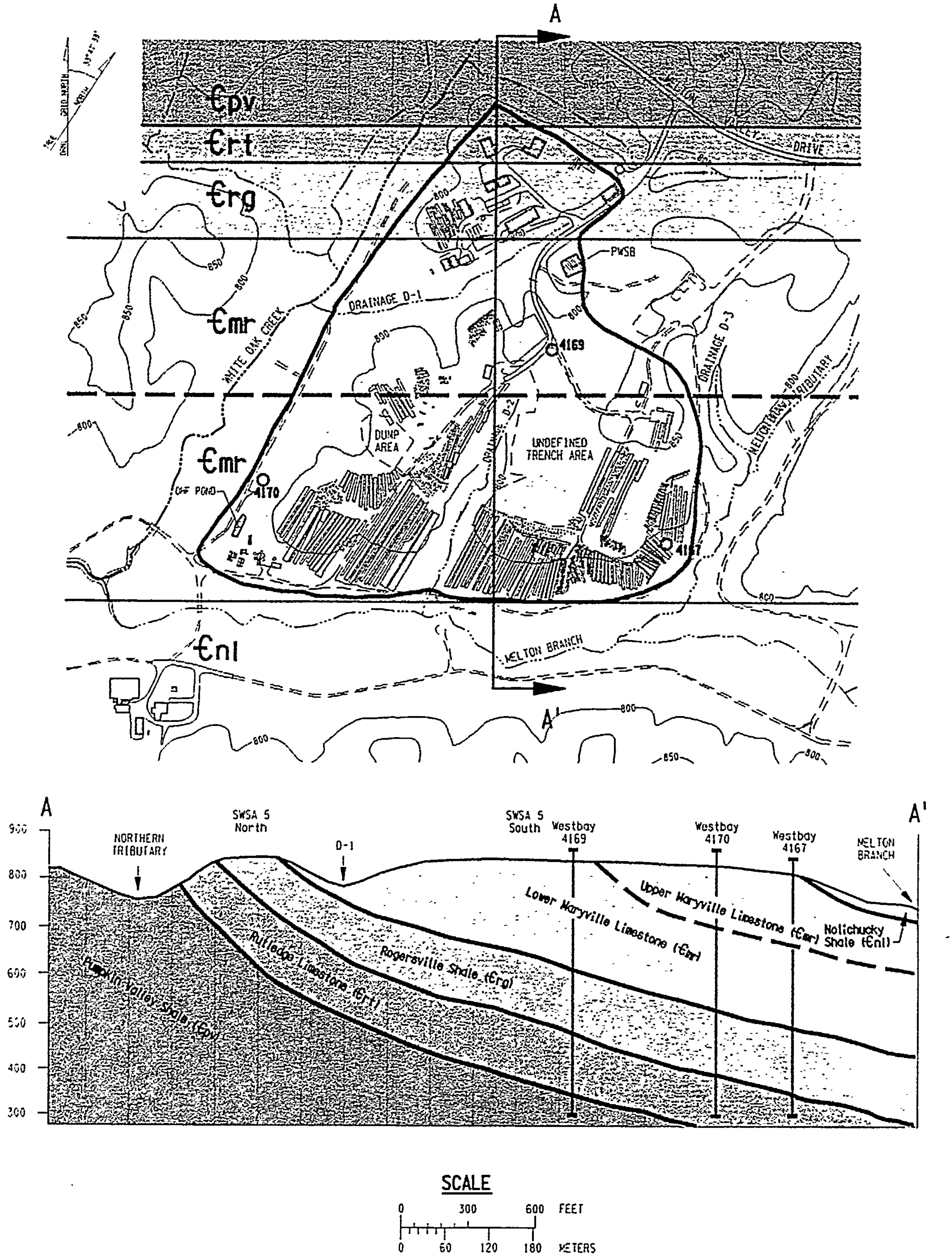

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Fig. 2.2. WAG 5 generalized geologic map.

Field descriptions of surface soils characterize them as being typically sandy silts or silty clays with abundant shale fragments. Soils overlying limestones are more clay-rich; those overlying shales and siltstones tend to be more loamy. Saprolite has the appearance of weathered, friable bedrock that retains much of the original bedding and structural features. These remnant structures are important because they provide preferential flow paths for groundwater and contaminant migration. Much of SWSA 5 South and the developed portions of the site (e.g., OHF, NHF) have a regolith with a significant fill component consisting of locally derived and imported (usually from elsewhere at ORNL) soils and saprolite. These materials generally had properties similar to those of the native regolith materials.

2.4 HYDROLOGIC MODEL

The preliminary hydrologic model for WAG 5 identified surface water as the principal conduit for contaminant migration, linking discharges and releases from WAG 5 source areas to White Oak Creek, Melton Branch, and downstream areas both on and off the ORR. The surface water and groundwater systems at WAG 5 are closely linked: an active stormflow zone combined with shallow groundwater circulation patterns creates a system where most of the precipitation that infiltrates the soil on the site discharges locally into either the on-site drainages or perennial streams (Melton Branch and White Oak Creek) that bound the site (Fig. 2.3).

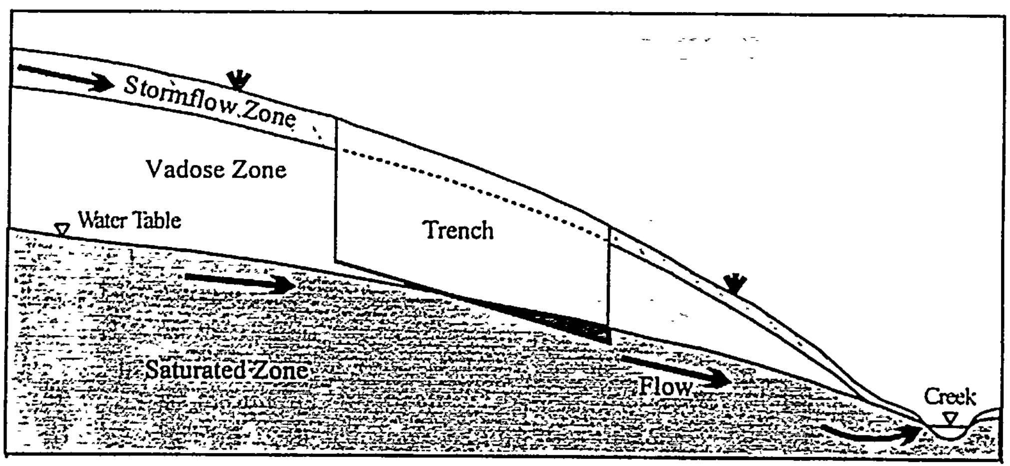

Fig. 2.3. Hydrological processes at WAG 5.

Information collected and evaluated for the WAG 5 RI resulted in a more detailed characterization of the hydrologic system at the site to refine and verify the preliminary hydrologic model. This section provides a summary of the principal components of this model, including

- precipitation patterns,
- surface water hydrology of WAG 5 and contiguous reaches of the adjacent receiving waters,
- shallow groundwater system (water table interval), and
- trench hydrology.

A summary discussion at the end of this section ties these components together into a refined hydrologic model for WAG 5. Appendix B1 presents a more detailed analysis of the hydrologic features of the site.

2.4.1 Precipitation Patterns and Site Rainfall Data

Precipitation is an important component of the hydrologic system because it controls the quantity of discharge from WAG 5. The precipitation gauge with the longest period of record in the Oak Ridge area is the Atmospheric Turbulence and Diffusion Laboratory monitoring station approximately 7 miles north of WAG 5. The long-term hourly rainfall record (1953–1990) was analyzed for seasonal variations and extreme occurrences (National Climatic Data Center 1990). These data show an average annual precipitation of 53.6 in. and a range in average monthly precipitation from a low of 3.02 in. (October) to a high of 5.73 in. (December).

The precipitation gauge closest to WAG 5 is at SWSA 4, approximately 0.3 mile to the northwest. The station is maintained by Energy Systems, and the data are recorded in breakpoint format. Figure 2.4 shows the monthly and maximum daily rainfall recorded from January 1993 to April 1994.

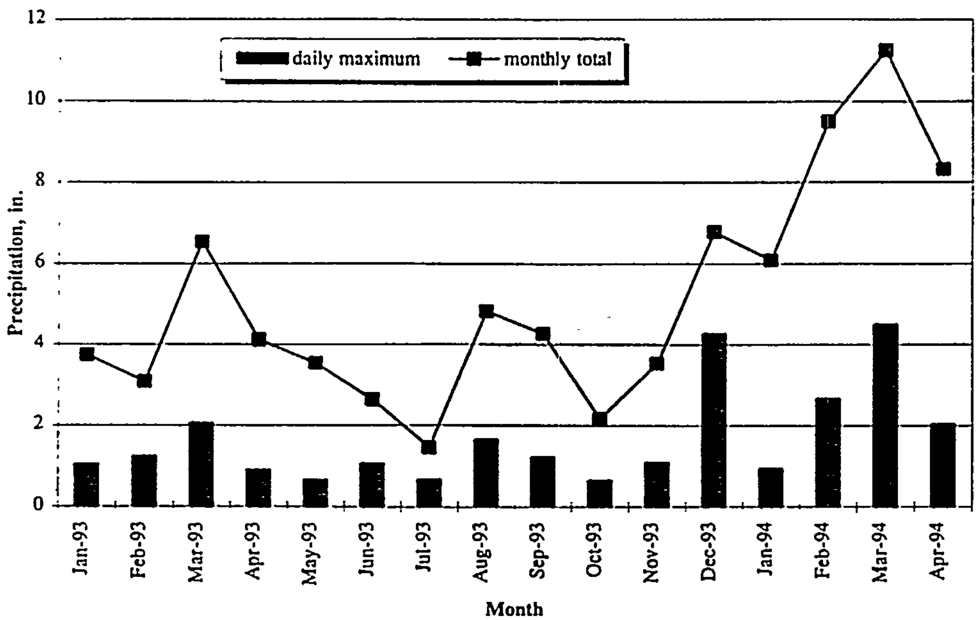

Fig. 2.4. Monthly and daily maximum precipitation.

2.4.2 Surface Water Hydrology

WAG 5 lies within the White Oak Creek watershed and is near the confluence of White Oak Creek and Melton Branch, the principal White Oak Creek tributary in Melton Valley. Topographic data and man-made surface water controls (e.g., concrete drainage ditches in SWSA 5 South) were used to divide the site into discrete drainage subbasins within the larger White Oak Creek and Melton Branch drainage basins (Fig. 2.5). The total drainage area associated with WAG 5 is 113.7 acres (the total WAG 5 area within the administrative boundary is approximately 70 acres). Fifty-three percent of this area (about 61 acres) discharges into White Oak Creek above its confluence with Melton Branch; the remaining 47 percent (53 acres) discharges to Melton Branch above its confluence with White Oak Creek.

White Oak Creek basin

The WAG 5 White Oak Creek basin has one main drainage course, D-1, running east to west along the southern perimeter of SWSA 5 North. About half of the WAG 5 White Oak Creek basin drains to D-1; the rest drains directly into White Oak Creek. Flow in D-1 was gauged via an H-flume installed for the RI field investigation. None of the flow from the White Oak Creek drainage area outside of the D-1 catchment is gauged.

Both of the WAG 5 impoundments are in the White Oak Creek drainage basin. The PWSB has a total storage capacity of about 257,000 gal, dimensions of 85 × 85 ft, and a maximum depth of 7.8 ft. The OHF pond, constructed in 1964, measures 20 × 100 ft and has a maximum depth of 6 ft and a storage capacity of 100,000 gal. The PWSB has no appreciable hydraulic influence on either groundwater or surface water at the site; it was constructed with a compacted clay and polyvinyl chloride (PVC) liner and there have been no recorded incidents of overflow. Conversely, the OHF pond is in direct communication with the shallow groundwater and therefore has a significant, if localized, impact on the water table configuration and shallow groundwater flow.

Continuous flow measurements in D-1 were used to evaluate and model the hydrologic system in the White Oak Creek basin. Figure 2.6 presents a hydrograph of the D-1 flow measured at surface water station SW001. D-1 is typically dry during summer and fall with an average flow of only 0.11 cfs (based on the 1993–1994 flow data). In general, the D-1 drainage course receives little contribution from baseflow and reacts quickly to storms. Most of the area is undisturbed (in contrast to the Melton Branch drainage area), and thus precipitation is more likely to be discharged through runoff and stormflow. The impervious areas in SWSA 5 North (buildings, pavement, concrete pads, etc.) contribute disproportionate runoff and cause relatively higher peak flows during storm events (as shown on the hydrographs from SW001).

The Hydrological Simulation Program—FORTRAN (HSPF) computer model was used to simulate long-term discharge in drainage D-1. HSPF calculates stream discharge by dividing flow into three components: surface runoff, interflow, and shallow groundwater discharge into the streams. Surface runoff is water that travels over the ground surface into the channel. Interflow is analogous to stormflow and describes that component of flow associated with a transient, perched water table at the approximate depth of the root zone. Water within the stormflow zone is transmitted laterally (downslope) until it reaches the stream channel. Groundwater discharge (and

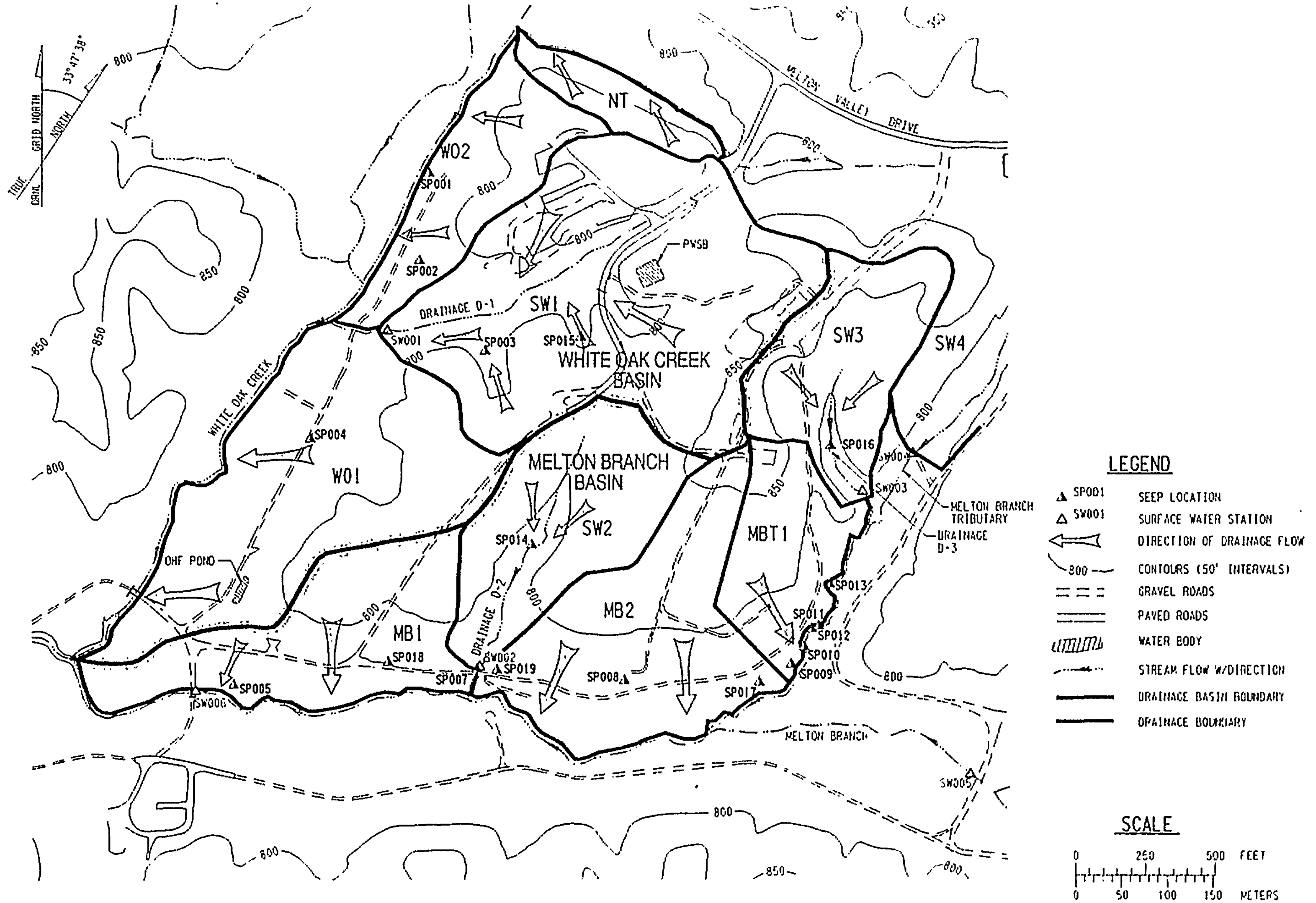

Fig. 2.5. Surface water drainage areas.

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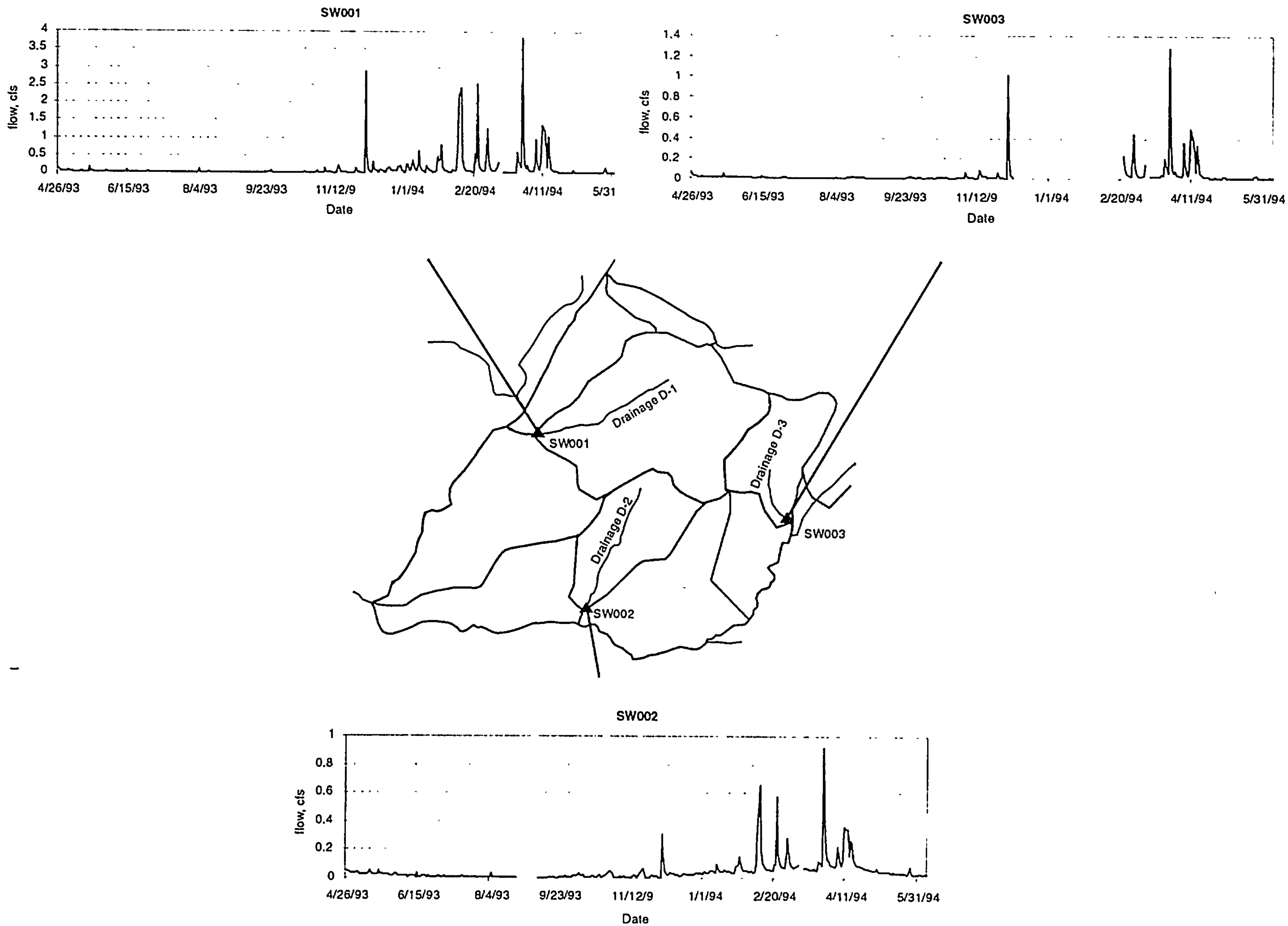

Fig. 2.6. Daily flows for D-1, D-2, and D-3.

resulting baseflow) occurs when the water table intersects the stream channel and the hydraulic potential causes groundwater discharge into the stream.

The model was calibrated using the measured flow at SW001 by adjusting the physical parameters describing the soils, vegetation, and topography. After the physical parameters were determined, streamflow in D-1 was simulated for a 41-year period using hourly precipitation data recorded in Oak Ridge from 1953 through 1993. The average annual water balance components for D-1, based on the 41-year HSPF simulation, are summarized below.

Component	Volume (in.)
Precipitation	53.9
Evapotranspiration	26.1
Total discharge	27.8
Surface runoff	7.6 *(27.3%)*
Interflow	8.5 *(30.6%)*
Groundwater	11.7 *(42.1%)*

The modeling shows that input from surface runoff is significant but overall discharge is dominated by subsurface flow. The presence of an active stormflow zone in D-1 was observed during spring 1994 at six specially constructed stormflow piezometers (Fig. 2.7). The piezometers are screened from a depth of 0.5 to 2.0 ft and were designed to monitor flow in the shallow soil zone. A 10-ft^2 piece of plastic was placed on the ground and sealed around the upland piezometer risers to prevent infiltration in the immediate area. Continuous water level recorders were temporarily installed in each piezometer to record response during storms (Fig. 2.7).

White Oak Creek is the receiving body for all surface water from this drainage area, whether directly (through runoff or discharge of interflow and groundwater) or indirectly (through runoff and discharge into D-1). White Oak Creek drains into White Oak Lake, an impoundment approximately 4000 ft downstream of the confluence of White Oak Creek and Melton Branch. White Oak Dam, located at the point where Highway 95 passes over White Oak Creek, has been modified a number of times since the lake was created in 1943 to better control water and sediment discharge from White Oak Lake; it currently maintains an elevation of 745 ft msl and creates a standing pond of 17 acres. The White Oak Creek Embayment extends 0.6 mile from White Oak Dam to its confluence with the Clinch River at Clinch River mile 20.8.

Continuous flow measurements are made at two stations on White Oak Creek downstream of WAG 5 as part of the National Pollutant Discharge Elimination System (NPDES) ambient surface water monitoring program (Clapp 1992). Station MS3 is at the southwest corner of WAG 5 just upstream of the White Oak Creek and Melton Branch confluence, and station MS5 is at White Oak Dam. The average flow in White Oak Creek at MS3 during the period October 1989–December 1993 was 11.3 cfs; the average flow at White Oak Dam was 14.8 cfs.

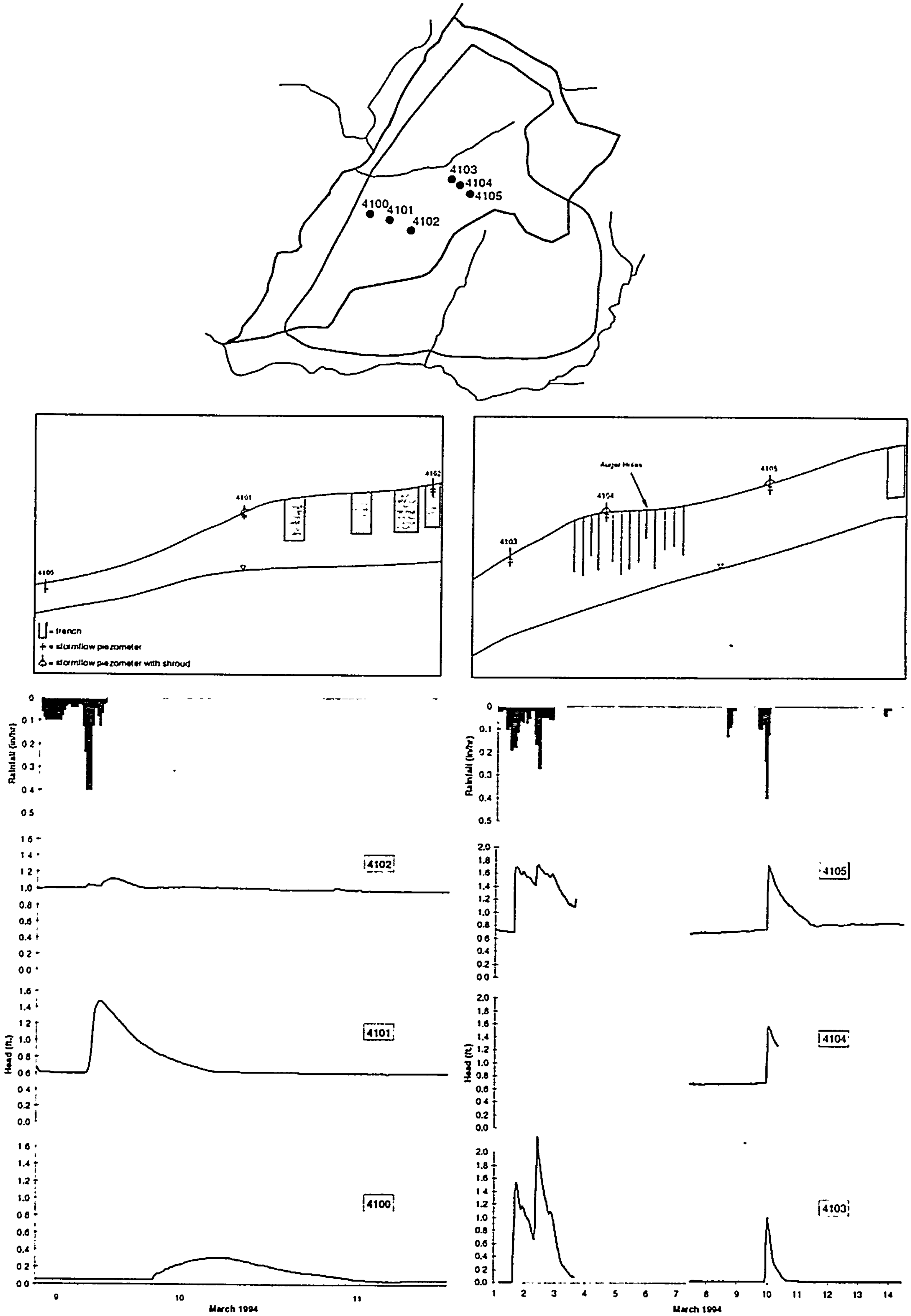

Fig. 2.7. White Oak Creek shallow stormflow piezometer hydrographs.

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Figure 2.8 shows the relationship between the WAG 5 contribution to flow in White Oak Creek and the percentage of flow over White Oak Dam attributable to discharges from WAG 5 (both White Oak Creek and Melton Branch). The total discharge into White Oak Creek from the WAG 5 White Oak Creek drainage area was estimated by assuming that the ungauged areas are hydrologically similar to D-1. Using this approach, the average discharge from the WAG 5 White Oak Creek area during October 1989 to December 1993 was 0.19 cfs, which represents 1.5% of the total flow in White Oak Creek at MS3 and 1.3% of the total flow at MS5 (White Oak Dam).

Five seeps were identified in the White Oak Creek drainage (Fig. 2.5). Most of the seeps were visible as areas of groundwater discharge, either discrete water flows or diffuse wet areas, mostly at the base of slopes or floodplain/stream channel margins. Given the low flows measured at the seeps, they apparently represent only a small portion of the total groundwater discharge into White Oak Creek and D-1 along the western side of WAG 5.

Melton Branch basin

The Melton Branch drainage basin is defined as those portions of the site where surface flow discharges directly into Melton Branch along the southern perimeter or indirectly to Melton Branch via the (unnamed) Melton Branch tributary that partially bounds the eastern portion of WAG 5. Flow monitoring was conducted during the RI in D-1 and D-2, the two main drainage courses in this part of the site, to evaluate the hydrologic system and support modeling efforts. Most of the flow (62%) from this area is ungauged and discharges directly into either Melton Branch or its unnamed tributary.

Figure 2.6 shows flow hydrographs for D-2 measured at surface water station SW002. Average flows in D-2 are low (0.05 cfs based on 1993–1994 data) but typically occur year-round due to a relatively large contribution from base flow (discussed below). In contrast to D-1, base flow is recognizable from mid-fall through early summer. Higher base flow in D-2 was attributed to the fact that most of the drainage area has been disturbed through excavation activities associated with trenching and drilling of auger holes. Disturbed areas typically have higher infiltration rates and more poorly developed stormflow zones.

The flow data were used to calibrate the HSPF model for the 41-year simulation as described above. The average annual water balance components for D-2 are summarized below.

Component	Volume (in.)
Precipitation	53.9
Evapotranspiration	24.7
Total discharge	29.2
Surface runoff	2.0 *(6.9%)*
Interflow	8.3 *(28.4%)*
Groundwater	18.9 *(64.7%)*

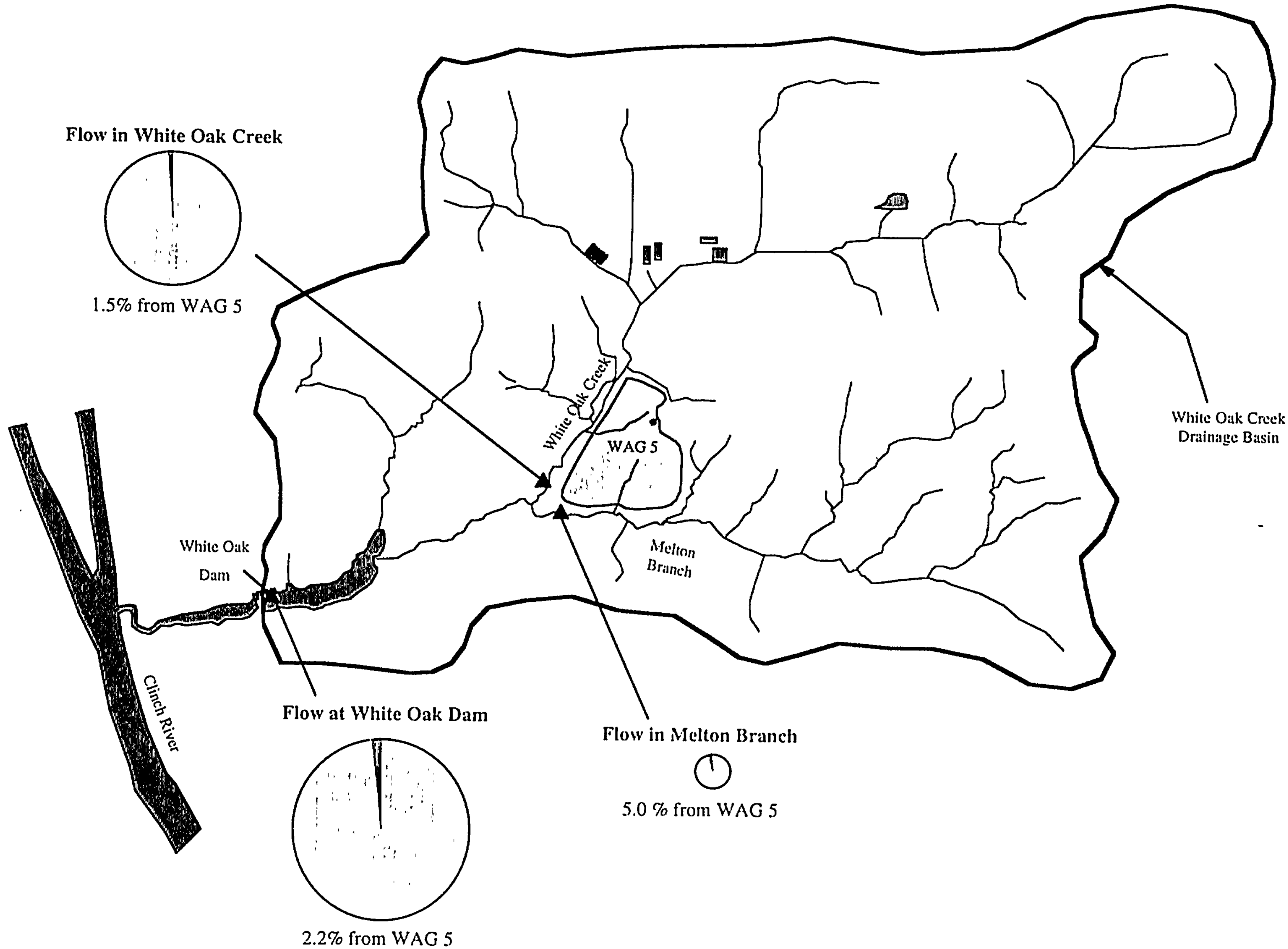

Fig. 2.8. Relative discharge in White Oak Creek, Melton Branch, and White Oak Dam.

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The HSPF simulations show that baseflow from groundwater discharge to D-2 is more than twice the contribution from interflow and an order of magnitude greater than runoff. The presence of an active stormflow zone (interflow) in the D-2 catchment was confirmed during spring 1994. Continuous water level recorders were temporarily installed in each of eight shallow stormflow piezometers (4099 and 4106–4112) to record the piezometers' response during a storm event. Figure 2.9 shows a plot of the hydrograph for each piezometer.

D-3 has a 9.3-acre drainage catchment on the northeastern side of WAG 5. Most of the area lies outside of the WAG 5 administrative boundary, but the catchment does receive runoff and other flow from the eastern portion of the WAG, including the landfill. In addition, D-3 is downgradient of the WAG 5 decontamination and investigation-derived waste (IDW) consolidation areas. Almost all of the D-3 drainage area is forested; a small fraction is grass-covered. The D-3 drainage channel is 800 ft long and discharges into the Melton Branch tributary.

Continuous flow measurements were made in D-3 from April 1993 until June 1994 at station SW003; average daily flows are shown in Fig. 2.6. Average flows in D-3 are the lowest of the three WAG 5 interior drainages. The drainage is mostly dry from late spring to mid-fall with an averaged flow of 0.03 cfs based on 1993–1994 data. Almost all of the area is undisturbed and would be expected to have a relatively well-developed stormflow zone. The hydrographs support this assumption and show that most precipitation is discharged via either stormflow or runoff. Appreciable baseflow occurs only during winter and early spring.

HSPF was used to simulate the long-term runoff in D-3. The results (summarized below) support interpretations based on analysis of the D-3 flow hydrograph that the catchment has a lower groundwater recharge and base flow contribution because the area has remained relatively undisturbed.

Component	Volume (in.)
Precipitation	53.9
Evapotranspiration	27.4
Total discharge	26.5
Surface runoff	4.9 *(18.5%)*
Interflow	9.1 *(34.3%)*
Groundwater	12.5 *(47.2%)*

Melton Branch is the receiving body for surface water from the Melton Branch drainage area. The total drainage area is 1.51 mile^2, all of which is in Melton Valley. Melton Branch drains into White Oak Creek opposite the southwest corner of WAG 5, at a point that coincides with the southwest corner of the WAG 5 drainage area. Flow and water quality are monitored at station MS4 (also identified as X13 and Melton Branch-1), a weir that is approximately 600 ft upstream of the Melton Branch and White Oak Creek confluence. Continuous flow measurements from MS4 for October 1989 through December 1993 indicate a mean daily flow of 3.1 cfs.

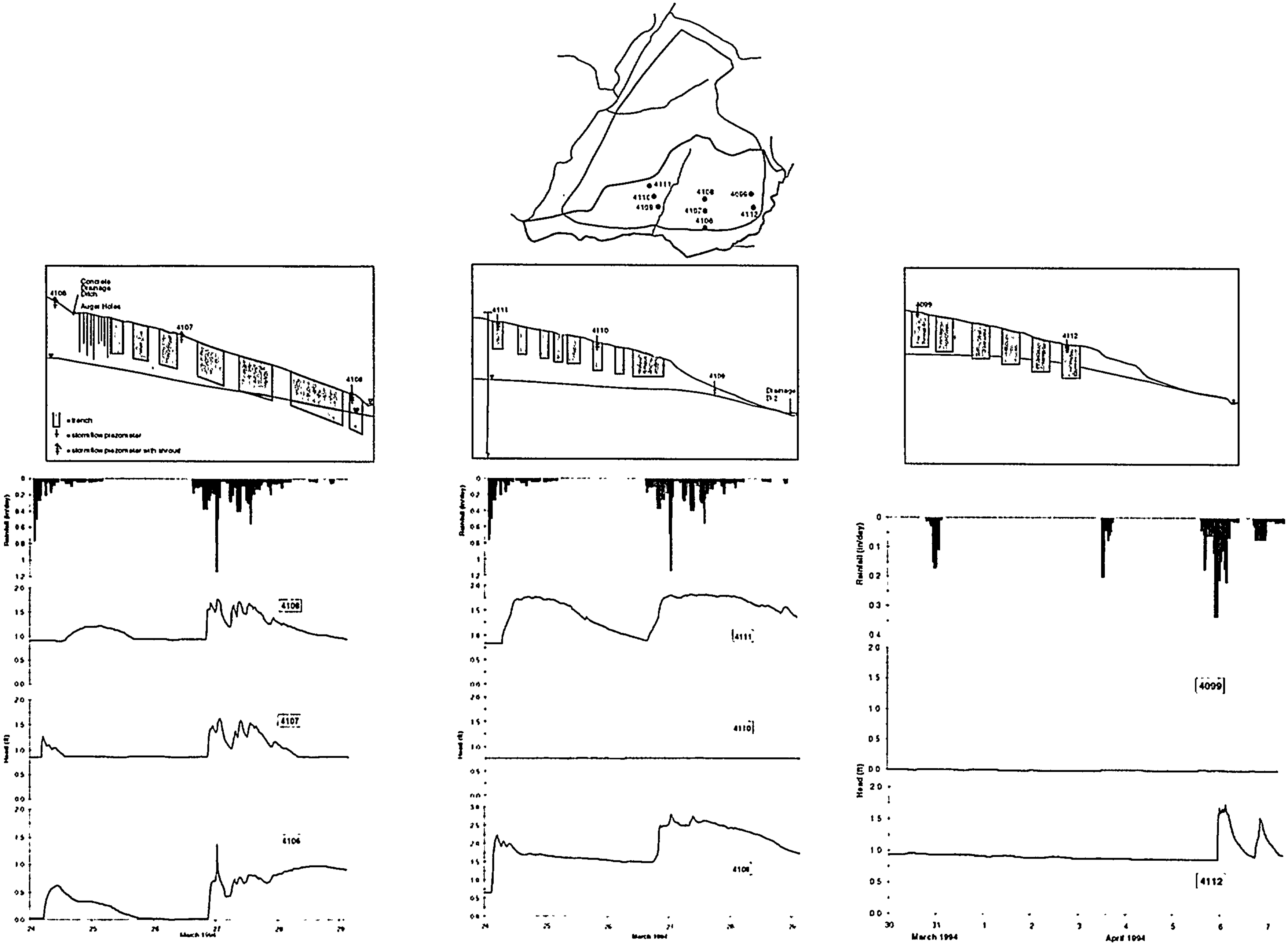


Fig. 2.9. Melton Branch shallow stormflow piezometer hydrographs.

The total discharge into Melton Branch from WAG 5 (i.e., the Melton Branch drainage area) was estimated by assuming that the ungauged drainage areas had characteristics similar to D-2 (data from the D-3 drainage basin were used only for that subarea). Using this approach, the average discharge from WAG 5 into Melton Branch for October 1989 to December 1993 was 0.18 cfs, which represents 5.8% of the total flow in Melton Branch at MS4 and 1.2% of the total flow at MS5 at White Oak Dam. Combining the White Oak Creek and Melton Branch drainage areas, the total discharge from WAG 5 during 1989–1993 was approximately 2.5% of the flow at White Oak Dam (Fig. 2.8).

Fifteen seeps were identified in the Melton Branch drainage area of WAG 5: SP00D, and SP005 through SP019 excluding SP015 (Fig. 2.5). Most of these seeps correspond to ones sampled for the WAG 2 RI and possibly earlier investigations (e.g., Duguid 1975). A notable exception was SP018, which was attributed to overflowing (bathtubbing) trenches in SWSA 5 South during the unusually wet conditions that characterized the winter and spring of 1994. Most of the seeps were visible as areas of groundwater discharge, either discrete water flows or diffuse wet areas, mostly at the base of slopes or floodplain/stream channel margins. Similar to White Oak Creek drainage, seeps that are visible probably represent only a small portion of the total groundwater discharge associated with the Melton Branch drainage area of WAG 5.

Surface water quality

The Tennessee Water Quality Control Board has classified White Oak Creek and Melton Branch as suitable for fish and aquatic life, recreation, irrigation and livestock watering, and wildlife (TDEC Rules, Chap. 1200-4-4). Surface water quality in White Oak Creek and Melton Branch generally meets NPDES permit requirements and EPA water quality criteria for freshwater aquatic life (Energy Systems 1993). Water quality sample results for the RI were consistent with results of water quality analyses conducted on a regular basis for the NPDES ambient surface water monitoring program. These results identified no significant water quality problems apart from those associated with radionuclides.

2.4.3 Groundwater Hydrology

Shallow groundwater at WAG 5 is a primary release mechanism and contaminant migration pathway linking buried wastes in the source areas to nearby surface waters in WAG 2 (primarily Melton Branch) and thus downstream areas, including areas off the ORR. Groundwater also constitutes a potential exposure pathway for the residential land use scenario evaluated for the baseline human health risk assessment. The hydrogeology of Melton Valley (and the ORR in general) has been examined in great detail by others (e.g., Moore and Toran 1992; Solomon et al. 1992; Webster and Bradley 1988).

The hydrologic model developed during the scoping phase of the RI identified the stormflow zone, vadose zone, water table interval, and deeper groundwater as the principal components of the groundwater system. The primary zones of interest for the WAG 5 RI are the water table interval and stormflow zone. Deeper groundwater, defined as that below the base level of the surrounding streams (White Oak Creek and Melton Branch), will be addressed as part of the Melton Valley Groundwater Operable Unit (GWOU); Fig. 2.10 shows the relationship between WAG 5 and the Melton Valley GWOU.

The following discussion summarizes the WAG 5 groundwater characterization and evaluation activities. Specifically, it addresses groundwater components of the hydrologic model as they relate to the release, migration, and discharge of contaminants from WAG 5 source areas. Appendix B1 presents site-specific data concerning the physical, chemical, and hydraulic characteristics of the stormflow zone, vadose zone, and water table.

Stormflow zone

The stormflow zone is a shallow layer with relatively high permeability (both horizontal and vertical) that extends from just below the ground surface to the approximate base of the root zone. Areas with paving or otherwise lacking in vegetation do not have stormflow zones. Because the vertical permeabilities in the underlying vadose zone are typically much lower, the stormflow zone becomes saturated during large precipitation events and transmits water laterally (downslope) to surface water systems (Moore 1989). Solomon et al. (1992) reported that >90% of active subsurface water flow occurs in the stormflow zone.

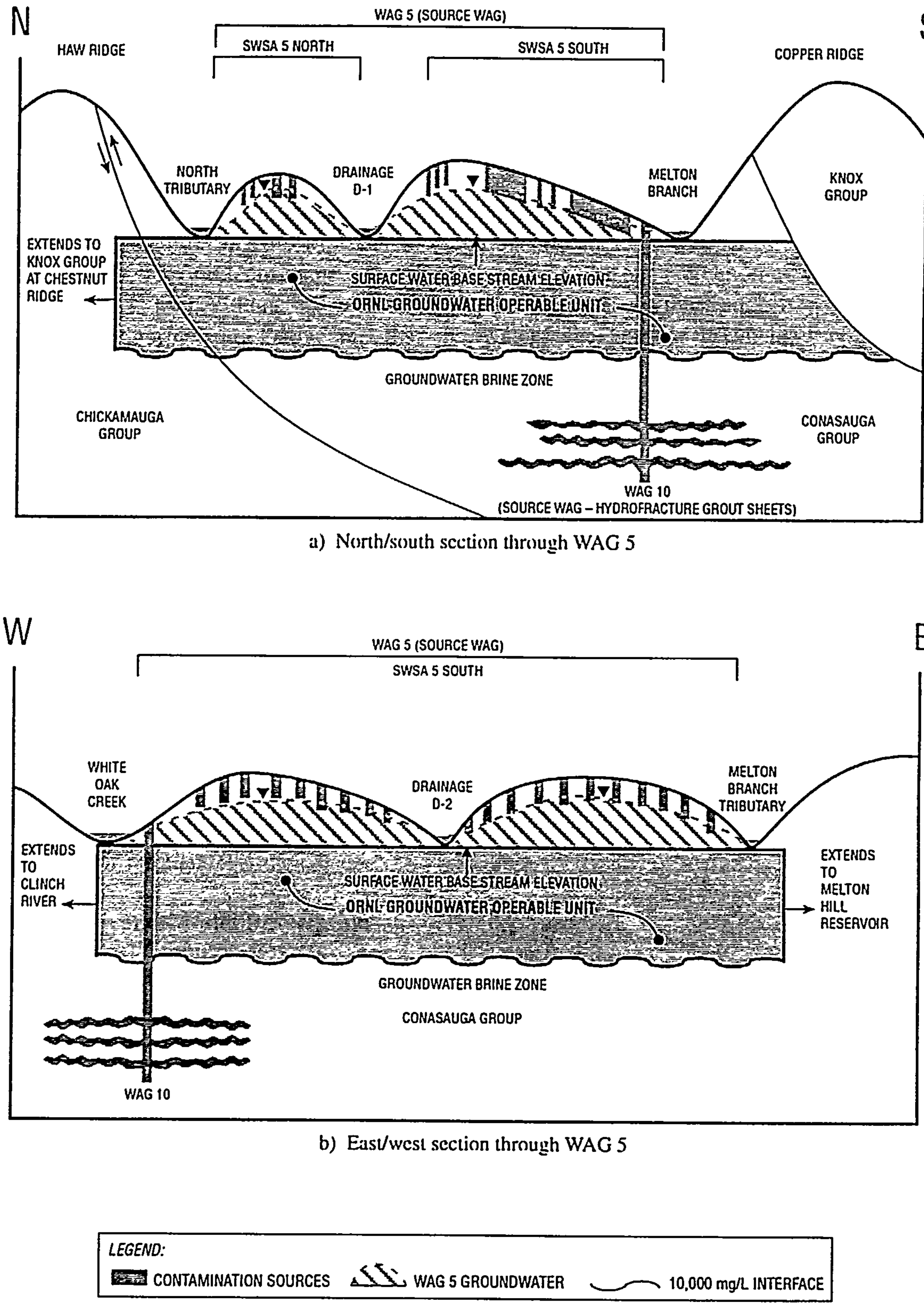
Stormflow zone responses to precipitation at selected piezometer transects are shown in Figs. 2.7 and 2.9. In general, an active stormflow zone is present over much of the site but often disrupted in the backfill materials over trenches, probably due to lateral variations in the vertical permeability of the backfill material. In many areas, the stormflow zone is not an uninterrupted pathway (to the downslope discharge point) for subsurface flow. When stormflow encounters areas of higher vertical permeability in trench backfill, potentially significant quantities of additional water (i.e., beyond that which directly infiltrates) are introduced into the trenches.

Flow hydrographs from drainages D-1, D-2, and D-3 also indicate an active stormflow zone that contributes, on average, approximately 30% of the total discharge (flow) in these drainages. The piezometer and surface water flow data support the conclusion that the stormflow zone is not the primary pathway for subsurface water migration at WAG 5. The significance of the zone involves its role in the recharge of water to the trenches and the resulting mobilization/release of contaminants.

Vadose zone

The vadose zone at WAG 5 consists of the unsaturated interval between the stormflow zone (or the ground surface where stormflow zone is absent) and the water table. Because the water table generally occurs near the bedrock/regolith interface, the vadose zone consists almost entirely of regolith, which is dominated at WAG 5 by fill materials, saprolite, and buried wastes. In contrast to the stormflow zone, the predominant direction of flow is vertical (downward) to the water table.

From a conceptual model perspective, the vadose zone is important because contamination released from upland trenches (i.e., those that do not become inundated) must travel through the vadose zone to reach the shallow groundwater. Interactions between the contaminants and the matrix materials of the regolith have a significant influence on the type and magnitude of contamination that actually reaches the water table. Where these interactions entail the transfer of significant levels of contamination to the matrix, the process can result in the creation of secondary sources within the vadose zone.



a) North/south section through WAG 5

b) East/west section through WAG 5

Fig. 2.10. Schematic description of the relationship between the source (WAG 5) and the integrator (GWOU).

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Shallow groundwater

The shallow groundwater interval at WAG 5 is the saturated interval in which most groundwater flow occurs and generally corresponds to the water table interval identified by Solomon et al. (1992). The designation usually is applied to the upper 10–30 ft of saturated material below the water table. The actual depth (and thickness) varies depending on topography; degree and depth of weathering; and structure, especially fracture abundance, orientation, and interconnectedness. In most areas, the shallow groundwater interval is within the saprolitic regolith materials, but it may extend upward into fill or natural soils and/or downward into the upper weathered portion of the bedrock.

The shallow groundwater system at WAG 5 is highly complex and dominated by fracture flow. Soil samples from below the water table indicate that some intergranular flow may also be present due to weathering and dissolution/leaching of bedrock materials. In addition, some saprolitic horizons have dense fracture networks that may approximate a porous medium for flow. The shallow groundwater interval has an average hydraulic conductivity (based on the geometric mean of 71 tests) of approximately 0.16 ft/day. These values correlate relatively well with slug-test-derived average conductivity values of 0.15 ft/day from Moore (1989) and 0.26 ft/day from Moore and Toran (1992).

The depth to the water table at WAG 5 ranges from less than 1 ft to more than 40 ft. Shallow water tables are typically associated with drainages and the floodplains of White Oak Creek and Melton Branch; maximum depth to water is at the topographically highest areas. The water table is typically highest between February and April (high base conditions) and lowest between August and October (low base conditions). Figure 2.11 presents water table surface maps that were contoured based on water level measurements made during high base (wet season) and low base (dry season) conditions.

The horizontal gradients are relatively constant at a given location during the year but fluctuate considerably from one topographic location to the next. Steeper gradients are present where topographic slopes are also steep—as expected, given the relationship between water table surface and topography. The average horizontal hydraulic gradients observed in 1993 were 0.07 during wet seasonal conditions and 0.06 during dry conditions. Average hydraulic gradients were calculated from differences in water table elevations measured along groundwater flow paths.

Continuous water level data were obtained from three 3-well clusters in WAG 5 (Fig. 2.12). The hydrographs for well cluster 0461-0463-0464, in the southern portion of SWSA 5 South near the Melton Branch floodplain, show a persistent upward gradient, indicating potential discharge conditions. Farther uphill in SWSA 5, well cluster 0440-0460-0458 shows a downward gradient, indicating recharge conditions. Well cluster 0468-0467-0466 showed a more complex relationship involving alternating recharge and discharge conditions and changes in the directional component with depth.

The continuous water level data provide further evidence of the complexity of the groundwater flow regime in WAG 5. Topographic locations are generally reliable indicators of vertical gradients, but conditions can vary significantly at a given location. This localized variability in the vertical

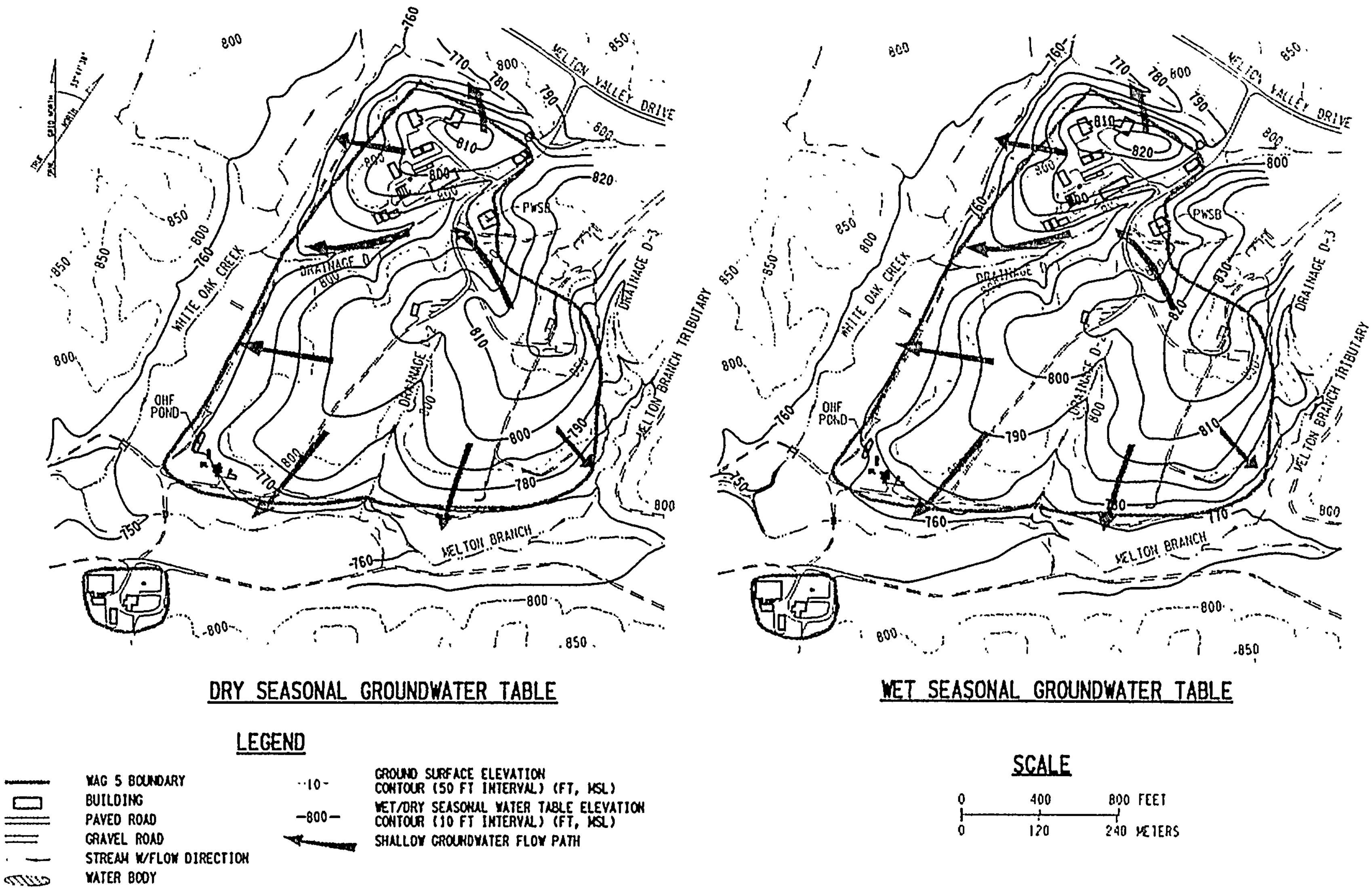

Fig. 2.11. Seasonal water tables and shallow groundwater flow paths.

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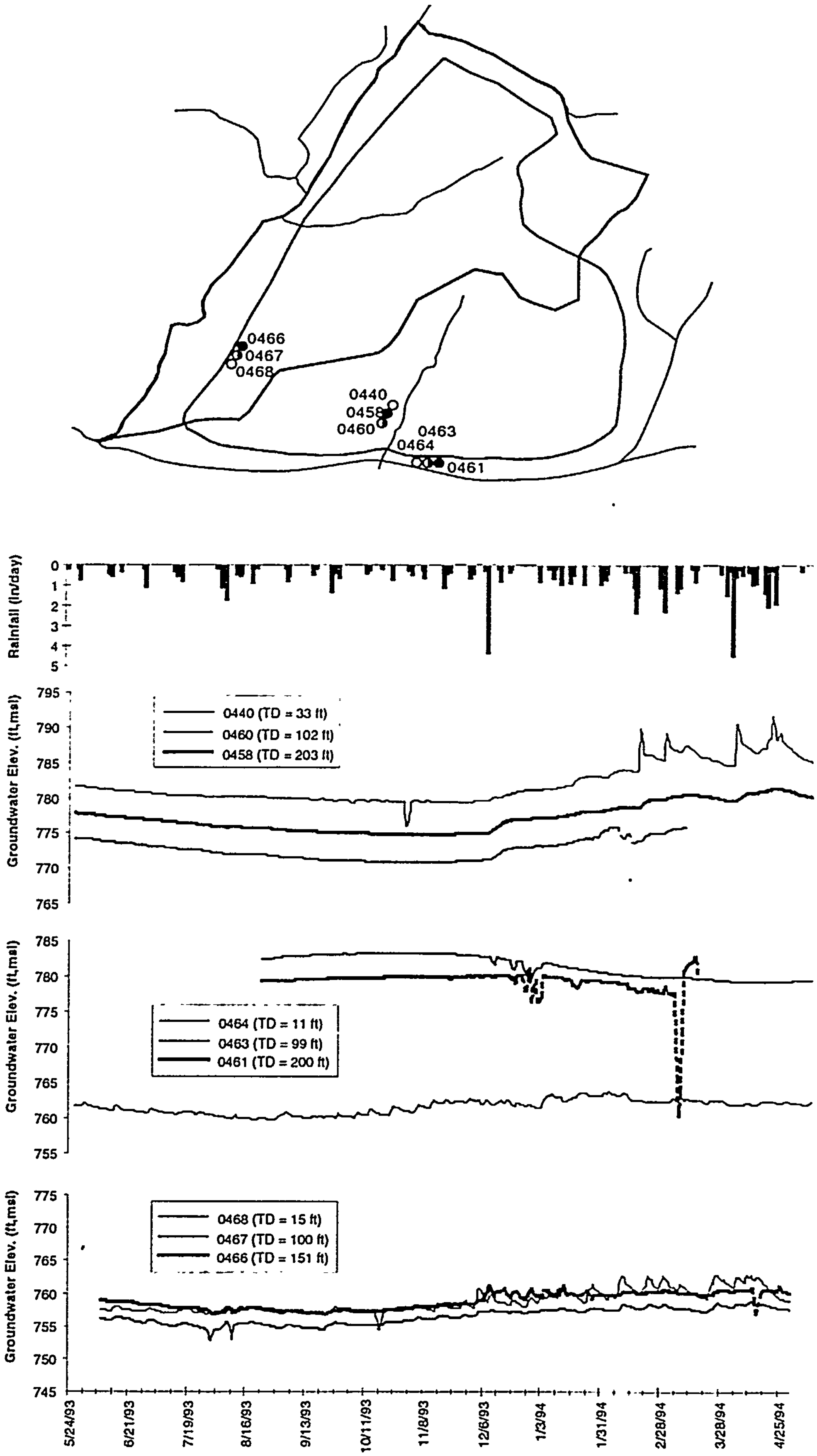

Fig. 2.12. Hydrographs for WAG 5 well clusters.

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gradient can be significant, even within a matter of feet, due to the anisotropic, fracture-dominated flowpaths in both the saprolite and bedrock.

2.4.4 Trench Hydrology

Trench hydrology plays a significant role in the release and transport of contaminants and thus is an important component of the site conceptual model. As illustrated in Figs. 2.13 and 2.14, inundation of the trenches is widespread in the downhill (southern) portion of SWSA 5 South and also in SWSA 5 North during the wet season. Segments (or in some cases the entire length) of the trenches in SWSA 5 South are inundated during the wet season. When the water level in an inundated trench is higher than the water table outside that trench, the trench is considered to be "bathtubbing." During the wetter months, the water level in the downslope ends of some bathtubbing trenches rises to the point where these trenches are entirely filled with water; a few have even overflowed onto the ground surface.

Transient, episodic saturation above the water table occurs in upland trenches when they fill with water faster than the water can drain through the sides or bottom. This condition is also a form of bathtubbing; the difference is that the water table in the trenches is perched. Bathtubbing of upland trenches occurs from with either higher infiltration or where the trench intercepts an active stormflow zone from upgradient/upslope areas. In many instances, however, bathtubbing trenches are not readily discernible from unconfined, inundated trenches on the basis of available water level data.

Trench water may discharge in several ways. Inundated trenches are in direct communication with shallow groundwater in the water table interval. For perched water tables in upland trenches, leakage through the trench bottoms (and sides) may be a significant source of contaminated recharge to the water table. Webster and Bradley (1988) suggested that trench water may also overflow into the stormflow zone. Flow from trench to trench is also a potentially significant pathway when trenches are in proximity.

2.4.5 Summary and Model Description

Figure 2.15 depicts the hydrologic model for WAG 5, which is based on an integration of precipitation, surface water, groundwater, and trench hydrologic data. The model shows that the surface water system is the primary integrator of hydrologic fluxes from WAG 5—most of the precipitation that is not lost to evapotranspiration eventually makes its way to White Oak Creek. The water balance components derived from the HSPF simulation (calibrated using flow data from D-1, D-2, and D-3) include an average annual precipitation of 53.9 in., of which an average 26.1 in. is lost to evapotranspiration, and 4.8 in. becomes runoff. The remaining 23 in. infiltrates the soil, and about 38% of this (8.3 in.) is removed via stormflow, while the remainder (14.7 in.) percolates through the vadose zone and recharges the shallow groundwater.

Circulation patterns in the shallow groundwater and stormflow intervals illustrate the close link between groundwater and surface water at WAG 5. Stormflow follows topographic gradient, and maps of the surface topography can be used to illustrate potential flow directions. Because the stormflow zone is poorly developed or disrupted due to trench excavation and backfilling, roads, and other features, it is not generally possible to trace a continuous flowpath from the point of infiltration

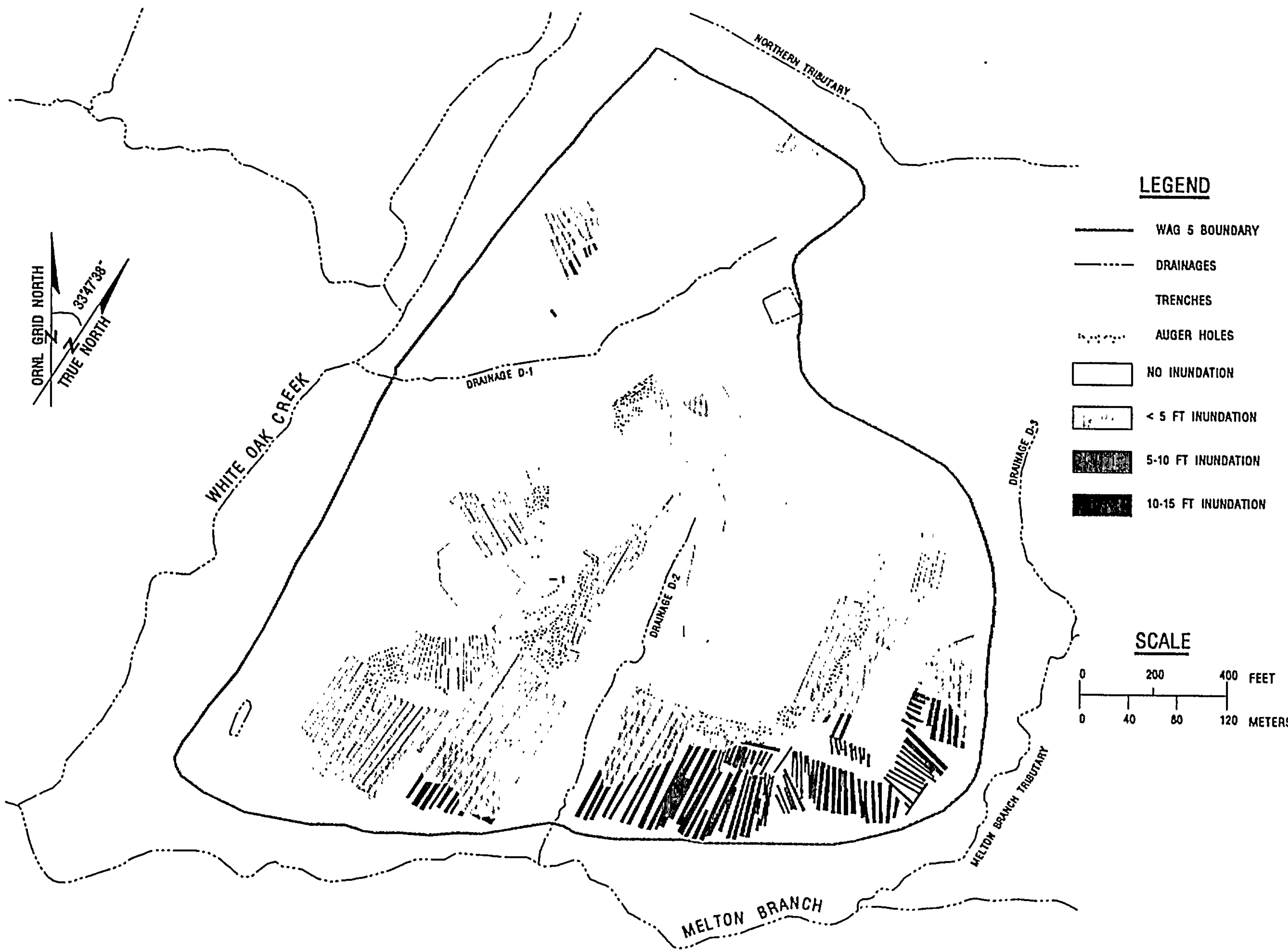

Fig. 2.13. Trench inundation levels (March 1993).

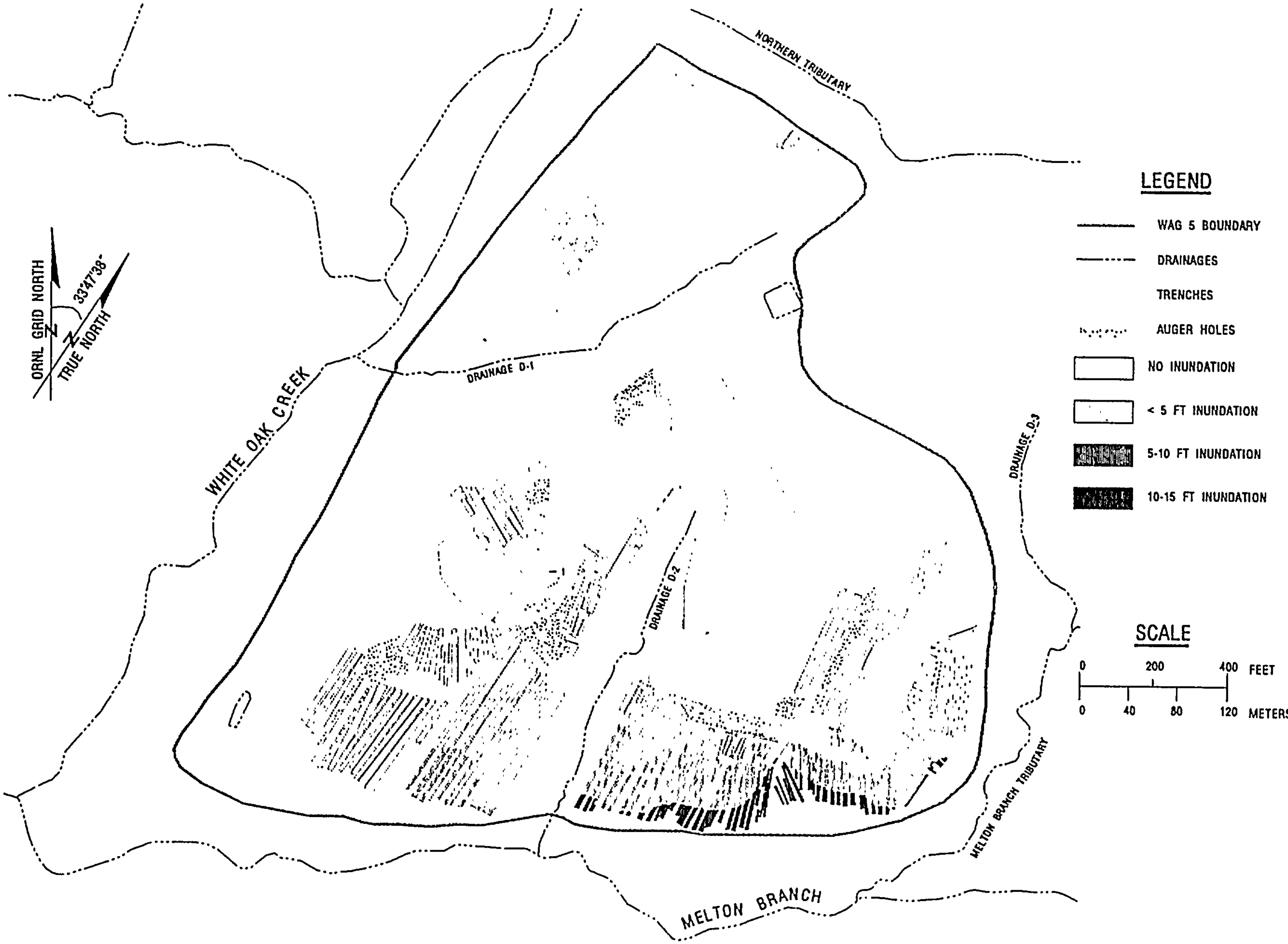

Fig. 2.14. Trench inundation levels (August 1993).

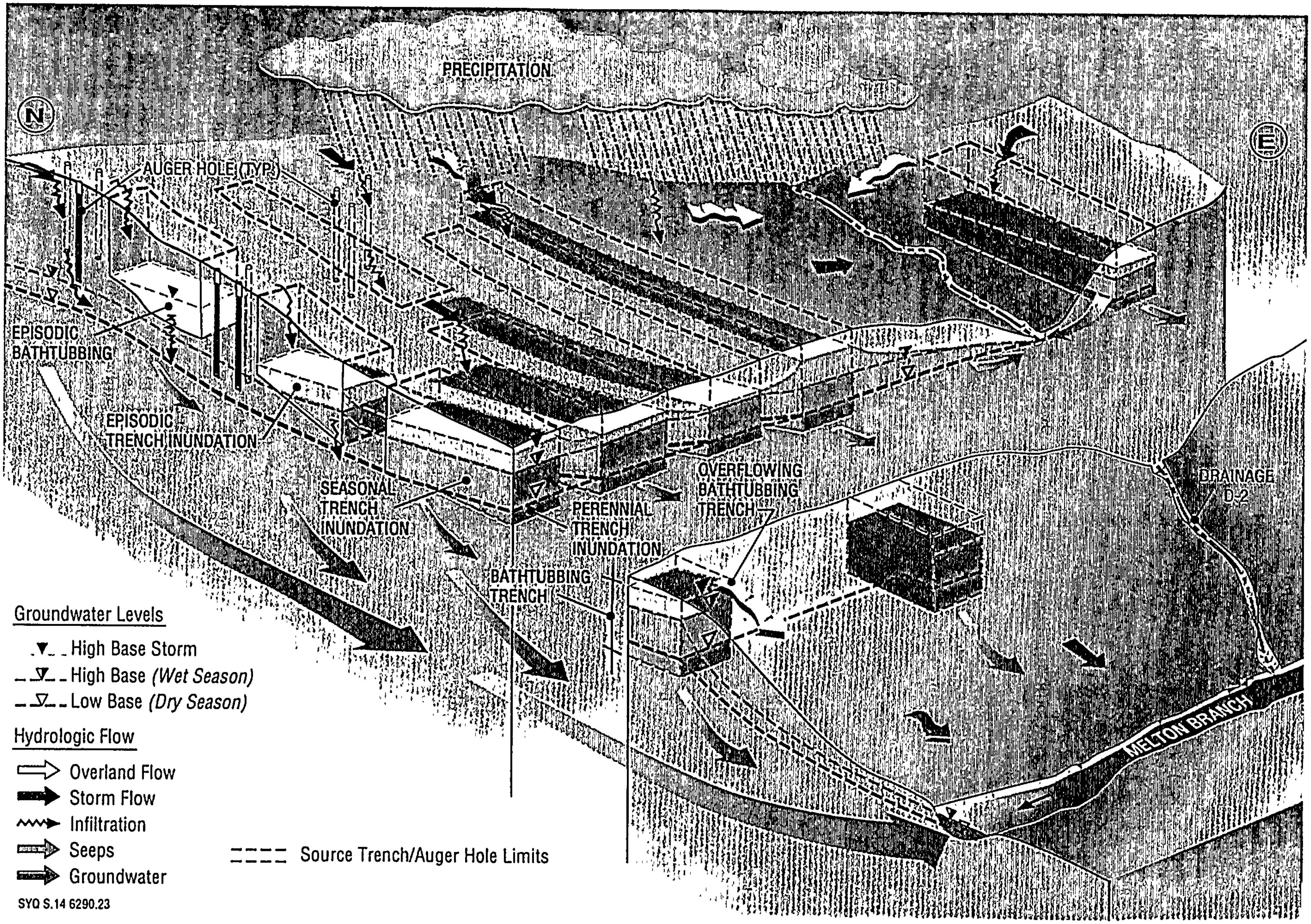

Fig. 2.15. WAG 5 hydrologic model.

to the point of discharge. These disruptions also have the unintended consequence of increasing the net recharge of water through the trench wastes and probably explain the diminished stormflow component of WAG 5 in contrast to that described elsewhere for the ORR (e.g., Solomon et al. 1992).

Groundwater flow in the shallow zone accounts for most of the subsurface flow occurring at WAG 5. The shallow flow regime is made complex by the presence of discrete flow paths associated with fractures, which appear to be areally extensive and exhibit a relatively high degree of interconnection. As a result, the bulk movement of shallow groundwater is dominated by flow paths that conform to hydraulic gradients that are not always obvious and are often oblique to the primary topographic gradient. Moore and Toran (1989) present a similar conclusion for the ORR hydrologic framework.

Groundwater flow generally follows the topographic slope, flowing from the upland areas toward seeps, springs, and other discharge points in the vicinity of the WAG 5 drainages, Melton Branch, and White Oak Creek. Groundwater flow divides nearly coincide with surface water drainage divides such that most groundwater flow in the White Oak Creek and Melton Branch drainage basins is toward discharge points along White Oak Creek and Melton Branch, respectively.

The HSPF model assumed that all of the water entering the subsurface at WAG 5 is eventually discharged to Melton Branch or White Oak Creek. There may be some recharge of the intermediate and deeper groundwater zones, but the total flux of water recharging these deeper zones is small [estimated by Clapp and Watts (1992) to be <1 cm/year]. Vertical gradient data show a mix of recharge and discharge potential between the water table and zones at depth, but it is likely that most intermediate groundwater also discharges into Melton Branch and White Oak Creek.

3. WAG 5 CONCEPTUAL MODEL

The framework of the site conceptual model was used to evaluate and present information related to site contamination sources—release mechanisms, migration pathways, and exposure points—as well as to integrate contamination data and baseline risk assessment results. This section summarizes the results of these data evaluation efforts through a brief summary of the nature and extent of contamination and a detailed presentation of the site conceptual model, which is actually a series of models based on the hydrologic system, migration and exposure pathways, and exposure scenarios (on site versus off site). The site conceptual model forms the basis of the remedial action strategy presented in Sect. 4.

3.1 WAG 5 STUDY AREAS

The assessment of contamination was based on a division of the site into 12 study areas. Study area boundaries were drawn on the basis of hydrology (i.e., surface water drainage and groundwater flow divides), defining characteristics (e.g., impoundment, tanks, buried waste in trenches), and waste types (e.g., TRU, fissile). Table 3.1 summarizes the basis for delineation of these study areas; Fig 3.1 identifies their locations.

3.1.1 WAG 5 White Oak Creek Drainage Basin

- *Process Waste Sludge Basin:* The 0.25-acre sludge basin and nearby areas (approximately 11.7 acres) in the northernmost portion of SWSA 5 South.

- *SWSA 5 North:* Area used for retrievable storage of TRU waste. Hydrologically isolated from rest of WAG 5 by surface water and/or groundwater divides, with drainage/discharge to D-1, White Oak Creek, and North Tributary. Includes Building 7831A.

- *Fissile Storage:* Area with 151 unlined auger holes and 2 trenches used for disposal of fissile wastes (^{235}U); also contains large landfill trench (trench 36) and 0.5-acre "ravine" landfill. Consists of approximately 4.7 acres with surface water and groundwater flow to D-1.

- *SWSA 5 South-White Oak Creek:* Westernmost portion of SWSA 5 South; bounded by Melton Branch and White Oak Creek drainage divide to east and White Oak Creek to west; includes some areas that drain to D-1. Area has 110 auger holes and 12 trenches used for disposal of radioactive solid wastes; includes 0.8-acre "dump area."

- *OHF Area:* Hydrofracture injection facility in the southwestern corner of WAG 5, divided into three source areas based on characteristics of units:

  - *OHF Waste Pit T-4*: Three-cell concrete pit used for temporary storage of radioactive solutions during OHF injection operations; one cell contains a 20-m^3 monolith of radioactive grout; the others contain small quantities of contaminated sediments and water.

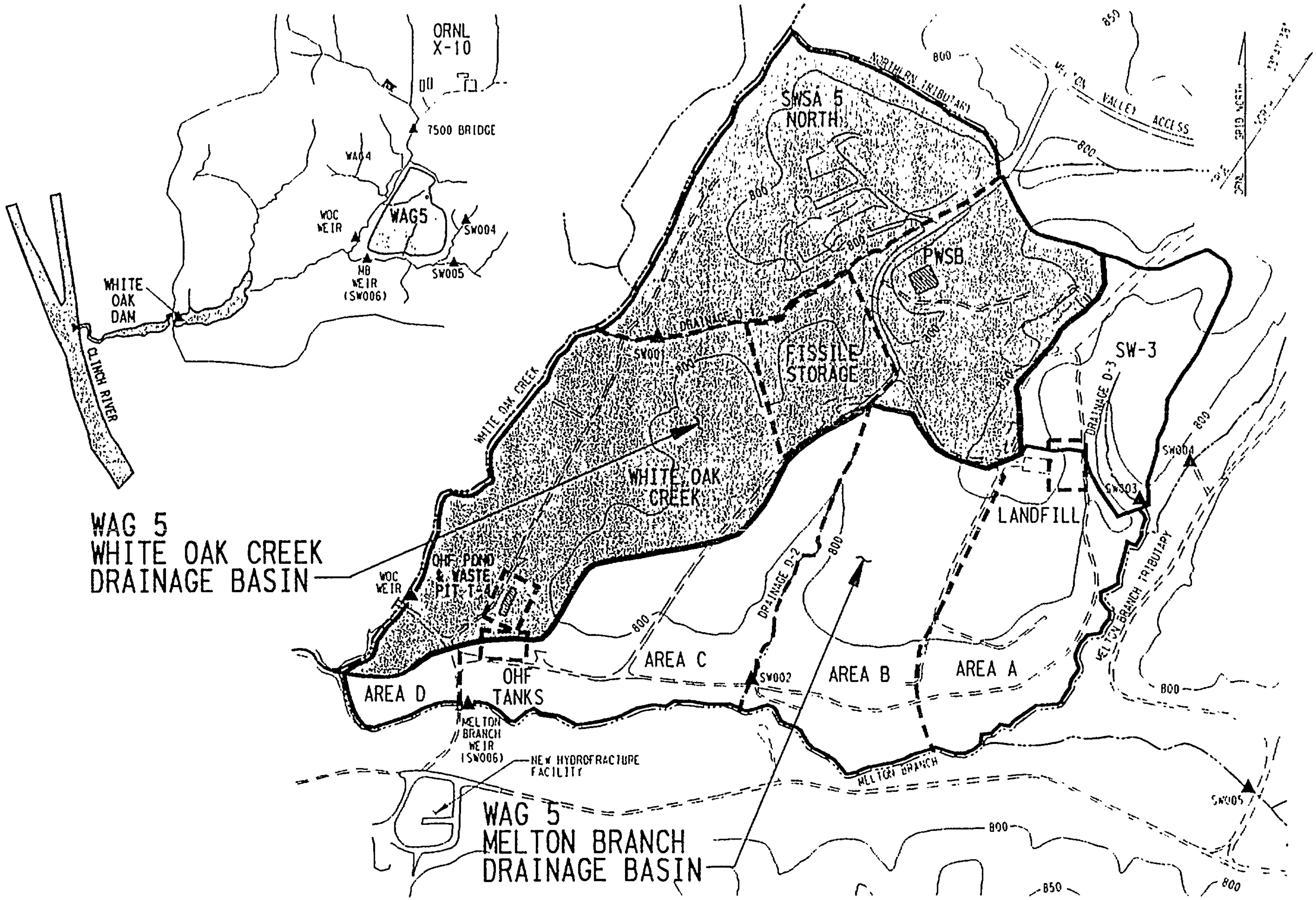

Fig. 3.1. WAG 5 drainages and study areas.

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Table 3.1. Study area identification matrix

STUDY AREA/WASTE UNIT	DEFINING CHARACTERISTIC [(TYPE OF UNIT)]	WASTE/CONTAMINANT TYPES	LOCATION AND HYDROLOGY
PROCESS WASTE SLUDGE BASIN	*Impoundment* PVC/clay-lined 85 by 85 by 7.8 ft	Radioactively contaminated sludge & sediment ^{90}Sr, ^{137}Cs, ^{60}Co, U, TRU (*Am, Cm, Pu*) Contaminated water ^{90}Sr, ^{137}Cs	• Small impoundment with surface water and groundwater drainage/discharge to D-1
SWSA 5 NORTH	*Trenches* • 27 partially inundated and bathtubbing *Storage vaults* • 8 stainless-steel and concrete-lined wells *Bldg. 7831A* • drain field from decon pad	Trenches: RH-alpha-contaminated and RH-TRU wastes in concrete casks and boxes α-emitters (Am, Cm, Cf, U, Pu), some with high β-γ Storage vaults: SC wastes including nuclear fuel materials	• Separate area of site within defined surface water and groundwater drainage divides • Surface water drains to White Oak Creek and D-1 • Drainage D-1 is apparent groundwater divide separating SWSA 5 North from SWSA 5 South, fissile storage, PWSB, etc.
FISSILE STORAGE	*Trenches* • landfill/trench 36 (partially inundated) • 2 upland trenches *Auger holes* • 151 unlined holes *Ravine landfill*	Fissile wastes ^{235}U, ^{233}U *(minor)* ^{239}Pu *(potential–small component)*	• Upland area with surface water and groundwater drainage/discharge to D-1 • Mostly upgradient from other SWSA 5 sources; some mingling of groundwater/surface water from undefined trench area
SWSA 5 SOUTH WHITE OAK CREEK	*Trenches* • 12 unlined trenches *Auger holes* • 110 unlined holes *Dump area*	Trenches: organics, high- and low-activity beta-gamma, TRU, miscellaneous, and acid waste Auger holes: organic and miscellaneous radioactive waste Dump: radioactive scrap metal	• Western portion of SWSA 5 with surface water drainage to White Oak Creek & D-1 • Area receives some drainage from SWSA 5 South area C

Table 3.1 (continued)

Study Area/Waste Unit	Defining Characteristic [*Type of Unit*]	Waste/Contaminant Types	Location & Hydrology
OHF	• *OHF waste pit T-4* • 3-cell concrete tank • *OHF waste storage tanks* • 5 carbon steel tanks • *OHF pond* 100,000-gal unlined impoundment	Waste pit: radioactive grout monolith, contaminated surface water and sediment Tanks: radioactive ILLW residues with ^{90}Sr, ^{137}Cs, ^{244}Cm, ^{239}Pu Pond: contaminated sediment (^{90}Sr, ^{137}Cs, ^{60}Co, Th, TRU) Contaminated water: ^{90}Sr, ^{137}Cs	• Small volume of contaminated soil in general area of pit; surface water runoff mostly to White Oak Creek, some to Melton Branch • USTs in vadose zone soils, mostly isolated from nearby sources of contamination (SWSA 5, OHF pond); surface water/groundwater drainage/discharge to Melton Branch • Small impoundment in hydrologic connection with groundwater; surface water and groundwater drainage/discharge to White Oak Creek
SW-3	*Hillside dump/landfill*	Surface debris/surface soil contaminated with β–γ emitters (USRADS)	• Area defined by surface accumulations of debris on hillside; drainage to D-3 and Melton Branch Tributary
SWSA 5 South Area A	*Trenches* • 56 inundated trenches • 23 upland trenches *Auger holes* • 121 unlined holes	Trenches: high- and low-activity β-γ, TRU, sludge, and biological waste Auger holes: most probably biological waste	• Area drained by Melton Branch Tributary; may receive drainage
SWSA 5 South Area B	*Trenches* • 45 inundated trenches • 29 upland trenches *Auger holes* • 177 unlined holes	Trenches: high- and low-activity β-γ, TRU, and biological waste Auger holes: waste types unknown	• Trenches and auger holes within Melton Branch surface water drainage; drainage D-2 is apparent groundwater divide between SWSA 5 South east and west
SWSA 5 South Area C	*Trenches* • 13 inundated trenches • 44 upland trenches • Undefined trench area *Auger holes and vaults* • 344 unlined auger holes • 13 concrete lined storage vaults	Trenches: high- and low-activity β-γ, TRU, and biological waste Auger holes: waste types primarily unknown Lined vaults: control rods and fission waste	• Area drains/discharges to Melton Branch and D-2; high ^{90}Sr flux seep within area
SWSA 5 South Area D	*No known disposal activities*	^{90}Sr	• Within Melton Branch and White Oak Creek floodplains; high ^{90}Sr flux seep within area

- *OHF Area Storage Tanks:* Five underground carbon steel tanks used for storage of ILLW prior to injection; tanks currently contain ILLW sludge residues.

- *OHF Pond:* Surface impoundment used between 1965 and 1979 as a temporary holding basin for waste solutions and decontamination water; currently contains 54 m^3 of contaminated sediments.

3.1.2 WAG 5 Melton Branch Drainage Basin

- *SW-3:* Drainage catchment (9.3 acres) for D-3 along the eastern perimeter of WAG 5; includes the hillside dumping area ("northeast landfill").

- *SWSA 5 South Area A:* Nine and one-half acres in the southeastern portion of WAG 5; drains primarily to Melton Branch Tributary; includes 79 trenches and 121 auger holes.

- *SWSA 5 South Area B:* Area bordered on the west by D-2; consists of approximately 15.8 acres, immediately west of SWSA 5 South area A; surface water drains to both D-2 and Melton Branch; includes undefined trench area; 74 trenches and 177 auger holes.

- *SWSA 5 South Area C:* Area to west of D-2; bounded on the west by the Melton Branch-White Oak Creek drainage divide. Includes high-activity trench area, auger hole "hot garden," and TRU and high-activity waste vaults; totals for area include 57 trenches and 344 auger holes.

- *SWSA 5 South Area D:* Seep area in Melton Branch floodplain opposite OHF, in the southwest corner of WAG 5; no primary sources identified.

Not all of the WAG 5 sites identified in Table 1.1 were designated as study areas for the RI report. In some cases, this was due to size—for example, the LLW lines and leak sites were evaluated in the context of the OHF and SWSA 5 South study areas in which they were contained; in other cases, there were no data to indicate that a release had occurred and/or field sampling had detected insignificant levels of contamination—for example, the NHF LLW tanks and surface facilities. Section 4 discusses the status of and recommendations for these sites.

3.2 NATURE AND EXTENT OF CONTAMINATION

Contamination in the WAG 5 study areas was evaluated from both on-site and off-site perspectives: on-site contamination occurs within or immediately adjacent to the WAG 5 administrative boundary; off-site contamination is the measured flux (quantity per unit time; e.g., Ci/year) being released from the site into Melton Branch or White Oak Creek. Some, but not all, of the contamination released from WAG 5 migrates off the ORR and into the Clinch River via White Oak Creek.

Appendix B2 presents a detailed evaluation of the nature and extent of contamination in WAG 5. This section highlights the significant findings and conclusions resulting from that evaluation.

3.2.1 On-Site Contamination

Contamination of environmental media at WAG 5 is generally related to hydrologic processes: water is the key release and transport medium, responsible for mobilizing the radiological (and chemical) contaminants in the wastes, moving them through the subsurface or across the land surface to the perennial streams that border the site and, finally, transporting them away from the site. Along the way, some of the contamination in the water is being transferred to other media—to surface soils along drainage paths and in seep areas, to subsurface soils (and saprolite) in the vadose zone and water table interval, and to sediment in the streams.

The distribution of contamination is thus a function of these hydrologic processes, and the presence or absence of contamination in a given area can be explained in strictly hydrologic terms—for example, the area is hydraulically downgradient of the source as described by groundwater flowpaths, or is downstream of a contaminated seep discharge point. Any explanation of contaminant distribution at WAG 5 must be based on hydrologic processes. For example, the trenches in SWSA 5 South exert considerable influence on the movement of water in the subsurface and, thus, the release and migration of contaminants. In addition to their status as a contaminant source, the hydrologic role of trenches is a fundamental part of the hydrologic model (see Fig. 2.14).

A summary of contamination in WAG 5 can be provided almost entirely in the context of site hydrology: the trenches inundated by groundwater are the most active sources and greatest contributors of contamination; groundwater is the principal release mechanism and contaminant migration pathway and thus is the most widespread contaminated medium at the site; and discharge of this groundwater and the resulting contamination of surface water creates on-site exposure points and leads to off-site (and sometimes off-ORR) transport of contaminants.

Contaminant sources

The 12 study areas contain numerous active and potential sources of contamination (Table 3.2); most of this source material is in the trenches and auger holes of SWSA 5 South. Disposal of wastes in unlined trenches and auger holes (the accepted practice at that time) has resulted in a significant ongoing release of contamination to the regolith (soils, saprolite, and fill), groundwater, surface water, and sediment. The most significant waste types are low-level radioactive solid wastes, and most of the wastes in this category were contaminated with a wide variety of alpha, beta, and gamma emitters. Other important waste types include high-activity beta-gamma waste, TRU waste, and fissile waste as well as organic and biological wastes that in some (or even most) cases were contaminated with various radionuclides.

The most active sources at WAG 5, and those responsible for the majority of the contamination, are the 230 solid waste disposal trenches and nearly 1000 auger holes at the site. Within this group, trenches that are inundated by groundwater (see Figs. 2.12 and 2.13) have contributed most of the contamination detected within or released from the site. A large number of trenches are at least

Table 3.2. Area-specific contamination summary for WAG 5

STUDY AREA	SOURCE STATUS & WASTE/ TYPES]	CONTAMINATION SUMMARY
PROCESS WASTE SLUDGE BASIN	*Inactive/potential source* • Surface water (220 m^3) with low activities of ^{90}Sr, ^{60}Co, ^{137}Cs • Sludge and sediment (960 m^3) with inventory of ^{90}Sr (8 Ci), ^{137}Cs (4 Ci), ^{60}Co (<1 Ci)	*All media* • No evidence of any releases of contamination from the PWSB
SWSA 5 NORTH	*Active sources* • 10 partially inundated and bathtubbing trenches with RH-alpha-contaminated LLW and RH-TRU wastes in boxes • Bldg. 7831A decon pad drain field *Inactive/potential sources* • 17 partially inundated and upland trenches with RH-alpha-contaminated LLW and RH-TRU in concrete casks *Inactive/unlikely sources* • 8 stainless-steel-lined storage vaults	*Groundwater* • Well 516 with high concentrations of ^{241}Am, ^{244}Cm (63–250 pCi/L in filtered samples collected in 1993; historically as high as 5940 pCi/L) • Episodic releases of transuranics (^{241}Am, ^{244}Cm, ^{238}Pu) create intermittent "plumes" with low levels of contamination migrating toward White Oak Creek, North Tributary, and D-1 *Soil* • No TRU contamination in soil borings on perimeter of 7802N trenches • No significant levels of contamination • Slightly elevated U/Th series in surface soils (probably not site-related) has risk impact *Seeps* • Low concentrations of transuranics in episodic (seasonal) releases along White Oak Creek *Downgradient surface water and sediment* • Infrequent detections of low concentrations of transuranic isotopes in White Oak Creek confirms release to downgradient surface water; overall flux is insignificant
FISSILE STORAGE	*Active sources* • Trench 36 (landfill) with debris; possibly includes sludge *Potential sources (may be active)* • 2 Fissile waste trenches with ^{235}U • 151 Fissile waste auger holes with ^{235}U, lesser amounts of ^{233}U • Ravine landfill	*Groundwater* • Limited data show ^{137}Cs in shallow groundwater; ^{137}Cs and ^{90}Sr in stormflow zone • Upgradient groundwater is contaminated with ^{90}Sr and ^{3}H from SWSA 5 South area B *Soil* • Surface soil in USRADS hot spot indicate elevated ^{137}Cs, ^{60}Co, ^{90}Sr, ^{234}U, and ^{238}U *Seeps* • Seep at base of trench 36 shows ^{235}U and other U/Th isotopes, ^{3}H, minor ^{90}Sr • No significant contamination in seep at base of ravine landfill *Downgradient surface water and sediment* • ^{235}U was detected in surface water and sediment of D-1; flux increases during storms • Discharge from this area contributes bulk of ^{90}Sr, ^{3}H, ^{60}Co, and gross alpha flux in D-1; overall contribution to contaminant flux in White Oak Creek is insignificant

Table 3.2 (continued)

STUDY AREA	SOURCE STATUS & WASTE/ TYPES]	CONTAMINATION SUMMARY
SWSA 5 SOUTH WHITE OAK CREEK	*Active sources* • 12 trenches with organic, transuranic, high and low activity, miscellaneous, and acid wastes • 110 auger holes with organic and miscellaneous radioactive wastes • Dump area with debris, miscellaneous wastes, and soil with ^{137}Cs, ^{90}Sr	*Groundwater* • Low levels of ^{137}Cs and ^{60}Co in shallow groundwater • High concentrations of VOCs in perimeter well 0978, including 1,2-DCE (1600–3300 mg/L) and vinyl chloride (2700–4000 mg/L); VOCs detected in lower concentrations in several other shallow wells, mostly in concentrations <100 mg/L *Soil* • High gamma exposures in surface soil over trenches based on USRADS • Surface soils in USRADS hot spot show relatively high ^{137}Cs, ^{90}Sr, ^{60}Co *Seep* • ^{60}Co, ^{90}Sr, TCE, DCE, and vinyl chloride in seep downgradient of source trenches *Downgradient surface water and seeps* • Discharges from this area are the largest component of radionuclide input to White Oak Creek from WAG 5; overall, radionuclide flux is negligible • VOCs not detected in White Oak Creek, apparently due to loss from volatilization
OHF WASTE PIT T-4	*Inactive/potential source* • 3-cell concrete pit containing 20 m^3 monolith of radioactive grout, contaminated water, and sediment	*Groundwater* • Upgradient groundwater is contaminated with ^{90}Sr and ^{3}H from SWSA 5 South Area C *Soil* • Localized areas of surface soil contamination (^{90}Sr, ^{137}Cs) attributed to incidental, *de minimis* releases from OHF operations; no evidence of release from the waste pit • Deeper soil contamination at depth of water table unrelated to waste pit *Downgradient surface water & sediment* • No specific contribution from waste pit T-4 identified
OHF WASTE STORAGE TANKS	*Inactive/potential source* • 5 carbon steel tanks with 20 m^3 of ILW sludge residues with >28,000 Ci ^{90}Sr, ^{137}Cs, ^{244}Cm, ^{239}Pu, ^{239}Pu, ^{60}Co, ^{144}Ce	*Groundwater* • Upgradient groundwater contaminated with ^{90}Sr and ^{3}H from SWSA 5 South Area C; no indication of release from tanks *Soil* • Localized areas with slightly contaminated surface soil (^{137}Cs, ^{238}Pu) • Deeper soil contamination (^{90}Sr) at depth of water table unrelated to waste storage tanks *Downgradient surface water and sediment* • No specific contribution from OHF waste storage tanks identified

Table 3.2 (continued)

Study Area	Source Status & Waste/ Types]	Contamination Summary
OHF Pond	*Active sources* • Sediment (54 m^3) with 79 Ci ^{137}Cs (62 Ci), ^{90}Sr (12 Ci) ^{244}Cm (5 Ci) • Surface water (380 m^3) with inventory <0.007 Ci, including ^{90}Sr, ^{137}Cs, ^{60}Co, ^{99}Tc, and ^{233}U	*Groundwater* • Pond in direct communication with water table • High concentrations of ^{137}Cs, ^{90}Sr, ^{60}Co, 233U, ^{244}Cm ^{238}Pu (also detected in pond) *Soil* • USRADS hot spot borings in vicinity of pond show elevated concentrations of ^{137}Cs; contamination attributed to releases during operations, not to overflow of pond *Downgradient surface water and sediment* • The bulk of the contaminant flux into White Oak Creek from OHF area is from discharge of contaminated groundwater from OHF pond • Overall input as a function of the total contaminant flux in White Oak Creek is minor
SW-3	*Potential source* • Hillside dump (0.2 ha) with clean and contaminated solid waste, debris, miscellaneous equipment, trash, drum, ^{137}Cs, ^{60}Co, ^{90}Sr, minor transuranics	*Groundwater* • Low concentrations of ^{60}Co and ^{3}H that periodically fluctuate *Soil* • USRADS hot spot in vicinity of drum had minor levels of ^{137}Cs and ^{90}Sr *Seeps* • No contamination in seep opposite base of landfill *Downgradient surface water and sediment* • Surface water samples from D-3 indicate little to no contamination
SWSA 5 South Area A	*Active sources* • 56 inundated trenches • 23 upland trenches trench types include 16 high-activity beta-gamma, 14 low-activity beta-gamma, 4 TRU, 1 sludge, 35 biological waste, 9 unknowns • 121 auger holes: most probably contain biological waste	*Groundwater* • Widespread, high levels of ^{3}H contamination with significantly higher levels in trenches • Southern area also has high concentrations of ^{137}Cs, ^{90}Sr, ^{14}C; highest levels were in trench water but contaminants have migrated throughout this portion of Area A • High gross alpha detected in several trench water samples but no appreciable migration from trenches has occurred *Soil* • Samples from USRADS hot spot show high levels of ^{137}Cs and ^{90}Sr • No evidence of widespread soil contamination outside of seep areas *Seeps* • Seeps discharging high concentrations of ^{3}H similar to levels observed in groundwater • Individual seeps with high gross alpha and/or ^{90}Sr, ^{14}C *Downgradient surface water and sediment* • Contributes 100% of ^{3}H flux in Melton Branch Tributary; also significant quantities of ^{90}Sr • Discharge from area A is a sizable contributor (20%) of ^{3}H flux in Melton Branch

Table 3.2 (continued)

STUDY AREA	SOURCE STATUS & WASTE/ TYPES]	CONTAMINATION SUMMARY
SWSA 5 SOUTH AREA B	*Active sources* • 45 inundated trenches • 29 upland trenches trench types incl. 5 high-activity beta-gamma, 17 low-activity beta-gamma, 13 biological waste, 31 unknown • 177 auger holes waste types unknown	*Groundwater* • Widespread, high levels of ^{3}H contamination with significantly higher levels in trenches • Several trenches with high ^{90}Sr, ^{3}H, and gross alpha; trench 61 had >1.0E+06 pCi/L ^{241}Am • Groundwater from undefined trench area has significant levels of ^{238}Pu and other TRU isotopes; chlorinated VOCs (TCE, DCE, vinyl chloride) also detected *Soil* • USRADS data show no surface soil contamination outside of seep areas *Seeps* • Seeps discharging high concentrations of ^{3}H into Melton Branch • VOCs in seeps along D-2 (possible sources include undefined trench area, area C) *Downgradient surface water and sediment* • VOCs in D-2 sediment downgradient of seeps; • Significant contributor (67%) of ^{3}H flux in Melton Branch 5
SWSA 5 SOUTH AREA C	*Active sources* • 13 inundated trenches • 44 upland trenches trench types include 14 high-activity beta-gamma, 7 low-activity beta-gamma, 8 TRU, 1 biological, 27 unknown • 331 auger holes *Inactive/unlikely sources* • 13 concrete-lined vaults	*Groundwater* • Widespread, high concentrations of ^{3}H • Several trenches with high ^{90}Sr, ^{3}H and gross alpha; smaller number with high ^{137}Cs • High concentrations of ^{90}Sr along flowpaths from trenches to seep discharge area *Soil* • Localized areas with high gamma exposures in seep discharge areas • Soil samples from USRADS hot spot locations show high ^{90}Sr, ^{137}Cs *Seep* • RI sampling results for SP006 had maximum filtered result of 689,550 pCi/L for ^{90}Sr *Downgradient surface water and sediment* • Significant contributor (60%) of ^{90}Sr flux in Melton Branch and at White Oak Dam (25%) • Removal action for interception and treatment of seep C discharges implemented in 1994
SWSA 5 SOUTH AREA D	No sources identified	*Groundwater* • Widespread ^{3}H (>1.0E+06 pCi/L); ^{90}Sr in vicinity of seep only *Soil* • No significant contamination; slightly elevated ^{137}Cs detected in floodplain soils near seep Seeps • Seep D major contributor of ^{90}Sr to Melton Branch • RI sampling showed maximum of 32,145 pCi/L of ^{90}Sr (filtered) *Downgradient surface water and sediment* • Removal action for interception and treatment of seep D discharges implemented in 1994

partially inundated year-round. Other trenches are seasonally inundated, and still others have perched saturation (a type of bathtubbing), also on a seasonal basis. Seasonal inundation or perched saturation of auger holes would also be expected but has not been confirmed. Saturation of the trench and auger hole wastes accelerates the deterioration of waste containers and packaging and mobilizes contaminants.

Types of contamination

The dominant radionuclide contaminants detected in environmental media and determined to be indicators of site-related contamination represent a mixture of fission products, induced activity (activation) products, fissile material, uranium isotopes, and transuranic radionuclides. Specific isotopes include ^{3}H, ^{90}Sr, ^{137}Cs, ^{60}Co, ^{99}Tc, ^{14}C, ^{235}U, ^{238}U, $^{238/239}$Pu, ^{241}Am, $^{243/244}$Cm, and $^{152/154}$Eu. Other radionuclides, including ^{40}K and members of the naturally occurring uranium/thorium decay series (e.g., ^{228}Th, ^{226}Ra) were also widely detected, but only rarely were these present at levels clearly indicating site-related contamination. A number of organic and inorganic chemical constituents, including vinyl chloride, trichloroethene, PCBs, mercury, and beryllium were also detected; however, in all but a few isolated instances, the occurrence and magnitude of chemical contamination was significantly less than that observed for the radiological contaminants.

From a human health risk perspective, the contaminants of concern are primarily radionuclides representing a smaller subset of the total suite of radionuclides detected. Based on their abundance and distribution as well as contribution to on-site risks (discussed in the next section), the most significant site contaminants are ^{90}Sr, ^{3}H, ^{137}Cs, ^{60}Co, $^{243/244}$Cm, $^{238/239}$Pu, ^{241}Am, $^{233/234}$U, ^{226}Ra, and ^{228}Ra. Of these contaminants, those most responsible for the risks calculated off site and immediately downstream are ^{90}Sr, ^{3}H, and ^{137}Cs. The nonradiological contaminants beryllium and vinyl chloride were also identified in at least one study area as being a significant risk contributor.

Distribution and magnitude of contamination

Table 3.2 also summarizes the nature and extent of WAG 5 contamination on area- and media-specific bases; Appendix B2 gives a more detailed description of the contamination. Selected highlights summarizing contamination on a WAG-wide basis are presented below.

- Levels of contamination in groundwater are significant throughout the SWSA 5 South area; the principal contaminants are ^{3}H and ^{90}Sr. Widespread and high concentrations of tritium are ubiquitous in SWSA 5 South (Fig. 3.2). The extent of ^{3}H contamination is probably due to its high specific activity (>9000 Ci/g), which essentially means that a small mass of the source can contaminate significant quantities of environmental media; and to its unretarded mobility in the subsurface (its mobility is essentially the same as that of water).

- High concentrations of ^{90}Sr are less widespread in shallow groundwater and typically were detected along migration pathways between source trenches and contaminated seep discharge areas. As shown by transect sampling in Melton Branch, ^{90}Sr migration pathways are discrete and reflect the anisotropic hydraulic properties of the regolith and the influences of geochemical reactions between soil particles and the contaminant (e.g., cation exchange with clays).

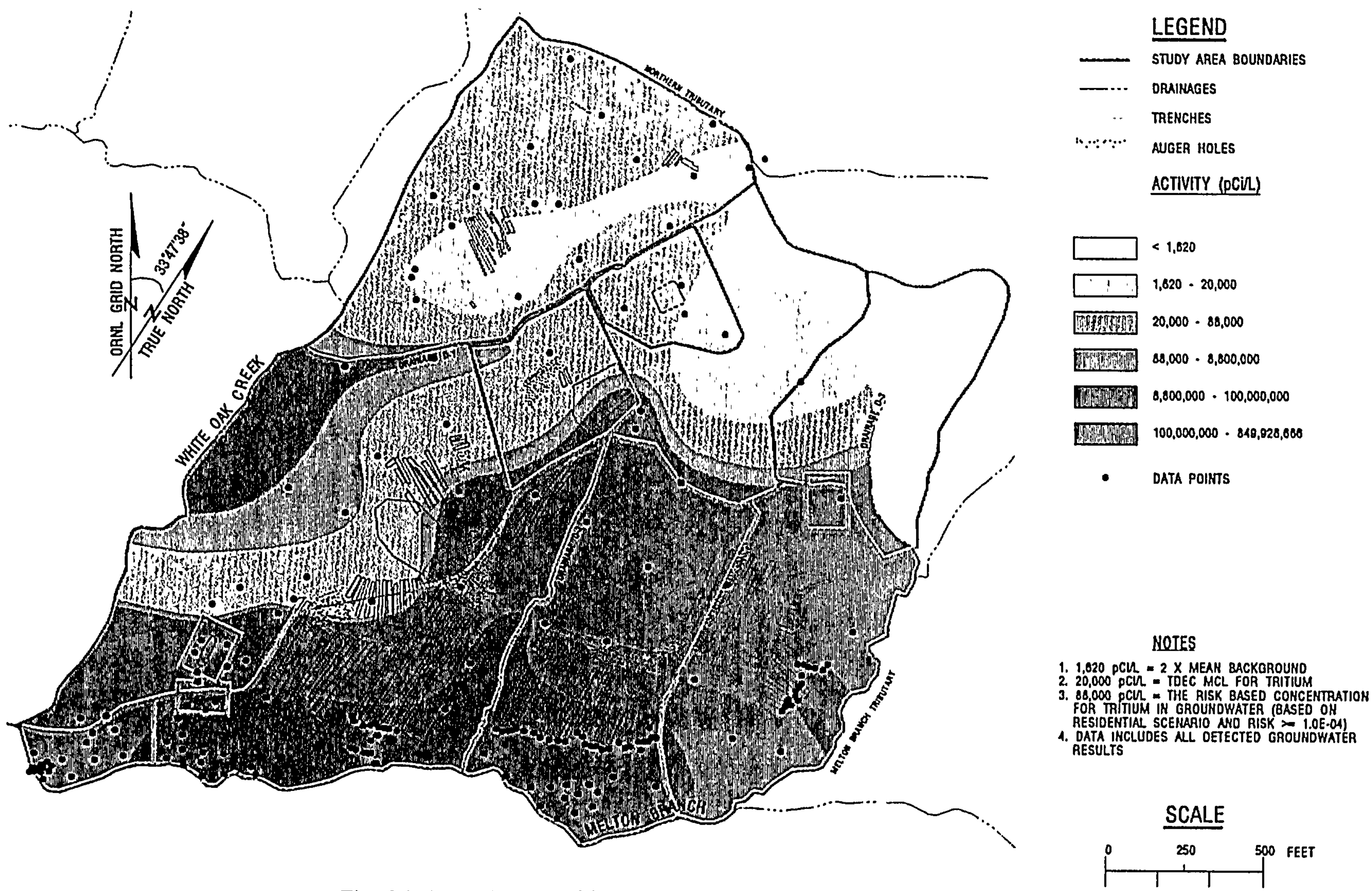


Fig. 3.2 Groundwater tritium plume.

- Cesium-137 has a strong affinity for adsorption onto clay particles and was shown to be much less mobile than ^{90}Sr in the surface and subsurface waters of WAG 5. The inventory of ^{137}Cs identified in SWSA 5 South is potentially significant.

- Sampling results from the inundated trenches in SWSA 5 South areas A, B, and C provided a screening level characterization (isotopic analyses were not performed) of the buried wastes. In comparison to the rest of WAG 5, these samples show extreme levels of activity in a number of the trenches, with activities at the microcurie and millicurie level.

- Contaminated seeps, representing discharge of contaminated groundwater, were identified along the southern perimeter of SWSA 5 South and along drainages D-1 and D-2. Discharges of ^{3}H and ^{90}Sr into Melton Branch are significant components of the overall flux of ^{3}H and ^{90}Sr being released from the ORR at White Oak Dam. Seeps contaminated by ^{90}Sr in SWSA 5 South areas C and D are the focus of an ongoing removal action by the ORNL ER Program.

- Soil contamination at WAG 5 is primarily limited to areas contaminated by seep discharges, overflowing (bathtubbing) trenches, or contaminated surface debris. In most cases, soil contamination is related to elevated levels of ^{137}Cs, ^{90}Sr, and ^{60}Co. Because of the ^{137}Cs and ^{60}Co, these areas also have relatively high gamma exposures. Naturally occurring uranium-thorium decay series radionuclides, particularly ^{228}Th, ^{228}Ra, and ^{226}Ra, were also detected in most soil samples; in some cases, the concentrations were such that an on-site risk was identified (see Appendix C1).

- Based on sampling in Melton Branch and White Oak Creek, however, release of transuranic radionuclides from WAG 5 is currently at negligible levels; these constituents are migrating through the subsurface and being discharged at seeps along Melton Branch, White Oak Creek, and interior WAG 5 drainages. There is also evidence of gross alpha (non-isotope-specific) transport from sources in SWSA South; elevated gross alpha concentrations were identified in a number of areas downgradient of inundated trenches that yielded samples with significant gross alpha activities. These long-lived radionuclides typically are relatively immobile in the subsurface; their mobility at WAG 5 may indicate a large inventory of the wastes and/or transport being facilitated by other processes (e.g., colloidal transport).

3.2.2 Off-Site Contaminant Flux

The RI included extensive characterization and modeling to quantify the amount of contamination leaving the site via Melton Branch and White Oak Creek. This effort included assessing the contaminant- and pathway-specific flux (e.g., runoff or stormflow) for each study area as well as the overall contribution from each drainage basin and WAG 5 as a whole. Appendix B2 presents detailed results of this evaluation.

WAG 5 White Oak Creek drainage basin summary

The 60.8-acre White Oak Creek drainage area of WAG 5 contains five study areas: PWSB, SWSA 5 North, fissile storage area, SWSA 5 White Oak Creek area, and OHF area. The annual water balance between surface runoff, interflow (stormflow), and groundwater for the WAG 5 White Oak Creek drainage area, based on the HSPF modeling, is presented below.

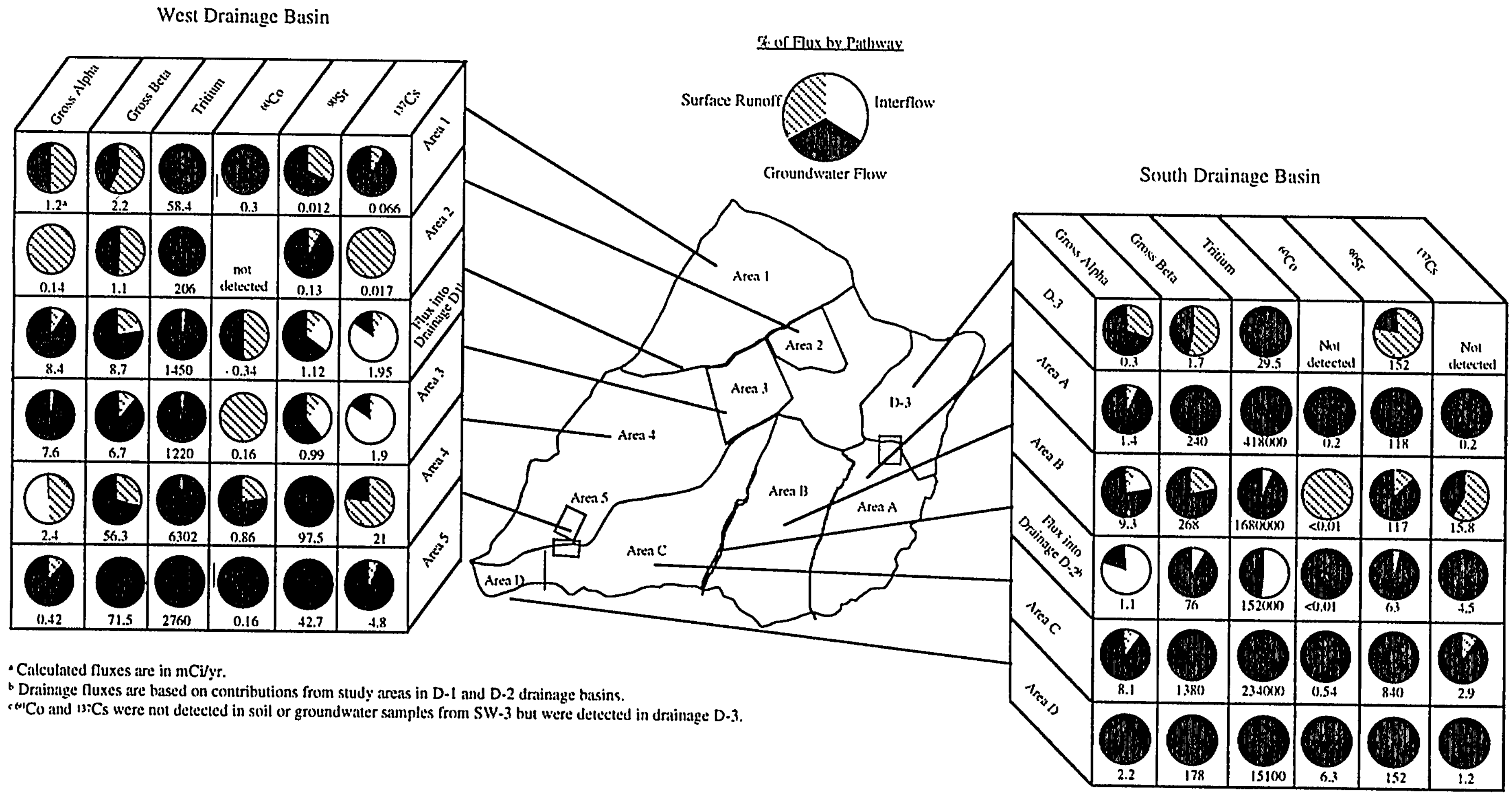
	Percent of Flow	Annual Discharge (m^3/year)
Surface runoff	27	47,500
Interflow	31	53,100
Groundwater flow	42	73,100
Total	100	173,700

WAG 5 releases to White Oak Creek were calculated on the basis of contaminant fluxes for gross alpha, gross beta, tritium, ^{60}Co, ^{90}Sr, and ^{137}Cs from each study area. Pathway-specific fluxes were calculated on the basis of average annual flow rate and average concentration found in that pathway during the RI sampling (note: the surface runoff pathway flux is based on erosion potential, sediment/soil transport in surface runoff, and average contaminant concentration in soil). Figure 3.3 presents the percent flux contribution of contaminants, broken down by study area and pathway. These results show that the groundwater pathway is dominant in the transport of contaminants to White Oak Creek, that the stormflow pathway is mostly insignificant, and that surface runoff of contaminated soil is an important contributor only in areas where soil is contaminated (e.g., SWSA 5 White Oak Creek area).

It is important to note that a contaminant flux from an area is not necessarily an indication of site-related contamination—background concentrations can result in a measurable flux—and that although a flow path may be active, the magnitude of the total flux contribution (also shown in the figure) is the best indicator of its relative significance. In many cases, the fluxes from an individual flow path or combined fluxes from a study area are insignificant and would be expected to have a negligible impact on water quality in White Oak Creek.

Table 3.3 summarizes the fluxes (and relative percentages) from each source, beginning with the study areas draining into D-1 and culminating with the total flux measured at White Oak Creek weir (opposite the southwest corner of WAG 5). Fluxes calculated from upgradient input (7500 bridge sampling station) and from WAG 4 are also presented (ORNL 1993). The results indicate a good correlation between calculated and observed (measured) fluxes, with results typically in the same order of magnitude. Differences between the two may be attributed to (but not limited to) assumptions in the surface water mathematical model; the use of average concentrations of analytes in each pathway and homogeneous soil properties and flow paths; and neglecting the effects of contaminant retardation in the soil matrix or sediment deposition in the streambed.

Figure 3.4 presents the relative percent fluxes from each study area in the White Oak Creek drainage basin and non-WAG 5 contributors in a funnel representation. Fluxes calculated from individual areas are combined into three hydrologically distinct groups: WAG 5 study areas draining into D-1; WAG 5 study areas draining directly into White Oak Creek (including the SWSA 5 North basin, which drains into the North Tributary); and non-WAG 5 contributors. The groups are combined to give relative percent contributions to the fluxes calculated at White Oak



ᵃ Calculated fluxes are in mCi/yr.
ᵇ Drainage fluxes are based on contributions from study areas in D-1 and D-2 drainage basins.
ᶜ ^{60}Co and ^{137}Cs were not detected in soil or groundwater samples from SW-3 but were detected in drainage D-3.

Fig. 3.3. Flux summary by study area and pathway for WAG 5 White Oak Creek and Melton Branch drainages.

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Table 3.3. Flux contributions to drainage D-1 and White Oak Creek weir

	Alpha Flux (mCi/yr)	(%)	Beta Flux (mCi/yr)	(%)	H-3 Flux (mCi/yr)	(%)	Co-60 Flux (mCi/yr)	(%)	Sr-90 Flux (mCi/yr)	(%)	Cs-137 Flux (mCi/yr)	(%)
Drainage D-1												
PWSB	0.14	(2%)	1.09	(13%)	206.00	(14%)	0.02	(1%)	0.13	(12%)	0.00	(0%)
SWSA 5 North	0.43	(5%)	0.60	(7%)	15.60	(1%)	0.01	(1%)	0.01	(1%)	0.17	(50%)
fissile storage	7.69	(91%)	6.65	(77%)	1222.00	(84%)	1.86	(95%)	0.99	(88%)	0.16	(49%)
SWSA 5 -WOC	0.19	(2%)	0.34	(4%)	7.82	(1%)	0.06	(3%)	0.00	(0%)	0.00	(1%)
Calculated total flux from drainage D-1	8.45		8.68		1451.43		1.95		1.13		0.34	
Measured flux at drainage D-1 (SW001)	6.16		5.47		1817.86		0.16		1.45		0.43	
White Oak Creek												
					Non-WAG 5 Sources							
7500 Bridge	80.11	(64%)	2870.71	(52%)	43291.22	(3%)	89.56	(99%)	761.35	(38%)	1080.68	(96%)
WAG 4	34.99	(28%)	2518.99	(46%)	1219968.00	(96%)	0.00	(0%)	1080.86	(55%)	20.30	(2%)
					WAG 5 Sources							
SWSA 5 North -> N. Trib.	0.04	(0%)	0.46	(0%)	8.20	(0%)	0.07	(0%)	0.00	(0%)	0.01	(0%)
SWSA 5 North -> WOC	0.76	(1%)	1.12	(0%)	34.60	(0%)	0.06	(0%)	0.01	(0%)	0.04	(0%)
-> Drainage D-1	6.16	(5%)	5.47	(0%)	1817.87	(0%)	0.16	(0%)	1.45	(0%)	0.43	(0%)
SWSA 5 WOC -> WOC	2.19	(2%)	56.02	(1%)	6311.60	(0%)	0.86	(1%)	94.76	(5%)	21.02	(2%)
OHF pond	0.42	(0%)	71.47	(1%)	2760.70	(0%)	0.16	(0%)	42.69	(2%)	4.77	(0%)
Calculated total flux into White Oak Creek weir	124.68		5524.25		1274192.19		90.87		1981.12		1127.26	
Measured flux at White Oak Creek weir	70.45		3009.17		640046.86		84.89		1388.86		1305.95	

Notes: 1. Percentages refer to calculated total flux, not measured flux.
2. WAG 5 data based on RI sampling and flow measurements.
3. White Oak Creek weir, 7500 bridge, and WAG 4 (T-2A weir) analytical data based on WAG 2 sampling, flow data collected by ESD surface water hydrology group.

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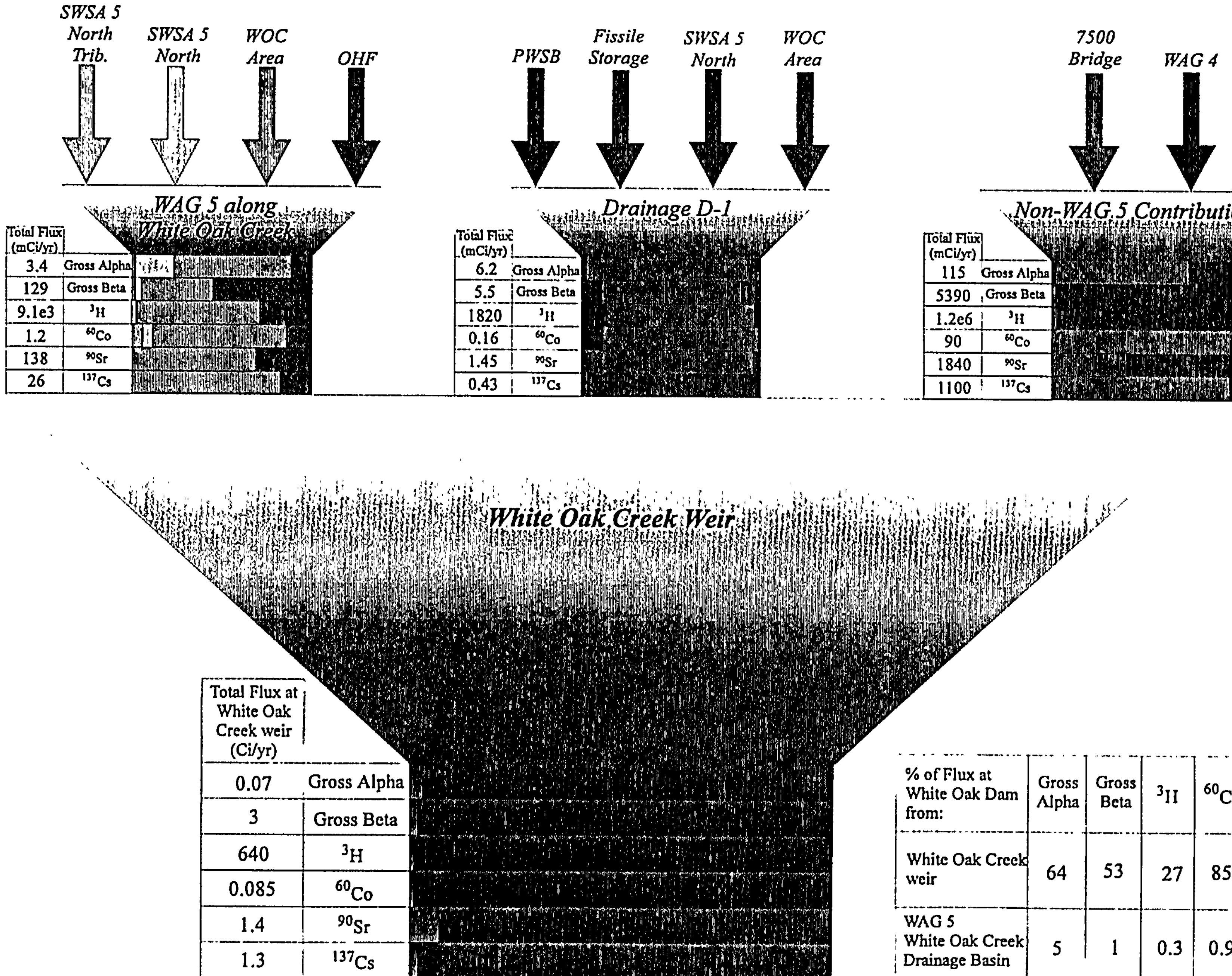

% of Flux at White Oak Dam from:	Gross Alpha	Gross Beta	^{3}H	^{60}Co	^{90}Sr	^{137}Cs
White Oak Creek weir	64	53	27	85	54	118
WAG 5 White Oak Creek Drainage Basin	5	1	0.3	0.9	4	2

Fig. 3.4. White Oak Creek contaminant flux summary.

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Creek weir. The figure also shows total fluxes measured at White Oak Creek weir and the relative percent flux from WAG 5 White Oak Creek drainage basin and weir to the total flux at the White Oak Dam.

For example, the OHF study area has a ^{90}Sr flux of 42.69 mCi/year, which is approximately 30% of the total ^{90}Sr flux (138 mCi/year) leaving WAG 5 study areas draining directly to White Oak Creek. Combining the 138 mCi/year with the ^{90}Sr fluxes from drainage D-1 (1.45 mCi/year) and non-WAG 5 contributors (1840 mCi/year), the total ^{90}Sr flux at the White Oak Creek weir is around 1980 mCi/year. The OHF area therefore contributes 2% (42.69/1980) to the total ^{90}Sr flux over the White Oak Creek weir.

In summary, flux calculations show that the WAG 5 White Oak Creek drainage basin is contributing only a small fraction (less than 5%) of the total measured flux of the principal radionuclide contaminants measured in the discharge from White Oak Dam. Most contamination measured at the White Oak Creek weir is from sources upstream of or adjacent to WAG 5 (i.e., WAG 1 upstream of 7500 bridge and WAG 4).

WAG 5 Melton Branch drainage basin summary

The 52.9-acre Melton Branch drainage area of WAG 5 contains five study areas: SWSA 5 South areas A, B, C, and D, and SW-3. The annual water balance between surface runoff, interflow (stormflow), and groundwater for the WAG 5 Melton Branch drainage area, based on the HSPF modeling effort, is presented below.

Water Flow	Percent of Flow	Annual Discharge (m^3/year)
Surface runoff	7	8,800
Interflow	28	36,600
Groundwater flow	65	82,500
Total	100	127,900

Pathway-specific contaminant fluxes for the Melton Branch study areas were calculated using the same approach as that used for White Oak Creek (Fig. 3.3); these results show the dominance of the groundwater pathway in the transport of contaminants to Melton Branch. The stormflow and surface runoff pathways are generally insignificant, except in SW-3, where most waste is at or near the surface and surface runoff and stormflow are more dominant.

Table 3.4 summarizes the fluxes (and relative percentages) from each source, beginning with SW-3 study area and culminating with the total flux measured at the mouth of Melton Branch. It also presents fluxes calculated from upgradient input (as measured at stations SW004 and SW005; see Fig. 3.1 for locations). The results indicate a good correlation between calculated and observed fluxes, similar to that obtained for White Oak Creek.

Table 3.4. Flux contributions to drainage D-2 and Melton Branch

	Alpha Flux mCi/yr	(%)	Beta Flux mCi/yr	(%)	H-3 Flux mCi/yr	(%)	Co-60 Flux mCi/yr	(%)	Sr-90 Flux mCi/yr	(%)	Cs-137 Flux mCi/yr	(%)
Drainage D-2												
Area B	1.7	(80%)	29.4	(77%)	146375	(62%)		(0%)	30.3	(84%)	4.40	(98%)
Area C	0.4	(20%)	8.7	(23%)	90400	(38%)	0.36	(100%)	5.9	(16%)	0.09	(2%)
Calculated total flux from drainage D-2	2.1		38.0		236775		0.36		36.2		4.49	
Measured total flux from drainage D-2	1.1		76.1		151875		not detected		63.2		4.50	
Melton Branch												
Non-WAG 5 Sources												
SW005	69.8	(73%)	127.3	(5%)	14826	(1%)	96.89	(93%)	14.5	(1%)	100.38	(63%)
SW004	5.6	(6%)	276.4	(12%)	0	(0%)	0.00	(0%)	128.5	(9%)	34.62	(22%)
WAG 5 sources												
Drainage D-3	0.3	(0%)	1.6	(0%)	30	(0%)	0.79	(1%)	0.5	(0%)	3.77	(2%)
Area A	1.4	(1%)	238.8	(10%)	481048	(20%)	0.20	(0%)	117.6	(8%)	0.23	(0%)
Area B -> Melton Branch	7.6	(8%)	87.6	(4%)	1649829	(67%)	0.00	(0%)	86.4	(6%)	11.33	(7%)
-> Drainage D-2	1.1	(1%)	76.1	(3%)	151877	(6%)	0.00	(0%)	63.2	(5%)	4.50	(3%)
Area C -> Melton Branch	7.7	(8%)	1370.5	(58%)	144063	(6%)	0.18	(0%)	834.6	(60%)	2.86	(2%)
Area D	2.2	(2%)	177.7	(8%)	15094	(1%)	6.27	(6%)	151.5	(11%)	1.17	(1%)
Calculated total flux at mouth of Melton Branch	95.6		2356.0		2456767		104.33		1396.9		158.86	
Measured flux at Melton Branch weir + area D	46.2		2497.7		1967713		51.85		1274.1		39.01	

Notes: 1. Percentages refer to calculated total flux, not measured flux.

2. All data is based on sampling and flow measurements taken during the RI.

3. Total flux is taken at mouth of Melton Branch since Area D is downstream of surface water station SW006.

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Figure 3.5 is a funnel diagram for Melton Branch constructed in the same manner as that for White Oak Creek. Fluxes calculated from individual areas were combined into four hydrologically distinct groups: (1) WAG 5 study areas draining into D-2; (2) WAG 5 study areas draining directly into Melton Branch; (3) WAG 5 and non-WAG 5 contributors to Melton Branch Tributary; and (4) contributors upgradient of WAG 5 along Melton Branch. The groups were then combined to give relative percent contributions to the fluxes calculated at the mouth of Melton Branch. Also summarized are the total fluxes at the mouth of Melton Branch (measured flux at Melton Branch weir plus the calculated flux from area D), the relative percent flux from the WAG 5 Melton Branch drainage basin, and flux from Melton Branch weir to the total flux at the White Oak Dam.

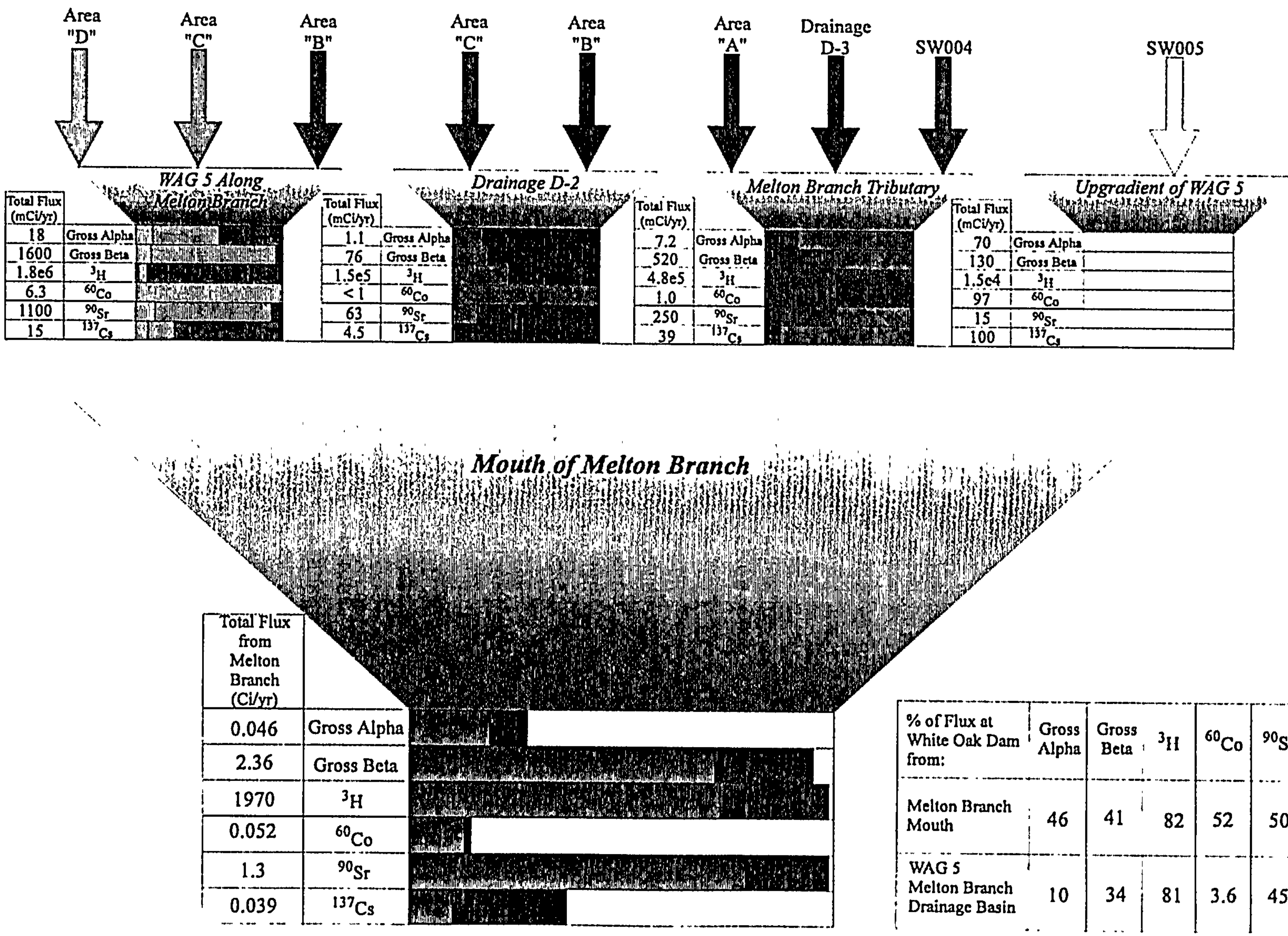
Flux calculations show that the WAG 5 Melton Branch drainage basin is contributing a significant proportion of the ^{3}H and ^{90}Sr fluxes measured in discharges from White Oak Dam, lesser amounts of gross alpha and ^{60}Co, and only a minor portion of the ^{137}Cs. The total tritium and ^{90}Sr fluxes from WAG 5 represent about 81 and 45%, respectively, of the ^{3}H and ^{90}Sr flux at the dam. These estimates are slightly greater than those calculated in previous studies [75 and 36%, respectively, as reported in ORNL (1993)]. Gross alpha, ^{60}Co, and ^{137}Cs fluxes were lower at 10, 3.6, and 0.5%, respectively.

Contaminant flux trends

Since WAG 5 is a major contributor of ^{3}H and ^{90}Sr to the White Oak Creek watershed, trends observable at White Oak Dam and Melton Branch should apply to the site. Figure 3.6 shows annual tritium flux measurements for White Oak Dam. The graph shows a significant increase in ^{3}H flux beginning in 1967, which correlates well with construction of waste trenches in SWSA 5 South area B—the area associated with the largest ^{3}H releases from WAG 5. Waste disposal in these trenches began in 1965 and was most active between 1966 and 1968 (see Appendix B2). From 1966 to 1967, the ^{3}H flux at White Oak Dam increased by a factor of four (3090 to 13,300 Ci/year), which suggests that ^{3}H migration began essentially immediately after the waste was placed in the trenches.

The figure also shows a steady decline in tritium flux over the last 20 years. To determine whether this decline is related to depletion of the source or simply to isotopic decay (i.e., from an essentially infinite source), the ^{3}H fluxes were normalized for precipitation to remove the bias due to annual variations in precipitation. An exponential best fit performed for the normalized ^{3}H fluxes provided an initial flux of 12,900 Ci for 1967 (compared to the observed value of 13,300 Ci); a radioactive decay curve for a constant source, based on the 1967 flux of 12,900 Ci, is also plotted on Fig. 3.6.

Assuming radioactive decay only, the predicted ^{3}H flux for 1993 is 2828 Ci; the normalized flux was estimated to be 2143 Ci, and the actual value was 1827 Ci. Given the error limits in estimating activity decay from flux values (flow rates times contaminant activity) and the similarity between the best fit curve of the normalized flux and the radioactive decay curve of tritium (Fig. 3.6), it appears that most of the decrease in ^{3}H activity can be accounted for by half-life decay. The corollary to this conclusion is that the tritium source is not being depleted and sufficient tritium remains in the source areas to be a potential problem for the extended future. In addition, based on the similarity of the normalized tritium fluxes and the radioactive decay curve, there apparently have been no new sources of ^{3}H in the White Oak Creek basin since the mid-1960s.



% of Flux at White Oak Dam from:	Gross Alpha	Gross Beta	^{3}H	^{60}Co	^{90}Sr	^{137}Cs
Melton Branch Mouth	46	41	82	52	50	3.5
WAG 5 Melton Branch Drainage Basin	10	34	81	3.6	45	0.5

Fig. 3.5. Melton Branch contaminant flux summary.

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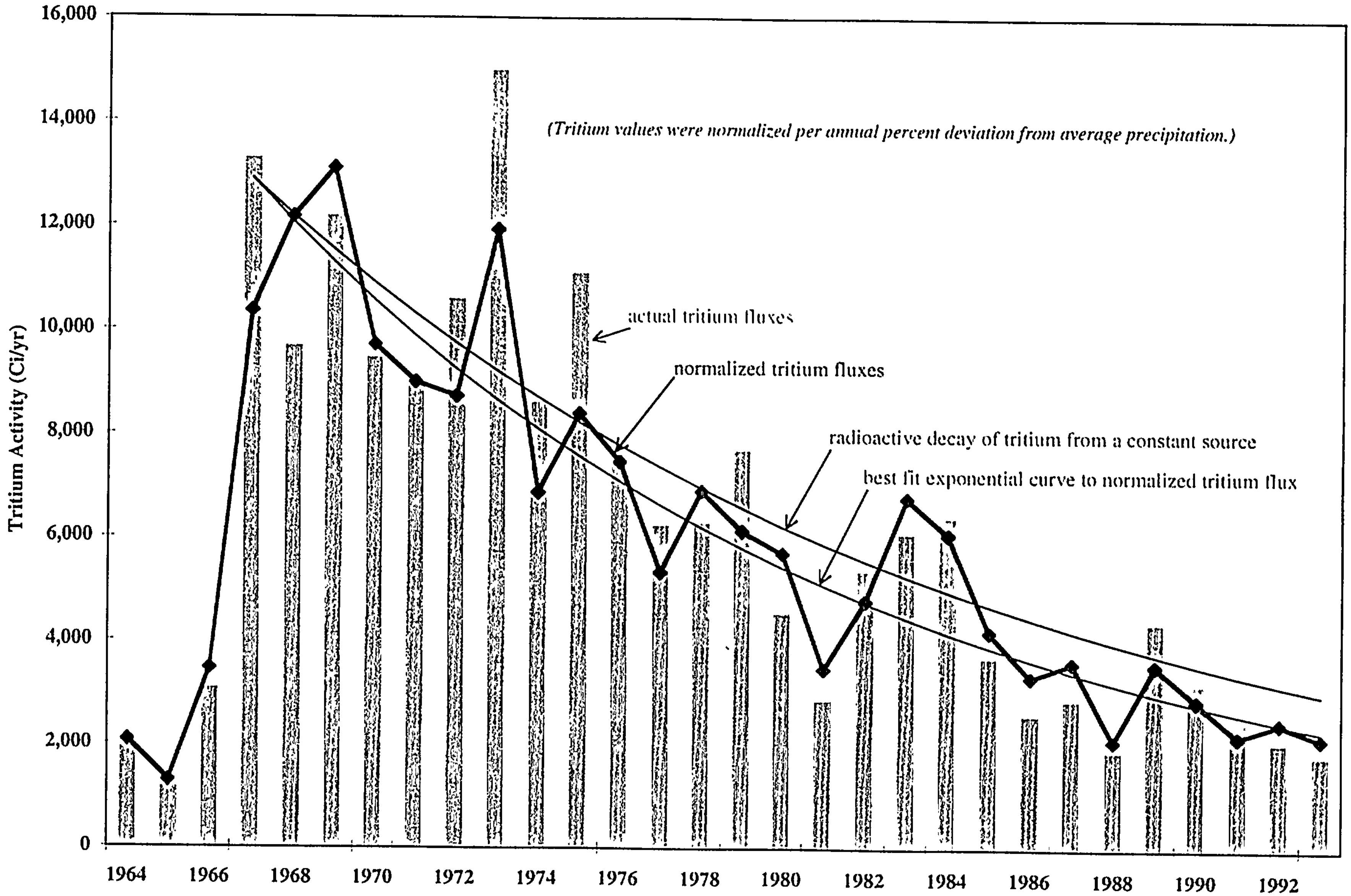

Fig. 3.6. Normalized tritium flux over White Oak Dam, 1964-1993.

Figure 3.7 is an extension of the radioactive decay curve of tritium that shows predicted concentrations rather than flux and is based on a flux of 12,900 Ci in 1967 and an average flow of 14.8 cfs at White Oak Dam. Based on radioactive decay alone, the tritium concentration in flow at White Oak Dam will be less than the maximum contaminant level (20,000 pCi/L) in the year 2010 and produce a risk less than 10^{-6} sometime after the year 2090.

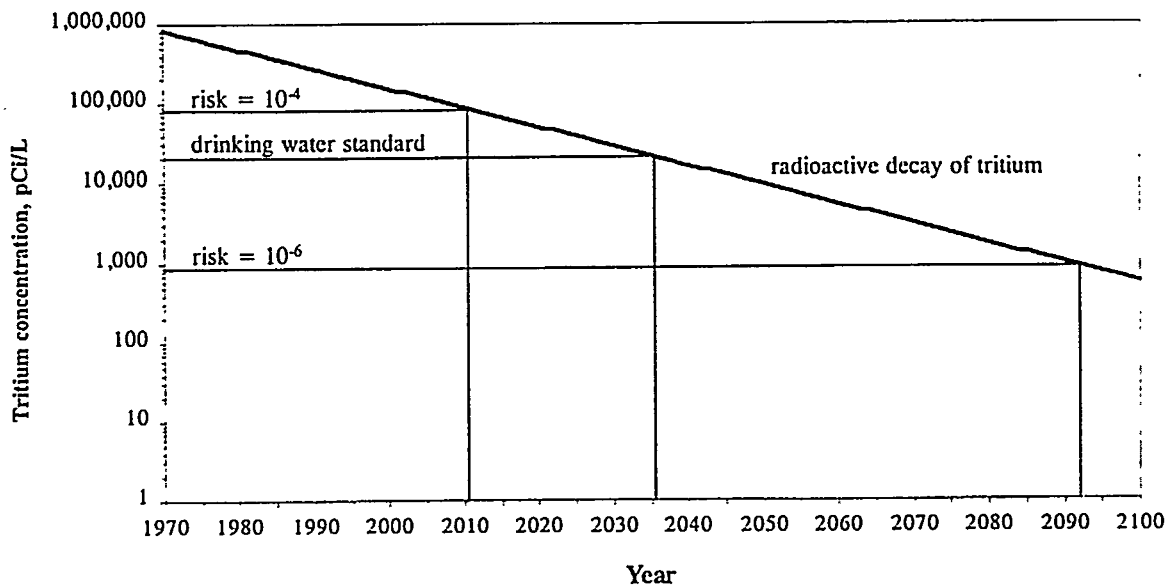

Fig. 3.7. Future tritium concentrations at White Oak Dam.

Data for ^{90}Sr at White Oak Dam are available from 1949 to the present and at Melton Branch weir from 1964 to the present. The historical trend at White Oak Dam shows a significant decrease between 1949 and 1961. Since 1962, however, the strontium flux over the dam has leveled off and appears to fluctuate primarily in response to annual precipitation levels. WAG 5 is only one of several major ^{90}Sr contributors to the White Oak Creek watershed, and therefore the data at Melton Branch weir are more representative of the site. Figure 3.8 shows the measured and normalized flux of ^{90}Sr at Melton Branch weir between 1964 and 1993; the flux from WAG 5 (the principal contributor of ^{90}Sr measured at the weir) was relatively constant over this period. The consistent level of strontium flux in Melton Branch since the early 1960s may be due to the activation of additional sources in WAG 5. Information presented in Appendix B3 indicates that the relative percent contribution of Melton Branch to the total ^{90}Sr flux at White Oak Dam is increasing, which in turn suggests that other sources in the White Oak Creek watershed are being depleted.

3.3 SITE CONCEPTUAL MODELS

The conceptual models presented in this section represent a summary of the risks, release mechanisms, and migration pathways associated with contamination on WAG 5. Four models are presented, three of which (termed "exposure scenario conceptual models") are alternately focused

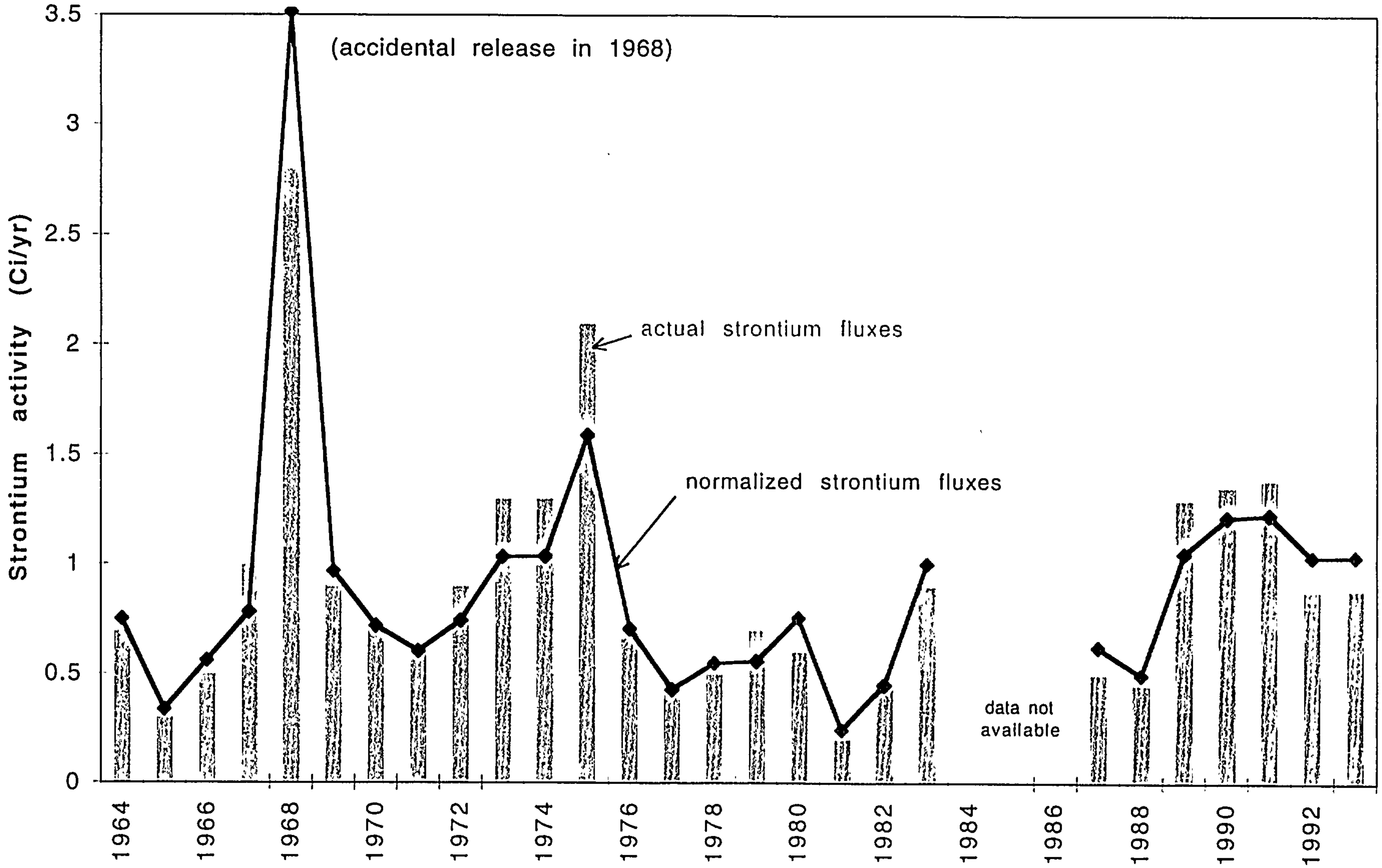

Fig. 3.8. Normalized strontium flux in Melton Branch, 1964—1993.

portrayals of the first, with shifts in emphasis to allow for integration of human health risks resulting from contaminants. Ecological risks are summarized separately in Sect. 3.4.

The information contained in the site conceptual models is a compilation of detailed "hydrologic" and "pathways" models constructed for each study area (Appendix B2, Volume 3). The individual models were constructed within a framework provided by an original site conceptual model (ORNL 1988), which, in turn, was based on data and information before environmental restoration activities began. The additional data collected through the RI allowed for validation and refinement of the original site model as it was applied to each study area and subsequently the site as a whole. Refer to the study area models in Appendix B2 for greater detail on source characteristics, physical proximity of sources to contaminant migration pathways and exposure points, quantification of hydrologic and contaminant fluxes, contaminant discharge points, and intermedia transfers. As intended, the site conceptual models allow for a summary look at the "big picture."

3.3.1 Human Health Risk and the Site Conceptual Models

The purpose of a risk assessment is to provide information necessary to determine whether remedial action is needed at a site, and, with input from the site conceptual models, to select the best remedy if action is warranted. The baseline risk assessment estimated potential threats to human health from WAG 5 for several different exposure scenarios under existing (baseline) conditions (i.e., assuming no remediation has occurred). Appendix C1 (Volume 4) presents details of the human health risk assessment and its results.

The exposure scenarios summarized in this section focus on carcinogenic risks, defined as the incremental probability that an individual will develop cancer as a result of exposure to a potential carcinogen via a specific exposure pathway (ingestion, inhalation, etc.). The risk is expressed as an excess number of cancer cases above the expected during a specified time for an exposed population. For example, a risk of 5.0×10^{-4} means that in an exposed population of 10,000 (1.0×10^{4}), there would be five contaminant-induced cancer cases in addition to the those that would occur in the same population if not exposed.

The risk calculations were based on contaminant concentrations in samples collected primarily from environmental media—groundwater, soil, surface water, and/or sediment—that were affected (or potentially affected) by migration of contaminants from WAG 5 wastes. In some cases, contaminated media may have high enough levels of contamination to function as secondary sources in addition to their role as contaminant migration pathways. In most areas of WAG 5 (exceptions being the two impoundments), the wastes themselves (primary sources) present relatively low risks to humans because they are buried below the surface and shielded by various containment methods (e.g., soil, asphalt, and concrete over trenches and concrete caps over auger holes). Risk is much more likely after the contaminants have migrated into an environmental medium that can be dermally contacted, ingested, inhaled, or transported to a location lacking sufficient shielding to protect a receptor from direct external radiation. Therefore, in terms of risk, the important aspects of the WAG 5 contaminant dynamics are the mechanisms by which risk-producing contaminants are released into the environmental media, the concentrations and transfer of the contaminants within (or through) these media, and the proximity of the contaminated media to potential receptors. The conceptual models are the tools used to describe and integrate these aspects.

The WAG 5 off-site risk scenarios are for hypothetical *residents* currently residing at either of the weirs on Melton Branch and White Oak Creek, just upstream of the two streams' confluence, and at White Oak Dam. Off-site risk was also examined in the context of an incremental risk contribution for a residential scenario at the Clinch River (i.e., off the ORR). Risks associated with hypothetical on-site *industrial* and *residential* scenarios were calculated for each of nine on-site contaminated areas.

As described in Sect. 3.1, the site was divided into ten study areas for the purpose of determining the nature and extent of on-site contamination. The nine areas examined for on-site risk analyses result from combining study areas A and B, and C and D, and then splitting the OHF study area into two risk analysis study areas (the "OHF pond" and the "OHF tanks"). Though the NHF area was included in the WAG 5 baseline risk assessment, contaminant concentrations and migration potential in the area are both low, and calculated risks are due to contaminants that may not be site-related. As a result, this area has been designated as a candidate for "deferred action" (see Sect. 4) and is not included in the conceptual models presented in this section.

Assumptions

The conceptual models reflect some assumptions that have been made. Although in several instances risk scenario calculations identified inhalation risks from contaminated particulates and vapors, volatilization and particulate emissions are regarded as relatively insignificant pathways for contaminant migration from WAG 5 under its current use and therefore do not appear in any of the individual study area conceptual models in Appendix B2. The primary reason for this is that the vast majority of site-related contamination at WAG 5 is in the subsurface, and most of the contaminants of concern have low volatility characteristics. In addition, the site surface is almost entirely covered with vegetation, which reduces the likelihood of particulate emissions. Site access controls and maintenance procedures minimize disturbance of the soils. In contrast, the inhalation exposure scenarios used in the risk assessments assume disturbance of the soils for various activities.

Limitations

The limitations of the conceptual models stem primarily from the lack of characterization data for the contaminant source terms and the partial characterization of the associated contaminant release mechanisms and migration flow paths. Health and safety concerns prohibited detailed characterization of the buried wastes, but such characterization was not deemed a requirement under the *observational approach* used to scope the RI field investigation. Contamination flux per migration pathway was calculated using average pathway-specific analyte concentrations and calculated water flux rates for each area. Contaminant release mechanisms were determined qualitatively only (primary, secondary, and/or potential). Uncertainties associated with these limitations were minimized by constructing detailed hydrologic models (based on extensive groundwater level and surface water flow data) and maximizing the use of historical information.

3.3.2 Attributes of the Conceptual Model

Figure 3.9 depicts the important features of the WAG 5 conceptual site model—its ability to identify and illustrate the sources of contamination (i.e., wastes), the applicable secondary sources/migration pathways, and the release mechanisms that link the two. The model reflects the hydrologic (primarily shallow groundwater) processes that govern the spread of contamination from the sources to on-site and off-site groundwater, surface water, sediments, and soils, creating the potential for exposures and risks. Release mechanisms are primarily bathtubbing in trenches and inundation of buried wastes with groundwater, particularly during high base conditions and, to a lesser extent, surface runoff, stormflow, and percolation of rainwater through the wastes. Though not a primary release mechanism, runoff and percolation of rainwater probably plays a slightly larger role in the White Oak Creek drainage areas than in the Melton Branch areas. Once in the groundwater, the contaminants are discharged onto surface soils and into the receiving streams via seeps (and bathtubbing in selected SWSA 5 South trenches).

To facilitate the assessment of the relationships between contaminant sources, release mechanisms, secondary source media, and area-specific on-site risks, the pathway-specific contaminant flux portion of the site conceptual model is modified to portray human health risks by exposure pathway and medium for on-site residential and industrial scenarios.

On-site resident exposure scenario

This scenario represents the hypothetical maximum exposures, where it is assumed that the site is abandoned tomorrow and free for occupation by a resident farmer. Though not necessarily a reasonable land use assumption, it does indicate the need for continued institutional control by DOE. The assumed exposure duration for the on-site resident is 350 days/year for 30 years.

To allow for a risk-based ranking of the different study areas, the model (Fig. 3.10) identifies the magnitude of total risk associated with each area (denoted by the length of the largest, gray-shaded bars as measured by the exponential risk scale at the top of the figure). Risks associated with the contaminant exposure pathways (external radiation, inhalation, ingestion of produce and contaminated media, and dermal contact) are denoted by the length of the smaller bars within each total risk bar. Finally, the lengths of the smallest bars within each exposure pathway bar denote the media-specific risks. Specific radionuclides and chemicals most responsible for the calculated risks are listed on a medium- and pathway-specific basis.

As shown in the model, significant increased risk of developing cancer ($>1.0 \times 10^{-4}$) exists at all nine areas. The highest risks calculated (2.0×10^{-1}) were for hypothetical residents at SWSA 5 South A and B and the SWSA 5 South White Oak Creek areas. The calculated risk is greater than 3.0×10^{-2} for hypothetical residents at the OHF pond, SWSA 5 South C and D, and fissile storage areas.

In most areas, exposure to direct external radiation from radionuclides in surface soils (0- to 2-ft depth) represent the most important exposure pathway and environmental medium (respectively) driving the total risks. Within this exposure pathway, ^{137}Cs is almost entirely responsible for the

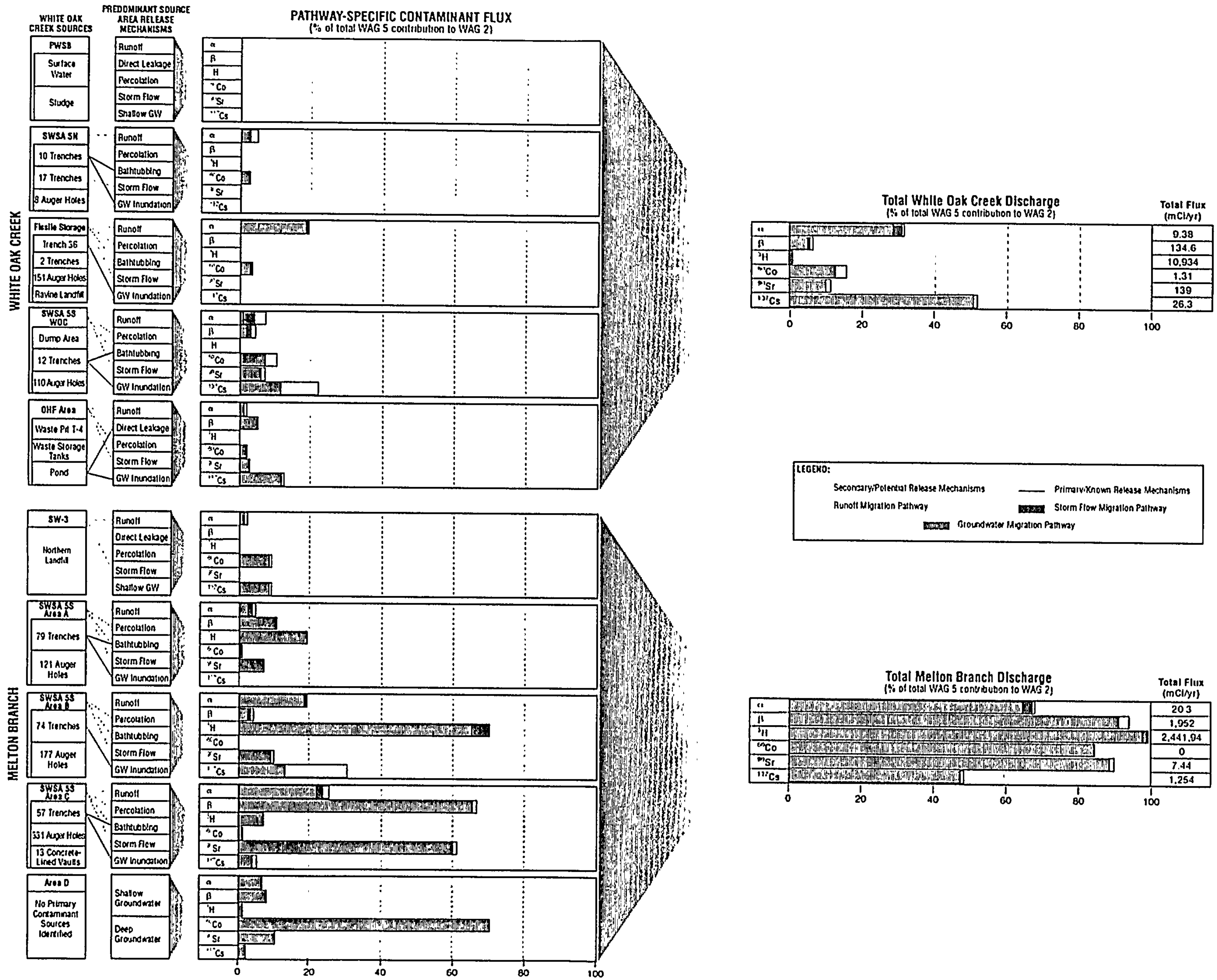

Fig. 3.9. WAG 5 site conceptual model.

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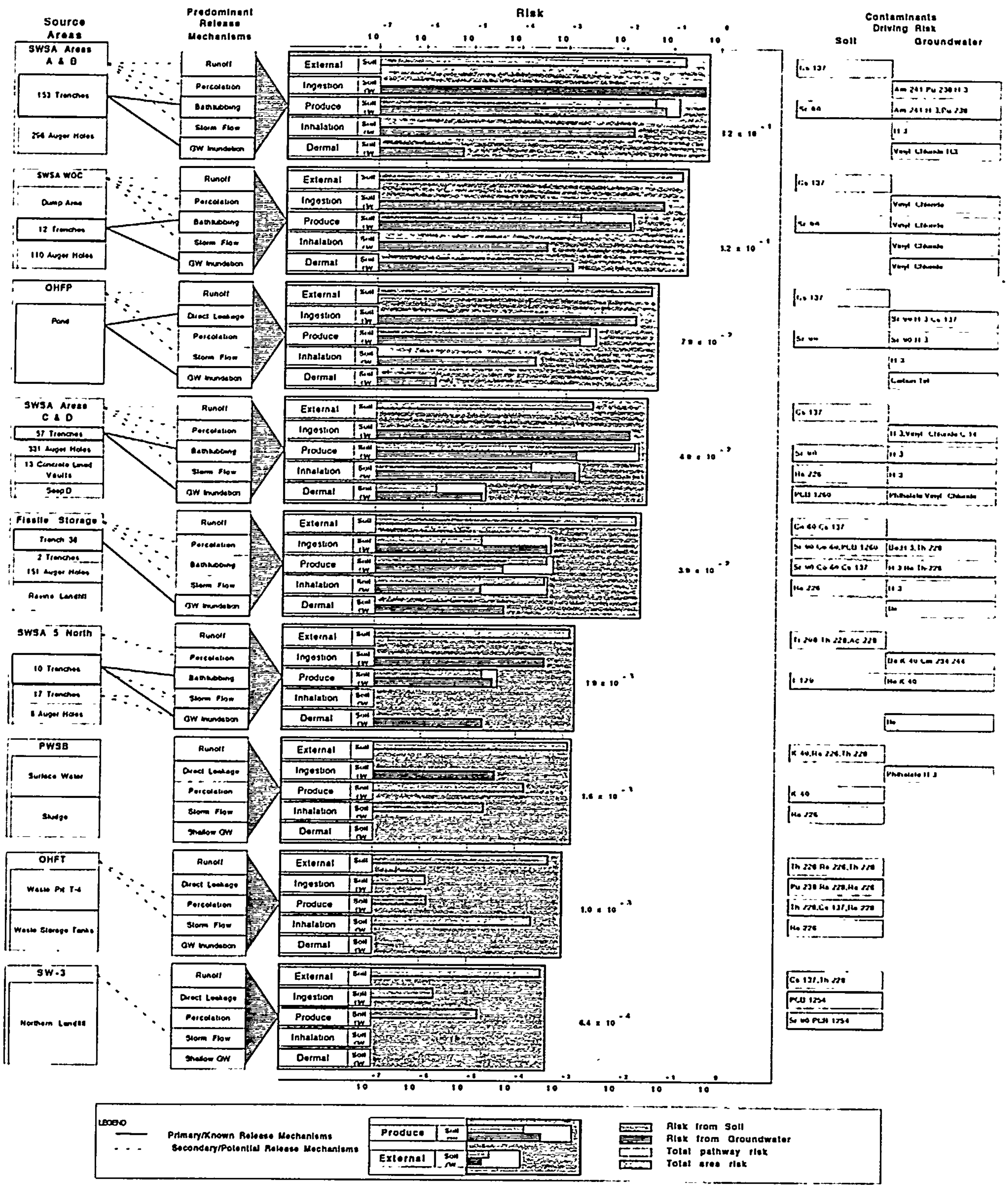

Fig. 3.10. On-site residential exposure scenario conceptual model.

risks in those areas with total risk values greater than 10^{-2}. The naturally occurring radionuclides ^{228}Th, ^{226}Ra, and ^{40}K generally drive external exposure risks in the remaining areas. These radionuclides are present only at very low concentrations and are not believed to represent site-related contamination. It should be noted, however, that these radionuclides were detected in samples from some of the study areas at concentrations slightly above background screening tests; this is probably attributable to the natural variability in concentrations of these radionuclides in site soils. Ingestion of groundwater and produce is the next most important exposure pathway contributing to risk. The risk-driving analytes for this pathway include ^{90}Sr, ^{3}H, ^{241}Am, and vinyl chloride.

Future contaminant concentrations. Figure 3.11 summarizes the expected future total cumulative risk under the residential exposure scenario from exposure to contaminated soil. The SWSA 5 North area poses the lowest carcinogenic risk to future residents; total risk from the different exposure pathways is expected to be less than 1×10^{-6} in less than 50 years. External exposure would be the primary exposure pathway, and ^{226}Ra and ^{228}Th concentrations in soil would be most responsible for the calculated future risks. The next lowest area of concern is SW-3, where external exposure would be the only pathway of concern and the driving contaminants would be ^{137}Cs and ^{228}Th. The figure shows that the total carcinogenic risk in this area would be less than 1×10^{-4} in approximately 60 years. In the remaining areas, the radionuclide contaminants are long-lived and at least 250 years would have to elapse before risk would be less than 1×10^{-4}.

On-site industrial exposure scenario

Figure 3.12 presents the industrial exposure conceptual model depicting calculated risks at the nine WAG 5 study areas. The scenario is based on the assumption that the site is abandoned and made immediately available for industrial use. The only medium considered is soil, and the assumed occupation time is for 8 h/day, 50 weeks/year, for 25 years (see Appendix C1 for further details).

Similar to the on-site residential model, the lengths of the large, gray-shaded bars to the right of each study area box depict total area-specific risks, and the smaller bars within depict individual exposure pathway risks. The total risks calculated for the industrial scenario exceed 1×10^{-4} for all nine areas, indicating the need for continued institutional controls under current conditions. Though the maximum risks, on the order of 1×10^{-2}, were slightly lower than those calculated under the residential scenario (1×10^{-1}), the overall risk-based ranking of the nine areas is similar for the two scenarios, as are the exposure pathways (external) and radionuclides (^{137}Cs) that drive the risks. Again, the three highest total risks were associated with SWSA 5 South A and B, SWSA 5 South White Oak Creek, and the OHF pond. At the five highest risk areas (all $>1 \times 10^{-3}$), external exposure to direct radiation accounted for essentially all of the total exposures and the responsible radionuclides were ^{137}Cs and ^{60}Co.

Off-site resident exposure scenario

Figure 3.13 details site contributions to calculated risks incurred by hypothetical residents opposite the southwest corner of WAG 5 at the weirs on Melton Branch and White Oak Creek.

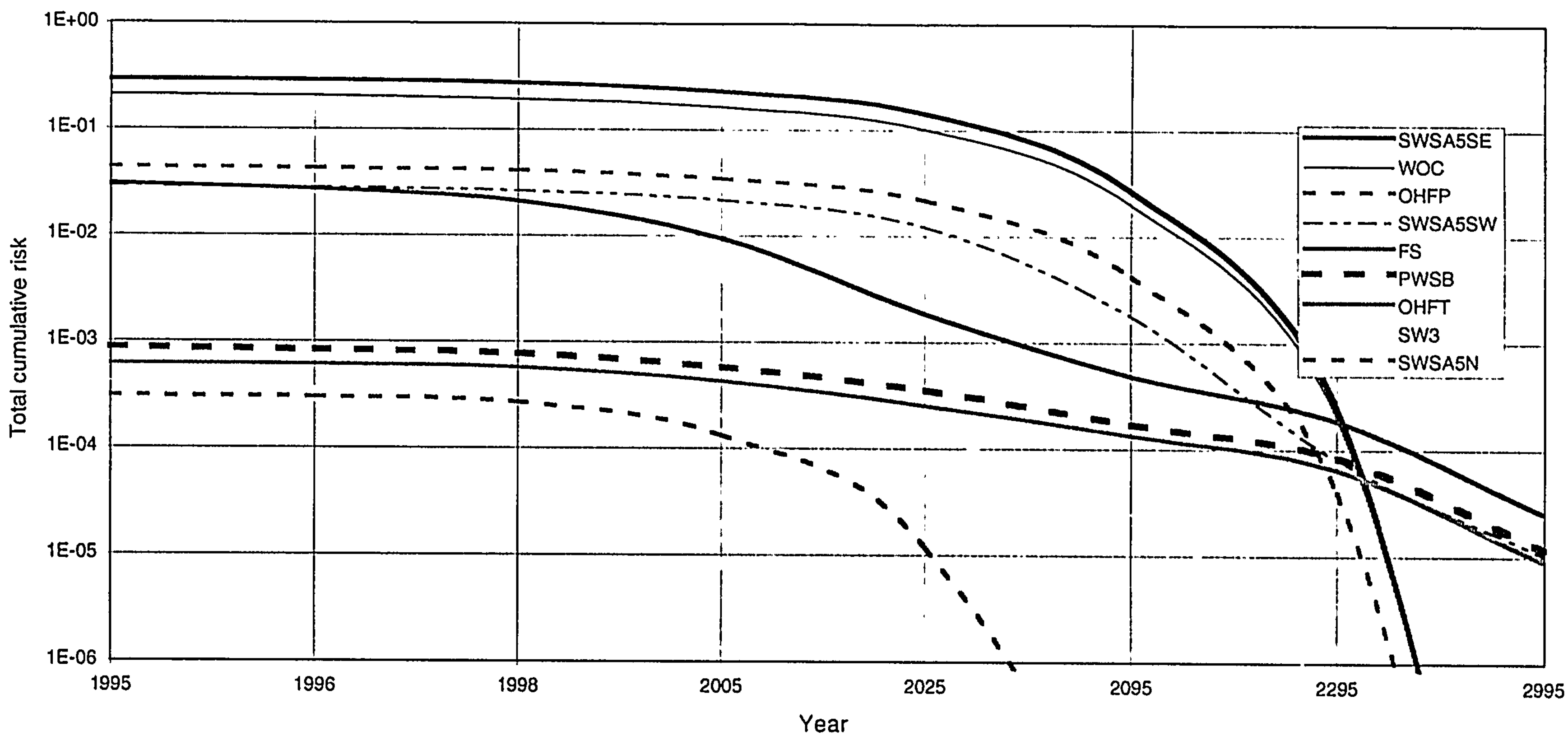

Fig. 3.11. Future risks calculated for WAG 5 study areas.

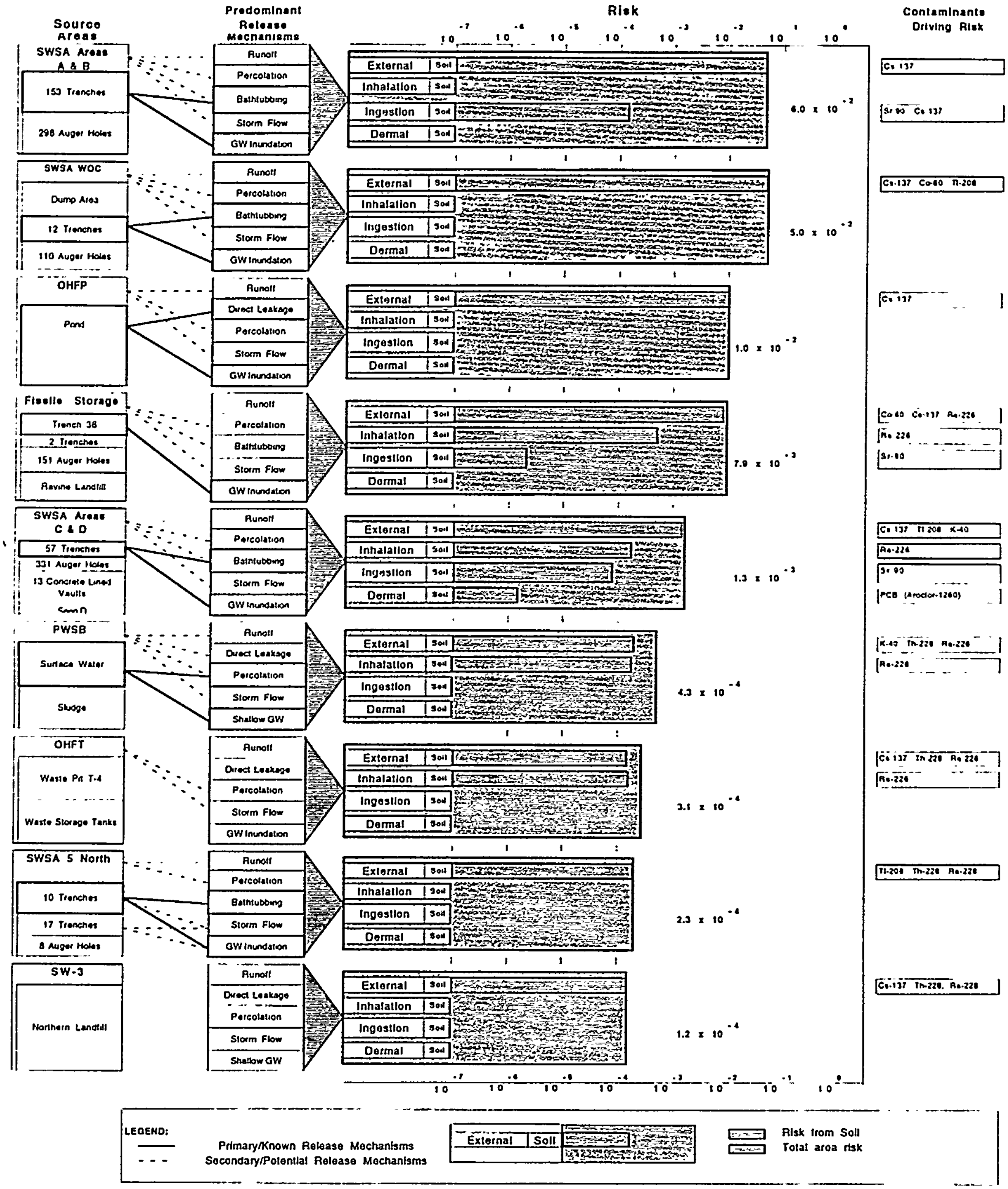

Fig. 3.12. On-site industrial exposure scenario conceptual model.

These weirs are downstream of all of the major source areas in WAG 5. Also shown is the WAG 5 contribution (in terms of a percentage) to the calculated risk from drinking the surface water at White Oak Dam. The drinking water risk at White Oak Dam is an important pathway for ORNL ER Program risk management purposes and is used to prioritize contaminants and source areas within the White Oak Creek watershed.

Melton Branch and White Oak Creek residential scenarios. Exposure routes for these scenarios are ingestion, dermal contact, and inhalation of contaminants in surface water. The exposure duration was assumed to be the same as that for the on-site residential scenario (350 days/year for 30 years). As expected, the risk results indicate that surface water immediately downstream of WAG 5 is not suitable for drinking water purposes. (It is important to note that these scenarios represent worst-case baselines established to comprehensively address the potential risks associated with the migration of contaminants from WAG 5 into White Oak Creek and Melton Branch.)

The total risk for a residential exposure is 5.9×10^{-4} at the White Oak Creek location and 2.4×10^{-3} at Melton Branch, indicating that both areas are unsuitable for residential use given current surface water conditions. The risk associated with the Melton Branch location is primarily attributable to migration of ^{3}H and ^{90}Sr from the trenches in SWSA 5 South. Groundwater inundation and bathtubbing in the trenches are the release mechanisms for these contaminants; shallow groundwater discharging to Melton Branch directly and via seeps is the contaminant migration pathway. By contrast, the primary source(s) of the contaminants driving the risk at the White Oak Creek location (^{90}Sr, PCBs, and ^{137}Cs), are upstream of WAG 5. The PCB concentrations detected in White Oak Creek are considered suspect but were included in the risk assessment because of regulatory requirements (see Appendix C1 for details). Assessment of the upstream (non-WAG 5) sources, release mechanisms, and migration pathways contributing to the risk at the White Oak Creek weir was not within the scope of this RI. Ingestion of drinking water is the primary exposure route for both locations; inhalation of ^{3}H-contaminated water vapors (during showering) represents an important secondary exposure pathway.

White Oak Dam surface water risk. Despite additional contaminant flux into White Oak Creek from sources downstream of WAG 5 (e.g., WAG 7), overall dilution of contaminant concentrations (and reduction in risks) occurs with movement downstream toward White Oak Dam. The risks associated with the drinking water pathway at the dam have averaged 5.0×10^{-4} over the last seven years. Strontium-90, ^{3}H, and ^{137}Cs flux from SWSA 5 South areas A, B, C, and D are responsible for approximately half of this risk (Fig. 3.10), making WAG 5 a significant contributor (relative to other WAGs) to the annual drinking water dose at the dam. Strontium-90 is the primary risk driver at White Oak Dam, and reducing its discharge from source areas has been the focus of recent ER remediation activities at ORNL. These activities include the construction of systems in 1994 to intercept and remove ^{90}Sr from contaminated seep discharges in seep areas C and D. These systems are expected to reduce the flux of ^{90}Sr at the dam significantly, but performance data from the systems are not yet available.

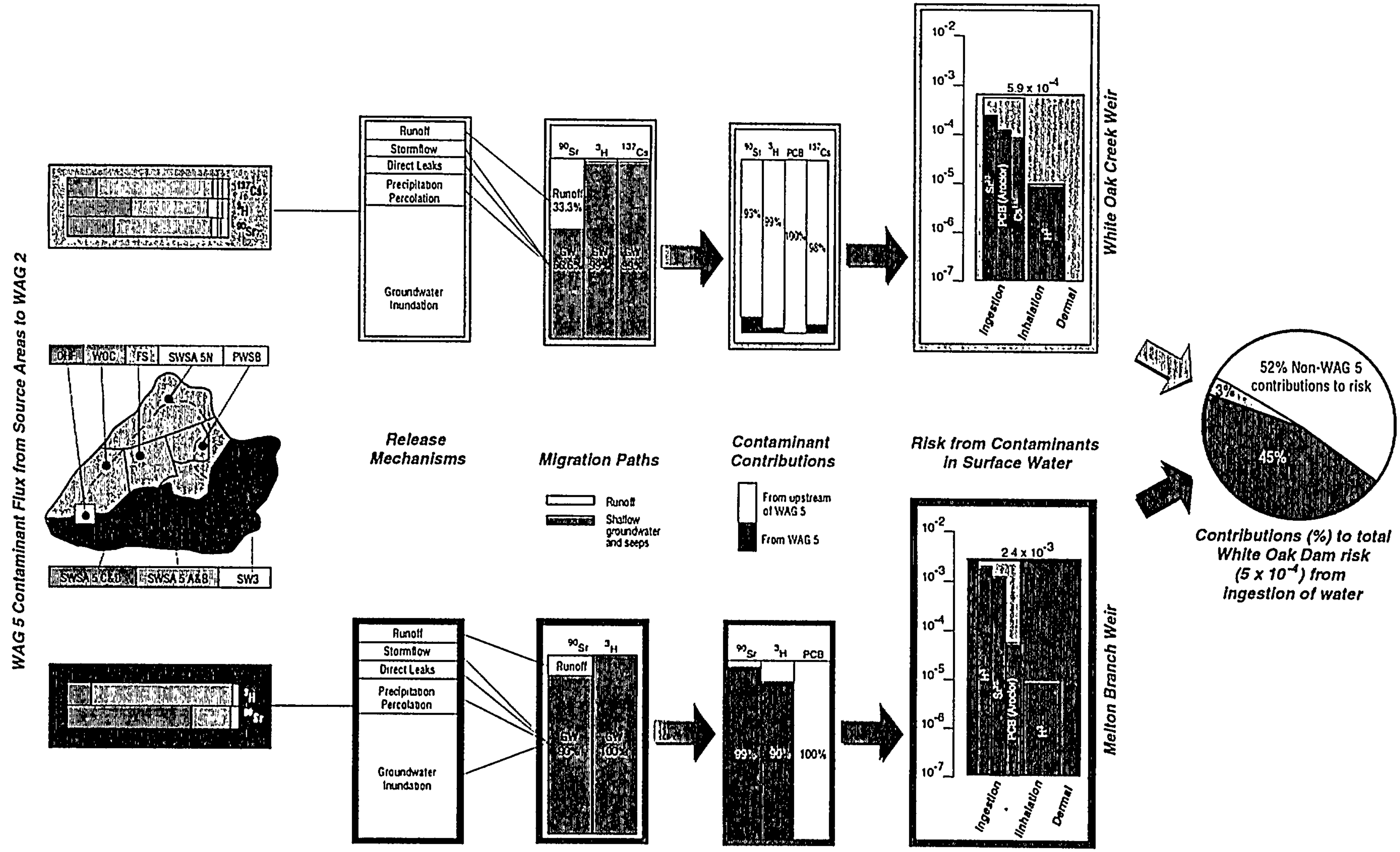

Fig. 3.13. Off-site resident exposure scenario site conceptual model.

Clinch River surface water risk. When discharges from the White Oak Creek watershed drain into the Clinch River, significant dilution occurs because of the much greater flow. The risk assessments conducted for the Clinch River to date have not focused on the primary contaminants of concern originating in the White Oak Creek watershed, and sampling results for these contaminants are limited. Consequently, the relative flows at Melton Branch/White Oak Creek weirs and at Melton Hill Dam were used to generate Clinch River dilution factors, which in turn were used to estimate contaminant concentrations and risks from current WAG 5 releases. The total carcinogenic risk from ingestion of surface water, calculated for the Clinch River downstream of the mouth of White Oak Creek, is approximately 2×10^{-6}; WAG 5 contributions were determined to account for about half of this risk (i.e., 1×10^{-6}). The drinking water risks at the Clinch River location were due primarily to ^{90}Sr and ^{3}H.

3.4 ECOLOGICAL RISK ASSESSMENT SUMMARY

Potential ecological impacts from contamination at WAG 5 were comprehensively evaluated for the baseline ecological risk assessment. The results of this assessment are presented in Appendix C2 (Volume 4); highlights are summarized in this section.

Ecological risks related to WAG 5 contamination were assessed for terrestrial and wetland plants, soil invertebrates, soil microorganisms and microbial processes, vermivorous (worm-eating) wildlife, fish, and benthic macroinvertebrates. On-site risks were assessed for the site in its current state and for a hypothetical future case where institutional controls are not maintained, succession occurs, and the site reverts to deciduous forest. Potential WAG 5 contributions to ecological risks to downstream (White Oak Creek) receptors were also evaluated.

Areas studied in the ecological risk assessment were not defined in the same way as elsewhere in the WAG 5 RI. Study areas for the human health risk assessment and other tasks were defined primarily by hydrology (surface water drainage and groundwater divides; see Sect. 3.1), and the six areas for the ecological risk assessment were defined according to available habitat and area history (Fig. 3.14). Habitat on five of these six areas (S5, TRU, OHF, NHF, and SB) consists primarily of grass-covered fields, pavement, or industrial structures. Each area is also associated with waste management activities such as storage and disposal. In contrast, the sixth area (WW) represents the remaining WAG 5 area that is essentially undisturbed (waste-related activities were minimal or nonexistent), and habitat is primarily deciduous forest. Because the presence of biota (and therefore exposure to and risks from contaminants) is dependent on past use of a site and available habitat, this approach was determined to be most appropriate for the ecological endpoints.

Risks to terrestrial endpoints (e.g., terrestrial plants; soil invertebrates, microorganisms, and microbial processes; and vermivorous wildlife) were evaluated for each of the six areas. Risks to aquatic endpoints (e.g., wetland plants, fish, and benthic macroinvertebrates) were addressed separately for each seep or drainage (D-1, D-2, and D-3). For clarity, on-site risks (both current and future) were ranked in four categories.

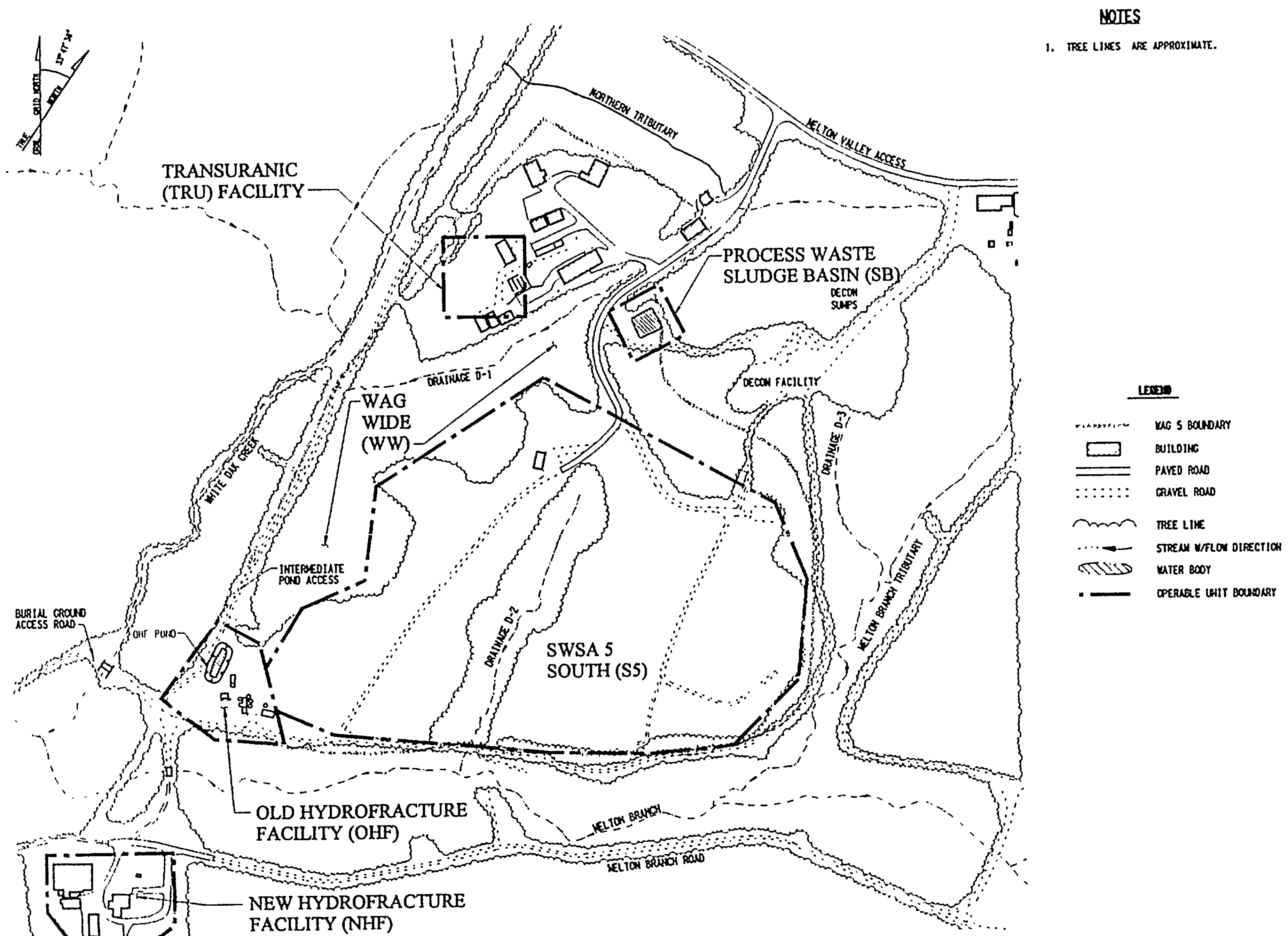

Fig. 3.14. Base map for ecological risk assessment with six ·sional units.

WAG5 BASE-SIX.D /5/94

1. *Likely impact:* Available evidence suggests there is a high probability that contaminant concentrations are high enough to result in adverse effects to endpoint populations or communities. For a site to receive a "likely impact" rank, (1) all lines of evidence (benchmarks, toxicity tests, and biomonitoring data) must suggest adverse effects, or (2) on-site mortality must be observed (excluding toxicity tests). No WAG 5 site or endpoint received a "likely impact" rank.

2. *Possible impact:* Available evidence suggests there is a possibility that contaminant concentrations are high enough to result in adverse effects to endpoint populations or communities. A "possible impact" rank is assigned when evidence suggests an impact but evidence is incomplete or contradictory, or confidence in the applicability of evidence is limited.

3. *Impact possible but unlikely:* Available evidence suggests there is a possibility that contaminant concentrations are high enough to result in adverse effects to endpoint populations or communities, but there is considerable uncertainty about the validity of the evidence. A "possible but unlikely" rank is similar to the "possible impact" rank except that confidence in the data is very low or supporting data indicate that adverse effects are unlikely.

4. *No impact:* There is no evidence to suggest that contaminant concentrations are high enough to result in adverse effects to endpoint populations or communities. A "no impact" rank is assigned when toxicity tests are negative, biomonitoring data indicate that site populations are not reduced relative to reference locations, and calculated exposures do not exceed toxicological benchmarks. For a site or endpoint to receive a "no impact" rank, no available data can suggest an adverse impact.

WAG 5's contribution to off-site risks to terrestrial and wetland plants, soil invertebrates, soil microbes, and vermivorous wildlife was evaluated by considering the magnitude with which contaminants exceeded toxicological benchmarks. This was assumed to be a measure of the degree of dilution needed to reduce contaminant concentrations to below toxic levels. For example, contaminants that only marginally exceed benchmarks would require minimal dilution and therefore are unlikely to contribute significantly to off-site risk. In contrast, contaminants with concentrations orders of magnitude greater than benchmark values are very likely to present off-site risks. For WAG 5, it was assumed that contaminants with dilution factors of 10 or less were unlikely to contribute significantly to off-site risk.

The contributions to off-site risks were ranked (Contribution Likely, Possible Contribution, Contribution Possible but Unlikely, and No Contribution) in a manner similar to that employed for on-site risks. Definitions of these categories are also comparable to those outlined for on-site impacts.

3.4.1 Terrestrial Endpoints

Risk evaluation results for terrestrial endpoints for the six areas within the WAG 5 boundary indicate that contaminants in these areas pose no more than possible impacts to on- or off-site endpoints, both currently and in the future (Fig. 3.15). With one exception, there was no impact for any endpoint (on-site current and future cases or contributions to off-site receptors) due to contaminants in the TRU, SB, and NHF areas. The exception was the possible (but unlikely)

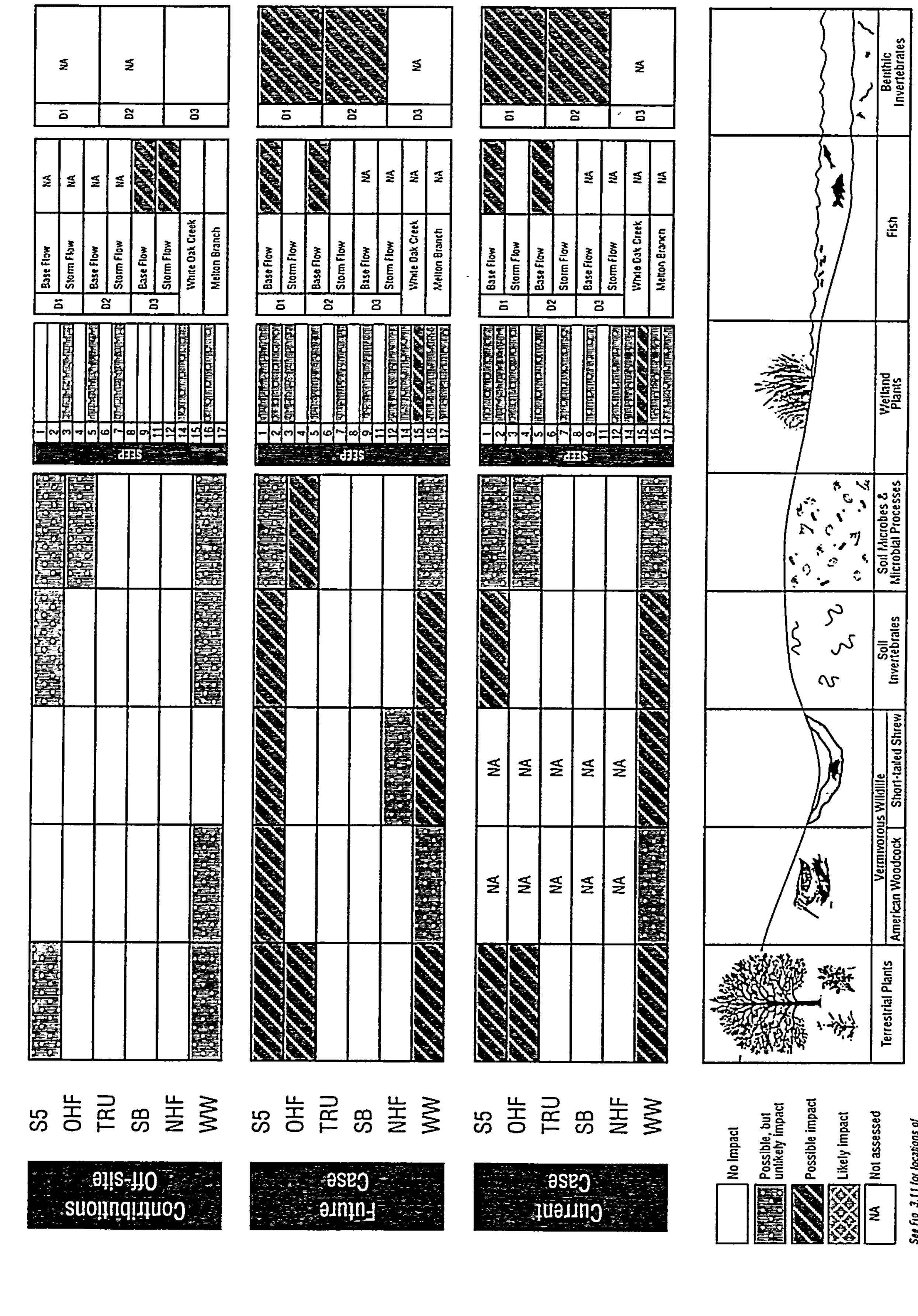

Fig. 3.15. Ecological risk summary.

5.14 6290.30

future impact to shrews in the NHF area due to barium concentrations in soil. For the current scenarios, risks to vermivorous wildlife were assessed only for the WW area (shown in Fig. 3.14) because it is the only suitable habitat for shrews in the site's current state.

In the S5 area, results indicate that metals in soil could produce a possible current or future impact to terrestrial plants (antimony, manganese, mercury, and selenium) and soil invertebrates (mercury). Future impacts to vermivorous wildlife in this area are possible as a result of radiation exposures that exceed International Atomic Energy Agency recommendations. Contributions from this area to impacts on off-site terrestrial plants, soil invertebrates, and soil microbes/microbial processes are considered possible (because of mercury and manganese soil concentrations) but unlikely (because the area is vegetated and the likelihood of off-site erosion of contaminated soil is minimal).

For the OHF area, results indicate the possibility of current and future impacts to terrestrial plants due to cobalt, manganese, and silver in soil. Manganese in soil also poses possible but unlikely current, future, and off-site impacts to soil microbes/microbial processes. The off-site contribution is considered unlikely because the possibility of erosion of contaminated soils is minimal.

At the WW area, soil metal contamination (mercury and zinc) could have possible current and future impacts on terrestrial plants, soil invertebrates (mercury and zinc), and the short-tailed shrew (barium). Current and future impacts due to mercury and zinc are considered possible but unlikely for the American woodcock. Contributions of contaminants impacting off-site endpoints are considered possible but unlikely (due to minimal erosion) for terrestrial plants (mercury), soil invertebrates (mercury), soil microbes/ microbial processes (zinc), and the American woodcock (mercury and zinc).

3.4.2 Aquatic Endpoints

WAG 5 contaminants pose no more than possible impacts to on-site or off-site aquatic endpoints, currently or in the future (Fig. 3.15). Risks were evaluated for wetland plants at the 15 seeps sampled during the high base event (April–May 1993), for fish in each on-site drainage (D-1 and D-2 for current and future cases; D-3, White Oak Creek, and Melton Branch for off-site contributions), and for benthic invertebrates in all three on-site drainages. Exposure of wetland plants to contaminants in the seeps may remain unchanged or decrease if the volume of seepage is reduced by the increased evapotranspiration resulting from reforestation. Therefore, risks identified for the current case are believed to represent those expected in the future. Similarly, in the absence of any changes to contaminant input to the aquatic systems at WAG 5, future on-site risks for fish and benthic macroinvertebrates should be identical to current on-site risks.

Contaminants in seeps 4, 6, 8, and 11 do not present a hazard to wetland plants (current or future cases), and they are not expected to contribute to impacts to off-site wetland plants. In seeps 1, 2, 3, 5, 7, 9, 12, 14, 16, and 17, possible but unlikely current and future impacts to wetland plants exist as a result of aluminum concentrations exceeding benchmark levels. Cobalt, iron, manganese, and nickel concentrations in seep 15 suggest possible impacts to wetland plants. It was determined that two-thirds of the seeps do not contribute to off-site (White Oak Creek) wetland plant risks, but aluminum concentrations in seeps 2, 5, 7, 14, and 16 exceeded benchmarks and suggest a possible but unlikely contribution.

Though drainages D-1 and D-2 do not support distinct fish communities and data are not conclusive, the evidence suggests possible current and future impacts. Fish in drainages D-1 and D-2 do not experience any adverse impacts during periods of stormflow; however, aquatic toxicity tests and chemical analyses indicate that they may be affected by chronic exposure to water from these drainages during base flow due to dissolved manganese and iron at D-2 and from an unidentified agent at D-1 (see Sect. C2.4.2.5 in Appendix C2). Acute effects are not expected at either location.

Risk evaluation results indicate possible current and future impacts on benthic invertebrate communities in drainages D-1 and D-2 due to nickel and Aroclor 1260 (D-1) and silver (D-2). Based solely on the evaluation of upstream and downstream benthic macroinvertebrate communities in Melton Branch and White Oak Creek near WAG 5, and contaminant concentrations in these waters, there does not appear to be an impact to off-site benthic macroinvertebrates resulting from releases from WAG 5 in either Melton Branch or White Oak Creek.

4. WAG 5 REMEDIAL ACTION STRATEGY

This section briefly discusses the historical background of the WAG 5 RI and evolution of the ORNL ER Program and presents an approach for future remedial actions at WAG 5. The objective is to provide a basis for future meetings involving DOE, TDEC, and EPA to discuss likely near-term and longer-term actions.

The initial RI work plan was completed and submitted to EPA in March 1988. On June 25 and 26, 1991, an observational approach workshop was held with participants from DOE, EPA, TDEC, and Energy Systems to review the status and direction of WAG 5 activities. Workshop participants agreed that that a large cap was the likely best interim remedial action, and the focus of the RI was redirected. The changes were incorporated in *Remedial Investigation Plan for Waste Area Grouping 5 at Oak Ridge National Laboratory, Oak Ridge, Tennessee, Volume 2: Appendices*, submitted for regulatory approval in December 1991.

Concurrent with the WAG 5 RI effort, the ER Program has expanded and taken new direction: the program strategy now allows a mixture of actions to remediate releases of contaminants to the environment. Remedial actions can focus on contaminant releases—for example, the recent installation of seep collection and treatment systems in WAG 5 that remove ^{90}Sr from groundwater discharges to Melton Branch. This type of action addresses the release of contaminants but not the sources. Source control actions typically involve measures that isolate, immobilize, treat, or remove contaminant sources—for example, the recent removal of ^{137}Cs-contaminated soils from WAG 13.

The program has also evolved to recognize that large and complex areas such as WAG 5 may effectively be addressed as small operable units. Increased technical knowledge and awareness of economic constrains have been significant factors. Response actions for these smaller units may be CERCLA removal or remedial actions and may be considered interim or final depending upon the level of protection provided relative to future site use.

This RI was conducted to provide information to identify and address risks from buried wastes and other contaminant sources and associated releases at WAG 5. Conceptual models that have been developed from this information can be used to identify areas to be remediated, likely approaches for remediation, and priorities. The results of the RI will be used to identify potential cleanup actions for WAG 5 as a scoping exercise before a feasibility study or EE/CA is begun for any or all of WAG 5.

This section presents potential remediation targets and possible ways to group study areas into remedial project areas, discusses prioritization of those areas (based on concerns), and suggests some possible near-term actions and additional investigations prior to undertaking these actions. This exercise is not intended to be exhaustive, but rather to provide sufficient information to clarify the results of the RI as a basis for making future decisions. Further refinement of the strategy is needed, and this may best be accomplished through a series of DOE-led workshops with TDEC and EPA to better define the issues and integrate the WAG 5 remedial projects into the FFA prioritization system.

4.1 REMEDIAL PROJECT AREAS

Future remediation work at WAG 5 will be constrained by a number of factors: technical feasibility, resource (funding) availability, and the overall risk management strategy for the ORR. A remedial action strategy for WAG 5 must recognize these constraints and at the same time ensure that significant problems are addressed in a timely fashion. Dividing the site into smaller "remedial project areas" allowing for phased cleanup actions is an approach that has been used elsewhere at ORNL and is particularly well suited for WAG 5; this approach also is consistent with the operable unit concept described in Section XII of the FFA (DOE 1992a).

The study areas described in Sect. 3.1 represent a logical division of the site by defining characteristics (e.g., impoundment, tanks, or waste trenches), hydrological conditions, and/or waste types. Dividing the site into these areas facilitated the evaluation and presentation of information in the RI Report.

Defining remedial project areas is the initial activity in the development of an overall remedial action strategy. Project area definition involves examination of source area characteristics in light of possible remedial action techniques; key characteristics include waste inventory and containment. Integrated with the baseline risk assessment into the site conceptual model, additional pertinent characteristics can be examined: migration activity and pathways (current and future), contributions to off-site contamination and risk, and on-site area-specific risk. Details regarding these characteristics used to define project areas are given in Volumes 2, 3, and 4 of this report. The following paragraphs provide summaries.

The site conceptual model described in Sect. 3 identifies the major sources at WAG 5, both active and potential, as well as those sources not likely to release any contamination to the environment. Buried wastes in trenches and auger holes are the major active contaminant sources; trenches inundated by groundwater provide the greatest contribution to contaminant levels in surrounding environmental media. The principal migration pathway is shallow groundwater (see Fig. 3.3); the discharge of contaminated groundwater transfers contamination to surface water, which then transports contamination off site.

In terms of contaminant flux, sources in the Melton Valley drainage basin (i.e., SWSA 5 South areas A, B, and C) contribute significant proportions of the total flux of ^{90}Sr and ^{3}H leaving the ORR at White Oak Dam. Most of this contamination exits from contaminated seeps along the southern perimeter of WAG 5; sources include both wastes (primary sources) and highly contaminated media (potential secondary sources).

Section 3 also summarizes results from the baseline human health and ecological risk assessments (see Appendix C, Volume 4, for additional details). The risk assessment identified the eastern and western portions of SWSA 5 South (areas A and B and the White Oak Creek section) as posing the greatest on-site risks (both industrial and residential). All of the study areas have onsite carcinogenic risks >1.0E-04; most have risks greater than 1.0E-02.

Section 3 also summarizes and evaluates WAG 5 contributions to off-site risks based on three residential scenarios: one at the Melton Branch weir (south of OHF), another at the White Oak Creek weir (west of OHF and upstream of the confluence with Melton Branch), and a third at White Oak Dam. At all three locations, excess carcinogenic risks for residential exposures exceeded the 1.0E-04 threshold. The greatest contributions to off-site risks at these locations are from the SWSA 5 South study areas (A, B, C and D).

A final consideration is the need to defer remedial action decisions for several areas that remain in active use by ORNL Waste Management or that are likely to be addressed by the Decontamination and Decommissioning Program. Table 4.1 lists potential remedial project areas for WAG 5 and provides the rationale for designation of each area. Figure 4.1 shows the locations of the nine project areas.

4.2 BASIS FOR REMEDIATION

This section presents an overview of the environmental problems and concerns associated with each remedial project area. Identifying the problems and concerns supports (1) identification of response actions necessary to achieve a given remediation target, (2) determination of the benefits that would result from implementing various actions, and (3) prioritization of potential actions. The discussion of problems and concerns for the WAG 5 remedial project areas is based on the following considerations

- *Source term*: inventory, waste volumes, contaminant types and distribution, source dimensions
- *Releases and impacts*: types of release mechanisms, extent of current releases, potential for future releases, flux (type and magnitude), affected area
- *Relative significance:* based on source term, type, extent, and magnitude of releases, resulting impacts (exposures and risks) both on and off site

Information concerning the problems and concerns associated with each remedial project area was drawn from information presented in Sections 1 through 3 of this Technical Summary and Appendices B and C (Volumes 3 and 4).

4.2.1 Source Term

Appendix B2 presents detailed information concerning the contaminant sources in WAG 5. This information is summarized here from a remedial project area perspective.

Table 4.2 provides estimates of radionuclide inventory and volume and areal dimensions of the sources within each project area. All of the remedial project areas have contaminant sources. In most cases, however, detailed characterization data were either not available or were available only as an aggregate (see Appendix B2 for further details). No information was available with regard to chemical inventories disposed of in WAG 5.

Table 4.2 indicates that the largest inventories of radioactive waste are associated with the Buried LLW Wastes project area; the bulk of this material is in the approximately 220 trenches in SWSA 5 South. Relatively large inventories are also present in the 27 trenches in SWSA 5 North and the 5 OHF waste storage tanks. Potentially significant secondary sources are also identified in the seep areas along Melton Branch and White Oak Creek.

Table 4.1. Potential WAG 5 remedial project areas

Remedial Project Area	Rationale
Surface impoundments • OHF pond *(Site 5.2)* • PWSB *(Site 5.6)*	Impoundments likely to be addressed using similar remediation approach and technologies
Buried wastes—LLW in trenches and auger holes *(comprises bulk of Site 5.7)* • SWSA 5 South areas A, B, and C • SWSA 5 South: White Oak Creek • Building 7831A drain field	Poorly characterized, heterogeneous buried wastes with radioactive and chemical contaminants; similarities in source characteristics, migration pathways, and flux due to location and burial practices; most significant contributors to off-site risk (exclusive of drain field); likely to be addressed using similar remediation strategy
Buried wastes—TRU and fissile wastes in trenches and auger holes • SWSA 5 North *(Site 5.10i)* • Fissile storage area *(part of Site 5.7)* • TRU trenches in SWSA 5 South *(part of Site 5.7)* • Classified burial area (SWSA 5 North)	Most of the wastes are well documented with regard to location and content; TRU, long-lived alpha-contaminated LLW and fissile wastes would require special considerations for remediation due to more stringent controls and handling considerations
OHF tanks • Waste Tanks *(Site 5.5)*	Underground storage tanks likely to be remediated as part of ORNL-wide inactive tanks remediation program
Landfills • Northeast landfill *(Site 5.14)* • Dump area and ravine landfill in SWSA 5 South *(part of Site 5.7)*	Similarities in source term (surface and near-surface debris), generally with low levels of contamination) and likely remediation approach [*Note: presence of more deeply buried and/or highly contaminated wastes would be addressed with buried wastes remedial project area*]
Melton Branch seep areas	Similar release mechanisms; likely to be remediated using similar technologies; seep discharges currently being addressed through collect and treat removal action
White Oak Creek seep areas	Similar release mechanisms; likely to be remediated using similar technologies
Miscellaneous storage vaults • Lined storage vaults in SWSA 5 South	Lined and/or double-contained tanks and vaults (wells) used to store liquid LLW and SC wastes; no evidence of release or contamination; final closure/remediation to be deferred to later date
OHF surface facilities *(Site 5.3)*	Active waste management operations in NHF and SWSA 5 North; remediation to be deferred pending relocation of activities and/or decisions regarding ORNL Decontamination and Decommissioning program

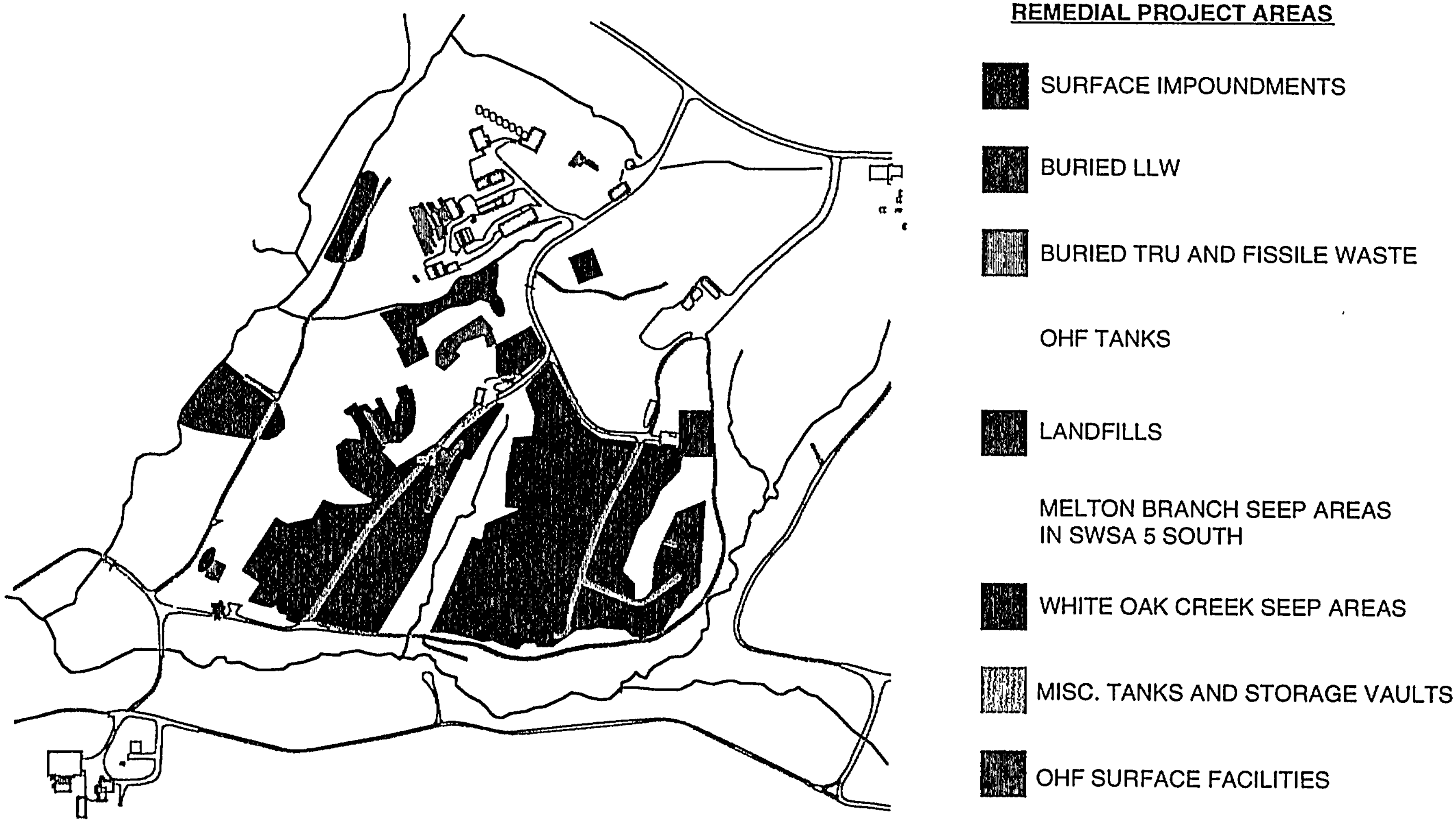

Fig. 4.1. Potential WAG 5 Remedial Project Areas

Table 4.2. Inventory, volume, and extent of contamination in remedial project areas

Remedial Project Area	Inventory/Waste Volume	Source Dimensions/Size
Surface impoundments	• 90 Ci • 1000 m^3 sediment • 500 m^3 surface water	Impoundments surface area of 0.22 acres; contamination plume from OHF Pond <1 acre
Buried LLW	• >200,000 Ci (*emplaced*) • 55,000 m^3 waste • Organics & metals (qnty unknown)	32 acres of trenches and auger holes in SWSA 5 south
Buried TRU and fissile wastes	• 800 Ci in SWSA 5 North • No inventory for fissile storage or classified burial area • 3250 m^3 waste	1.8 acres of surface area, including 7802N trenches, fissile storage trenches & auger holes, TRU trenches in SWSA 5 South, and Classified Burial Area
OHF tanks	• 29,000 Ci • 25 m^3 (residual sludges)	No contamination associated with tanks; tanks and immediate vicinity consists of 0.1 acre
Landfills	• 18,500 m^3 of waste • No inventory data	2.5 acres (*3 landfills in SWSA 5 South*)
Melton Branch seep areas	• >40,000 m^3 of secondary source material (*contaminated soil*)	12 acres along southern margin of SWSA 5 South
White Oak Creek seep areas	• >11,000 m^3 of secondary source material (*contaminated soil*)	3 acres in scattered areas along D-1 and western edge of SWSA 5 South
Misc. storage vaults	• 10 m^3 volume est. (*no data*) • No data on inventory	1000 ft^2 (*immediate vicinity of vaults in SWSA 5 South*)
OHF surface facilities	• 4 Ci	2000 ft^2 (*2 bldgs*)

Specific inventory data for each type of contaminant were not available, and it therefore is useful to evaluate the remedial project areas in the context of contaminants detected during environmental monitoring activities (e.g., sampling of soil, groundwater). Table 4.3 summarizes information concerning the distribution and relative predominance of the major contaminant types in each project area (discussed in greater detail in Appendix B2). The buried LLW in SWSA 5 South contains the most diverse suite of contaminants. In most cases, these contaminants are present at significant levels. The table also shows the relationship between contaminants in the primary sources (buried wastes) and at the seep discharge points. While the buried wastes, tanks, and impoundments contain a wide variety of contamination, the principal contaminants at the seep discharge points are ^{3}H, ^{90}Sr, and, to a lesser extent, ^{137}Cs.

4.2.2 Releases and Impacts

The remedial project areas include several sources associated with significant, ongoing releases of contamination (Table 4.4). Sources in SWSA 5 South contribute large proportions of the total flux of ^{90}Sr and ^{3}H detected in surface water at White Oak Dam. Most contamination at the dam is derived from the buried wastes in WAG 5, particularly the wastes in the southern and topographically lower portions of the site. Ongoing releases are also associated with the buried TRU and fissile wastes, landfills, and OHF pond, but the magnitude of these releases is much smaller than that occurring in SWSA 5 South.

Table 4.3. Summary of contaminant types and distribution in WAG 5 remedial project areas

Remedial Project Area	Transuranic *Am, Cm, Pu*	Other α *U, Th, Ra*	Fission Prod. *Sr, Cs*	Other β–γ *Co*	Tritium	Organics
Buried LLW wastes	Major	Major	Major	Common	Major	Common
Buried TRU & fissile	Major	Common	Common	Common		
OHF tanks	Common	Common	Major	Major		
Surface impoundments			Major	Common		
Misc. storage vaults	Major	Common		Common		
Melton Branch seeps			Major		Major	
Landfills			Common			
White Oak Creek seeps			Common		Common	Common
OHF surface facilities						

EXPLANATION: Major constituent (dark shading); Common constituent (hatched); Minor constituent (blank box); Insignificant (blank box)

The dominant release mechanism is inundation of buried waste, which results in direct release to groundwater. In SWSA 5 South, approximately 90 trenches are at least partially inundated during the wetter months of the year. Other important release mechanisms include episodic, perched saturation in trenches (i.e., the water table does not rise above the base of the trenches) and seep discharge of contaminated groundwater from the buried waste areas. Discharge occurs both onto the ground surface and directly into the channels of Melton Branch and White Oak Creek.

Table 4.4 also summarizes the impact of current releases; the most significant, in terms of contaminant flux and resulting exposures and risks, are associated with discharges from the seep areas along Melton Branch. This flux is driven by the release of contamination from the buried wastes in SWSA 5 South, most of which is LLW. The fluxes associated with the other WAG 5 remedial project areas are much smaller in magnitude, and in most cases represent only minor contributions to the flux from the buried LLW.

Analyses of contaminant flux data indicate that releases from buried wastes and seep areas are likely to continue well into the future (see Sect. 3) because the release mechanisms currently active will continue to be active. Given the age of the wastes and contaminant trends shown in monitoring data, no significant changes in type, location, or magnitude of releases are expected. However, it is likely that not all of the containers buried in the trenches, auger holes, and landfills have ruptured, and changes in contaminant flux may occur as these remaining containers fail. A major unknown is the long-term integrity of the specially designed containment systems currently buried in WAG 5; these include waste containers such as the concrete casks used to dispose of TRU and alpha-contaminated LLW, the concrete and/or steel walls of the OHF storage tanks and SWSA 5 South storage vaults, and the liner of the PWSB.

The future impact of ongoing future releases is not likely to change significantly. Some decline in the concentrations of certain constituents would be expected, particularly for radionuclides such as ^3H with relatively short half-lives, but data are insufficient to estimate the rate at which depletion of the source would occur. Failure of the containment systems associated with the OHF tanks, storage vaults, and buried TRU and fissile wastes would result in potentially significant impacts as highly concentrated, high-activity and/or long-lived radionuclides were released to the subsurface. Because most of these contaminants are relatively immobile in the subsurface, however, the impacts would be localized.

Table 4.4. Assessment of current and future releases from WAG 5 remedial project areas and resulting impacts

Remedial Project Area	Current Release		Future Releases (next 30–100 years)	
	Status	Impact	Potential	Impact
Surface impoundments	• Active releases from OHF pond • No evidence of release from PWSB	• Minor contribution to groundwater already contaminated from upgradient SWSA 5 South areas	• Releases from OHF pond continue • Release from PWSB not likely due to liner	• No change from current conditions
Buried LLW	• Active release from inundated trenches	• Significant flux of ^{3}H and ^{90}Sr to groundwater	• Large-scale releases expected to continue	• Current impacts will decrease due to ^{3}H decay
Buried TRU and fissile wastes	• Active release due to inundation and perched saturation (bathtubbing)	• Contributes to contaminated seep discharges; minor impact due to low flux	• Releases expected to continue; may increase as secure containers (e.g., casks) are breached	• Long-term impacts may be significant
OHF tanks	• No evidence of release	• No impact	• Likelihood of release increases due to ongoing corrosion of tanks (cathodic protection no longer functioning)	• Potentially significant impact on Melton Branch due to high activity of wastes
Landfills	• Active release	• Contributes to overall impact from SWSA 5 South	• Active releases will continue	• Gradual depletion of source and decay may diminish impact
Melton Branch seep areas	• Active, large-scale release	• Significant flux and impact to Melton Branch	• Large-scale releases will continue	• Current impacts will decrease due to ^{3}H decay
White Oak Creek seep areas	• Active release	• Minor contribution and impact to White Oak Creek	• Releases will continue	• No significant change from existing conditions
Misc. storage vaults	• No evidence of release	• No impact	• Containment unlikely to fail within 30–100 years	• Not likely to have impact; however, if containment fails, significant impact possible to SWSA 5 South groundwater
OHF surface facilities	• No evidence of release outside of buildings	• No impact outside of buildings	• Unlikely to release unless buildings collapse	• Localized impact in OHF area

4.2.3 Relative Significance

The information presented in the preceding sections concerning the source term, area of contamination, releases, and resulting impacts for the WAG 5 remedial project areas was used to qualitatively rank the project areas (Table 4.5). These rankings provide a useful comparison of the project areas based on the different types of problems at the site as well as a potential framework for prioritization of WAG 5 remedial actions.

Table 4.5. Qualitative ranking of WAG 5 remedial project areas

	Inventory/Source Term	Area of Contamination	Impacts from Current Release	Potential Impacts of Future Release
Decreasing ↓	Buried LLW	Buried LLW wastes	MB seep areas	MB seep areas
	Buried TRU/fissile wastes	MB seep areas	Buried LLW	Buried LLW
	OHF tanks	WOC seep areas	WOC seep areas	Buried TRU/fissile wastes
	Surface impoundments	Landfills	Buried TRU/fissile wastes	OHF tanks
	Misc. storage vaults	Buried TRU/fissile wastes	Landfills	WOC seep areas
	MB seep areas	Surface impoundments	Surface impoundments	Surface impoundments
	Landfills	OHF surface facilities	OHF tanks	Misc. storage vaults
	WOC seep areas	OHF tanks	OHF surface facilities	Landfills
	OHF surface facilities	Misc. storage vaults	Misc. storage vaults	OHF surface facilities

The problems and concerns associated with each WAG 5 remedial project area have been evaluated both individually and relative to one another on a WAG-wide basis. The next step in the process is to define remediation targets so that appropriate, area-specific response actions can be identified and evaluated in terms of cost and technical feasibility. The results of this evaluation will be used to support decisions on the actual remediation work to be done on WAG 5.

4.3 POTENTIAL REMEDIATION TARGETS

Remediation targets are essentially land use and/or restoration goals that were developed to cover a full spectrum of potential remediation scenarios for WAG 5 (Table 4.6). Evaluating a range of alternatives is consistent with EPA guidance on the conduct of CERCLA feasibility studies (EPA 1988). This approach provides a stronger foundation to support risk management decisions and also ensures that realistic restoration goals are identified. The list of targets includes the following.

- *Monitoring*: Continued monitoring and maintenance to detect changes in site exposures, releases or other conditions so that appropriate future actions would be taken if needed.

- *Stabilization*: Action would be taken as needed to prevent an increase in contaminant flux of fission products and transuranics and minimize impacts to ORNL surveillance and monitoring activities.

- *Recreational use*: Expanded actions would be taken to make the site (or at least most of the site) safe for recreational use and as wildlife habitat.

Table 4.6. WAG 5 remediation targets

Target	Land Use	Overall Objective	Scope of Remediation
Monitoring	• Existing site controls and restrictions continue	• Continue monitoring to detect changes in site exposures, releases, or other conditions	• Monitoring and maintenance • Institutional controls
Stabilization	• *Existing site controls and restrictions continue*	• Prevent increases in contaminant flux of fission products and transuranics • Minimize risk impacts to surveillance and monitoring activities • *Attain objectives for monitoring target*	• Control off-WAG releases of fission products and transuranics to prevent increase in flux • Reduce on-site exposure risks impacting surveillance and monitoring (e.g., limited capping, removal of contaminated surface debris)) • *Monitoring and maintenance* • *Institutional controls*
Recreational use	• WAG 5 is incorporated into ORR wildlife management area • Limited access to recreational users (hunters—*no fishing*) • Wildlife habitat • Modified site controls and restrictions	• Remediation as needed to make the site (or at least most of the site) safe for recreational use and as wildlife habitat • *Attain objectives for stabilization and monitoring targets*	• Selective excavation and capping of areas w/high direct exposures and/or direct contact risks • Isolate (physical barriers) where removal/capping not feasible • Remove contaminated vegetation (using ecological-risk-based cleanup goals) • Fill and cap ponds • *Control off-WAG releases of fission products and transuranics to prevent increase in flux* • *Monitoring and maintenance* • *Institutional controls*

Water quality	• Site is incorporated into ORR wildlife management area
	• Expanded access to recreational users (hunting and fishing)
	• *Wildlife habitat*
	• *Modified site controls and restrictions*
		• Attain ARARs such as state water quality standards in receiving streams bordering the site (White Oak Creek and Melton Branch)
		• *Attain objectives for stabilization, monitoring, and recreational use targets*
			• Hydrologic isolation of waste sources
			  • capping of source areas to minimize recharge
			  • groundwater interception and other measures to control off-WAG releases of contamination
			• Remediate sediment hot spots within internal drainages
			• Selective excavation and capping of hot spots (areas w/high direct exposures and/or direct contact risks) in areas not associated with trenches, auger holes, or landfills
			• *Isolate (physical barriers) where removal/capping not feasible*
			• *Remove contaminated vegetation (using ecological-risk-based cleanup goals)*
			• *Fill and cap ponds*
			• *Monitoring and maintenance*
			• *Institutional controls*

Remove wastes	• Potential for limited industrial use • Some restrictions and controls	• Relocate high-activity and long-half-lived wastes to more secure disposal facility • Allow limited industrial use of the site • *Attain objectives for monitoring, stabilization, recreational use, and water quality targets*	• Excavate buried wastes in trenches, auger holes, and landfills • Remove all surface accumulations of waste from landfills • D&D of OHF surface facilities • Excavate and close ponds • Close all tank systems • *Control off-WAG releases of contamination to attain water quality ARARs* • *Remediate sediment hot spots within internal drainages* • *Selective excavation and capping of hot spots (areas w/high direct exposures and/or direct contact risk) in areas not associated with trenches, auger holes, or landfills* • *Isolate (physical barriers) where removal/capping not feasible* • *Remove contaminated vegetation (using ecological-risk-based cleanup goals)* • *Monitoring and maintenance* • *Institutional controls*

- *Water quality*: Relatively aggressive remediation measures would be taken so that discharges from the site attained ARARs such as Tennessee water quality standards in Melton Branch and White Oak Creek.

- *Remove wastes*: Relocate high-activity and long-half-life wastes to a more secure industrial facility and, in the process, potentially render the site suitable for limited industrial use

Table 4.6 summarizes the assumed land use, overall objective, and general scope of remediation associated with each remediation target. As shown in the table, the targets represent increasingly protective goals, entailing progressively more aggressive remediation efforts. Read as a continuum, each target incorporates the objectives and scope of the preceding target, such that the final one, entailing removal of wastes, would also accomplish the objectives for attaining water quality standards, recreational use, stabilization, and monitoring. Unrestricted and residential uses of the site were not considered as remediation targets because the likelihood of a feasible remedy for groundwater contamination is very low.

4.4 RESPONSE ACTIONS AND REMEDIATION POTENTIAL

The remediation targets were used to develop a remediation strategy matrix (Table 4.7) that is intended to function as the primary tool for guiding the remedial action strategy for WAG 5. For each remedial project area, the matrix presents general response actions, cost, and a feasibility rating. The value of the matrix is that it ties together the actions and costs with the likelihood of success; it also allows for a comparative analysis among the various remediation targets and project areas.

- *Actions*: The general response actions are *representative* and should not be construed to represent the only viable actions for a given remediation target. A more rigorous analysis of response actions, remediation technologies and costs, such as would be conducted for a feasibility study, would be necessary to justify the application of a specific action or technology in an area.

- *Costs*: The cost data are intended to provide a relative measure of the potential funding required to achieve the objectives for a given target. These data should be viewed as preliminary, order-of-magnitude estimates and should not be used beyond the development of this strategy. The sources of cost information included the WAG 5 baseline and cost estimates from other ER projects involving WAG 6 and the WAG 1 surface impoundments.

- *Feasibility index:* The feasibility index is a rating based on qualitative analysis of the implementability, effectiveness, and overall technical feasibility of carrying out an action (or set of actions) and achieving the objectives of the remediation target. The rating scale of 1–3 was selected to allow for a comparative analysis among the various actions and targets.

Table 4.7 shows that both cost and technology limitations increase with increasing scope and complexity of the remediation targets. Actions necessary to attain the objectives for the monitoring and stabilization targets could be readily implemented with a relatively high degree of confidence that the overall goals would be achieved. The feasibility index is lower for the expanded actions associated with the recreational use scenario, due primarily to uncertainty regarding the ability to identify and effectively mitigate all on-site exposures potentially affecting recreational users of the site.

Table 4.7. WAG 5 remediation strategy matrix

Remedial Project Area	Monitoring		Stabilization			Recreation			Water Quality			Remove Wastes		
	Cost	*FI*	Action	Cost	*FI*	Action	Cost	*FI*	Action	Cost	*FI*	Action	Cost	*FI*
Surface Impoundments	$100	*3*	• *Monitor. and maint.*	$100	*3*	• Fill and cap ponds • *Monitor. and maint.*	$2,300	*3*	• Stabilize sed., cap ponds • *Monitor, and maint.*	$12,000	*3*	• Excavate ponds • Off-site disposal	$18,000	*2*
Buried LLW	$400	*3*	• Selected capping of hot spots • *Monitor. and maint.*	$1,000	*3*	• Capping/excavation of hot spots • *Monitor. and maint.*	$2,000	*2*	• Hydrologic isolation (capping, subsurface barriers and drains) • *Monitor. and maint.*	$147,000	*1*	• Excavate wastes • Off-site disposal • *Monitor. and maint.*	$6,052,000	< *1*
Buried TRU and fissile wastes	$300	*3*	• *Monitor. and maint.*	$300	*3*	• Capping/excavation of hot spots • *Monitor. and maint.*	$1,000	*2*	• Hydrologic isolation (capping, subsurface barriers and drains) • *Monitor. and maint.*	$8,000	*1*	• Excavate wastes • Off-site disposal • *Monitor. and maint.*	$340,000	< *1*
Landfills	$100	*3*	• Surface cleanup • *Monitor. and maint.*	$250	*3*	• Capping of hot spots • *Surface cleanup* • *Monitor. and maint.*	$750	*2*	• Hydrologic isolation (capping, subsurface barriers and drains) • *Surface cleanup* • *Monitor. and maint.*	$11,500	*2*	• Excavate wastes • Off-site disposal • *Monitor. and maint.*	$118,000	*1*
Melton Branch seep areas	$400	*3*	• Selected actions to control TRU and fission product releases • Selected capping of hot spots • *Monitor. and maint.*	$3,500	*2*	• Capping/excavation of hot spots • Access barriers • *Selected actions to control TRU and fission product releases* • *Monitor. and maint.*	$4,500	*2*	• Intercept discharges (hydrologic isolation) • Remediate sediments in internal drainages • *Access barriers* • *Capping/excavation of hot spots* • *Monitor. and maint.*	$15,000	*1*	• *Intercept discharges (hydrologic isolation)* • *Remediate sediments in internal drainages* • *Access barriers* • *Capping/excavation of hot spots* • *Monitor. and maint.*	$15,000	*1*
White Oak Creek seep areas	$250	*3*	• Selected actions to control TRU and fission product releases • Selected capping of hot spots • *Monitor. and maint.*	$2,000	*2*	• Capping/excavation of hot spots • Access barriers • *Selected actions to control TRU and fission product releases* • *Monitor. and maint.*	$2,750	*2*	• Intercept discharges (hydrologic isolation) • Remediate sediments in internal drainages • *Access barriers* • *Capping/excavation of hot spots* • *Monitor. and maint.*	$5,000	*2*	• *Intercept discharges (hydrologic isolation)* • *Remediate sediments in internal drainages* • *Access barriers* • *Capping/excavation of hot spots* • *Monitor. and maint.*	$5,000	*1*
OHF tanks	$50	*3*	• *Monitor. and maint.*	$50	*3*	• Access barriers • *Monitor. and maint.*	$100	*3*	• Remove contents • *Monitor. and maint.*	$5,000	*3*	• Remove tanks and clean/close area	$7,000	*2*
Misc. storage vaults	$100	*3*	• *Monitor. and maint.*	$100	*3*	• Access barriers • *Monitor. and maint.*	$200	*3*	• *Access barriers* • *Monitor. and maint.*	$200	*3*	• Remove vaults	$20,000	*1*
OHF surface facilities	$100	*3*	• *Monitor. and maint.*	$100	*3*	• Access barriers • *Monitor. and maint.*	$200	*3*	• *Access barriers* • *Monitor. and maint.*	$200	*3*	• D&D of OHF buildings	$27,000	*1*

All costs in $1000's; monitoring cost estimates are annual costs

FI = Feasibility index; based on implementability, effectiveness and overall technical feasibility; higher values indicate greater feasibility

A much higher level of uncertainty is associated with the ability of the actions identified to attain the objectives of the water quality and waste removal targets. For the water quality target, complexities in the site hydrogeologic system, the absence of source control actions, and the potentially insurmountable difficulties in treating all of the discharges from the site render the primary components of the action—isolation of SWSA 5 South and interception of discharges along Melton Branch—as technically impracticable. A similar conclusion applies to the target of waste removal, due to the health and safety concerns associated with excavating the buried wastes and problems in trying to dispose of the excavated materials.

4.5 PRELIMINARY SCOPING OF REMEDIAL ACTIONS

The purpose of this section is to establish a framework for identifying potential near-term actions while at the same time establishing long-term goals for problems that cannot be addressed with current technologies or resources. This is accomplished through an evaluation of the strategy matrix in the context of potential benefits expected from implementing the actions under the various remediation targets. The information presented herein is intended as a starting point for future discussion between DOE, EPA, and TDEC concerning the most appropriate course of action for follow-on remediation activities.

The most significant environmental problems at WAG 5 are related to the inventory of radioactive wastes, ongoing releases, and resulting impacts from the buried LLW wastes in the trenches and auger holes in SWSA 5 South. In terms of engineering feasibility, effectiveness, or cost, there are no reasonable options that offer a comprehensive solution to the buried LLW waste problems. Options are available for selectively addressing components of the problem, as recently demonstrated through the removal action to collect and treat ^{90}Sr discharges from seep areas C and D. Actions such as these do not, however, address the buried waste source and therefore do not represent a final solution. Future technology developments or changes in the contaminant dynamics of the site may offer opportunities to implement final actions involving source control and/or isolation technologies; consequently, a comprehensive solution should be the long-term goal for the buried LLW waste.

The absence of a clear path for near-term resolution of the most significant problems does not preclude identification of near-term actions that can effectively mitigate some of the more manageable problems. A principal consideration in the identification of these near term actions is whether it makes sense to remediate portions of WAG 5 when other problems are not addressed (at least in the near term). The benefit from any actions toward cleanup of WAG 5 must therefore be weighed against the impact of not remediating the entire site—for example, it may not make sense to remediate a relatively small area adjacent to or surrounded by a much larger and more highly contaminated area. Additionally, it may not be prudent to undertake certain types of actions when the site conceptual model has shown that the area will be recontaminated in the future. An effective way to conduct this evaluation is to establish the benefits associated with the various response actions identified in the remediation strategy matrix (Table 4.7).

Table 4.8 summarizes the expected overall risk reduction benefits that would result from achieving the objectives for each remediation target. The evaluation is qualitative and based on the assumption that the objectives established for the targets (see Table 4.6) would be achieved. It is

Table 4.8. Benefits expected from reducing risk at WAG 5

Remediation Target	On-Site Land Use	Risk Reduction	
		On Site	Off Site
Monitoring	Current uses continue	Existing conditions unchanged	Existing conditions unchanged
Stabilization	Current uses continue	Low	Low to moderate
Recreational use	Limited recreational use (hunting)	Significant	Moderate
Water quality	Expanded recreational use (hunting and fishing)	Significant	Significant
Remove wastes	Potential for limited industrial use	Majority of on-site risks would be eliminated	Significant

important to note that the risk reduction expected for each target is measured against the proposed land uses (and exposures). For example, significant on-site risk reduction is expected for recreational use because the exposure scenario would be based on limited use by hunters.

Figure 4.2 summarizes the expected risk reduction benefits on a project-area-specific basis. Similar to Table 4.8, the evaluation was based on a qualitative assessment of risk reduction with the assumption that the target objectives identified in Table 4.6 would be achieved. The charts show that the most significant levels of risk reduction would be achieved with the water quality and waste removal targets, while moderate (but still measurable) risk reduction could be achieved through the stabilization and recreational use targets. Given the lower costs and greater feasibility for the stabilization and recreational use targets, cost-effective risk reduction is an attainable goal for near-term actions under either scenario.

The most appropriate near-term actions are those that demonstrate definite progress toward remediation of the site and are consistent with any future remedial actions and land uses. Both stabilization and recreational use provide a number of opportunities to implement such actions (see Tables 4.6 and 4.7 for details). Both targets entail actions that address on-site and off-site impacts; the recreational use has the added benefit of opening up at least portions of the site to expanded use (hunting, wildlife habitat). The actions necessary to attain the on-site objectives established for these targets mostly would involve widely demonstrated technologies—capping, excavation, access barriers, etc.—that could be readily implemented. Actions to address off-site releases likely would be similar to those recently implemented to intercept and treat ^{90}Sr discharges from seep areas C and D. Additional collect-and-treat systems would focus on further control of ^{90}Sr and other fission products as well as transuranics, if further monitoring and evaluation indicate that release of transuranics is a problem.

Examples of specific actions that could be undertaken as progress toward achieving the stabilization or recreational use target include filling and capping of the OHF pond and PWSB, cleanup of surface debris in the landfills, and excavation and/or capping of hot spots in areas with contaminated soil (and high exposures). All of these actions could be implemented largely on the basis of existing data and would represent meaningful progress toward eliminating on-site impacts. The contribution these areas make to the off-site release of contamination also would be reduced. Future actions would not be constrained, and in fact might be somewhat simplified by the reduction of on-site exposures.

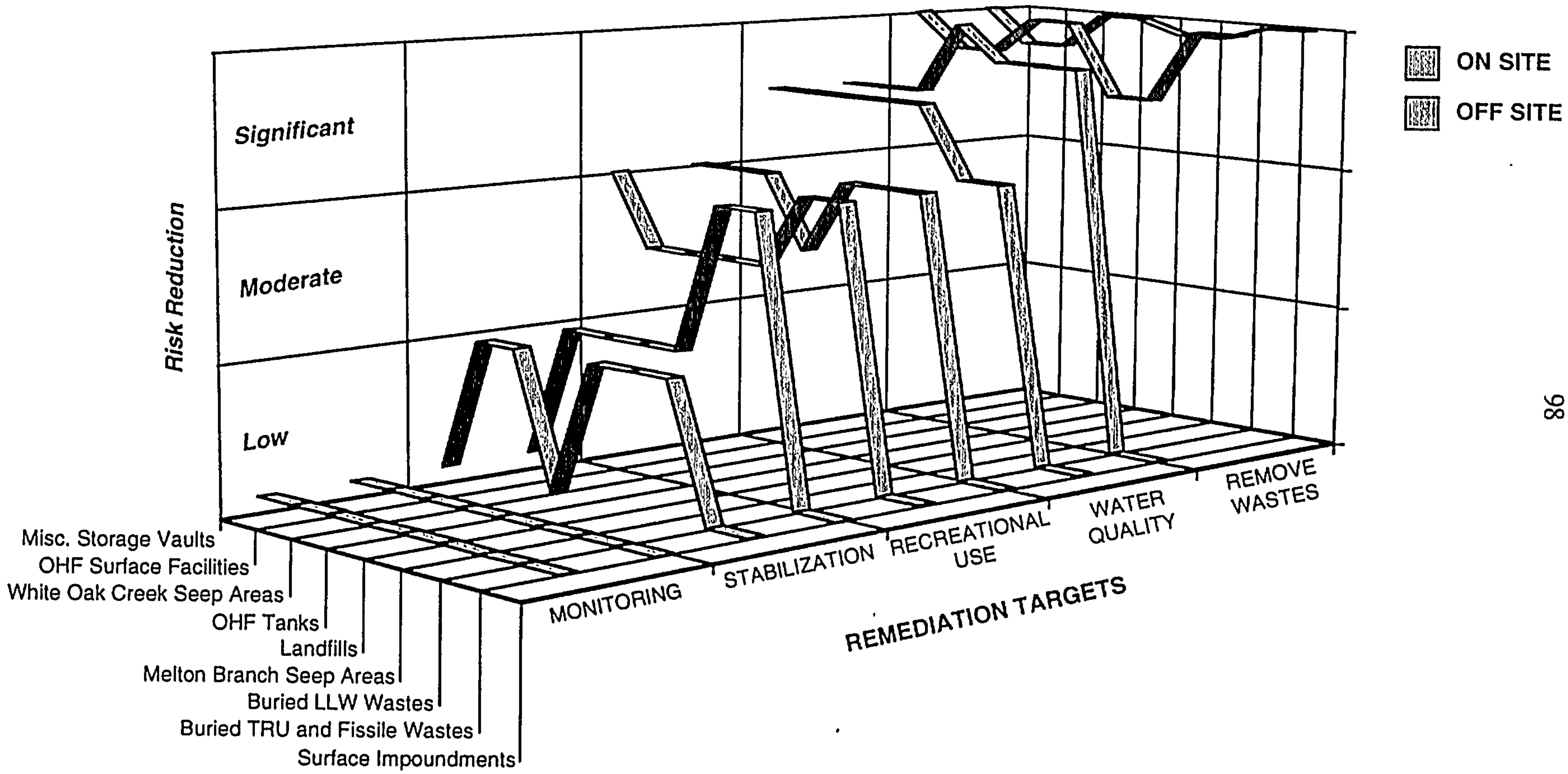

Fig. 4.2. Risk reduction comparison for WAG 5 remediation targets.

Other near-term actions designed to achieve the stabilization or recreational use targets are also possible, namely those intended to control the release of fission products and transuranics from the seep areas. These actions would require additional data collection efforts focusing on the hydrologic system and contaminant flux in the seep discharge areas. Because removal actions have already been implemented in seep areas C and D, data collection likely would focus on the southeastern corner of WAG 5 (seep areas A and B).

Monitoring is an integral component of the stabilization and recreational use targets. Monitoring objectives would include collecting information needed to evaluate the protectiveness of existing and newly implemented remedial measures as well as gathering information needed to assess the application of newly developed technologies.

In summary, evaluation of cost, feasibility, and potential benefits associated with the WAG 5 remediation targets indicates that the most appropriate near-term goals should be based on the stabilization or recreational use targets (Table 4.9). Near-term actions would thus be limited to smaller and more manageable tasks such as pond closure or hot spot capping. In the longer term, more aggressive (and costly) remedial actions can be considered if new technologies become available or site conditions change such that more aggressive actions become feasible. All near-term actions would constitute definite progress toward final remediation and could be designed and implemented to be consistent with future actions and land uses.

Table 4.9. Near-term and long-term remedial action considerations

Target	Near Term	Long Term	Additional Data Needs
Monitoring	Monitoring will be an integral component of any actions likely to be taken	Continued monitoring will be a long-term activity	None
Stabilization	Accomplishes some risk reduction through control of off-site releases of fission products and transuranics	Could be a long-term solution; also easily incorporated into more robust remedial actions	More detailed delineation of surface soil contamination and continued monitoring of off-WAG flux
Recreational use	Represents cost-effective risk reduction and progress toward greater utilization of the site	Could be a long-term solution	More detailed delineation of surface soil and vegetation contamination
Water quality	Expensive and technically impracticable given hydrogeologic complexity and insurmountable difficulties in treating collected water	Not likely to be technically feasible or cost effective	Expanded monitoring and assessment as needed to support future evaluations of this target
Remove wastes	Not reasonable given funding limitations and health and safety concerns; also entails a transfer of risk to another location and does not address secondary sources	Not likely to be technically feasible or cost effective	Continued monitoring to evaluate the status of the source; detailed waste characterization data would be needed to support future evaluations

4.6 NEXT STEPS FOR THE WAG 5 REMEDIAL ACTION STRATEGY

The purpose of this remedial action strategy discussion was to present an approach for grouping components of WAG 5 into remedial project areas, identify a range of possible options (targets) for remediation (near term and longer term), describe a possible basis for prioritizing actions, and suggesting a course of action for the next phase of environmental restoration work at the site. A final remedial action strategy, representing a consensus among DOE, TDEC and EPA, will be reached through a series of post-RI workshops to better define the issues affecting remediation decisions, select remediation targets, and integrate the WAG 5 remedial projects into the FFA prioritization system.

A number of follow-on activities will occur after the finalization of the WAG 5 remedial action strategy. These activities will be the prelude to initiation of further characterization, feasibility study, or removal action efforts.

- *Identification of project areas for early and final actions.* Candidates for early and final remedial action will be identified using elements of the *phased approach* as described in DOE's Phased Approach/Early Action Guidance (Dailey 1994). The phased approach integrates early and final actions to achieve a more logical and efficient solution to site problems. Considerations for early action include (1) urgency of the problem, (2) level of understanding about the problems in a given area, (3) intended scope of action, and (4) FFA/regulatory considerations. Early actions also are appropriate where a potential cleanup alternative and scope can be readily identified (e.g., closure of the impoundments).
- *Prioritization of remedial actions.* Prioritization of remediation activities will consider the problems at the site as well as the designation of project areas for early and final remedial action. Cost-effective risk reduction will be the goal of all remedial activities at WAG 5 (and elsewhere on the ORR), and those actions capable of accomplishing the greatest levels of risk reduction for the least cost will be given priority.
- *Defining the sequence of activities leading to remediation.* The specific tasks, scope, and funding requirements for WAG 5 remediation would be identified to support evaluation of the WAG 5 projects in the context of ORR-level ER activities. These data also will be input into the Activity Data Sheet (ADS) for WAG 5, depending on the possible actions to be implemented and the information available versus that needed to proceed with the next step (in most cases a feasibility study or EE/CA). Most of the WAG 5 sites have sufficient data to proceed to the feasibility study phase. Some data gaps that do exist could be easily addressed through focused data collection as part of a predesign investigation or treatability study. A logic-based sequence of activities will be developed that identifies the activities necessary to progress toward final cleanup, including treatability studies, proposed plan, predesign field investigations, remedial design and construction, and post-remedial action monitoring.
- *ORR-level prioritization and funding.* When sites within WAG 5 have been prioritized, the prioritization scheme will be evaluated in the context of the entire ER Program for the ORR. This evaluation will be accomplished using the environmental risk benefit assessment matrix (ERBAM) used to support work planning and establish ER Program budget priorities. The methodology for applying ERBAM is presented in the ER risk-based prioritization document (ES/ER/TM-112/Rev. 1). The other principal input into this phase of the process is ER Program funding and other resource constraints (e.g., management and staffing).
- *Implementation schedules.* Annual schedules for implementation of WAG 5 remediation tasks will be developed as part of the annual ADS cycle. This process will also identify milestones for the current year and expected milestones for the next two years.

5. RECOMMENDATIONS

This section presents recommendations for follow-on activities at WAG 5. The recommendations will be expanded to include potential remediation activities based on the results of the WAG 5 remedial action workshops discussed in Section 4.

- **Further characterization efforts at WAG 5, such as those associated with a Phase II RI, are not warranted.** Additional investigation work may be needed to support future cleanup actions, but that work should be specifically focused on the data gaps related to implementation of that action. An example of this was the expanded investigation in SWSA 5 South area C to support the design of an interceptor trench and treatment unit.

- **Continued monitoring of contamination in WAG 5 is needed to better focus future remediation.** Monitoring should be focused on the surface water pathway, which is the primary integrator of contaminant migration and flux. On-site monitoring of selected wells, seeps, and drainages should also continue. Existing monitoring programs that focus on environmental compliance should be modified as necessary to enhance their value from an environmental restoration perspective. For example, the existing monitoring program for the perimeter wells should be modified to provide a focused effort that specifically addresses monitoring needs based on proximity to a specific source or migration pathway.

- **Hydrologic monitoring of WAG 5 should continue.** Continuous water level recorders in WAG 5 wells should be maintained and, in some cases, transferred to other locations to further verify the hydrologic model. A more detailed record of water levels in the inundated trenches in SWSA 5 South would be useful in evaluating potential remedial actions for both seep discharges and buried waste sources.

- **Source documentation efforts initiated by the ORNL ER Data Management Group should continue.** These efforts provided key insight into SWSA 5 South waste types, burial locations, and disposal dates essential to the development of viable, area-specific conceptual models. Continued compilation of historical information for SWSA 5 is likely to yield even more valuable information that may affect the scope and priority of future remedial actions.

- **Environmentally relevant information in classified waste management/waste disposal files and data bases should be declassified.** This information is not likely to change the overall understanding of the SWSA 5 South source term, but it needs to be integrated into the decision-making process for future remediation.

- **Additional water quality data should be collected from drainage D1.** This information is needed for different flow regimes to identify the contaminant(s) responsible for the toxicity indicated in this drainage by the ecological risk assessment.

- **Additional chronic toxicity testing should be performed for sediments in drainages D-1 and D-2.** Concentrations of nickel, silver, and PCB Aroclor 1260 exceed ecological risk assessment benchmarks in these drainages. To determine toxicity, chronic sediment toxicity testing using either *Chironomus tentans* (a midge) or *Hyalella azteca* (an amphipod) should be performed.

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