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Phase I Remedial Investigation Report of Waste Area Grouping 2 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

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Phase I Remedial Investigation Report of Waste Area Grouping 2 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

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Editor

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ACRONYMS

ALARA	as low as reasonably achievable
ANSI/ASME	American National Standards Institute/American Society of Mechanical Engineers
ARARs	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulation
DOE	Department of Energy
EPA	Environmental Protection Agency
ER	environmental restoration
FFA	Federal Facility Agreement
HSWA	Hazardous and Solid Waste Amendments
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NQA	Nuclear Quality Assurance
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Environmental Response
OU	operable unit
PCB	polychlorinated biphenyl
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFD	reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
S&A	sampling and analysis
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SI	site investigation
TDEC	Tennessee Department of Environment and Conservation
USRADS®	Ultrasonic Ranging and Data System
WAG	Waste Area Grouping
WOC	White Oak Creek
WOCE	White Oak Creek Embayment
WOL	White Oak Lake
WQC	water quality criteria

EXECUTIVE SUMMARY

This report presents the activities and findings of the first phase of a three-phase remedial investigation (RI) of Waste Area Grouping (WAG) 2 at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, and updates the scope and strategy for WAG-2-related efforts. WAG 2 contains White Oak Creek (WOC) and its tributaries downstream of the ORNL main plant area, White Oak Lake, White Oak Creek Embayment on the Clinch River, and the associated floodplain and subsurface environment. The WOC system is the surface drainage for the major ORNL WAGs and has been exposed to a diverse array of contaminants from operations and waste disposal activities at ORNL. Water, sediment, soil, and biota in WAG 2 are contaminated and continue to receive contaminants from upgradient WAGs. WAG 2 acts as the integrator for contaminant fluxes from the contributing source WAGs and as the conduit transporting contaminants to the Clinch River. This report includes field activities completed through October 1992.

The remediation of WAG 2 is scheduled to follow the cessation of contaminant input from hydrologically upgradient WAGs. RIs and remedial actions are under way or planned for contaminated areas upgradient of WAG 2. While upgradient areas are being remediated, the strategy for WAG 2 is to conduct a long-term monitoring and investigation program that takes full advantage of WAG 2's role as an integrator of contaminant fluxes from other ORNL WAGs and focuses on four key goals:

1. Implement, in concert with other programs, long-term, multimedia environmental monitoring and tracking of contaminants leaving other WAGs, entering WAG 2, and being transported off-site.

2. Provide a conceptual framework to integrate and develop information at the watershed-level for pathways and processes that are key to contaminant movement, and so support remedial efforts at ORNL.

3. Provide periodic updates of estimates of potential risk (both human health and ecological) associated with contaminants accumulating in and moving through WAG 2 to off-site areas.

4. Support the ORNL Environmental Restoration Program efforts to prioritize, remediate, and verify remedial effectiveness for contaminated sites at ORNL, through long-term monitoring and continually updated risk assessments.

To accommodate the long-term environmental monitoring to be conducted in WAG 2 while upgradient areas are remediated, the WAG 2 RI was conceived in three phases: Phase I includes submission of the final components of the RI and the implementation of the field component of the RI (scoping surveys of the site to determine the need for interim corrective measures, preliminary identification of remedial alternatives, and initiation of the monitoring and investigation efforts); Phase II includes a long-term (10 to 15 years) multimedia environmental monitoring effort, preliminary stages of site characterization addressing the nature and extent of contamination, and a series of investigations of the pathways and processes important for contaminant movement; and Phase III includes the focused sampling and analysis to support the baseline risk assessment, feasibility study, and implementation of remedial actions. Based on the extensive site knowledge developed during Phase II, Phase III activities will be focused and streamlined consistent with the DOE "streamlined approach for environmental restoration (or

SAFER)."

Expansion of the WAG 2 RI efforts. In early FY 1992, the remedial investigation for WAG 2 was integrated with the ORNL Environmental Restoration Site Investigations program to better achieve their complementary objectives and provide an integrated basis of support for the ORNL ER Program. The combined effort was named the WAG 2 and Site Investigations (WAG 2 & SI) Program. The Site Investigation activities are a series of monitoring efforts and directed investigations that support other ER activities by providing information for (1) watershed hydrology; (2) contaminants, pathways, and fluxes for groundwater at the ORNL site, (3) shallow subsurface hydrologic pathways that move contaminants to nearby streams and that create contaminated subsurface areas that can act as secondary sources of contaminants; and (4) biological populations and contaminants in biota, in addition to other support and coordination activities. These efforts fill key information gaps by providing a watershed- or site-level perspective that is needed to effectively manage remedial actions at the ORNL site.

The WAG 2 & SI program is a key component of ORNL's remedial action strategy wherein WAG 2 has been termed an integrator operable unit because contaminant fluxes from source areas (upgradient WAGs) are integrated in WAG 2 as they move to the Clinch River. Monitoring in WAG 2 serves to identify key source areas and support a risk-based prioritization for the sources, and it will be used to guide and assess the performance of remedial efforts for contaminant source units at ORNL. Investigations conducted as part of the WAG 2 & SI program (e.g. investigations of subsurface pathways of contaminant movement from trenches in WAG 5 to surface water in WAG 2) support investigations in the source units, selection of alternatives for source control, development of performance criteria, and verification of remedial effectiveness.

Components of the Phase I RI. Activities to complete Phase I of the RI for ORNL WAG 2 include the updating of several support plans, completion of a contaminant screening, submission of the field sampling and analysis plan (SAP), required site surveys, and implementation of the field sampling efforts. Field activities were begun in March 1992. This report covers field activities completed through October 1992.

The updated support plans included a quality assurance and quality control plan, a health and safety plan, a waste management plan, and a field sampling and analysis plan (SAP). The plans were updated from information presented in the RI work plan to better meet the needs of the RI for WAG 2.

An SAP has been prepared to support the RI work plan for WAG 2 (ORNL 1990). The general objectives of the SAP plan are to support a multimedia environmental monitoring and characterization program to (1) define and monitor the input of contaminants from adjacent WAGs; (2) support a mass-balance approach to determining sources, sinks, and transport of contaminants in WAG 2 based on hydrologic fluxes; (3) document long-term trends in contaminant pools and fluxes; and (4) develop models that predict potential contaminant releases under future conditions. The WAG 2 monitoring and investigation efforts are intended to be flexible and dynamic to provide continuing information on the sources and fluxes of contaminants, to provide information for contaminant pathways and process controlling contaminant movement needed to support remedial efforts in upgradient areas (e.g., performance assessment), to provide monitoring data for contaminated media in WAG 2 during the interim period, and to respond to new information for contaminants or areas of concern in WAG 2 or adjacent areas. As a result of the long-term nature of the RI and the need for flexibility, the

WAG 2 SAP will be updated every two years (or as new information or new activities require).

The National Environmental Policy Act dictates that environmentally sensitive areas such as archeological sites, critical habitats, and floodplain and wetlands be determined for WAG 2. These surveys were conducted during Phase I to document the status of environmentally sensitive areas and to guide our sampling efforts to avoid any potentially sensitive areas in WAG 2. The results of these assessments and surveys are described in this report.

Early efforts for the WAG 2 RI included a contaminant screening report for WAG 2. A risk-based contaminant screening for WAG 2 and information for adjacent areas indicate that a number of contaminants pose significant concern for risk to human health and the environment. WAG 2 is currently under institutional control, and access is restricted. However, contaminants are currently being released from WAG 2 to off-site areas, and in the event that institutional control would be lost, contaminants in WAG 2 would constitute a highly significant risk to future occupants. Floodplain soils and aquatic sediments contain large quantities of contaminants. Most of the major contaminants in WAG 2 are particle reactive and are found associated with soils and sediments. Data for soils and sediments are available for few areas in WAG 2 and are more extensive for gamma emitting radionuclides than for metals, organic contaminants, or other radiological contaminants. External exposure from radionuclides (^{137}Cs and ^{60}Co) in sediments is a high priority for further evaluation (i.e., potential excess lifetime cancer risk $>10^{-4}$). The contaminant screening indicated that ^{90}Sr, ^{3}H, and polychlorinated biphenyls are concerns for human health from the surface water ingestion pathway. Additional data are also needed for ^{152}Eu, ^{154}Eu, ^{137}Cs, ^{235}U, arsenic, and thallium. Because groundwater discharges to surface water prior to leaving the WOC watershed, surface water is an important point of exposure to groundwater contaminants. Groundwater in WAG 2 has localized contamination by radionuclides, organics, and metals. Tritium, ^{90}Sr, and lead in groundwater are of concern for human health. Additionally, data are required for all classes of contaminants in groundwater, as well as data for groundwater pathways and fluxes.

Biota in WAG 2 have accumulated organic, inorganic, and radiological contaminants. Data from species surveys, bioaccumulation monitoring, and ambient toxicity testing suggest that severe effects are not occurring in the aquatic habitats of WAG 2. Some chemicals in surface water and sediments occurred at concentrations that are potentially toxic to sensitive species. Other chemicals that were not detected had detection limits that were higher than toxic thresholds. Additional data for nonradiological contaminants for aquatic biota and data for all classes of contaminants in terrestrial biota are needed. PCBs in fish were high priority for human health risk. Additional information is also required for ^{137}Cs and mercury in fish. Data for organic (semivolatile and volatile) compounds in several media were not sufficient to draw preliminary conclusions because for many compounds the analytical limit of detection was above the level of concern for health or environmental risk. Gross organic contamination of groundwater is found only in limited areas.

The list of applicable or relevant and appropriate regulations (ARARs) was originally presented in the WAG 2 RI Plan. ARARs that pertain to the Phase I seep data are updated in this report. As part of the ongoing RI process, compliance with ARARs will be used to screen the potential contaminants of concern (PCOCs). Consideration of ARARs alone is not sufficient because ARARs are not available for all contaminants, and ARARs do not always provide a consistent level of protection for humans or the environment. However, consideration of ARARs does provide a means of ensuring that the RI/FS for WAG 2 will proceed in such a way as to comply with regulatory standards. This section provides a brief update of the available federal and state chemical- and location-specific ARARs for COCs presented in Sect. 8.1 of the RI Plan. In addition to ARARs, EPA-recommended "action levels" for contaminants in sediments and surface water are presented to assist in selection of COCs for protection of aquatic organisms in these environmental media. No attempt will be made in this report to determine whether the regulations will be either applicable or relevant and appropriate. Action-specific ARARs will be addressed during selection of remedial alternatives for the feasibility study.

During Phase I, two extensive screening sampling rounds were conducted for WAG 2 seeps (groundwater discharge areas). Samples were collected from approximately 35 seep locations and 100 tributary and stream locations once during a wet-season and once during a dry-season baseflow condition. Data generated from these surveys have identified areas where subsurface contaminants are discharging to the surface water system. ^{3}H and ^{90}Sr were found to pose the greatest risk at White Oak Dam (WOD) from the water ingestion pathway. The highest concentrations of ^{3}H and ^{90}Sr are seen in seeps and tributaries in and around WAGs 4 and 5. Elevated levels of ^{60}Co in seeps and streams were found primarily in and around WAG 7, whereas the distributions of ^{137}Cs and gross alpha are more distributed among WAGs. In general, dissolved metal concentrations were below federal and state criteria (ARARs) in most of the seeps sampled in and around WAG 2.

Contaminant fluxes (the product of contaminant concentration and stream flow) were estimated for those locations where flow data is available. The ^{3}H and ^{90}Sr fluxes at WOD during the wet season baseflow sampling were about 9 and 3 times greater, respectively, than the fluxes during the dry season baseflow sampling. Results from both sampling rounds indicate that WAG 5 is the source for over one-half of the ^{3}H flux in the WOC watershed, with WAG 4 being the other major contributor. WAGs 1 and 5 are the main sources of ^{90}Sr, with WAG 4 being a significant contributor during the wet season.

A radiological survey of the floodplain in WAG 2 was conducted using the Ultra Sonic Ranging and Data System (USRADS). Results from the preliminary contaminant screening found ^{137}Cs in aquatic sediment and floodplain soils to be the primary contributor to human-health risk. USRADS walkover data for gamma radiation are being used to estimate initially the extent of sediment and soil contamination, to locate and define hotspots (discrete areas of high activity) and contaminant input areas and to provide information for gamma contamination for areas for which no data currently exist.

Implementation of Phase II field activities has occurred as described in the SAP; however, only seep data and gamma walkover survey data had been collected as of October 1992 (the end of the Phase I period).

1. INTRODUCTION

1.1 PURPOSE

This document reports on the efforts for the first phase of the Department of Energy's (DOE's) three-phased remedial investigation (RI) of Waste Area Grouping (WAG) 2 at Oak Ridge National Laboratory (ORNL) located in Oak Ridge, Tennessee. WAG 2 consists of White Oak Creek (WOC) and its tributaries downstream of the ORNL main plant area, White Oak Lake (WOL), White Oak Creek embayment (WOCE) on the Clinch River, and the associated floodplain and subsurface environment (Fig. 1.1). The WOC system is the surface drainage for the major ORNL WAGs and has been exposed to a diversity of contaminants from operations and waste disposal activities in the WOC watershed. WAG 2 acts as a conduit through which hydrologic fluxes carry contaminants from upgradient areas to the Clinch River. Water, sediment, soil, and biota in WAG 2 are contaminated and continue to receive contaminants from upgradient WAGs.

It is important to note that the RI Plan for ORNL WAG 2 is not to be a prototypic RI plan. The WOC system is located on the DOE Oak Ridge Reservation (ORR) (Fig. 1.1 and pockets) and drains an area of ~16.8 km^2 that includes ORNL and associated WAGs. The WOC system has been exposed to contaminants released from ORNL and associated operations for 47 years and continues to receive input from adjacent WAGs. Recognizing that full implementation of an RI is inappropriate while contaminants continue to enter the system, a phased effort has been adopted in response to the need to take initial steps to protect the public and the environment and to characterize and assess risks associated with WAG 2 and the limitations imposed by changing contaminant input.

1.2 REGULATORY INITIATIVE

The DOE ORR was added to the National Priorities List in December 1989. A Federal Facility Agreement (FFA) [under Sect. 120 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 and Sect. 6001 of the Resource Conservation and Recovery Act (RCRA)] between DOE, the U.S. Environmental Protection Agency (EPA) Region IV, and the Tennessee Department of Environment and Conservation (TDEC) was signed and made effective January 1, 1992. These parties intend to coordinate DOE's CERCLA/RCRA response obligations with the corrective measures required and conducted by DOE under its current Hazardous and Solid Waste Amendments permit, and they expect the response actions under the FFA, together with the corrective measures under the permit, to achieve comprehensive remediation of releases and threatened releases of hazardous substances, hazardous wastes, pollutants, or contaminants at or from ORNL.

The RCRA corrective action process and the CERCLA remedial action process are similar and operate in a parallel manner, as shown in Fig. 1.2. In addition, the requirements of the National Environmental Policy Act (NEPA) will be integrated into the RCRA corrective action and CERCLA remedial action processes (see Fig. 1.2). On August 2, 1988, the DOE Office of the Assistant Secretary for Environment, Safety, and Health issued DOE Notice 5400.4, which established DOE's policy of integrating the statutory requirements of NEPA and CERCLA. Such integration is intended to (1) avoid

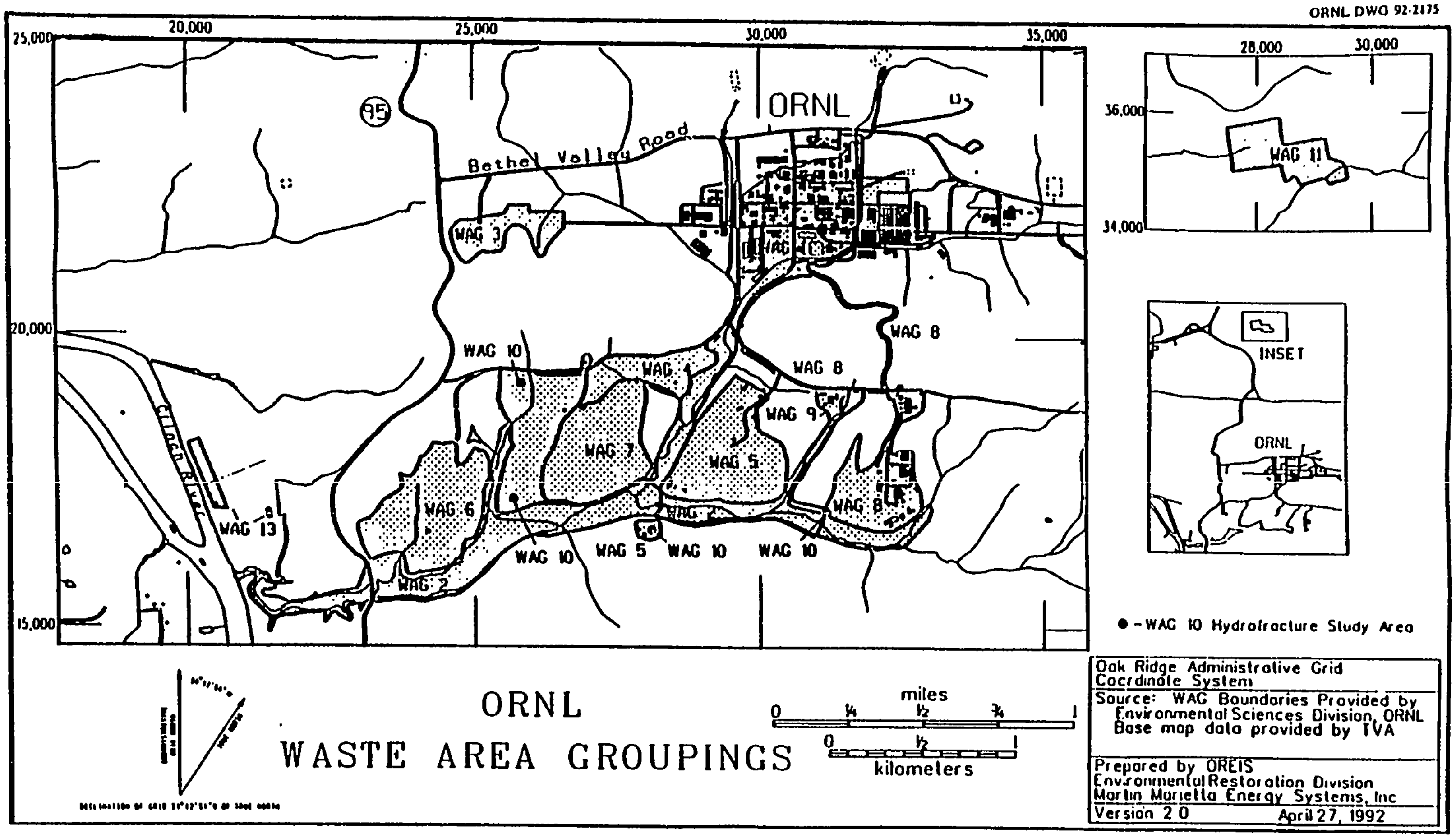

Fig. 1.1. ORNL waste area groupings map.

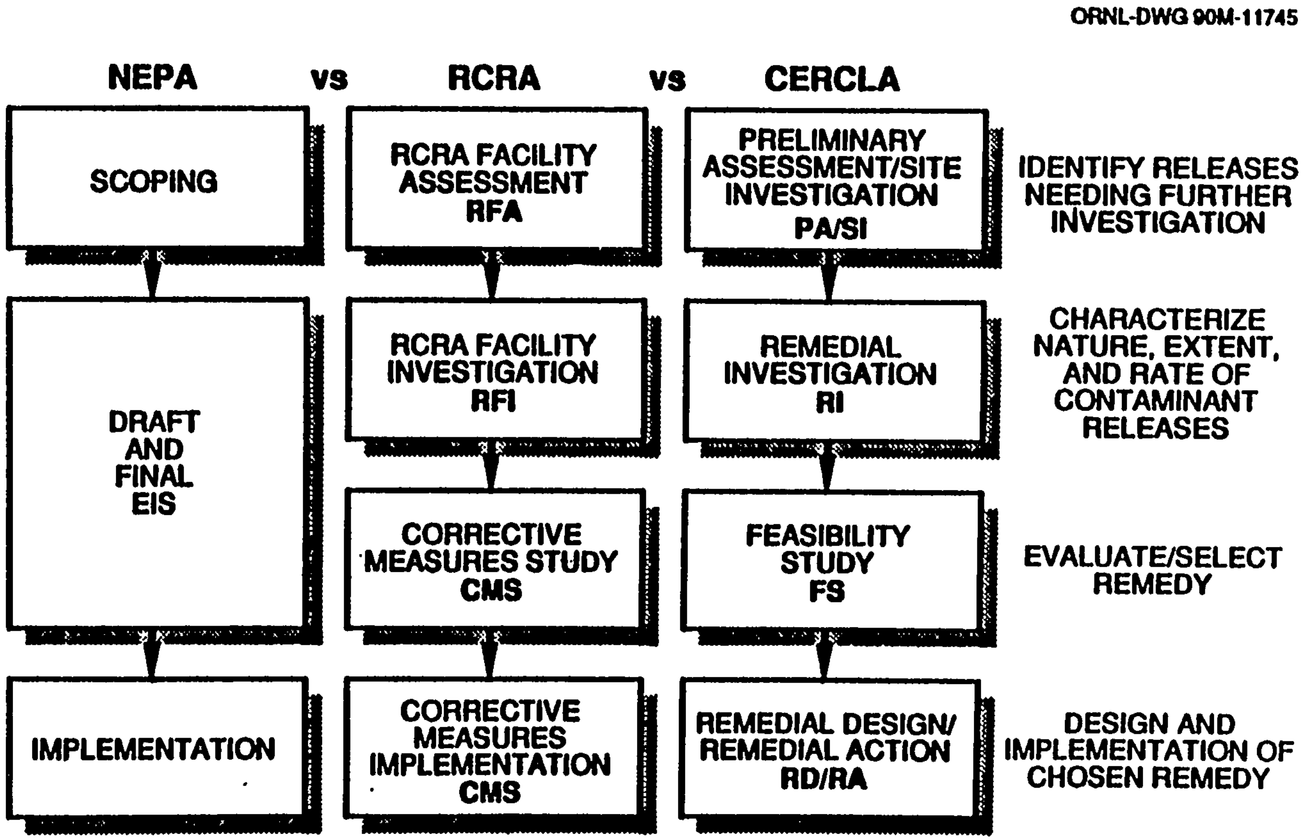

Fig. 1.2. Comparison of the NEPA process, the RCRA corrective action process, and the CERCLA remedial action process.

duplicated effort and the associated larger commitment of resources that would be needed to implement both NEPA and the CERCLA Remedial Investigation/Feasibility Study (RI/FS) separately, (2) avoid conflicts in analysis and the choice of a remedial alternative, and (3) minimize the risk of delaying remedial actions on procedural grounds. Levine et al. (in press) have provided specific guidance for the integration of NEPA and CERCLA requirements during corrective action/remedial action responses at DOE facilities.

1.3 OAK RIDGE RESERVATION ENVIRONMENTAL RESTORATION PROGRAM

A site-specific plan has been developed for ORR that addresses corrective activities, environmental restoration (ER), and waste management operations (Jones et al. 1990). ORNL is managed for DOE by Martin Marietta Energy Systems, Inc. (Energy Systems). Energy Systems manages the environmental, safety, and health programs at ORNL and supports the DOE Oak Ridge Operations (DOE-ORO) organization in the management of the overall environmental, safety, and health program. The responsibility for all environmental restoration and waste management activities has been placed with the Energy Systems Assistant Manager for Environmental Restoration and Waste Management. A series of corrective activities have been identified and prioritized at ORNL to bring the facilities into compliance with applicable federal, state, and local requirements (Jones et al. 1990). DOE corrective activities and Environmental Restoration and Waste Management Operations programs must comply with the Atomic Energy Act, other federal and state statutes and regulations, and DOE orders (Sect. 1.2.3 of *DOE Environmental Restorations and Waste Management Five-Year Plan,* January 1993). The major federal and state statutes applicable to corrective activities, environmental restoration, waste operations, and other applicable agreements and orders are summarized in the *Site-Specific Plan for the Oak Ridge Reservation Environmental Restoration and Waste Management* (Jones et al. 1990).

The state of Tennessee administers its own RCRA program under the Tennessee Hazardous Waste Management Act through TDEC. Region IV of EPA administers the federal RCRA program, including the Hazardous and Solid Waste Amendments.

1.4 ORNL ENVIRONMENTAL RESTORATION PROGRAM

The ORNL site was established in 1943, and 47 years of operations have produced a diverse legacy of contaminated inactive facilities, research areas, and waste disposal areas that are potential candidates for remedial action. ORNL initially developed a site specific Remedial Action Program that represents a comprehensive effort to meet new regulatory requirements at about 250 sites (Trabalka and Myrick 1987). The Remedial Action Program has been superseded by the ER Program through Energy Systems (Jones et al. 1990).

Because of the large number of sites and the hydrologic complexity at ORNL, the strategy developed in response to regulatory requirements has been oriented toward WAGs rather than individual sites. The WAGs are generally defined by watersheds that contain contiguous and similar remedial action sites. In some cases, there has been hydrologic interaction among the sites within a WAG, making individual sites hydrologically inseparable. The use of groupings provides perimeter monitoring of both groundwater and surface water and the development of a response that is protective of human health and environment. Twenty WAGs have been identified at ORNL, of which 13 are definite candidates for further action.

The ORNL ER Program was established to coordinate DOE's response obligations to the CERCLA and RCRA and other relevant regulations. The program manages remedial efforts to achieve comprehensive remediation of releases and threatened releases of hazardous substances, hazardous wastes, pollutants, or contaminants at or from ORNL. The ORNL ER Program follows a structured path of site characterization, site maintenance and surveillance, interim corrective action, alternate assessment, technology development, engineering design, and eventual site closure or remediation.

1.5 WAG 2 RI STRUCTURE

Expansion of the WAG 2 RI efforts. In early FY 1992, the remedial investigation for WAG 2 was integrated with the ORNL Environmental Restoration Site Investigations program to better achieve their complementary objectives and provide an integrated basis of support for the ORNL ER Program. The combined effort was named the WAG 2 and Site Investigations (WAG 2 & SI) Program. The Site Investigation activities are a series of monitoring efforts and directed investigations that support other ER activities by providing information for (1) watershed hydrology; (2) contaminants, pathways, and fluxes for groundwater at the ORNL site, (3) shallow subsurface hydrologic pathways that move contaminants to nearby streams and that create contaminated subsurface areas that can act as secondary sources of contaminants; and (4) biological populations and contaminants in biota, in addition to other support and coordination activities. These efforts fill key information gaps by providing a watershed- or site-level perspective that is needed to effectively manage remedial actions at the ORNL site.

The WAG 2 & SI program is a key component of ORNL's remedial action strategy wherein WAG 2 has been termed an integrator operable unit because contaminant fluxes from source areas (upgradient WAGs) are integrated in WAG 2 as they move to the Clinch River. Monitoring in WAG 2 serves to identify key source areas and support a risk-based prioritization for the sources, and it will be used to assess the performance of remedial efforts for contaminant source units at ORNL. Investigations conducted as part of the WAG 2 & SI program (e.g. investigations of subsurface pathways of contaminant movement from trenches in WAG 5 to surface water in WAG 2) support investigations in the source units, selection of alternatives for source control, development of performance criteria, and verification of remedial effectiveness.

1.6 OBJECTIVES OF THE WAG 2 RI

The RI Plan for WAG 2 (ORNL 1990), submitted in December 1990, presents a strategy that takes advantage of the location of WAG 2 as a conduit and integrator of contaminant fluxes from the other ORNL WAGs. The WAG 2 RI Plan reviewed data for contaminants in WAG 2. This section summarizes the salient findings of that review and notes preliminary data needs. To take full advantage of WAG 2's role as an integrator of contaminants from other ORNL WAGs, we have developed a long-term S&A strategy aimed at four key goals.

1. Implement, in concert with other programs, long-term multi-media environmental monitoring and tracking of contaminants leaving other WAGs, entering WAG 2, and being transported off-site.

2. Provide a conceptual framework to integrate and develop information at the watershed-level for pathways and processes that are key to contaminant movement, and so support remedial efforts at ORNL.

3. Provide periodic updates of estimates of potential risk (both human health and ecological) associated with contaminants accumulating in and moving through WAG 2 to off-site areas.

4. Support the ORNL ER Program efforts to prioritize, remediate, and verify remedial effectiveness for contaminated sites at ORNL through long-term monitoring and continually updated risk assessments.

Past practices have resulted in the widespread contamination of WAG 2. Discharges and releases from existing operations and contaminated areas are a continuing source of contaminants to WAG 2 (see ORNL [1990] Sects. 5 and 6). Although substantial information exists for some radiological contaminants in some areas and for media in other areas, media data are frequently not available or are insufficient, and data for nonradiological contaminants are generally sparse. Because WAG 2 is actively receiving contaminants and releasing contaminants to the Clinch River (off-site), we need information on contaminant pathways and fluxes. We need to develop the means to monitor those fluxes important for human health and environmental risk considerations. In addition, we need models to link contaminant transport through the watershed, to predict contaminant releases under future conditions, and to evaluate risks to off-site areas.

1.6.1 Surface Water Quality

Surface water quality is monitored at several locations in the WOC watershed (see Clapp et al. 1992 and ORNL 1990). Surface water quality in WAG 2 generally meets the National Pollutant Discharge Elimination System (NPDES) permit requirements and contaminant concentrations because WOC inputs to the Clinch River are all below drinking water standards after mixing and dilution with the Clinch River. The concentrations of some metals are elevated above background, and high concentrations of ^{3}H and ^{90}Sr in streams in the Melton Branch arm of the drainage system would constitute a human health risk if consumed (Sect. 4). Thus, contaminant inputs need to be quantified (e.g., monitoring of seeps and tributaries), and the fate of key contaminants needs to be determined. Additional data are needed for metals and organic contaminants from all reaches.

1.6.2 Soils, Sediments, and Sediment Transport

Although contaminants enter WAG 2 primarily in soluble form, most of the contaminants of concern in WAG 2 are particle reactive (e.g., ^{137}Cs, ^{60}Co, PCBs, lead, mercury) and so are found associated with aquatic and floodplain sediments. Contaminated sediments can be mobilized during high-discharge events and by human activities. Thus, sediments are an important pathway for transport and exposure for these contaminants. Data for the WOCE and WOL indicate that large inventories of contaminants reside in the sediments. These inventories reflect the contributions of upgradient contaminant source areas. The primary risk to off-site areas results from the transport of ^{137}Cs in sediments (Blaylock et al. 1991). Because sediments are mobilized and transported during storms, we need information for contaminant transport during high-flow conditions to track contaminant releases. Further, there is a need to be able to predict contaminant releases during extreme hydrological events (e.g., a storm with a 100-year return frequency) and to incorporate the influences of watershed modification as a result of remedial actions (e.g., capping) and other development on the contaminant releases. Thus, we need to develop and validate models capable of predicting sediment transport at the watershed level and that link WAG and non-WAG areas with the Clinch River.

There are large areas of the WAG 2 floodplain for which no data exist. For most other areas of the floodplain, few data for nonradiological contaminants exist. Sediment analyses may be useful for identifying contaminant sources. Data for sediments are also needed to determine the inventories of contaminants in the system as these relate to the potential for contaminant transport off-site and the evaluation of corrective measures.

1.6.3 Surface Water Hydrology

Hydrologic fluxes drive contaminant fluxes; hence, data for watershed hydrology are needed. Accurate information for surface water discharge is needed to construct reach-by-reach mass balances of contaminant transport needed to quantify fluxes and to identify source areas. Basic information for hydrology (precipitation, evapotranspiration, surface water flow) are needed to drive models of contaminant transport and to provide a basis for evaluating changes in contaminant movement.

1.6.4 Groundwater (Subsurface Environment)

The hydrogeology of the WOC watershed was discussed in the WAG 2 RI Plan (ORNL 1990). Existing information suggests that groundwater contamination can be important in localized areas but is not widespread (see ORNL [1990], Sect. 6.3). In the WOC watershed, groundwater elevations (water table) tend to follow surface topography. Greater than 95% of groundwater discharges into surface water prior to leaving the watershed, and no substantial flow leaves the basin as groundwater (Solomon et al. 1991). Additional information for fluxes and flow pathways of deep groundwater are needed to evaluate contaminant fate, transport, and exposure for individual WAGs and for the entire watershed. Because groundwater phenomena occur on a large scale (i.e., greater than a single WAG), aspects of subsurface transport of contaminants benefit from watershed-level information.

Because virtually all of the groundwater flux in the WOC watershed discharges to surface water prior to leaving the watershed, the identification and monitoring of springs and seeps (groundwater discharge areas) can help to identify, quantify, and track contaminant fluxes. This information is important for evaluating contaminant transport and potential exposure routes for risk assessment, determining the nature and extent of contamination, and designing remedial actions.

The stormflow zone is a shallow zone approximately corresponding to the root zone of the vegetation that is much more permeable than the unsaturated zone (Moore 1988). Stormflow is transient but may be a locally important pathway for water following precipitation events (Moore 1988; Solomon et al. 1991). The role of the stormflow zone for contaminant transport into WAG 2 is currently being investigated by the WAG 2 SI Program. An understanding of hydrologic and contaminant fluxes in the stormflow zone and techniques to monitor stormflow are needed to ensure that the remedial alternatives selected are appropriate for mitigating contaminant fluxes. Monitoring in WAG 2 can provide information on contaminant fluxes via the stormflow zone and, so, meet the needs of WAG 2 and source WAGs in evaluating contaminant fluxes.

Contaminants moving through the subsurface can diffuse into soil and rock matrices. These contaminated fractures and pore spaces can act as secondary sources that continue to release contaminants after the upgradient primary sources (buried wastes) have been remediated. Information on this process is needed to evaluate corrective measures for the ORNL WAGs.

1.6.5 Biota

The Biological Monitoring and Abatement Program (BMAP) provides extensive information for contaminants in aquatic and some terrestrial biota (see ORNL [1990], Sects. 5 and 6). Aquatic biota accumulate ^{137}Cs, ^{60}Co, ^{90}Sr, mercury, PCBs, and chlordane. The influence of sediment contaminants on the aquatic biota needs to be evaluated. Floodplain vegetation is contaminated with radionuclides (primarily ^{3}H, ^{90}Sr, and ^{99}Tc); however, few data are available for other contaminants. Resident and migratory waterfowl accumulate contaminants and are a potential pathway of exposure for the public to contaminants from WAG 2.

Terrestrial biota are important for the movement of contaminants and the potential transfer to humans. Terrestrial biota may also be at direct risk from exposure to contaminants. Data for terrestrial biota are generally needed.

1.6.6 Other Sources of Information

A number of monitoring programs, assessment programs, as well as RIs are under way in the WOC watershed or directly downgradient (i.e., the Clinch River RI [CRRI]). These programs constitute an important source of information and provide opportunities for collaboration. Interactions with these projects and programs are discussed in Clapp et al. 1992 Sect. 2.3.1. Besides current monitoring programs, data to satisfy some of the identified data gaps can be obtained from historical information. WAG 2 made extensive use of historical data in the development of the WAG 2 RI Plan (ES/ER-14&D1) and is actively engaged in data integration with current monitoring programs.

1.7 RATIONALE AND SCOPE

Remedial investigations and remediations are either under way or are planned for contaminated areas hydrologically upgradient of WAG 2; therefore, contaminant inputs will change as individual upgradient areas are remediated and as natural decay processes occur. Because remediations undertaken in WAG 2 in the short term could be negated by future contaminant input, implementation of corrective measures in WAG 2 will likely follow the completion of remediation of upgradient WAGs. However, because the WOC system acts as a conduit for contaminants from upgradient areas and because WAG 2 has accumulated contaminants that may represent near-term hazards, a phased remedial investigation in WAG 2 has been initiated.

WAG 2 is complex and dynamic with diverse sources of contaminants and fluxes driven by changing environmental conditions. Rather than an exhaustive site characterization for all contaminants, media, and flow pathways, we will (1) focus on contaminants and pathways of greatest concern and (2) monitor and gather sufficient information for processes controlling or driving contaminant fluxes to construct an appropriate conceptual model for contaminant source areas and fluxes in WAG 2. This approach is analogous to the observational approach and allows the early identification of remedial alternatives and focuses efforts on the gathering of data useful for evaluating alternatives to reduce risk.

1.8 STRATEGY AND EARLY EFFORTS

The goals of the preliminary stages of the sampling and analysis plan (SAP) (i.e., the first 2 years of efforts described herein) were: (1) scoping and screening studies to form a basis for statistical design of longer-term sampling and monitoring programs; (2) development of procedures, selection of sites, and initial implementation of the monitoring and tracking efforts; and (3) collection of information for components and contaminants for which few data exist to update the preliminary evaluations of human health and ecological risk. Data from surveys and initial sampling efforts are being used to stratify the system for later sampling efforts, to estimate the initial level of variance for parameters of interest, and to determine the cost required to reduce the uncertainty in the estimates of risk. These activities support the four key goals listed previously as well as support the preliminary components of the RI for WAG 2 (i.e., preliminary site characterization, updated estimates of health and ecological risk, development of a site conceptual model, and identification of operable units).

The general objectives and goals of the preliminary stages of the SAP have been listed previously. As noted, the initial efforts focused on selected radionuclides that are major contributors to human health risks, and fewer samples will be analyzed for metals, organics, and other radionuclides. This approach allows us to focus on primary sources of risk and to determine if data for selected radionuclides can be used to guide future sampling for other contaminants of concern.

Much of the effort during the first 2 years focused on completing the Phase I activities described in this report. Phase I activities consisted of submission of the final components of the RI Plan and the implementation of the field component of the RI (seep, tributary, and floodplain soils gamma walkover scoping surveys; preliminary identification of remedial alternatives; and initiation of Phase II multimedia environmental monitoring and investigative efforts). Phase II monitoring and investigative efforts are generally described below. Sediments, are an important source area for all contaminants of concern, except ^{3}H and ^{90}Sr, and contaminants are transported off-site with sediments during high-discharge events. Sediment and contaminant transport during storms will be quantified, and preliminary inventories of major contaminants in sediments will be developed. Models will be developed in collaboration with other projects to predict contaminant input into WAG 2, movement within WAG 2, and transport to the Clinch River. Hydrologically driven contaminant transport models are needed because contaminant transport will vary due to natural environmental factors (e.g., precipitation), changing land use in the watershed (e.g., increased paving), and remedial activities (e.g., capping) in upgradient WAGs.

Seeps and tributaries provide useful points at which to detect, quantify, and monitor contaminant input from adjacent WAGs to WAG 2. Seeps are especially important as connections between contaminated groundwater and surface water in WAG 2. Seeps and tributaries contributing to contaminant fluxes will continue to be identified and monitored.

Data now becoming available from environmental monitoring efforts at ORNL will be used to evaluate the nature and extent of groundwater contamination and to determine the pathways of groundwater transport. Hydrogeologic investigations will evaluate the importance of groundwater flow from adjacent WAGs through WAG 2 to discharge in local streams. Data provided by the seep sampling program will also support the groundwater efforts.

We are gathering preliminary data for contaminants in biota (e.g., PCBs) that (1) are important for potential human health risk, (2) are needed to update estimates of ecological risk, and (3) can be useful as indicators of contaminant availability in the system. WAG 2 efforts will serve as a focal point for ecological assessment in the White Oak Creek watershed.

Monitoring activities at ORNL [e.g., Biological Monitoring and Abatement Program, NPDES, and environmental surveillance surface water and groundwater monitoring] provide an important source of information as well as opportunities for collaboration on data collection. Activities related to environmental restoration [e.g., RIs and RCRA facility investigations (RFIs)] underway in the WOC watershed and the Clinch River (Off-Site ER Program) by necessity are linked to the WAG 2 project. Data from all activities are being evaluated for utility and acceptability under WAG 2 RI data quality objectives. These projects and monitoring programs are being integrated with the WAG 2 RI S&A efforts. It is important to use any and all available data. WAG 2 is actively pursuing technical information exchange among other ER projects, as well as ORNL monitoring programs.

The monitoring program supports a mass-balance (i.e., input, storage, and release) approach for discrete reaches of WAG 2. Reaches will be subdivided as required based on contaminant input, inventory, and potential remedial action. This approach translates to the identification of operable units to be considered for corrective measures or eliminated from further efforts. Data from these efforts will be used to update the risk assessment and refine the remedial planning approach. The multimedia environmental monitoring effort will evolve as new information becomes available and as needs and conditions change.

1.9 WORK SCHEDULE AND DELIVERABLES

The proposed schedule for the WAG 2 RI (Fig. 1.3) has been divided into three phases: Phase I consists of submission of the RI plan and a scoping survey of the site to determine the need for interim corrective measures, Phase II includes the multimedia environmental monitoring program currently being implemented and preliminary stages of site characterization to be conducted during the period in which remedial efforts were underway in upgradient WAGs (the interim 10 to 15 year period), and Phase III consists of the formal components of a typical RI consistent with CERCLA. Phase I was partially completed with submission of the RI plan. As noted in the plan, the complexity of the WAG 2 system did not allow completion of the preliminary contaminant screening analysis or formulation of a detailed SAP at the time the document was submitted.

The WAG 2 RI plan is not a prototypic work plan but will be developed and submitted in stages during the period that upgradient WAGs are being remediated as new information becomes available and as needs and conditions change. Annual addenda to the SAP will be presented to regulators in July for comment, and interim RI reports will be published on an as-needed basis. We recognize that the EPA and the TDEC have reserved the right to require modifications at any stage of these efforts. Furthermore, we recognize that availability of funding resulting from changes in prioritization under the FFA may affect the schedule of activities.

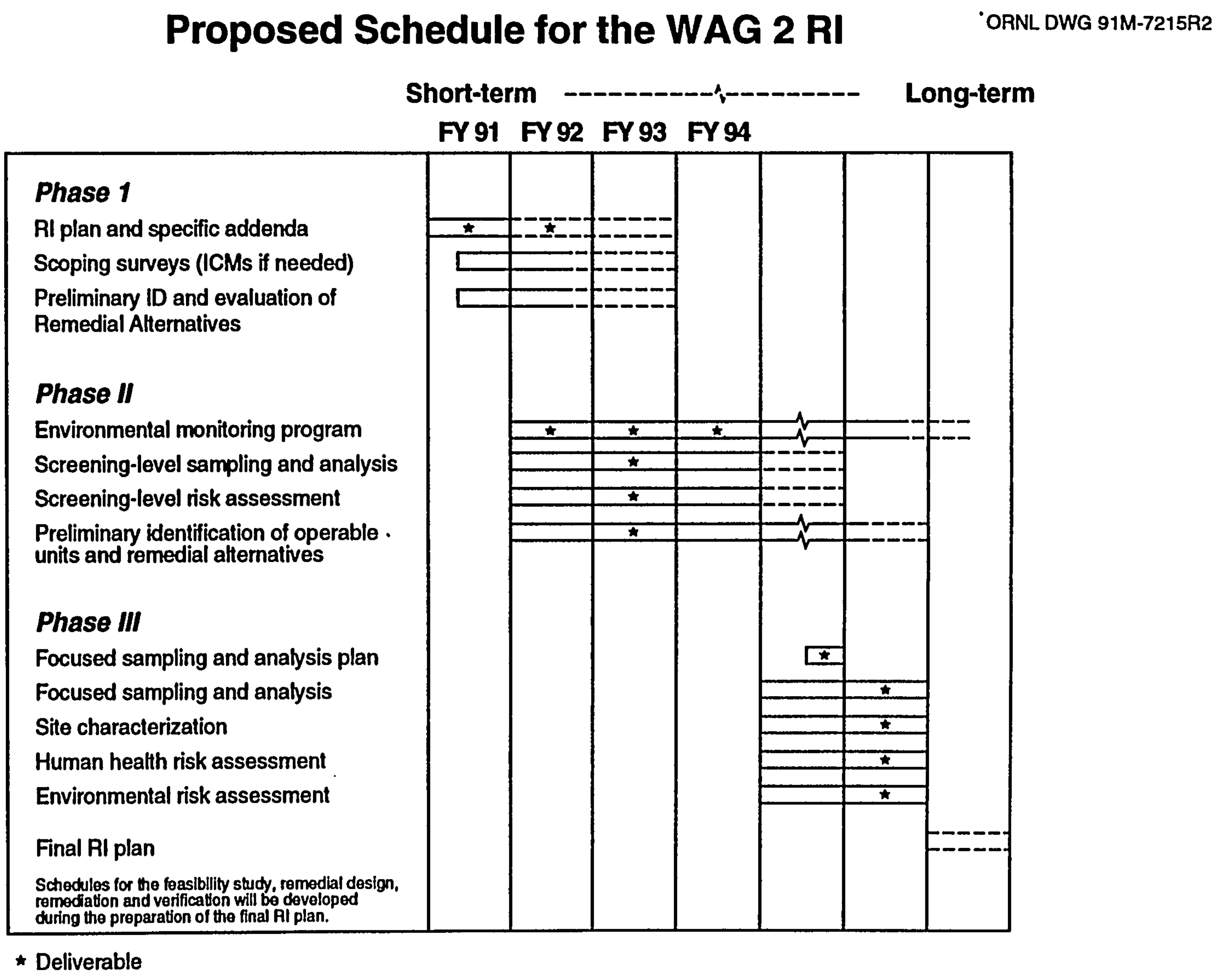

Fig. 1.3. Proposed schedule for the WAG 2 RI.

1.10 REPORT ORGANIZATION

This report is organized as follows:

- Section 2 describes updated addenda to the RI Plan.
- Section 3 describes Phase I activities related to the National Environmental Policy Act.
- Section 4 summarizes the human health and ecological screening-level risk assessment conducted as part of Phase I.
- Section 5 presents updates on applicable or relevant and appropriate requirements since the publication of the RI Plan.
- Section 6 presents the Phase I seep and tributary sampling and analysis results.
- Section 7 presents the sampling methodology and results of WOC floodplain gamma walkover survey conducted with the Ultrasonic Ranging and Data System.
- Section 8 describes the process of setting preliminary remedial action goals for WAG 2.
- Section 9 summarizes the conclusions and recommendations of the aforementioned sections.

2. UPDATED SUPPORT PLANS

2.1 INTRODUCTION

The WAG 2 RI Plan is structured with a short-term component to be conducted while upgradient WAGs are being investigated and remediated and a long-term component that will complete the RI process following the remediation of upgradient WAGs. This approach calls for a staged effort (characterization, monitoring, risk assessment, remedial action) which is continuously enhanced as new data is generated. WAG 2 is not a prototypic RI and therefore updated support plans to the RI Plan are necessary to reflect current efforts. The RI support plans which were developed during Phase I are described below.

2.2 SAMPLING AND ANALYSIS PLAN

The SAP for the WAG 2 RI (Boston et al. 1992) was issued in February 1992. The purpose of the SAP is to collect physical data and to collect and analyze environmental samples for physical, chemical, and biological parameters to support the WAG 2 environmental monitoring program and to form a basis for the preliminary components of the formal remedial investigation/feasibility study (RI/FS) for WAG 2. The SAP for the WAG 2 RI project will also make important contributions to the management of remedial activities in the WOC watershed. Because Phase II sampling and analysis activities are long-term (10 to 15 years), addenda to the SAP will be published every 12 to 24 months.

These SAP activities support a multimedia environmental monitoring program that defines and tracks contaminant inputs into WAG 2, address the short-term needs to protect the public and the environment, support other remedial efforts at ORNL, and form a basis for the eventual remediation of WAG 2. Specifically, the SAP supports the preliminary components of the RI/FS for WAG 2 by (1) providing a preliminary characterization of the nature and extent of contamination in WAG 2, (2) quantifying the risk to human health and the environment resulting from the contamination, (3) identifying operable units, and (4) developing a conceptual model to evaluate potential corrective measures for the WOC watershed. The Phase I and preliminary Phase II S&A components described in the SAP are outlined below.

A. SEDIMENT SAMPLING PLAN

1. Conduct floodplain radiological walkover and stream sediment surveys.
    a. Radiological walkover.
    b. Floodplain soil sampling.
    c. Preliminary stream sediment sampling.

2. Sample contaminant transport during storms.

3. Quantify and track contaminant inventories in stream sediments and identify contaminant sources.
    a. Distribution and inventory of radiological contaminants in stream sediments.
    b. Stream gravel survey program.

4. Develop models to predict sediment transport for the WOC watershed.

   a. Develop a quantitative data base for evaluating phenomena observed (stage-discharge-sediment flux) during high-discharge events.
   b. Predict contaminant transport under future conditions.
   c. Provide estimates of uncertainty in model results.
   d. Link models for sediment transport in the WOC watershed with similar efforts for the Clinch River RI.

B. SURFACE WATER SAMPLING PLAN

1. Determine contaminant fluxes in surface water.

2. Identify tributaries that contribute significantly to contaminant flux within WAG 2.

3. Monitor tributaries to quantify contaminant fluxes.

4. Identify areas (discrete or diffuse) of groundwater discharge that contribute significantly to contaminant flux in the streams.

5. Monitor seeps to quantify contaminant fluxes.

C. GROUNDWATER SAMPLING PLAN

1. Incorporate existing and incoming data into a dataset to serve as a reference for testing hypotheses and interpreting groundwater flow and geochemical data.

2. Conduct statistical pattern recognition analysis of groundwater data.

3. Evaluate the importance of groundwater flow in migration of contaminants from adjacent WAGs.

4. Cooperate with ongoing investigations to evaluate the role of the stormflow zone in contaminant transport in WAG 5 and to evaluate the importance of matrix diffusion and the creation of secondary source areas for contaminant release from WAG 5 to WAG 2.

D. BIOTA SAMPLING PLAN

1. Expand an existing model of the WAG 2 ecosystem to incorporate organisms at risk and important pathways to humans.

2. Integrate BMAP data and data from other WAGs to quantify contaminant movement through the food chains.

3. Obtain data on contaminant levels in organisms identified as important but not covered by BMAP or other WAG programs.

4. Continually update ecological assessment.

2.3 QUALITY ASSURANCE PLAN

The WAG 2 Quality Assurance (QA) Plan (ORNL/ER-134) was published in December 1992 as an addendum to the Remedial Investigation plan for Waste Area Grouping 2 at Oak Ridge national Laboratory, Oak Ridge, Tennessee (ES/ER-14&D1). The QA Plan is designed to comply with the Environmental Restoration Program's QA Program, and with ES/ER/TM-4R2 (Energy Systems 1992), Department of Energy (DOE) Order 5700.6C, U.S. Environmental Protection Agency (EPA) QAMS-005/80 and American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1 guidelines. EPA QAMS-005-80 (EPA 1980) contains EPA's guidance for project QA/Quality Control (QC) plans. ANSI/ASME NQA-1 (ANSI/ASME 1989) has been adopted as the main QA/QC standard. Because this plan falls under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulation, the WAG 2 QA plan is subject to. Office of Solid Waste and Environmental Response (OSWER) Directive 9502.00-6C (EPA 1987a), OSWER Directive 9355.0-76 (EPA 1987b), and OSWER Directive 9355.3-01 (EPA 1988a).

QA is an integral component of the WAG 2 & SI Project efforts. Audits and surveillances were performed by DOE-ORO, MMES Central QA, and WAG 2 QA staff to review and evaluate the adequacy of field and laboratory performance, and to ascertain whether the QA Plan was completely and uniformly implemented. Results of the audits and surveillances were documented and reported to WAG 2 and ER management. Corrective actions generated were monitored by the WAG 2 QA Coordinator.

2.4 HEALTH AND SAFETY

The Health and Safety Plan for the Remedial Investigation of the WAG 2 will be updated as an addendum to the WAG 2 RI Plan. This document expands upon the Health and Safety Plan described in the RI Plan. The objectives of the Health and Safety Plan is to ensure that safe working conditions exist during all sampling and laboratory activities by describing applicable policies, requirements, quality assurance measures, and methods. The Health and Safety Plan is designed to comply with appropriate DOE orders, Occupational Safety and Health Administration (OSHA) Standard, 29CFR 1910 and 1926, applicable Environmental Protection Agency requirements, and consensus standards.

2.5 WASTE MANAGEMENT PLAN

The WAG 2 Waste Management Plan will be updated and published as an addendum to the RI Plan. This document expands upon the Waste Management plan presented in the WAG 2 RI Plan. The updated Project Waste Management Plan was developed in accordance with published regulatory standards that are used as compliance documents at ORNL and other DOE-owned or DOE-controlled sites. The Project Waste Management Plan defines the criteria used and methods to be used for managing waste generated during activities associated with WAG 2. The waste management strategy adopted in this Plan manages waste generation on a systematic basis using the most appropriate combination of waste reduction, segregation, treatment, storage, and disposal practices, while protecting the environment and human health through ALARA (as low as reasonably achievable) practices.

3. NEPA DOCUMENTATION

3.1 INTRODUCTION

Section 102 of The National Environmental Policy Act (NEPA) of 1969 as amended (NEPA, Pub.L 91-190,42 U.S.C.4321-4347) establishes national policies and goals for the protection of the environment. All Federal agencies are required to give appropriate consideration to the environmental effects of their proposed actions in their decision making. In January 1992, WAG 2 received permission to proceed with Phase I activities after conducting an Internal Environmental Assessment (see Appendix A). Additional NEPA documentation efforts were initiated for planned Phase II activities and are described in the following paragraphs.

During the Fall of 1992, surveillances were conducted to describe threatened and endangered species, wetlands, and archeological resources located within WAG 2. These surveys were conducted to assess overall protection of human health and the environment and to achieve compliance with Applicable or Relevant and Appropriate Requirements (ARARs). The wetlands surveillance was used specifically to support the development of the Floodplain and Wetlands Assessment as required under NEPA.

3.2 WETLANDS DELINEATION

Prior to preparing the Floodplain and Wetlands Assessment, wetlands located within WAG 2 boundaries were identified and delineated. Field methodology for wetland identification was based on the 1987 U.S. Army Corps of Engineers (USACOE) Wetland Delineation manual. In accordance with the USCOE methods, the following three characteristics are diagnostic of wetlands:

1. the prevalent vegetation consists of macrophytes typically adapted to wetland soil and hydrological conditions;
2. the substrate is undrained hydric soil; and
3. the area is inundated either permanently or periodically at depths <6.6 ft, or the soil is saturated to the surface at some time during the growing season of the prevalent vegetation.

Results of the wetland delineation survey are shown in Fig. 3.1. This survey indicates that approximately one-third of the WAG 2 area is comprised of wetland areas. Most of the wetland areas were observed to have free water within 12 in. of the surface and/or saturated soils during all spring and summer site visits. On the September site visit, some of the wetland areas did not have the previously described wetland conditions.

3.3 FLOODPLAIN AND WETLAND ASSESSMENT

Executive Order 11988, Floodplain Management, and the National Environmental Policy Act of 1969 (Public Law 91-190; 91Stat. 852; 42USC 4321-4347) requires each Federal agency to ensure that any action taken in a floodplain or wetland are evaluated and impacts are minimized. To meet this requirement, a wetlands survey and a floodplain and wetlands assessment was prepared to describe proposed actions, discuss the effects of that action on the

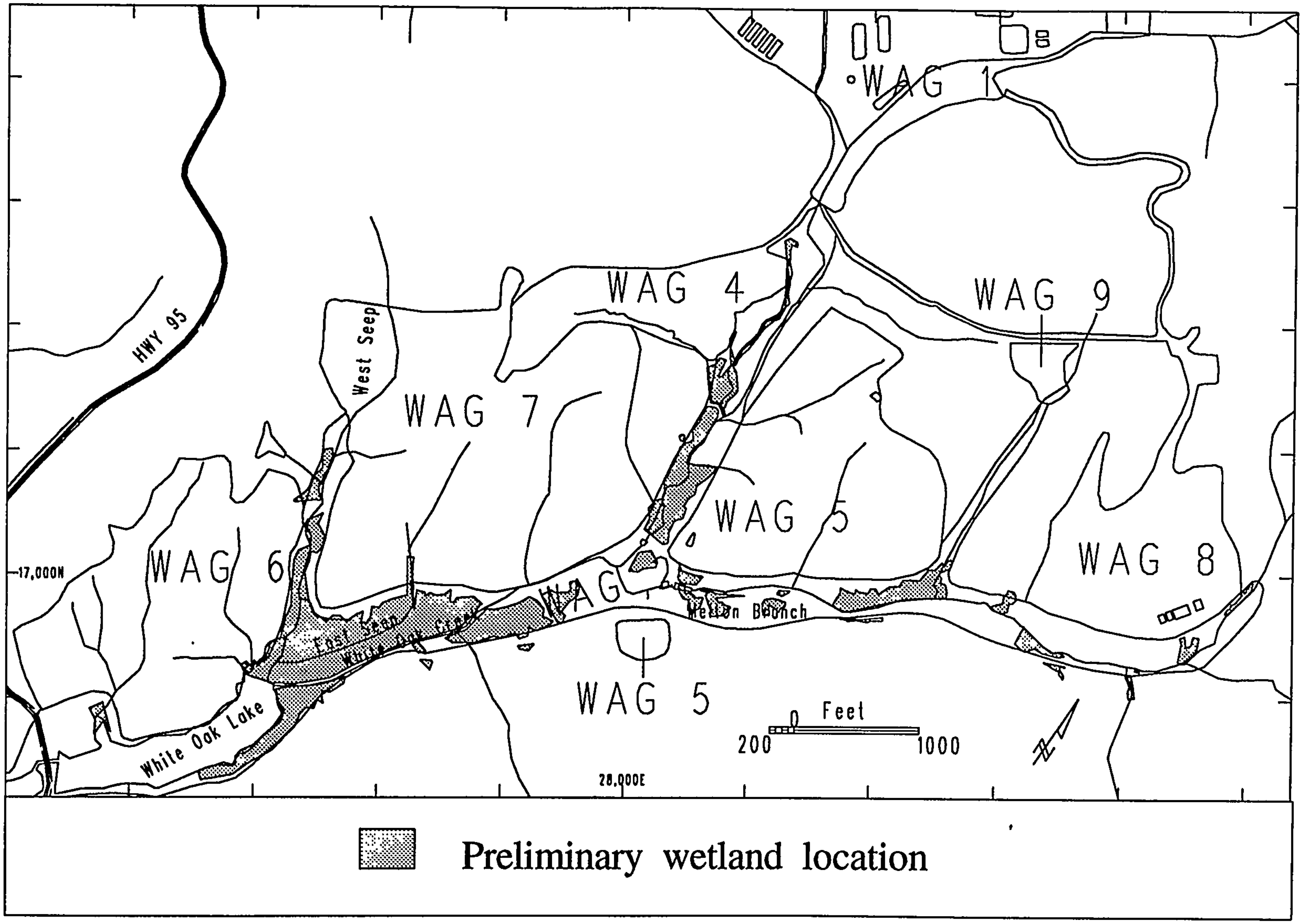

Fig. 3.1. Wetlands delineation map.

floodplain and wetlands, and consider possible alternatives to potential wetland and floodplain disturbance.

A Floodplain and Wetlands Assessment was prepared in accordance with the Department of Energy's (DOE) Code of Federal Regulation 10CFR 1022. Since the proposed WAG 2 actions did not require either an Environmental Assessment or an Environmental Impact Statement, the Floodplain and Wetlands Assessment was prepared as a separate document. A Notice of Floodplain and Wetlands Involvement (NOI) was submitted to DOE-HQ in November 1992 and is pending publication in the Federal Register. A Statement of Findings has been prepared and will be published in the Federal Register following 15 day NOI public review period. The use of an existing categorical exclusion (CX-GEN-207) is anticipated following publication of the Floodplain Statement of Findings.

3.4 THREATENED AND ENDANGERED SPECIES

Surveys of threatened and endangered plant and animal species were conducted in compliance with the Threatened and Endangered Species Act of 1973, 50 CFR Part 402. During these surveys, the WAG 2 area was explored for plant or animal species that are listed or proposed for listing as endangered (E), threatened (T), or of special concern (S) by the State of Tennessee and/or the U.S. Fish and Wildlife Service and for potential habitat for these species.

Results of the threatened and endangered plant survey indicate that two-state-listed species, lesser ladies tresses (*Spiranthes ovalis*) and butternut (*Juglans cinerea*), were found in the survey area. In addition, it is highly likely that an unlisted but rare species, the river bulrush (*Scirpus fluviatis*), is growing in a wetland adjacent to White Oak Lake. A list of rare plant species found on the Oak Ridge Reservation (ORR) and an explanation of the status codes is presented in Table 3.1.

Results of the threatened and endangered animal species surveys on WAG 2 indicate that no threatened or endangered animal species (aquatic and terrestrial invertebrates and vertebrates) or critical habitat listed, or proposed to be listed by the U.S. Fish and Wildlife Service is known to be present on the WAG 2 site. However, the endangered Indiana bat is a potential summer visitor to the ORR. Several animal species listed by he State of Tennessee as threatened (T), endangered (E), or in need of management (INM) are known to occur on the ORR. Environmental considerations for any proposed project that would disturb habitats where T, E. or INM species occurs must include the potentially affected species. Table 3.2 indicates the locations where T,E, or INM species may occur on the ORR. Any proposed project that would not affect habitats in these locations would not be expected to affect the species. Results of this survey do not impact proposed activities for WAG 2.

3.5 ARCHEOLOGICAL AND HISTORIC SITES

In August, 1992 a reconnaissance was conducted to assess adverse impacts to cultural resources located within the WAG 2 boundaries in compliance with the National Historic Preservation Act of 1966 (Public Law 89-665; 16 USC 470; 80 Stat. 915), NEPA, and Executive Order 11593 (May 13, 1971). The reconnaissance included the White Oak Lake impoundment and the Melton Branch and White Oak Creek floodplain and consisted of a pedestrian survey and shovel tests. Terrain features, vegetation cover, soil conditions and prior disturbances were noted and were coupled with shovel test excavations on moderate to high probability areas. The soil material was then trowel-sorted to investigate the potential for historic remnants.

Based on the reconnaissance, a search of the site files at the Tennessee Division of Archeology, and a search of the National Register of Historic Places, the project will have no impact on any property included in or eligible for inclusion in the National Register of Historic places pursuant to 36CFR60.4(d).

Table 3.1. Rare plant species found on the Oak Ridge Reservation (ORR)

Scientific name	Common name	State status	Federal status
Aureolaria patula	Spreading false-foxglove	T	C1
Carex gravida	Gravid sedge	S	
Cimicifuga rubifolia	Appalachian bugbane	T	C2
Cypripedium acaule	Pink lady-slipper	E*	
Delphinium exaltatum	Tall larkspur	E	C2
Diervilla lonicera	Northern Bush-honeysuckle	T	
Elodea nuttallii	Nutall waterweed	S	
Fothergilla major	Mountain witch-alder	T	
Hydrastis canadensis	Golden seal	T	3C
Juglans cinerea	Butternut	T	C2
Lilium canadense	Canada lily	T	
Lilium michiganense[a]	Michigan lily	T	
Liparis loeselii	Fen orchid	E	
Panax quinquefolium	Ginseng	T	3C
Platanthera flava var herbiola	Tubercled rein-orchid	T	
Platanthera peramoena	Purple fringeless orchid	T	3C
Saxifraga careyana	Carey saxifrage	S	3C
Spiranthes ovalis	Lesser ladies-tresses	S	

[a] *Lilium michiganense* may have extirpated from ORR by the impoundment at Melton Hill.

Explanation of status codes used (adapted from the Tennessee Department of Conservation, Ecological Services Division, Rare and Endangered Plant Listing, January 17, 1991):

State
E = Endangered. Species now in danger of becoming extinct in Tennessee because of (a) their rarity throughout their range, or (b) their rarity in Tennessee as a result of sensitive habitat destruction or restricted area of distribution.
E* = Taxa considered to be endangered in Tennessee due to evidence of large numbers being taken from the wild and lack of commercial success with propagation or transplantation.
T = Threatened. Species likely to become endangered in the immediately foreseeable future as a result of rapid habitat destruction or commercial exploitation.
S = Special concern. Species requiring special concern because of (a) their rarity in Tennessee because the state represents the limit or near-limit of their geographic range, or (b) their status is undetermined of insufficient information.
Federal (Determined by the U.S. Fish and Wildlife Service)
C1 = Taxa for which the U.S. Fish and Wildlife Service has on file substantial information on biological vulnerability and threats to support the appropriateness to list them as endangered or threatened species. Included are those taxa whose status in recent past is known, but may have already become extinct.
C2 = Taxa for which information now in possession of the Service indicated that proposing to list them as endangered or threatened is appropriate, but for which substantial data on biological vulnerability and threat(s) are not currently known or on file to support a proposed rule.
3C = Taxa that have proven to be more abundant or widespread than was previously believed and/or those that are not subject to any identifiable threat.

Note: The taxa listed in Categories 1 and 2 may be considered candidates for addition to the list of endangered and threatened plants and, as such, consideration should be given them in environmental planning.

Table 3.2. Possible location of threatened, endangered, or in need of management species on the Oak Ridge Reservation

Species	Status	Location
		U.S. Fish and Wildlife Service
Indiana bat	E[a]	Vicinity of East Fork Poplar Creek
		State of Tennessee
Tennessee dace	INM[b]	Bear Creek drainage, Ish Creek, and tributaries of East Fork Poplar Creek (siltation due to erosion in the vicinity of the creeks must be avoided)
Osprey	E	Vicinity of Melton Hill Lake and Clinch River
Sharp-shinned hawk	E	Area Between Jones Island, Grubb Island, and 5-kV power line
Cooper's hawk	T[c]	Entire Oak Ridge Reservation[d]
Grasshopper sparrow	T	Large grassy fields
Black-crowned night-heron	INM	Clinch River
Black vulture	INM	Entire Oak Ridge Reservation[d]; an active nest site is located on Chestnut Ridge between Highway 95 and New Zion Patrol Road
Red-shouldered hawk	INM	Forests and fields along the Clinch River and relatively large streams[d]
Common barn owl	INM	Freel's bend and vicinity

No threatened or endangered animal species is known to occur on the WAG 2 site, and none should be affected by the proposed activities.

[a] Endangered.
[b] In need of management.
[c] Threatened.
[d] During survey or construction activities at a project site, project personnel should report any observations of hawks or vultures indicating possible nesting on the site or vicinity.

4. RISK ASSESSMENTS

4.1 INTRODUCTION

During Phase I, a human health and ecological risk screening analysis was conducted for contaminants found in WAG 2. The purpose of this section is to describe the methodologies and summarize the results of the human-health and ecological screening-level risk assessments reported in the Screening of Contaminants report issued in September, 1992 (Blaylock et al. 1992). To avoid redundancy, risk assessment data tables are not presented in this report but can be found in Blaylock et al. 1992. WAG 2 is a surface-water integrator operable unit (OU) that receives contaminants from several source OUs. For human health risk assessment purposes, WAG 2 was divided into four sections identified as reaches (Fig. 4.1). Reach 1 extends from the weir on White Oak Creek upstream to the 7500 bridge at WOC km 3.5. Reach 2 extends from the weir on Melton Branch upstream to km 1.5. Reach 3 extends upstream from White Oak Dam to the weirs on White Oak Creek and Melton Branch and includes White Oak Lake and its floodplain. Reach 4 is White Oak Creek Embayment. By analyzing the data from each reach separately, contaminants and exposure pathways of concern in each reach can be identified. The ecological risk component is not presented according to reach. Because WAG 2 is an integrator unit, results of the screening analyses can be used as a reference for measuring the effectiveness of remedial activities.

4.2 HUMAN HEALTH

4.2.1 Human Health Screening-Level Risk Assessments

Two human-health screening-level risk assessments have been completed for WAG 2 and they were based primarily on historical data. One assessment included White Oak Creek Embayment (Reach 4) (Blaylock et al. 1993) and the other included White Oak Lake and its tributaries (Reaches 1, 2, and 3) (Blaylock et al. 1992). Prior to 1992, White Oak Creek Embayment was included in the Clinch River Remedial Investigation (CRRI) (Energy Systems 1990); however, high levels of ^{137}Cs were found in sediment samples taken near the mouth of the embayment during Phase I of the CRRI. As a result, a coffercell-type sediment-retention structure was constructed at the mouth of the embayment in 1992 and the embayment is now considered part of WAG 2 (Leslie and Kimmel 1992).

An observational approach is used in the WAG 2 Remedial Investigation, i.e., as data become available, they are subjected to a screening analysis, and the results of these preliminary assessments are used to focus future sampling efforts on the contaminants of greatest concern to human health. The preliminary risk screening provides a means of estimating the contribution of different areas, media, and contaminants to the risk of adverse health effects for the entire system.

Future sampling efforts also need to be guided by data gaps and full scan analytical samples with appropriate detection limits to ensure that all necessary data are available to assess risks and develop remedial alternatives. The balance between focusing strictly on the "priority" contaminants in WAG 2 and filling data gaps on other contaminants should be guided through the use of data quality objectives. Adequate data will be collected to fill identified data quality objectives.

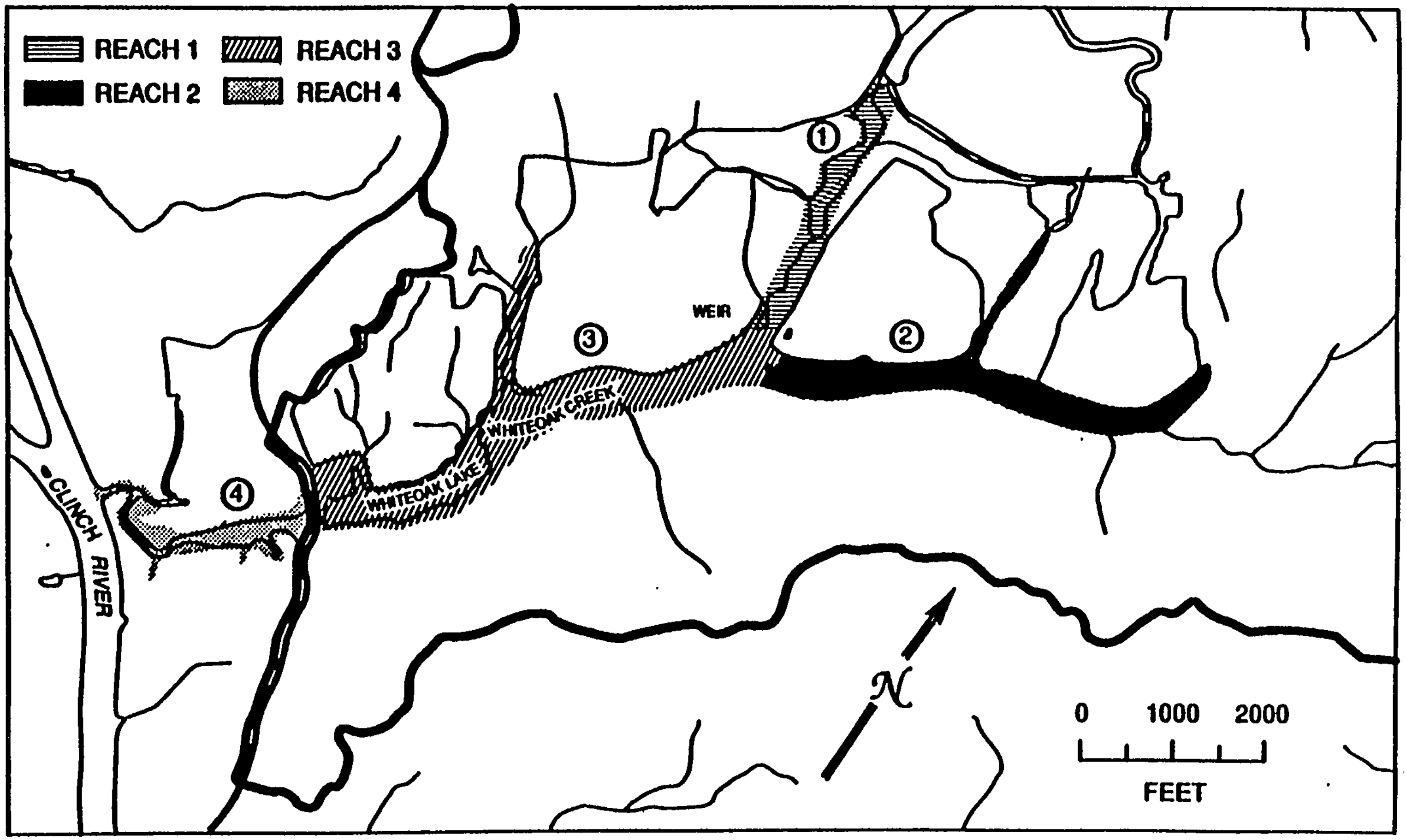

Fig. 4.1. WAG 2 reaches defined for human health and ecological risk screening.

4.2.2 Screening Approach

The purpose of the two screening assessments was to identify the contaminants in WAG 2 that are of concern to human health and to provide guidance for the collection of additional data that can be used to conduct a baseline risk assessment. The screening assessments used a dual approach to estimate the potential for adverse human health effects (Blaylock et al. 1992, 1993). One approach used conservatively biased calculations and assumptions to identify contaminants, exposure pathways, and reaches that have a low priority for further investigation. It is unlikely that these conservative calculations would underestimate the potential maximum exposure to an individual in the critical subgroup of the population. The other approach used nonconservative calculations and assumptions to identify contaminants, pathways, and reaches that have a high priority for further investigation. These nonconservative risk estimates should not substantially overestimate maximum exposures to critical subgroups of the population. The results provided by the screening assessments do not constitute a baseline risk assessment and are not intended to address issues regarding compliance with regulatory limits.

4.2.3 Exposure Pathways

Only four exposure pathways were considered in the WAG 2 screening assessments (Blaylock 1992): (1) external exposure from shoreline sediment and floodplain soils, (2) ingestion of sediment and floodplain soil, (3) ingestion of fish, and (4) ingestion of water. The exposure pathways were for a resident scenario. Calculations were also made for an intruder scenario. The intruder scenario represented a highly improbably but nevertheless possible situation where a hunter/fisherman enters WAG 2 illegally and obtains fish, waterfowl, and venison for food over a ten-year period.

4.2.4 Data Bases

Data used in the screening assessments were obtained from monitoring programs, surveys, and scientific studies and included measurements of contaminants in sediment/floodplain soil, water, deer, fish, and waterfowl. Data were available for both surface water and groundwater; but, because the groundwater data were incomplete at the time of the assessment, they were analyzed separately.

The data were divided into two data sets for use in the screening analyses. One set consisted of contaminants for which at least one measurement for a contaminant was above the level of detection (detectable contaminants). The other data set consisted of contaminants for which all measurements were below the level of detection (nondetectable contaminants). The lowest detection limit was used to represent the nondetectable contaminants in the data sets. The upper 95% confidence limit of the arithmetic mean was used as the contaminant concentration for both detectable and nondetectable contaminants in the conservative screening scenarios. The geometric mean was used as the contaminant concentration of detectable contaminants in the nonconservative and intruder scenarios, and the lowest limit of detection that was reported for nondetectable contaminants was used in nonconservative screening scenarios. Nondetectable contaminants were not considered in the intruder scenario.

The lowest detection limit for the screening level risk assessment was used in order to provide a more conservative screening of the nondetectable contaminants and to accommodate small sample numbers in some cases. The results of the screening level risk assessment are reported in ORNL/ER-62/R1, *Screening of Contaminants in Waste Area Grouping 2 at Oak*

Ridge National Laboratory, Oak Ridge, Tennessee. Future baseline risk assessment will follow the standard EPA Region IV risk assessment practices to use half the detection limit value for the nondetects to represent their concentrations, rather than using the lowest detection limit.

4.2.5 Criteria for Screening-Level Risk Assessments

In the screening assessments, screening indices were calculated for each contaminant in WAG 2 to quantify the risk of adverse health effects for the different exposure pathways. These indices are based upon EPA-approved or -suggested slope factors for carcinogens and toxicity reference doses (RFDs) for noncarcinogens. Slope factors are based upon an estimate of the lifetime risk of an incremental cancer incidence per unit of exposure. The RFD is an exposure level (threshold) below which no adverse health effects should occur.

Conservative and nonconservative screening criteria were applied to the EPA action level (Federal Register March 8, 1990) to categorize contaminants as low priority, high priority, or requiring further investigation before being designated as either high or low priority. Low priority indicates that a contaminant is of little concern for further investigation; high priority requires either immediate consideration for remediation or further analysis; and contaminants identified as neither low nor high priority must be evaluated further before this determination can be made. Fig. 4.2 summarizes the screening criteria that was used for categorizing carcinogens, and Fig. 4.3 summarizes the criteria for noncarcinogens.

4.2.6 Media

Water. Surface water in the WAG 2 OU is a component of an integrated hydrologic system. Most of the surface water in WAG 2 is shallow groundwater that has emerged at the surface. Surface water is important because it transports contaminants in the dissolved state and on suspended particles from contaminated areas in the White Oak Creek (WOC) watershed into White Oak Lake (WOL). Contaminants released in surface water over White Oak Dam may be absorbed on to particles and subsequently deposited as sediment in White Oak Creek Embayment or they may be carried in a soluble form into the Clinch River. Surface water is one of the primary pathways by which contaminants are released to the off-site environment from the ORR. Potential direct exposure to humans from contaminants in surface water can occur from (1) the consumption of water, (2) the consumption of biota which have accumulated contaminants from water, and (3) recreational activities.

Monitoring wells are located within the boundary of WAG 2 to measure the concentration of contaminants in the groundwater. These wells are placed at strategic locations[1] to provide data for use in hydrologic models designed to elucidate the role of groundwater in transporting contaminants from one area to another. As a result, the reported concentrations of contaminants in groundwater may not be representative of actual groundwater concentrations within a reach. A separate screening analysis was conducted for the ingestion of groundwater because the data were incomplete at the time of the screening analysis. No groundwater data were available for Reach 4 (Blaylock et al. 1993). With respect to representativeness of groundwater well contaminant concentrations, the monitoring wells referred to in this section were intended to

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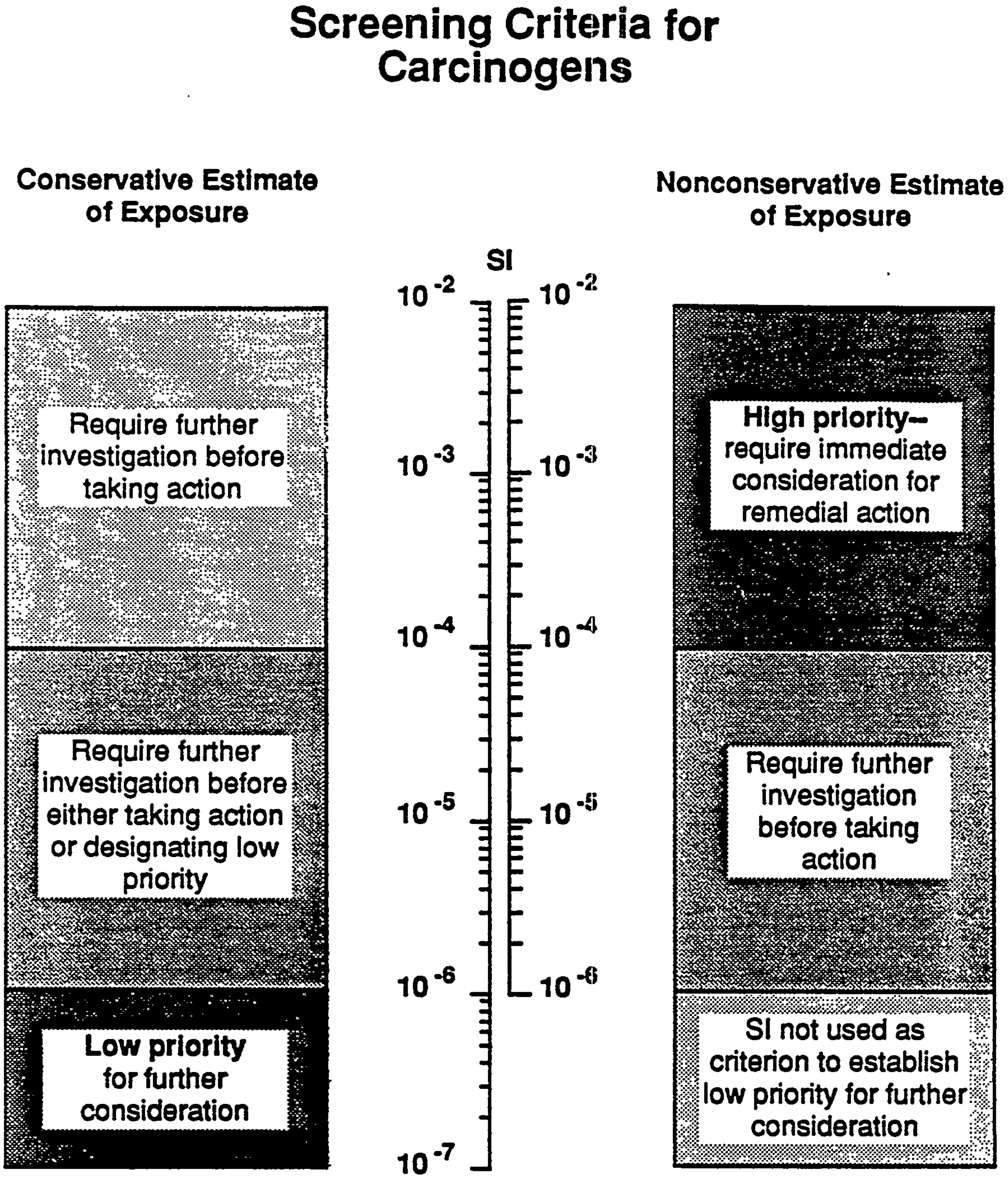
[1] Additional references with monitoring well locations: *Second Annual Report of the Environmental Monitoring and Assessment Program at Oak Ridge National Laboratory* (ORNL/ER-180) and the *Annual Work Plan—1994 for the Waste Area Grouping 2 and Site Investigations Project at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (ORNL/ER-196).



Screening index (SI) = exposure multiplied by a lifetime cancer slope factor

Fig. 4.2. Criteria for screening of carcinogens.

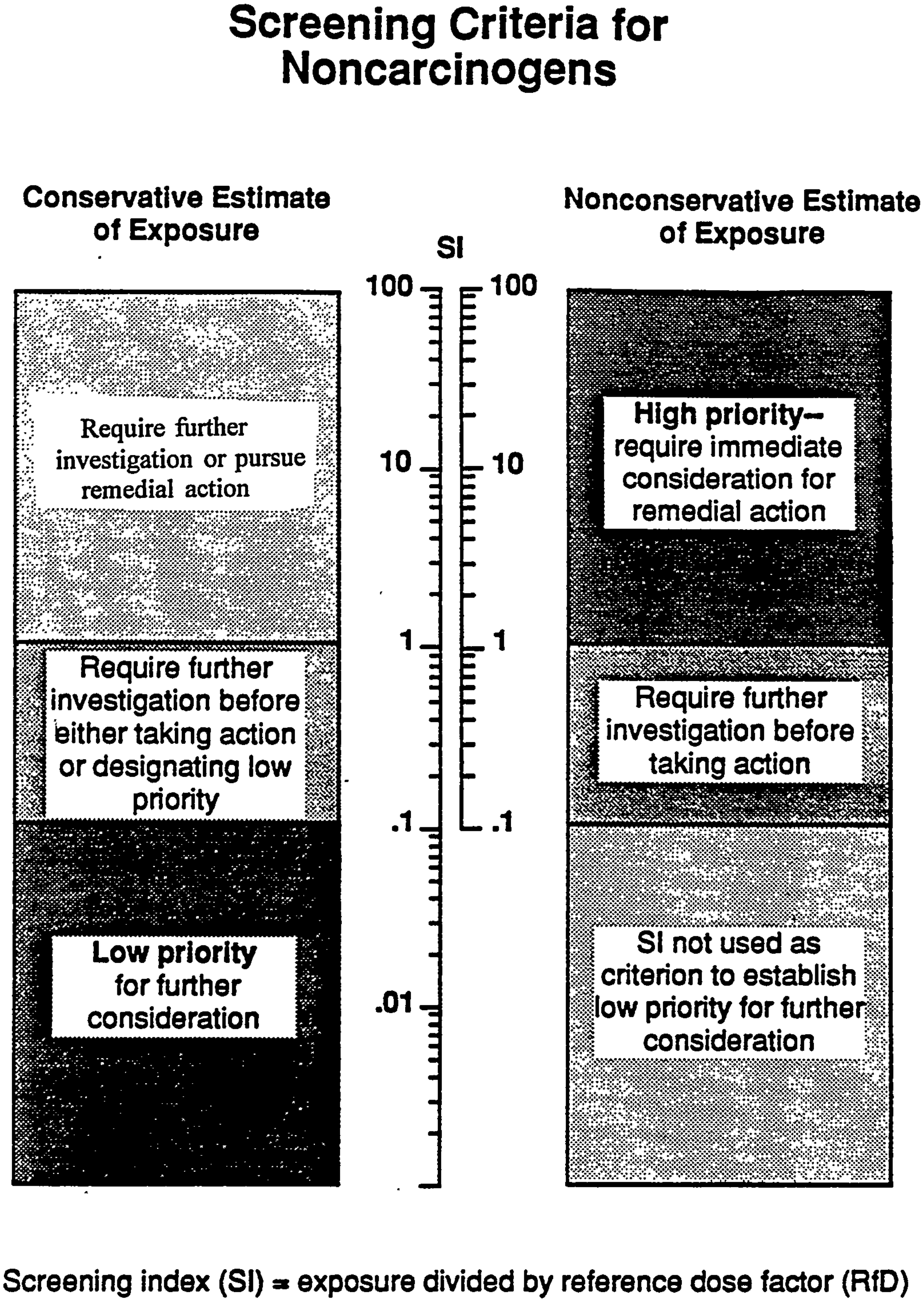


Fig. 4.3. Criteria for screening of noncarcinogens.

identify groundwater contaminant transport pathways; the data collected from these wells were not intended to characterize the contaminant concentrations for the entire site. However, WAG 2 groundwater characterization was planned and conducted in FY 1994. These characterization data will be used in addition to the monitoring well data to conduct iterative screening level risk assessments. Therefore, the monitoring well data will be suitable for risk assessments and modeling.

Sediment. Radionuclides are the primary contaminants that are found in sediment in WAG 2, and most are particle reactive and are associated with sediment and floodplain soil. Much more data were available for radionuclides, especially gamma-emitters, in sediment/soil than were available for organic and inorganic contaminants. External exposure to radionuclides and inadvertent ingestion of sediment were the only exposure pathways that were considered for sediment/soil.

A contaminant screening report was issued (ORNL/ER-62/R1), *Screening of Contaminants in Waste Area Grouping 2 at Oak Ridge National Laboratory, Oak Ridge, Tennessee)*, which describes historical organic and inorganic contaminant data. This information is summarized for human health in Table 4.1 of the Phase I RI report. Since the publication of the RI report, additional organic and inorganic soil and sediment data have been collected. These sampling efforts are described in detail in the FY 1994 Annual Work Plan (ORNL/ER-196).

Biota. Fish are collected from White Oak Lake and its tributaries annually as part of the Biological Monitoring and Abatement Program (BMAP). Tissues from these fish are analyzed for radionuclides, PCBs, and a limited number of inorganic contaminants. These samples provided most data used in the fish ingestion pathway. Data for waterfowl were also obtained from BMAP studies. Concentrations of radionuclides in venison were based on analyses of tissue taken from deer killed during managed hunts on the ORR.

4.2.7 Contaminants of Concern

Contaminants with screening indices for the resident scenarios that indicated a high priority for consideration of remedial action are shown in Table 4.1. Carcinogens that were classified as high priority contaminants (screening index $>1 \times 10^{-4}$) were: Aroclor 1254, fish ingestion pathway for Reaches 1, 3, and 4; ^{137}Cs, external exposure to sediment in Reaches 1, 3, and 4; and ^{60}Co, external exposure to sediment in all reaches. The screening index for arsenic in water exceeded 1×10^{-4}, but this value may be an artifact because only a small fraction of the samples analyzed had concentrations above the limits of detection. Thallium, a noncarcinogen, had a screening index >1 for the water ingestion pathway in Reaches 1, 2, and 3, which classified it as a high priority contaminant, but only one sample was analyzed from each reach.

In the intruder scenario, Aroclor 1254 in fish in Reaches 1, 3, and 4; ^{137}Cs in fish in Reach 1; ^{137}Cs in sediment (external exposure) in Reaches 1, 3, and 4; and ^{60}Co in sediment (external exposure) in Reaches 1, 2, and 3 were designated high priority contaminants (Table 4.1). There is currently no direct public access into the White Oak Creek Embayment (WOCE) Reach 4 area. A coffer cell sediment retention structure was constructed in 1992 at the mouth of the WOCE and security fences along the banks preclude such access. No slope factors or RfDs were available for a number of organic and four inorganic (aluminum, copper, lead, and zirconium) contaminants that were detected in the different media; therefore, screening indices could not be calculated for these contaminants. An EPA uptake/biokinetic model based on health effects of children (0–6 years old) was used for lead, and the model indicated that the concentration of lead in WAG 2 would not be detrimental to human health.

Table 4.1. Contaminants and exposure pathways classified as high priority for consideration of remedial action in different reaches of WAG 2

Contaminant	Reach	Media	Exposure pathway
	Resident scenario		
Aroclor 1254 (PCB)	1, 3, 4	Fish	Ingestion
^{137}Cs	1, 3, 4	Sediment	External exposure
^{60}Co	1, 2, 3, 4	Sediment	External exposure
Arsenic[a]	2, 3, 4	Water	Ingestion
Thallium[b]	1, 2, 3	Water	Ingestion
	Intruder scenario		
Aroclor 1254 (PCB)	1, 3, 4	Fish	Ingestion
^{137}Cs	1	Fish	Ingestion
^{137}Cs	1, 3, 4	Sediment	External exposure
^{60}Co	1, 2, 3	Sediment	External exposure

[a] Potential artifact.

[b] Value based on one sample per reach.

A description of the methodology, procedure, and model outputs are presented in Appendix B. All model outputs estimate that lead concentrations in WAG 2 samples would not be detrimental to human health with the exception of those outputs that include groundwater values. It is stated in the lead risk assessment (Appendix B) that groundwater values should not be used as model inputs because they do not represent a realistic exposure ratio.

Approximately two-thirds of the contaminants that were analyzed from WAG 2 had concentrations that were below detection limits. These contaminants were screened as a separate category using the lowest detection limit. Nonconservative screening of these contaminants was used to identify contaminants for which lower detection limits are a high priority.

Although remediation alternatives for WAG 2 will not be considered until remediation of upgradient WAGs is completed, the screening-level risk assessments serve as guides to determine short-term human health and environmental risks, identify the need for interim actions, and direct future sampling efforts.

4.3 ECOLOGICAL RISK

A screening assessment of ecological effects in WAG 2 was conducted concurrently with the human health assessment and is reported in Blaylock et al. 1992. The purpose of the screening assessment was to identify hazards associated with contaminants in WAG 2, prioritize them with respect to their potential risks, and identify data needs on the basis of that analysis. The ecological assessment is concerned with risks to populations and communities of nonhuman organisms that occur on site or may occur there in the future.

4.3.1 General Approach

An iterative hierarchical approach to the assessment of ecological risks is taken at the Oak Ridge Reservation (ORR) (Suter et al. 1992). The lowest level is the individual waste site or source control operable unit (OU), or waste area grouping (WAG). These sites constitute the source of release of contaminants to the wider environment, or integrator OUs. Integrator OUs receive and integrate the releases from multiple waste sites and other sources of contamination or disturbance. The integrators for aqueous contaminants are watersheds. At ORNL, the integrator OU for aqueous contaminants is WAG 2. The integrator for terrestrial contaminants is either a portion of the ORR or the entire ORR, depending on the release and migration of contaminants and the endpoint species being evaluated.

4.3.2 Ecological Risk Assessment Activities at WAG 2

This assessment considered three lines of evidence concerning the risks to nonhuman organisms posed by contaminants in WAG 2: biological surveys, toxicity tests of ambient media, and exposure/response analysis for measured contaminant concentrations. The biological survey data indicate that aquatic effects are not severe because a diverse and productive aquatic community is found in WAG 2. However, comparison of the aquatic biota to those of reference streams indicates that the composition of the benthic invertebrate community may be modified and fish reproduction may be disrupted. Biological survey data are not available for terrestrial biota.

Recent toxicity tests of water from WAG 2 do not indicate toxicity to *Ceriodaphnia dubia* or to larval fathead minnows in 7-day exposures. It is the intent in Phase II to conduct toxicity tests in sediments and soils for the baseline risk assessment.

Comparison of media concentrations to toxicological benchmarks produced ambiguous results because of the large number of chemicals that were not detected but had limits of detection higher than potentially toxic concentrations. Mercury and PCBs were found at potentially toxic concentrations in both water and sediments in all reaches. Aluminum, cadmium, chromium, copper, and lead exceeded national ambient water quality criteria and state standards, and twelve other metals exceeded potentially toxic concentrations. Of the chemicals that had been detected in sediments and for which available concentrations could be estimated, barium, cobalt, mercury, silver, zinc, benzene, di-n-butyl phthalate, methylene chloride, and PCBs are potentially toxic to benthic organisms. Selenium and possibly cadmium were found in fish flesh at concentrations indicative of toxic effects. Mercury and PCBs occurred in fish flesh at concentrations that are potentially toxic to piscivorous wildlife based on dietary toxicity data, and many other chemicals occurred at concentrations that would exceed the reference dose for human health effects when wildlife consumption rates were used. No analyses could be performed for toxic effects on terrestrial organisms other than piscivorous wildlife. Contaminants in terrestrial biota (raccoons) are currently being evaluated by WAG 2 in conjunction with the Biological Monitoring and Abatement Program. Raccoon hair and adipose tissue are being evaluated for Cs-137, mercury, and PCB/pesticides.

One can conclude from this evidence that ecotoxicological effects may be occurring in WAG 2, but they are not as severe as would be suggested by the exposure/response analysis using the reported chemical concentrations. This discrepancy is due in part to the conservatism of the screening criteria, but the authors believe that the principal factor is the inappropriateness of many of the analyses as estimators of bioavailable concentrations. Therefore, future activities should focus on estimation of actual exposure levels. In addition, chemical and biological data are needed from terrestrial portions of WAG 2. Future assessments will focus on improving the relevance of exposure/response estimates to conditions in WAG 2 and will continue to attempt to reconcile the three lines of evidence concerning ecological effects.

4.3.3 Summary of the Ecological Risk Characterization

Because there is no complete inventory of the chemicals that have been disposed of in the White Oak Creek watershed, it was not possible to identify a complete list of potential contaminants of concern *a priori*. Instead, it is necessary to either establish that no significant toxic effects are occurring in WAG 2 or perform a survey of watershed contaminants that is sufficiently sensitive and reliable for a complete screening to be performed. This assessment was not intended to satisfy either of these strategies. Although severe effects are not occurring in the aquatic habitats of WAG 2, there is some evidence of effects on fish reproduction and on benthic invertebrate community composition. Toxicity tests of surface water have not found toxicity. Some chemicals in all media occurred at concentrations that are potentially toxic and many chemicals that were not detected had detection limits that were higher than both toxic and regulatory thresholds. Therefore, although it is clear that severe toxic effects are not occurring, there are still significant uncertainties concerning the ecological risks posed by WAG 2. These additional data needs include surveys of biotic communities, additional abiotic and biotic sampling, and toxicity testing to reduce future uncertainty concerning ecological risk (Blaylock et al. 1992). Phase II sampling intends to collect toxicity data on soils and sediments to conduct ecological risk assessments.

5. UPDATED ARARs

As part of the ongoing RI process, compliance with Applicable or Relevant and Appropriate Requirements (ARARs) will be used to screen the Potential Contaminants Of Concern (PCOCs). Consideration of ARARs alone is not sufficient because ARARs are not available for all contaminants and ARARs do not always provide a consistent level of protection for humans or the environment. However, consideration of ARARs does provide a means of ensuring that the RI/FS for WAG 2 will proceed in such a way as to comply with regulatory standards. If a PCOC exceeds an ARAR it will become a Contaminant Of Concern (COC). Future sampling efforts will focus on identifying contaminant sources and prioritizing and monitoring the effectiveness of remedial actions.

Seeps flow into WOC or Melton Branch, which ultimately flow into the Clinch River. The Clinch River is classified by the Tennessee Water Quality Control Board for domestic water supply, industrial water supply, fish and aquatic life, recreation, irrigation, and livestock watering and wildlife uses; WOC and Melton Branch are classified for all these uses except domestic water supply (TDEC Rules, Chap. 1200-4-4). Requirements under federal or state law may be *either* applicable *or* relevant and appropriate to CERCLA cleanup actions, but not both. However, requirements must be *both* relevant *and* appropriate for compliance to be necessary. Within White Oak Creek and Melton Branch state criteria for the protection of freshwater organisms and state recreation criteria are legally applicable requirements. State drinking water criteria and federal criteria[2] must be both relevant *and* appropriate to be requirements. However, they may not be appropriate due to institutional controls preventing the consumption of water and aquatic organisms from WAG 2.

A preliminary listing of ARARs for WAG 2 was presented in the RI Workplan (ORNL 1991). These ARARs will be revised and updated for incorporation into the WAG 2 Annual Work Plan. Available chemical-specific criteria, promulgated under federal and state law, that are relevant to seep sampling Rounds 1 and 2 are presented here for comparison to the results and analytical detection limits. Tables 5.1, 5.2, and 5.3 list the ARARs for the PCOCs. PCOCs from the first two rounds of seep samples (primarily metals) which exceeded ARARs are discussed in Sect. 6 and are presented in Appendix D. Metal results exceeding ARARs are presented in Sect. 6. Organics, with the exception of volatiles, are not considered PCOCs in WAG 2 seeps. Samples for volatile organic contaminants were collected during the 1993 wet-season baseflow seep and tributary sampling. The ARARs for radionuclides, which are already considered COCs, are presented in Table 5.4. The Tennessee state surface water quality criteria for domestic water supply are identical to the federal maximum contaminant levels (MCLs) listed in Table 5.1. The state water quality criteria for the consumption of aquatic organisms (the criteria for protection of recreation uses), and for protection of fish and aquatic life, are listed in Tables 5.2 and 5.3, respectively, for comparison to surface water sampling results to determine extent of any contamination. In the absence of a state criterion for a specific chemical, a federal criterion is listed if available. The current and proposed MCLs for radionuclides are presented in Table 5.4.

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[2] Not adopted by the state.

Table 5.1. Chemical-specific federal regulations for protection of human health relevant to WAG 2 seeps task[a]

Chemical	RCRA[b] maximum concentration limits (μg/L)	Safe Drinking Water Act MCLs[c] (μg/L)	Safe Drinking Water Act MCLGs[d] (μg/L)
Antimony[e]		6	6
Arsenic	50	50	NA
Barium	1,000	2,000	2,000
Beryllium[e]		4	4
Cadmium	10	5	5
Chromium (total)	50	100	100
Copper[f]		TT[f]	1,300
Cyanide[e]		200	200
Fluoride		4,000[g]	4,000
Lead	50	TT[f]	0
Mercury	2	2	2
Nickel[e]		100	100
Nitrate (as N)		10,000	10,000
Selenium	10	50	50
Silver[h]	50		
Sulfate[i]		400,000/500,000	400,000/500,000
Thallium[e]		2	0.5

[a] Federally promulgated regulations under RCRA and the SDWA are included in this table. Clean Water Act regulations are listed in Tables 5.2 and 5.3. Tennessee state drinking water MCLs/MCLGs (Chapter 1200-5-1 of the Rules of the TDEC) are identical to the federal.

[b] RCRA = Resource Conservation and Recovery Act (40 CFR 264.94).

[c] MCL = maximum contaminant level (40 CFR 141).

[d] MCLG = maximum contaminant level goal (40 CFR 141).

[e] 57 *FR* 31776 (July 17, 1992). Effective January 17, 1994.

[f] When the "action level" of 15 or 1300 μg/L, for lead or copper, respectively, measured in the 90th percentile at the consumer's tap, is exceeded, corrosion control studies and treatment requirements are triggered. However, an OSWER memorandum (dated June 21, 1990) recommends that a final cleanup level of 15 μg/L for lead in groundwater usable for drinking water is protective of sensitive subpopulations; this is guidance, not an ARAR.

[g] Applies to community water systems only.

[h] The interim SDWA MCL was revoked for this chemical (56 *FR* 3526, January 30, 1991; effective July 30, 1992) and a secondary MCL established instead.

[i] This is a **proposed** MCL/MCLG only (55 *FR* 30370, July 25, 1990). EPA has deferred setting a final MCL/MCLG for sulfate pending further study (57 *FR* 31776, July 17, 1992).

NA = not available.

Table 5.2. Federal and state ambient water quality criteria, for the protection of human health, relevant to WAG 2 seeps task (μg/L)

Chemical	WQC for aquatic organisms and drinking water[a]	WQC for aquatic organisms alone[a]	TDEC WQC for aquatic organisms alone[b]
Antimony	14	4,308	4,310
Arsenic	0 (0.018)	0 (0.14)	
Beryllium	NA[c]	NA[c]	1.3
Cadmium	NA[c]	NA[c]	
Chromium (III)	NA[c]	NA[c]	670,000
Copper	1,000 (org)[d]	NA	
Cyanide	700	220,000	
Lead	NA[c]	NA[c]	
Manganese	30[e]	NA[e]	
Mercury	0.14	0.15	0.15
Nickel	607	4,584	4,600
Selenium	NA[c]	NA[c]	
Silver	NA[c]	NA[c]	
Thallium	1.7	6.3	
Zinc	5,000 (org)[d]	NA	

[a] The criterion value of zero for all potential carcinogens is listed in the table. Concentrations in parentheses for potential carcinogens correspond to a risk of 10^{-6}.

[b] WQC for the protection of humans from consumption of aquatic organisms during recreational use (TDEC Rules, Chap. 1200-4-4). TDEC has adopted the federal water quality criteria based on a risk of 10^{-5} rather than 10^{-6} for all carcinogens.

[c] WQC withdrawn in the National Toxics Rule [57 *FR* 60848 (December 22, 1992)].

[d] Criteria designated as organoleptic are based on taste and odor effects, not human health effects. Health-based WQC are not available for these chemicals.

[e] New WQC published in the National Toxics Rule [57 *FR* 60848 (December 22, 1992)].

NA = not available.

Source: USEPA. 1992. EPA Region IV Criteria Charts (December).

Table 5.3. Federal and state ambient water quality criteria, for the protection of freshwater organisms, relevant to WAG 2 seeps task

Chemical	Maximum (μg/L)[a]	24-h (μg/L)[b]
Aluminum[c]	750.[d]	87[d]
Arsenic (III)	360	190
Cadmium	1.8[e]	0.66[e]
Chloride[c]	860,000	230,000
Chromium (VI)	16	11
(III)[c]	984.[e]	117[e]
Copper	9.22[e]	6.54[e]
Cyanide	22	5.2
Iron[c]	NA	1,000
Lead	33.8[e]	1.32[e]
Mercury	2.4	0.012[f]
Nickel	789.[e]	88[e]
pH	NA	6.5–9
Selenium (inorganic selenite)	20.	5
Silver	1.23[e]	NA
Zinc	65.[e]	59[e]

[a] One-hour average concentration not to be exceeded more than once every 3 years.

[b] Four-day average concentration not to be exceeded more than once every 3 years.

[c] Federal criteria only.

[d] pH 6.5–9.0.

[e] Water hardness dependent criteria expressed as function of total hardness (mg/L) as follows (values displayed correspond to a hardness of 50 mg/L as $CaCO_3$):

Maximum = $\exp\{m_A[\ln(\text{hardness})] + b_A\}$ 24-h = $\exp\{m_C[\ln(\text{hardness})] + b_C\}$

	m_A	b_A	m_C	b_C
Cadmium	1.128	−3.828	0.785	−3.490
Copper	0.942	−1.464	0.854	−1.465
Lead	1.273	−1.460	1.273	−4.705
Nickel	0.846	3.361	0.846	1.164
Silver	1.72	−6.52		
Zinc	0.847	0.860	0.847	0.761

[f] Based on marketability of fish.

Sources: EPA 1992. Environmental Protection Agency Region IV Criteria Chart (December). Chapter 1200-4-3 of the Rules of the Tennessee Department of Environment and Conservation.

Table 5.4. Radionuclide-specific ARARs for groundwater and surface water contamination at the Oak Ridge Reservation

Radionuclide	Current SDWA MCLs[a]	Proposed SDWA MCLs[b]
Radium[c]	5 pCi/L	20 pCi/L
Gross alpha[d]	15 pCi/L	15 pCi/L
Gross beta	4 mrem/year	4 mrem/year
Natural uranium		20 μg/L[e]
Radon-222		300 pCi/L
Strontium-90	8 pCi/L	42 pCi/L
Tritium	20,000 pCi/L	60,900 pCi/L
All other manmade radionuclides	4 mrem/year[f]	4 mrem/year[f]

[a] SDWA MCL = Safe Drinking Water Act maximum contaminant level.

[b] Proposed rule, July 18, 1991 (56 FR 33050); final rule delayed until 1994.

[c] The present MCL applies to combined ^{226}Ra and ^{228}Ra; the proposed MCL applies to each separately.

[d] The present MCL excludes radon and uranium but includes ^{226}Ra; the proposed MCL excludes all three radionuclides.

[e] Approximately equal to 30 pCi/L.

[f] If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 mrem/year.

6. SEEP AND TRIBUTARY SURVEY

6.1 INTRODUCTION

6.1.1 Conceptual Model

The major pathways for water and contaminant movement in the subsurface are through the shallow water table and the stormflow zone according to the hydrologic framework for the ORR (Solomon et al. 1992). Water that infiltrates the soil surface moves through shallow pathways intercepting and leaching contaminants from primary sources (trenches) and/or secondary sources (downgradient soil matrix) and then emerges at seeps and springs where it discharges to the surface water system. Because of the close link between groundwater and surface water regimes, seeps and springs mark the dominant groundwater and contaminant flow pathways. Besides visible seeps, groundwater seepage directly into stream channels also occurs. The term seep is used in this report to refer to all contaminated groundwater discharge including diffuse seepage areas, discrete seeps, and springs, whether they discharge to the ground surface or directly into a stream. Tributaries within the WOC watershed serve as spatial integrators of contaminant releases from subbasins adjacent to WAG 2. Based on this conceptual model, water quality sampling of seeps, springs, and tributaries is an effective means of identifying contaminant releases to WAG 2.

6.1.2 Objectives

A monitoring program for tributaries and seeps was initiated as part of the WAG 2 surface water program because surface water is the primary transport pathway for contaminants through and out of the WOC watershed. The primary objective of the WAG 2 RI Seep and Tributary Task is to identify seeps and tributaries that are responsible for the contaminant fluxes to the main channels of WAG 2 and to quantify their input to the total contaminant flux. Contaminants posing the greatest potential human health risk from water ingestion at WOD (^{3}H and ^{90}Sr) are relatively non–particle reactive, thus the emphasis during the first year was primarily on soluble contaminants. The transport of sediment-associated contaminants is being addressed by the WAG 2 sediment sampling efforts during Phase II (Boston et al. 1992). Efforts will continue to be closely coordinated to identify contaminant source areas and quantify fluxes. The WAG 2 seep team also interacts with other ER efforts to gather data needed to prioritize seeps/source areas for focused corrective actions and for longer term monitoring to evaluate the effectiveness of remedial actions.

6.2 SAMPLING PROGRAM

6.2.1 Selection of Sampling Locations

The initial phase of the WAG 2 RI Seep and Tributary Task included a literature review of historic seeps and a site walkover to identify these historic seeps and any other visible seeps. A review of the existing data on contaminated seeps and related studies is given in the WAG 2 SAP. A summary of the historic seeps is given in Table 6.1. Specific historic seep locations are given in individual reports referenced in Table 6.1. The site walkover and selection of sampling locations was conducted during wet-season baseflow conditions in February and early March 1992. Visible areas of groundwater discharge were prevalent in WAG 2 and the adjacent areas. The physical features varied from boggy areas to discrete springs. Seep sampling locations were

Table 6.1. Summary of historic data for seeps in and near WAG 2

WAG	Seep ID	Date	^{90}Sr (pCi/L)	^{3}H (Ci/L)	^{137}Cs (pCi/L)	^{60}Co (pCi/L)	Reference
7	RS-1	3/73	<135	NA	<45	<90	Duguid 1975
7	RS-2	3/73	<495	NA	<135	17342	Duguid 1975
7	RS-3	3/73	9	NA	<90	46847	Duguid 1975
7	RS-4	3/73	36	NA	<135	5180	Duguid 1975
7	RS-5	3/73	23	NA	<225	25450	Duguid 1975
7	RS-6	3/73	32	NA	<135	6036	Duguid 1975
7	RS-7	3/73	<135	NA	<225	215766	Duguid 1975
7	RS-8	3/73	901	NA	1712	<225	Duguid 1975
4	S-1	1/74	495	NA	<5.4	<10.8	Duguid 1975
4	S-2	8/73	203153	NA	2430	54	Duguid 1975
4	S-3	3/73	6261	NA	81	81	Duguid 1975
4	Seep[a]	4/80	24327	NA	NA	NA	Huff 1982
4	BTT[b]	1/89	28836	6.00×10^{4}	675	67.5	Hicks
5	5nW-2	3/90	NA	.01	67.5	67.5	Wickliff 1991
5	5NW-1	3/90	NA	.02	67.5	67.5	Wickliff 1991
5	5NS-1	3/90	NA	.02	67.5	67.5	Wickliff 1990
5	S-1	11/73	9	NA	NA	NA	Duguid 1975
5	S-2	11/73	<14	NA	NA	NA	Duguid 1975
5	S-3	11/73	<36	NA	NA	NA	Duguid 1975
5	S-4[c]	3/74	13963964	54	NA	NA	Duguid 1975
5	S-5	3/74	157658	27	NA	NA	Duguid 1975
5	S-5	3/74	3604	22	NA	NA	Duguid 1975
5	S-7	3/74	2387	77	NA	NA	Duguid 1975
5	S-8	3/74	<45	2	NA	NA	Duguid 1975
5	S-9	3/74	61261	212	NA	NA	Duguid 1975
5	S-10[d]	3/74	16171	104	NA	NA	Duguid 1975
5	S-11[d]	3/74	10541	171	NA	NA	Duguid 1975
5	S-12[d]	3/74	586	20	NA	NA	Duguid 1975
5	S-13[d]	3/74	12477	22	NA	NA	Duguid 1975
5	S-14	3/74	90	6	NA	NA	Duguid 1975
5	S-15	3/74	3919	432	NA	NA	Duguid 1975
5	S-16	3/74	135	90	NA	NA	Duguid 1975
5	T-2[e]	1980	207900	NA	NA	NA	Spalding & Munro 1984
5	HRT[f]	7/88	1458	370	486	67.5	Hicks

[a] Seep and surrounding area appeared to contribute approximately 60% to ^{90}Sr flux from WAG 4.

[b] BTT contributed 15 to 24% of ^{90}Sr flux in WAG 4 tributary in 1989.

[c] No longer exists because of corrective action (Duguid 1976).

[d] Below trench 117, which was treated (1979–81) with caustic soda, etc. (Spalding 1984).

[e] T-2 may be same as Duguid's S-5. Strontium-90 is reported as a yearly average. In 1980, Melton Branch had a ^{90}Sr discharge of 424 mCi and T-2 contributed 20% of the ^{90}Sr discharge.

[f] HRT seep may be the same as Duguid's S-15.

chosen from those discharge areas that were more prominent and that were known or suspected to be contaminated. Downgradient sampling locations on tributaries were chosen to monitor seepage areas that were very diffuse. Only a few of the seeps identified by Duguid (1975) almost 20 years ago were located during the walkover. A total of about 35 seep locations was identified and marked for sampling and analyses (Fig. 6.1).

Most seeps identified in previous studies represent fairly discrete areas of groundwater discharge and were located primarily by inspection. Little information exists about areas where contaminated groundwater discharges directly into tributaries or main stream channels. Increases in contaminant concentrations along stream reaches (transects) can be used to identify areas where contaminated groundwater is discharging directly into the stream. Thus, sampling locations along the stream transects of WOC and Melton Branch were selected approximately every 100 m. (Fig. 6.2). Transect sampling locations were also selected along the WAG 4 tributary at approximately every 20 m. After the first round of sampling, a few transect sampling locations were added to the WAG 6 tributaries to provide information for the development of the Environmental Monitoring Plan for WAG 6. Transect sampling locations were generally selected below riffles in the streams to ensure better mixing and representativeness for the reach just above the location.

Tributaries to Melton Branch, WOC, and WOL are known to transport contaminants to WAG 2. Quantifying contaminant releases (or contaminant fluxes) from different areas in the watershed hinges on the ability to obtain stream flow measurements. Contaminant flux referred to in this report may more accurately be termed contaminant mass flow and is the product of the contaminant concentration and stream flow. Contaminant fluxes can be estimated at those sampling locations where weirs, flumes, or other structures exist that facilitate stream flow measurement; therefore, tributary and main stream locations throughout the watershed were added to the sampling program.

6.2.2 Sampling Methods and Procedures

Contaminant transport pathways, transport processes, and source areas may vary depending upon different hydrologic conditions that exist during a year. Consequently, two extensive screening sampling rounds were conducted during 1992, one during wet-season baseflow conditions (Round 1) and one during dry-season baseflow conditions (Round 2). Samples were collected from approximately 35 seep locations and 100 tributary and stream locations (Figs. 6.1 and 6.2). Many of the seeps and small tributaries were discovered to be ephemeral and could not be sampled during the dry season.

Samples were collected using WAG 2 SOP 3202, "Collection of grab samples from seeps, small tributaries, and streams." Copies of all WAG 2 project-specific standard operating procedures (SOPs) are available from the WAG 2 project manager. All seep and stream samples (excluding transect samples) were field filtered using a peristaltic pump, silastic tubing, and highflow in-line filters (0.45 µm). At each location new tubing and a new filter were installed in the pump. The filter was then attached to the output end of the tubing on the other side of the pumphead. The intake end of the tubing was positioned in the seep or channel away from sediment and debris. Sample bottles were opened just prior to sample collection, and the filter tip was placed just inside the mouth of the bottle. After collection the filter was removed from the tubing, and the bottles were capped, wiped dry as needed, and stored in a cooler until they were returned to the laboratory. Sample types, precleaned bottle types, and sample ID numbers were confirmed using field forms and sampling plans.

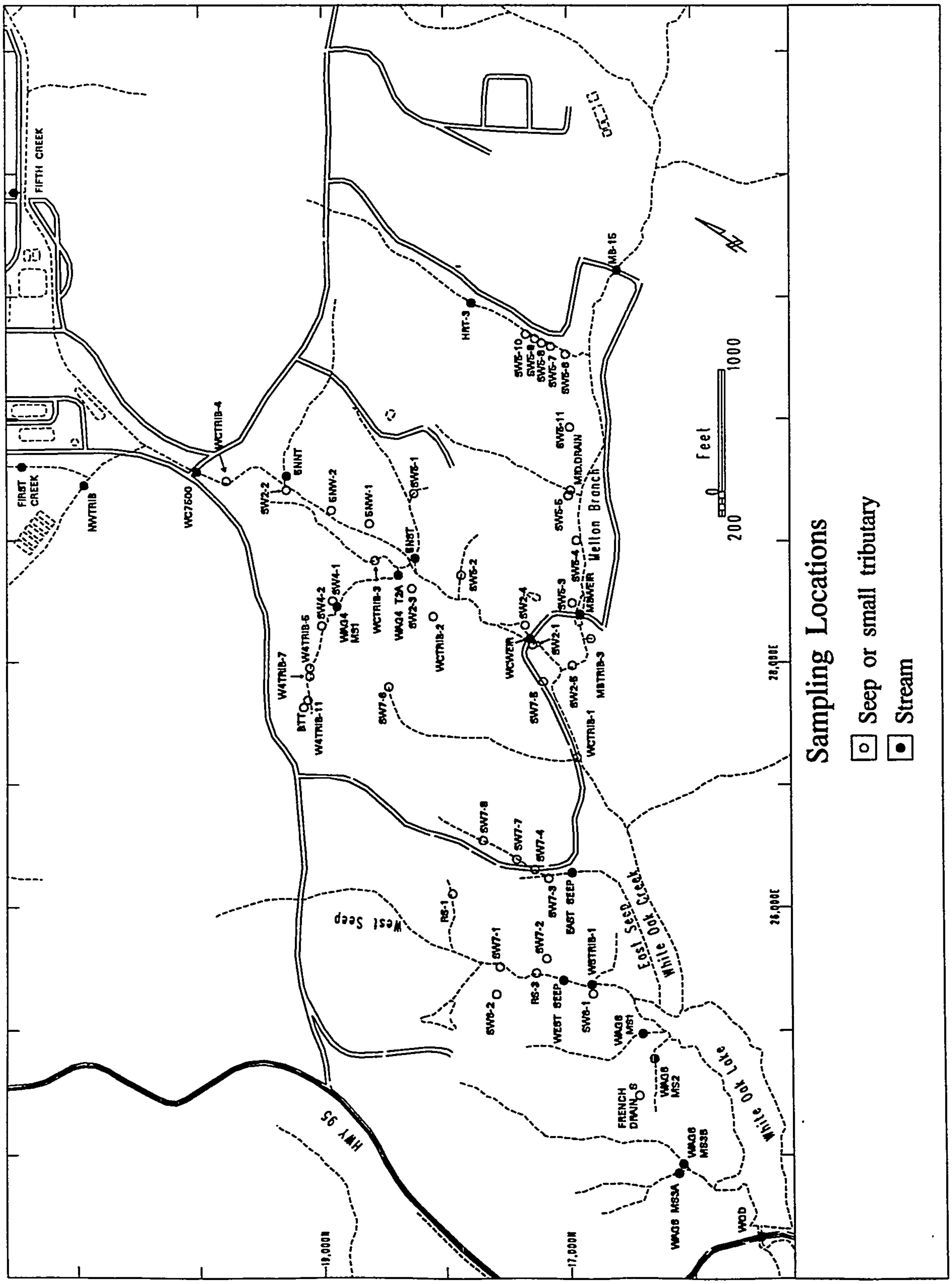

Fig. 6.1. WAG 2 seep, tributary, and stream sampling locations.

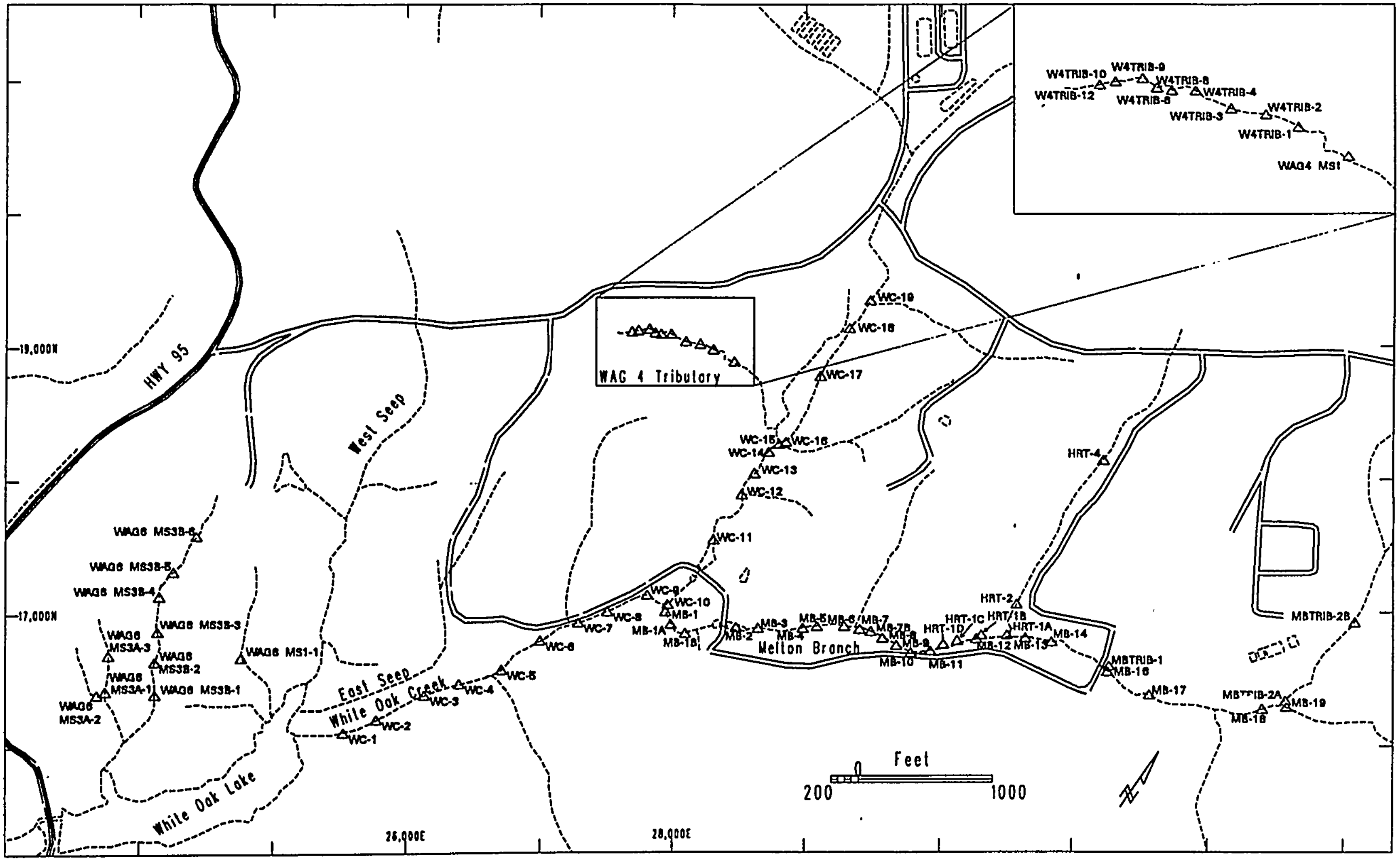

Fig. 6.2. WAG 2 transect sampling locations.

Transect samples were collected using a simple grab method. The sample types and ID numbers were confirmed, and the labeled and precleaned bottles were taken to the stream, opened, and dipped below the surface as close to the center of the stream as possible. The bottles were then capped, wiped dry, and placed in a cooler. Sample dates and location information were recorded on controlled forms.

Field parameters (pH, specific conductance, and temperature) were measured using SOPs 3206, ''Maintenance, daily standardization, post-survey check, and quarterly calibration of Horiba meter,'' and 3210, ''Measurement of field parameters using Hydrolab Surveyor II or Surveyor III instruments,'' for Rounds 1 and 2, respectively. The instruments were placed directly into the seep or stream downstream of the intake tubing so that the site would not be disturbed. For those seeps with very low flow, a sample was pumped, without a filter, into the instrument measurement chamber. All field measurements, sample dates, and location information were recorded on controlled forms.

Flow measurements were made following SOP 3201, ''Measurements of flow rates in streams.'' For those seep or stream locations where the flow discharges from a pipe, small weir, flume, etc. such that a container could be placed to collect the water, timed volume flow measurements were made at the time of sample collection. For stream locations where weirs or flumes exist and verified stage-discharge relationships are available, stage measurements were recorded at the time of sample collection. Stream flow estimates were made from the stage measurements and existing stage-discharge rating equations. All field measurements, sample dates, and location information were recorded on controlled forms.

Samples were transported to the laboratory and processed as described in WAG 2 SOP 3202. Transect samples for ^{90}Sr were filtered through 0.45-µm disposable filters and acidified. All other samples were split into appropriate aliquots and preserved as required. Laboratory chain-of-custody forms were completed, and sample information was verified. Samples were then transferred to internal or external laboratories for analysis.

A general list of analyses for the different type of locations is given in Table 6.2. Emphasis was put on identifying sources of ^{3}H and ^{90}Sr along stream reaches because these two contaminants are relatively nonparticle reactive and pose the greatest potential human health risk at WOD from water ingestion.

The SW-846 methods were used for all inorganic analyses, but results were reported in Contract Laboratory Program (CLP) format. The radiochemical methods varied, as samples were split at a frequency of 10% between internal WAG 2 operated laboratories located within the Environmental Sciences Division of ORNL and Oak Ridge Institute for Science and Education. The 10% split samples were delivered to Oak Ridge Institute for Science and Education for confirmation of the WAG 2 results. Table 6.3 shows the radionuclide versus laboratory analysis method.

Table 6.2. Analyses and locations for seep and tributary sampling

Parameter(s)[a]	Method	Laboratory	Locations[b]		
			Seeps and small tributaries	Streams	Stream transects
Gamma Scan—Water (Filtrate)	4009[c]	Internal	x	x	
Gamma Scan—Particulate (Filter)	4009[c]	Internal	x	x	
^{3}H	4006[c]	Internal	x	x	x
	600[d]	External	x	x	x
^{90}Sr	4011[c]	Internal	x	x	x
	ORAU[e]	External	x	x	x
Gross Alpha	900.0[d]	External	x		
Gross Beta	900.0[d]	External	x		
ICP Metals (Ag, Al, B, Ba, Be, Ca, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, Sb, Si, Sr, Tl, V, Zn)	6010[f]	External	x	x	
AA Metals (As, Cd, Hg, K, Pb, Sb[g], Se)	7000[f] Series	External	x	x	
Cyanide	9010[f]	External		x[h]	
Anions (Cl, Fl, No_3, P, SO_4)	300.0[i]	External	x	x	
Alkalinity	4013[c]	Internal	x	x	
Field Parameters (Sp. Cond., pH, Temp.)	3206[c] 3210[c]	NA	x	x	x

[a] All water samples, except for ^{3}H from transects, were filtered.

[b] See Figs 6.1 and 6.2.

[c] WAG 2 Standard Operating Procedures.

[d] EPA. 1980. "Prescribed procedures for measurement of radioactivity in drinking water," EPA-600/4-80-032. Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

[e] ORAU (Oak Ridge Associated Universities). 1991. "Determination of strontium-90 and -89 in soil and sediment." Laboratory Procedures Manual for the Environmental Survey and Site Assessment Program.

[f] EPA. 1986. "Test methods for evaluating solid waste," SW-846, 3d ed. Office of Solid Waste and Emergency Response, Washington D.C.

[g] Antimony was analyzed by graphite furnace in the second round.

[h] Cyanide samples were collected at the main weirs only (i.e., MB-15, MBWEIR, WC7500, WCWEIR, WOD).

[i] EPA. 1983. "Methods for the chemical analysis of water and waste," EPA 600/4-79-020. Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Table 6.3. Methods of radionuclide analysis

Radionuclide	Analysis by WAG 2	Analysis by ORISE
^{90}Sr	Cerenkov Radiation Counting	Precipitation Method
^{137}Cs, ^{60}Co	Gamma Counting	NA
Gross Alpha/Beta	NA	Gas Proportional Counting
^{3}H	Liquid Scintillation	Liquid Scintillation

6.3 QA/QC PROGRAM OVERVIEW

All seep sampling and analytical efforts are supported by the WAG 2 QA Plan (ORNL/ER-134). This plan outlines the WAG 2 QA program, including documentation and training requirements, and identifies the data quality objectives process, and field and laboratory QC samples, along with other aspects determined from the guidance documents described in Sect. 2.2.

6.3.1 Field QC Samples

All field activities followed standard record keeping and chain-of-custody procedures, including recording site-specific information in waterproof notebooks, with routine reviews of the notebooks. Sample custody was established by the sampling team upon collection, through the use of standard chain-of-custody forms, and was maintained throughout sample processing and delivery to analytical services. The goal for frequency of submittal of field QC samples was once for every 20 samples, as appropriate.

Field QC samples included field duplicates, field blanks, and laboratory rinsates. EPA Region IV ESD SOP QAM, Sect. 4.3.3, also specifies the need for preservation blanks. However, field preservation blanks were not used for the sampling procedure described because sample cooling was the preservation method used. The field QC sample types used are described below:

Field duplicate. Field duplicates, which consist of a duplicate sample from one sampling location, indicate whether the field sampling technique is reproducible. Duplicate samples were obtained at a collection frequency of 10% for all sample matrices.

Field blank. One field blank, consisting of source water (distilled or deionized water) used for decontamination, will be collected for every 20 samples or once per sampling event, whichever is greater. Field blanks will also be used to detect airborne metal or organic contaminants present at the time of sample collection. One field blank container consisting of distilled or deionized water will be opened during the collection of 1-in-20 metal or organic samples.

Laboratory rinsate. A laboratory rinsate consists of rinse water from the decontamination of laboratory equipment. Analysis of the laboratory rinsate determines whether decontamination procedures are adequate. Laboratory rinsates will be collected prior to each day of activities or at a minimum of 1 in 20 cleanings of any given piece of equipment.

Field QC samples have discrete sample numbers and are submitted as "blind" to the laboratories. Results for QC samples will not be used to adjust the results obtained for original samples. If contaminants are found in the blanks, attempts will be made to identify the source of contamination, and corrective action will be initiated. Results of field QC samples are reported in Sect. 6.5, QC Summary.

6.3.2 Laboratory Quality Control Samples

The laboratory QC program ensured that all data generated and reported were scientifically valid, consistent with accepted methods, and of known accuracy. Results from QC samples were used to document data quality, verify that the analytical system was functioning for a given matrix/analyte, identify when additional corrections needed to be made to the analytical system, and determine the effect of these corrections. Laboratory QC samples included method blanks, calibration/continuing calibration blanks, sample container cleaning blanks, laboratory duplicates, matrix spikes, laboratory control samples (LCSs), calibration standards, and performance evaluation samples.

Laboratory QC samples include the following:

Method blank. A method blank is a blank sample made up of a pure, noncontaminated substance (usually distilled or deionized water or silica sand) that is subjected to all of the sample preparation (e.g., digestion, distillation, and extraction) and analytical methodology applied to the samples. The method blank is used to check for contamination from within the laboratory that might be introduced during sample analysis.

Calibration/continuing calibration blank. A calibration blank is the substance that is used to zero the instrument. The calibration blank comprises the solvent used for the preparation of the calibration standards and samples. The calibration blank accounts for any interferences from the solvent matrix.

Laboratory duplicates. The laboratory analyst prepares laboratory duplicates for each sample by homogenizing a sample as thoroughly as possible and taking two separate aliquots of that sample for analysis. The duplicate sample, however, should never be a method blank, trip blank, or field blank. The purpose of laboratory duplicates is to check the precision of the analyst, the sample preparation methodology, and the analytical methodology.

Matrix spikes. A matrix spike is an aliquot of a sample to which a known concentration of the compounds of interest has been added. The matrix spike is subjected to the same sample preparation and analytical methodology applied to the samples. The sample to be spiked is selected prior to sample submittal by the administrative services contractor (ASC); however, the spiked sample cannot be a method blank, trip blank, or field blank. The purpose of the matrix spike is to check for interferences or false readings caused by the sample matrix.

Blank spike or laboratory control sample. The blank spike, or LCS, is a blank sample (usually distilled or deionized water or silica sand) to which a known concentration of the compounds of interest has been added. The blank spike is subjected to the same sample preparation and analytical methodology applied to the samples. The purpose of the blank spike is to check the accuracy of the analyst, the sample preparation methodology, and the analytical methodology. The level of accuracy is measured by calculating the percent recovery (%R).

Statistical analyses are performed utilizing the results of QC sample analyses. Each laboratory applies precision and accuracy criteria to each parameter that is analyzed. When analysis of a sample set is completed, the QC data are reviewed and evaluated through the use of control charts to validate the data set. Laboratory QC standards will include the following:

Calibration standards. Calibration standards comprise the compounds of interest at known concentrations. Calibration standards are prepared from EPA reference material or commercially available, certified reference materials traceable to the National Institute of Standards and Technology (NIST), using the same solvent used for sample preparation at the same concentration. Semivolatile and volatile organic analyses by gas chromatography/mass spectrometry require one point calibration by current CLP criteria. Calibration standards for other methods require at least three concentration levels plus a blank standard throughout the calibration range required for the analysis. Calibration standards are not subjected to all of the preparation (e.g., extraction, distillation, and digestion) that is applied to the sample; rather they are used (1) to initially calibrate the instrument by providing reference points throughout the calibration range and (2) to establish linearity throughout the calibration and working ranges of the instrument. The instrument is checked continually throughout the analysis with the calibration standards to check for instrument drift.

Performance evaluation samples. Performance evaluation samples consist of known concentrations of the analytes submitted to the laboratory being audited. These samples are obtained through various EPA-sponsored programs and private vendors to provide an objective evaluation of laboratory performance and comparison with other participating laboratories.

Results of the laboratory QC samples are reported in Sect. 6.5, QC Summary, and are further described in Sect. 6.6, Data Validation Summaries.

6.3.3 Data Validation Strategy

The WAG 2 analytical data validation strategy is to support a data validation team responsible for establishing a validation program to meet WAG 2 validation needs and to ensure WAG 2 compliance with all available guidance documents. The responsibilities of the analytical data validation team included validating existing data collected in 1992 for the seeps and tributaries task.

The data generated during Phase I of the WAG 2 project were validated according to project-specific procedures. The procedures for validation of samples analyzed for chemical parameters were prepared in accordance with the ER division document "*Requirements for Quality Control of Analytical Data for the Environmental Restoration Program*" ES/ER/TM-16, EPA documents regarding the CLP for organic and inorganic analyses, and guidance documents "*USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*" *(DRAFT) December 1990, rev. June 1991*, and "*Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analysis*" *USEPA. July, 1988*. The procedure for validation of samples analyzed for radiological parameters were prepared in accordance with ES/ER/TM-16, and method-specific requirements.

The data are validated based on the requirements of QC levels developed by CERCLA and adopted by the ER Division. These levels are based on the type of site to be investigated, the level of accuracy and precision required, and the intended use of the data. These levels are defined in terms of data characteristics summarized in the following Table 6.4.

Table 6.4. ER QC levels

ER quality level	Characteristics of data
A	Qualitative or semiquantitative analysis, indicator parameters, immediate response in field.
B	Semiquantitative or quantitative analysis, compound specific, rapid turnaround in the field, may use an on-site laboratory.
C	Quantitative analysis, compound specific, usually an off-site laboratory.
D	Quantitative analysis, compound specific, usually an off-site laboratory.
E	Qualitative to quantitative analysis, method specific, unique matrices.

Levels C and D are very similar; the differences lie in the amount of documentation from the laboratory. Level D requires all raw data and full documentation of any and all processes performed on the analytical samples from laboratory receipt until data reporting; Level D analytical validation involves manual recalculation of reported samples and QC values from raw data. Level C requires only the deliverables specified in the CLP documentation and associated WAG 2 Statement(s) of Work; Level C analytical validation requires no recalculation of sample or QC values. Chemical data for the 1992 seeps-and-tributaries samples were validated to either Level C or D. Radiological data for the 1992 seeps-and-tributaries samples were validated to Levels B, C, or D depending on the completeness and quality of data supplied by the laboratories.

Seep and tributary samples collected were analyzed as Level D samples at a frequency of 10 to 25%, as required in ORNL/ER 58. All critical samples, determined by the principle investigator, are analyzed at Level D. All level D samples are validated and the results of the validation are reported in Sect. 6.6.

Analytical data validation qualifiers have been placed on data validated for the 1992 seeps-and-tributaries task. All qualifiers that could be used are summarized below:

J -	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
U -	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
UJ -	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R -	The sample results are rejectd due to serious deficiencies in ability to analyze the sample and meet QC criteria. The presence of absence or the analyte cannot be verified.
N -	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."
NJ -	The analysis indicates the presence of an analyte that has been tentatively identified, and the associated numerical value represents its approximate concentration.

Only the J, U, UJ, and R qualifiers have been used on the 1992 seeps-and-tributaries data; as no organic data were collected, the qualifiers N and NJ were not used.

6.4 RESULTS

Results from the two extensive screening sampling rounds are given in Appendices B and C. Figs. 6.3 through 6.7 summarize the distribution of radionuclide concentrations at the seep, tributary, and main stream locations found during this extensive screening. Concentrations in Figs. 6.3 through 6.7 are averages of wet- and dry-season sampling rounds except for those locations where only one concentration was available. A few seep locations were only sampled once because the seep was dry during the second round of sampling or because the location was added after the first round. A total of 19 seep and small tributary locations were dry during the second round of sampling.

6.4.1 Tritium

Elevated ^{3}H levels were detected at many of the seep, tributary, and main stream locations. The seep SW5-7 on the east edge of WAG 5 (see Fig. 6.1) had the highest concentrations of 100 and 127 µCi/L during Rounds 1 and 2, respectively. Another location in WAG 5, SW5-11, had a similarly high concentration of 97 µCi/L during Round 1. Location SW5-11 is unique in that it is a sump (rather than a seep), which intercepts contaminated groundwater just below waste trench 117 (Spalding 1984). The area was dry during Round 2, so samples were not collected. In general, the higher concentrations of ^{3}H are seen in seeps and tributaries in and around WAGs 4 and 5 (Fig. 6.3).

6.4.2 Strontium-90

Similar to ^{3}H the highest concentrations of ^{90}Sr are seen in seeps and tributaries in and around WAGs 4 and 5 (Fig. 6.4). Location SW5-11 (the sump just below waste trench 117) in WAG 5 also had the highest concentration of ^{90}Sr (1,181 nCi/L). Although SW5-11 is not visibly a groundwater discharge area, a ^{90}Sr plume in the subsurface is known to be dispersing from this area (Spalding 1984). The seep SW5-4 on the southeast edge of WAG 5 (see Fig. 6.1) had the highest ^{90}Sr concentrations detected in any of the seeps (485 and 573 nCi/L during

Rounds 1 and 2, respectively). The other extremely high ^{90}Sr concentration (143 nCi/L) was measured in seep SW2-5, which discharges into Melton Branch just before its confluence with WOC (Fig. 6.1).

6.4.3 Cesium-137

Elevated levels of ^{137}Cs are not as widespread as the ^{3}H or ^{90}Sr contamination in seeps and streams in the WOC watershed (Fig. 6.5). Less than half of the locations sampled had ^{137}Cs activities above detection. The portion of ^{137}Cs associated with particulates vs the portion dissolved (i.e., <0.45 μm) in the sample varied depending on the site. A seep in WAG 7, SW7-6, had the highest ^{137}Cs concentration (306 pCi/L) associated with the particulate portion of the water sample, while the ^{137}Cs associated with the dissolved phase was below detection. A seep in WAG 4, BTT, which is known to be groundwater discharge from a bathtubbing trench, had the highest ^{137}Cs concentration (216 pCi/L) in the dissolved phase, while the ^{137}Cs associated with the particulate portion was 23 pCi/L. Both of these seeps were dry during Round 2. Results of samples from WOC were consistently among the highest ^{137}Cs levels measured. The dissolved ^{137}Cs concentrations were greater than the particulate concentrations at WC7500 and decreased downstream to WOD while the particulate portion generally increased.

6.4.4 Cobalt-60

Less than a third of the locations sampled had ^{60}Co activities above detection (Fig. 6.6). Elevated levels of ^{60}Co were almost exclusively found in seeps and streams in and around WAG 7. The high ^{60}Co concentrations are dominantly in the dissolved phase rather than associated with particulates.

6.4.5 Gross Alpha and Gross Beta

The distribution of gross alpha levels is scattered among the WAGs with the highest concentrations (ranging from about 10 to 40 nCi/L) detected in seep SW5-4 and sump sample SW5-11 in WAG 5 and in seep RS-3 in WAG 7 (Figs. 6.7 and 6.1). Gross beta levels generally corresponded with ^{90}Sr concentration. Strontium-90 and its daughter ^{90}Y are the primary beta-emitting radionuclides. Elevated gross beta levels were also associated with locations with elevated ^{60}Co.

6.4.6 Metals

Dissolved metal concentrations were generally below federal and state criteria, ARARs, in most seeps sampled in and around WAG 2 (Appendix C). Metal results exceeding current ARARs are presented in Appendix D. Some current criteria were not promulgated when these data were collected. Due to a variation in analytical procedures (see Sect. 6.6) Round 2 metal results, with the exception of Hg, may be higher than Round 1.

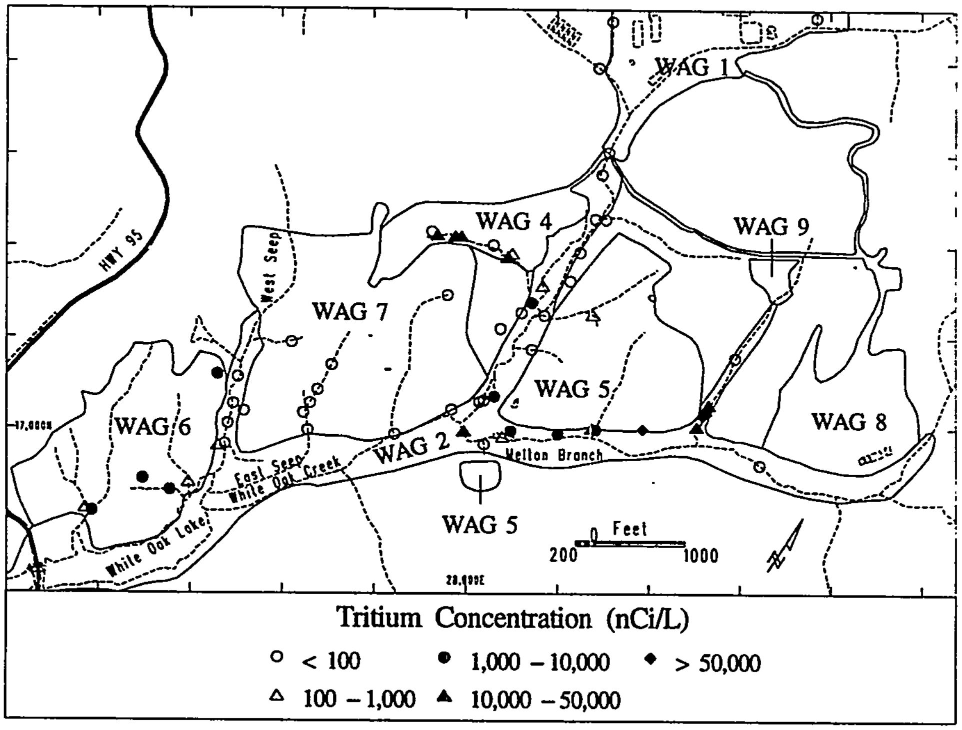

Fig. 6.3. Tritium concentrations at seep, tributary, and stream locations.

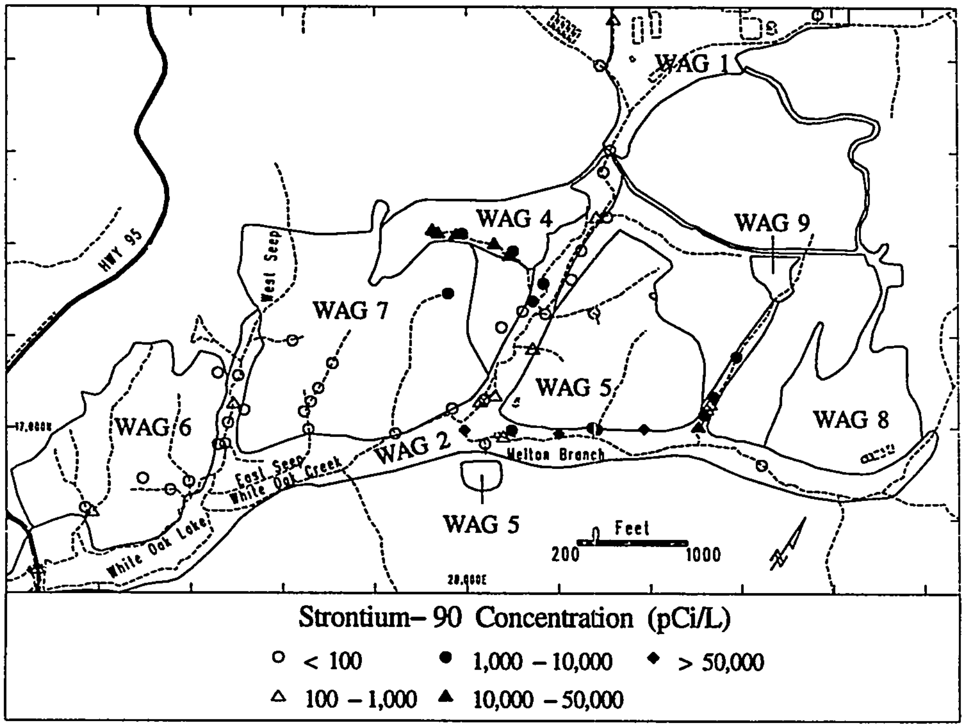

Fig. 6.4. Strontium-90 concentrations at seep, tributary, and stream locations.

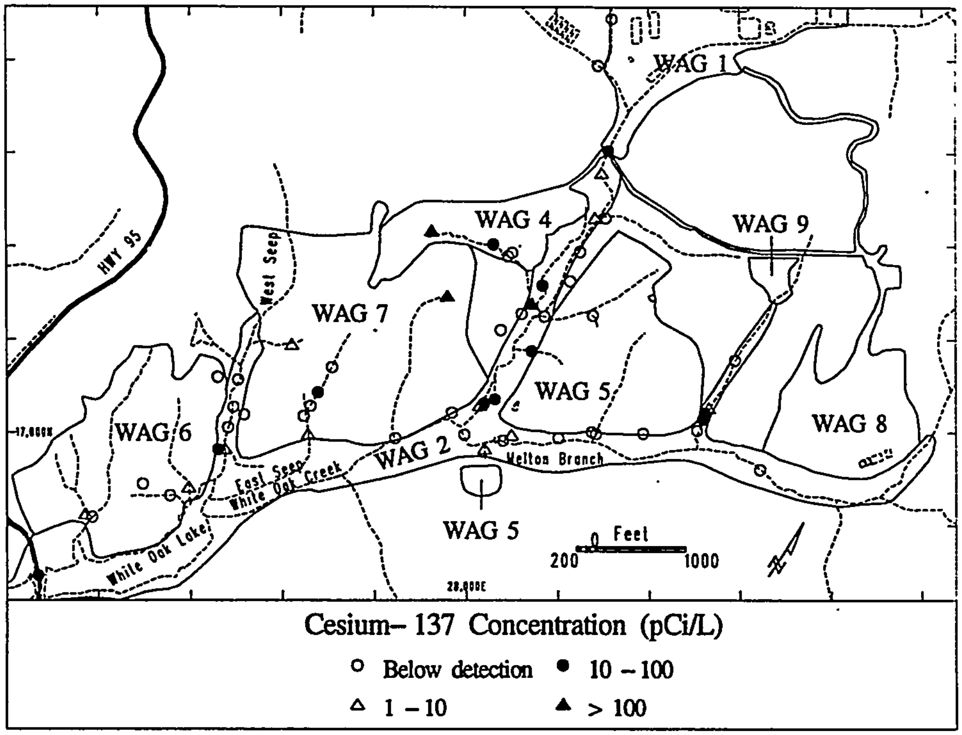

Fig. 6.5. Cesium-137 (combined particulate and dissolved) concentrations at seep, tributary, and stream locations.

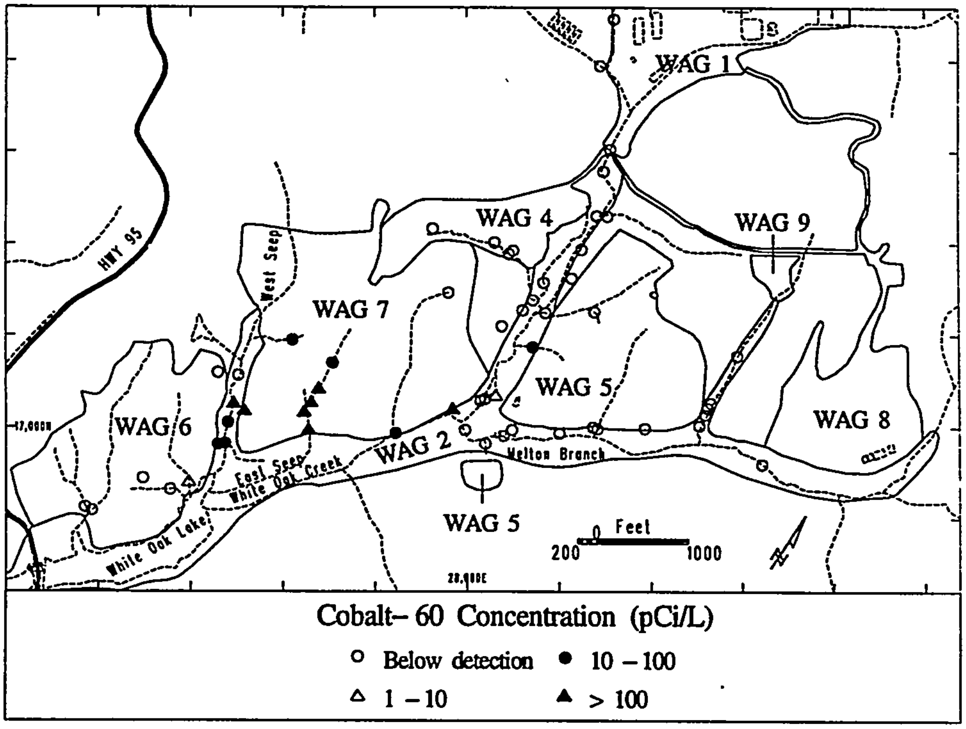

Fig. 6.6. Cobalt-60 (combined particulate and dissolved) concentrations at seep, tributary, and stream locations.

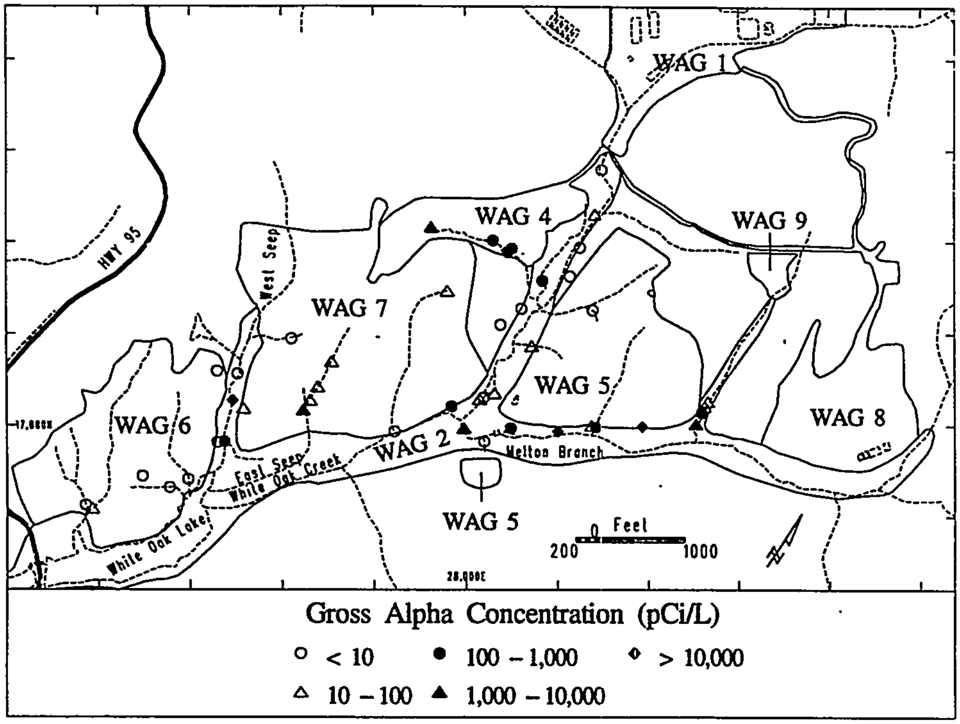

Fig. 6.7. Gross alpha concentrations at seep, tributary, and stream locations.

Round 2 thallium results were an order of magnitude higher than both Round 1 and historical data (Blaylock et al. 1991). This may be the result of analytical method variation, elemental interferences (e.g., Ca, Fe, and Mg), natural sources, or a combination of the three. Seasonal variations probably do not account for the higher concentrations in Round 2. There is a general trend of increasing thallium with increasing calcium concentrations in Round 2. It is suspected that calcium could have interfered with the method used in Round 2. However, there were no qualifiers on the Round 2 thallium results (see Sect. 6.6). Thallium detection limits exceeded the current drinking water and federal recreation criteria in both rounds. These may not be appropriate criteria for WAG 2 (see Sect. 5). Future analysis of thallium will be done by graphite furnace in order to meet the current drinking water MCL and recreation criteria and to reduce interferences.

Arsenic detection limits also exceeded the federal recreation criteria in both rounds. RS-1 and RS-3, which are WAG 7 seeps, had the highest levels of arsenic, 14 and 22 $\mu g/L$, respectively. Two seeps in WAG 7—RS-3 and SW7-3—exceeded the state recreation criteria for mercury. RS-3 and SW7-3 also exceeded the chromium criteria for the protection of freshwater organisms. Antimony was marginally higher than the SDWA MCL at seven locations around WAG 2 including RS-3. Nickle was detected in one of the WAG 4 seeps above the freshwater organism criteria during the first sampling round; however, the seep was dry during the second round. Copper and zinc were present at concentrations above the freshwater organism criteria in Melton Branch during the dry season sampling. These metals were seen both at the downstream and upstream locations (MBWEIR and MB-15), suggesting that WAG 8 might be the source for the elevated copper and zinc.

6.4.7 Anions

Chloride, fluoride, nitrate, phosphate, and sulfate results were typical of stream and groundwater concentrations with a few exceptions (Appendix C). Samples from Melton Branch at MB-15 and MBWEIR typically had higher levels of the anions with sulfate being the most unusual, ranging from 132 to 403 mg/L. The highest chloride concentrations—29 and 44 mg/L—were found at seep SW7-3 (see Fig. 6.1) during Rounds 1 and 2, respectively. WAG 7 seep RS-3 had some of the highest concentrations of fluoride (11 mg/L), nitrate (77 mg/L), phosphate (28 mg/L), and sulfate (190 mg/L). In general, higher anion concentrations were seen during Round 2 when conditions were drier than normal.

6.4.8 Alkalinity and Field Parameters

Alkalinity, specific conductance, pH, and temperature are general water chemistry parameters that may be useful in characterizing seasonal variability, hydrologic pathways, and/or source area inputs (Appendix C). Data for these parameters are qualitative and are incorporated in the overall assessment of the data.

6.5 QC SUMMARY

Both qualitative and quantitative criteria are used as indicators of the quality of the seep and tributary data. In determining whether the data are usable, especially in the decision process, the integrity and authenticity of the data must be evaluated, and the analytical uncertainty must be known. Indicators generally used to assess the data quality are precision, accuracy, representativeness, comparability, and completeness. These parameter acceptance values, used in WAG 2 data assessment, are found in "Requirements for Quality Control of Analytical Data," ES/ER/TM-16.

Precision is the degree of mutual agreement between independent measurements made under identical, specified conditions. Standard deviation (STD), coefficient of variation (CV), and relative percent difference (RPD) are used to express precision. Analysis of laboratory duplicates provides an assessment of the precision associated with the laboratory method. Analysis of field duplicates provides a total assessment of the overall precision of the sample data because it includes both the field and laboratory variability. Evaluation of sampling precision may be determined from the difference between the overall precision and the analytical precision. The usefulness of the precision data is limited to samples that contain contaminants at concentrations above the method detection limit.

$$\mathrm{CV} = 100\ (\mathrm{STD/mean})\ .$$

$$\mathrm{RPD} = \frac{|\,D_1 - D_2\,|}{(D_1 + D_2)/2} \times 100\ ,$$

where D_1 is the value of the first measurement and D_2 is the value of the second measurement.

Accuracy is the closeness of agreement between an observed value and an accepted reference value.

Accuracy was primarily measured through the use of laboratory control samples (LCSs) as a percent recovery (%R) calculation:

$$\%R = \frac{LCS_{\text{measured}}}{LCS_{\text{known}}} \times 100$$

When used correctly, blanks, both in the field and the analytical laboratory, provided a means of checking for bias resulting from contamination. Blanks must be treated the same way the samples are treated. When contamination is found, the causes must be eliminated. Use of blank results to correct sample results can add more variability to the result because blank results are also subject to analytical error. No blank corrections were performed on Rounds 1 and 2 data. Calibration standards at the required concentrations and frequency were used to estimate the data variability.

Representativeness expresses the degree to which the data accurately reflect the analyte or parameter of interest at an environmental site. Several factors may contribute to whether a sample result is representative of the sampling site. SOPs and approved analytical methods must be used both in the field and in the analytical laboratory. Any measures taken to ensure that bias has not been introduced into the sampling and analysis will contribute to sample representativeness. These measures include proper preservation; use of standard analytical methods; adherence to appropriate holding times; and use of field and laboratory blanks, equipment rinsates, and proper containers. Rounds 1 and 2 seep and tributary data collection efforts incorporated these measures to ensure representativeness. Results of blank samples are described in the following text.

Comparability is the confidence with which one data set can be compared with another data set generated by a different sampling event or by a different laboratory. The use of accepted methods and SOPs and participation in intralaboratory performance evaluation testing demonstrate comparability. Sample collection, preservation, storage, preparation, analysis, and reporting must be consistent for comparability to be achievable.

Completeness is a measure of the amount of valid data obtained from the sampling and analysis process. Analytical completeness is typically expressed as the total number of samples taken for which acceptable analytical data are generated divided by the total number of samples actually collected divided by the total number of samples planned to be collected. Seep and tributaries data completeness was >95% for the overall sampling and analysis process.

The following section summarizes the seep and tributary data assessment based on the data quality indicators described above.

6.5.1 Tritium

Precision. For each observed tritium concentration there is a measure of uncertainty given by the CV of the measurement that was estimated from the STD of the observed count data. The CV expresses the measurement or counting error as a percent of the measured tritium concentration. A statistical assessment of the complete tritium data set indicates that at least half of the observed CV values are <1% and at least 95% are <11%.

Twenty-two laboratory duplicates were analyzed for tritium for a measure of laboratory precision. These analyses show that 86.4% of the results agree within ±20% RPD, with the remaining 13.6% showing RPD >±20%.

Twenty-three field duplicates were analyzed for a measure of overall sampling precision of the sample data. These analyses show that 87.0% of the results agree within ±20% RPD, with the remaining 13.0% showing RPD >±20%.

Accuracy. Twenty-three LCSs were analyzed for a measure of laboratory accuracy for tritium analyses. All LCS results were within acceptable %R limits of 75–125%.

Representativeness. Twenty-two method blanks were analyzed for a measure of background and cross-contamination. All blanks showed either the absence of contamination or contamination within acceptable limits. Twelve matrix spikes were analyzed for a measure of matrix interference with the analyses. These analyses show that 83.3% of the results agree with the recovery range of 75–125%, with the remaining 16.7% showing outside the acceptance limits. However, insufficient data preclude assessment of %R for five of these matrix spikes.

Comparability. Sixteen samples were split and sent to an outside laboratory for confirmation results of tritium data generated in the ESD radiochemistry laboratories. Results of these confirmation analyses show that 81.3% of the results agree within ±20% RPD, with the remaining 18.7% showing RPD >±20%.

6.5.2 Strontium-90

Precision. The measurement or counting errors associated with the ^{90}Sr results were determined, and a CV for each ^{90}Sr measurement was estimated. A statistical assessment of the complete ^{90}Sr data set indicates that at least half of the observed CV values are <10%. However, the 95th percentile of the CV observations equals 155%. Another statistical assessment of only those ^{90}Sr results that were significantly greater than background indicates that at least half of the observed CV values are <10% and at least 95% are <50%.

Two hundred fifty-five laboratory duplicates were analyzed for a measure of laboratory precision. Out of this total, 206 laboratory duplicates showed activity above background and have been used here to better represent laboratory precision. These analyses show that 83.5% of the results agree within ±20% RPD, with the remaining 16.5% showing RPD >±20%.

Twenty-two field duplicates were analyzed for a measure of overall precision. Out of this total, fifteen field duplicates showed activity above background and have been used here to better represent overall precision. These analyses show that 86.7% of the results agree within ±20% RPD, with the remaining 13.3% showing RPD >±20%.

Accuracy. There were no laboratory control samples run for this nuclide.

Representativeness. Thirty-six blanks were analyzed for a measure of background and cross-contamination. All blanks showed either the absence of contamination or contamination within acceptable limits. Matrix spikes were not performed in the analyses of samples for ^{90}Sr.

Comparability. Nineteen samples were split and sent to an outside laboratory for confirmation results of ^{90}Sr data generated in the ESD radiochemistry laboratories. Of these samples, fifteen had activities above background (based on ESD results). Results of these fifteen confirmation analyses show that 66.7% of the results agree within ±20% RPD, with the remaining 33.3% showing RPD >±20%. The method used by the confirmation laboratory is more sensitive than the analytical method used in the ESD laboratories. For samples showing activities greater than 150 pCi/L, all but one of the confirmation analyses agreed with ±20% RPD.

6.5.3 Cesium-137 and Cobalt-60

Precision. Most of the samples counted for gamma-emitting radionuclides had ^{137}Cs and ^{60}Co concentrations below detection. For each detectable ^{137}Cs concentration, a CV of the measurement was estimated from the STD. The CV expresses the measurement or counting error as a percent of the ^{137}Cs concentration. A statistical assessment of the data associated with the dissolved portion of the sample indicates that at least half of the observed CV values are <25%, and at least 95% are <95%. A statistical assessment of the data associated with the particulate portion of the sample indicates that at least half of the observed CV values are <22%, and at least 95% are <123%. The higher CVs are generally associated with lower concentrations.

For each detectable ^{60}Co concentration, a CV of the measurement was estimated. A statistical assessment of the ^{60}Co data associated with the dissolved portion of the sample indicates that at least half of the observed CV values are <12%, and at least 95% are <47%. A statistical assessment of the ^{60}Co data associated with the particulate portion of the sample indicates that at least half of the observed CV values are <23%, and at least 95% are <48%. Similar to ^{137}Cs data, the higher CVs are generally associated with lower concentrations.

Three field duplicate samples were analyzed for ^{137}Cs with RPD values of 6.1, 7.1, and 26% for the dissolved portion and 6.3, 8.5, and 134% for the particulate portion. Three field duplicate samples were analyzed for ^{60}Co with RPD values of 3.3, 5.2, and 9.3% for dissolved portion and 0, 67, and 187% for the particulate portion. There were no laboratory duplicates, matrix spikes, or LCSs run for this nuclide.The high RPD value for the particulate portion may indicate that bottom sediment was disturbed or introduced during sampling.

Accuracy. There were no laboratory duplicates, matrix spikes, or LCS run for this nuclide.

Representativeness. Thirty-one blanks were analyzed for a measure of background and cross-contamination. All blanks showed either the absence of contamination or contamination within acceptable limits. Matrix spikes were not performed in the analyses of samples for either ^{137}Cs or ^{60}Co.

6.5.4 Gross Alpha and Gross Beta

Precision. For each observed gross alpha and beta concentration, there is a measure of uncertainty given by the CV. A statistical assessment of the gross alpha data set indicates that at least half of the observed CV values are <10%, and at least 95% are <536%. A statistical assessment of the gross beta data set indicates that at least half of the observed CV values are <1.4%, and at least 95% are <79%.

Eleven laboratory duplicates were analyzed for a measure of laboratory precision for gross alpha and gross beta analysis. These analyses show that 45.5% of the results agree within ±20% RPD, with the remaining 54.5% showing RPD >±20%.

Seven field duplicates were analyzed for gross alpha and gross beta. These analyses show that 45.5% of the results agree within ±20% RPD, with remaining 54.5% showing RPD >±20%.

Accuracy. LCSs were analyzed for gross alpha and gross beta analyses (10% total). Seventy percent of the gross alpha and beta LCS samples fell outside the acceptable range of 80–120%. Matrix spikes were analyzed, which may provide a rough estimate of total laboratory performance. Percent recoveries for matrix spikes may fall outside acceptable QC ranges due to matrix interferences; a complete evaluation of laboratory method accuracy is not possible. Fourteen matrix spike samples were analyzed. These analyses show that 58% of the gross alpha results and 64% of the gross beta results were within QC criteria of 75–125% recovery, with the remaining 42% gross alpha and 36% gross beta showing recovery outside criteria.

Representativeness. All method blanks (11) analyzed for gross alpha and beta fell within acceptable limits indicating that no contamination occurred in the laboratory.

6.5.5 Metals

Precision. Laboratory duplicates range from 2–11 samples were analyzed with each metal analyses for measures of laboratory precision and accuracy. All duplicate values were within acceptable QC limits (±20%), with the exception of one pair with an RPD of 28% for vanadium.

Eight field duplicates were analyzed for metals. All duplicate RPD values for metal were within ± 20%, with the exception of one pair with RPDs of 27.5% and 33.7% for Ni and V, respectively; one pair with an RPD of 22.2% for Be; and one pair with an RPD of 22.6% for Tl.

Table 6.5 illustrates the number of method blanks, calibration blanks, and matrix spike samples analyzed for measures of contamination and matrix effects for each metals analyses. In some cases, method blank values were not reported for individual metals, but calibration blank values were reported. All matrix spike results were within acceptable percent recovery limits of 75–125%.

Accuracy. LCSs ranged from 2–11 samples per metal analysis as a measure of laboratory accuracy. All LCS results were within acceptable %R limits of 75%–125%.

Representativeness. Metal analysis results for field blanks indicate that airborne metal contaminants were not present at the time of sampling, with the exception of a field blank opened at seep SW7-5, which had 50 μg/L Cu, 55.2 μg/L Ni, 27.9 μ/L Pb, and 105 μg/L Zn. However, the actual sample from the concentration of these metals in seep SW7-5 was below detection limits. The source of this contamination is not known. Rinsate samples had metal concentrations near or below detection, with the exception of one from Round 1 which had 11.3 μg/L Ag.

Table 6.5. Quality control samples for metals: contamination and matrix effects

Metal	Method blanks frequency	Calibration blanks frequency	Matrix spike frequency
Al	2	34	5
Sb	2	22	5
As	2	45	2
Ba	2	15	5
Be	2	16	5
Cd	2	44	2
Ca	2	40	5
Cr	2	17	5
Co	2	18	5
Cu	2	18	5
Fe	2	40	5
Pb	2	39	2
Mg	2	40	2
Mn	2	11	5
Ni	2	28	5
K	2	30	7
Se	2	40	6
Ag	2	14	5
Na	2	14	2
Tl	2	15	5
V	2	18	5
Zn	2	18	5
Mo	2	18	2
Bo	2	19	2
Si	2	23	2
Sr	2	23	2
Hg	NA	14	2

6.5.6 Anions

Nine laboratory duplicates were analyzed for a measure of laboratory precision for anion analysis. All anion laboratory duplicate pairs were within the quality control range of ±20 relative percent difference (RPD).

Nine field duplicates were analyzed for anions. All duplicate RPD values for each anion were within ±20%, with the exception of one pair exceeding ±20% for chloride, nitrate, sulphate, and fluoride and one pair exceeding ±20% for chloride and fluoride.

Twenty six calibration blanks were analyzed for a measure of background and cross-contamination. All calibration blanks showed no contamination. No data regarding method blanks were provided. Method contamination cannot be assessed.

No laboratory control samples were analyzed for anions analysis; however, matrix spikes were analyzed, which may provide a rough estimate of total laboratory performance. Percent recoveries for matrix spikes may fall outside acceptable quality control ranges because of matrix interferences; a complete evaluation of laboratory method accuracy is impossible. While matrix spike percent recovery criteria have not been established for anions, percent recovery ranges were between 82 and 120%.

6.6 DATA VALIDATION SUMMARIES

Upon receipt from the laboratory, all data packages were inventoried for completeness and compliance with the WAG 2 Statement of Work. The presence of certain samples at Level D deliverable requirements was verified. The nonconforming items identified were resolved with the laboratory. The data packages were then validated in accordance with requirements of WAG 2 project procedures. Validation of the Level D samples included recalculation of analytical results from raw data at a frequency described in WAG 2 project procedures. If calculations revealed errors in reporting, corrections were made to the analytical results, and recalculation of results was performed until no further calculation errors were detected.

6.6.1 Radionuclide Analytical Data Validation Summary

Analytical validation of all radionuclide data was performed within WAG 2 with guidance provided from the document "Requirements for Quality Control of Analytical Data," ES/ER/TM-16, and the WAG 2 radionuclide data validation procedure based on the requirements of this document. Although deficiencies were found during the data validation process, data were found to be useful for their intended purpose (see Sect. 6.7.1).

Data resulting from the analyses of seep-and-tributary task samples by WAG 2 were qualified J at QC Level C, except for ^{90}Sr, which was qualified J at QC Level B (see Sect. 6.3.3) because of lack of evidence of initial or continuing calibration data. Some quality control requirements stated in ES/ER/TM-16 were not met by the WAG 2 laboratories. When the laboratories analyzed these samples, approved quality control requirements for radiochemical analyses were not available from Environmental Restoration (ER). However, radionuclide analyses were performed according to project-specific standard operating procedures and QA/QC requirements. These requirements were released by ER in December 1992 in ES/ER/TM-16, after the analysis of the samples by WAG 2. The data were validated according to the requirements of this document, as this document was the only existing guidance from ER for radiochemistry quality control.

WAG 2 laboratory results. Table 6.6 summarizes the analytical data validation results for the radionuclide analyses completed in WAG 2 laboratories by WAG 2 technical staff.

Table 6.6. Summary of data validation results for radionuclide analyses performed by WAG 2 laboratory

Nuclide	J	UJ	R	Number of samples	Qualifier sum	Percent usable at level C	Percent usable at level B
^{3}H	278		17	295	295	78	100
^{90}Sr	162			162	162	0	100
^{137}Cs	231			231	231	100	100
^{60}Co	231			231	231	100	100

Tritium. All tritium data have been qualified J at QC Level C because of deficiencies in quality control, except for samples qualified R, listed below. Prior to August 1992, no dark adaption was done prior to analysis. Lack of dark adaption may have resulted in somewhat underestimated tritium values, particularly in lower concentrations. Laboratory duplicates and matrix spikes were not analyzed for some batches of samples. In some cases, labeling discrepancies concerning dates of analysis were discovered. Data discrepancies do not directly affect sample quantitation, but they do affect the ability to define the identity of a sample and, thus, affect the reliability of sample results.

The following samples have been qualified R because concentrations were less than five times the amount in the method blank, in addition to the deficiencies listed above.

3008
3009
3012
3015
3017
3019
3021
3023
3026
3030
3035
3037
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3039
3043
3044
3072
3073
3074
3075
3089
3090
3091
3092
3093
3099
3100
3101
3102
3103
3105
3131
3291
3295
3296
3307
3311
3313
3314
3315
3318
3330
3331
3332
3333
3334
3335
3336
3337
3338
3369
3376
3377
3379
3387
3388
3396
3400
3401
3403

Strontium-90. All ^{90}Sr data have been qualified J at QC Level B. The Cerenkov radiation counting method was used in the analysis of ^{90}Sr. Various quality control deficiencies precluded a quantitative usability assessment through the analytical validation effort. Initial calibration and continuing calibration could not be verified as having been run. Raw data changes were made with no signature, date, or reason for change.

Cesium-137 and Cobalt-60. All gamma data have been qualified J at Level C because of deficiencies in quality control. The general procedure for sample preparation and analysis for gamma has not included a Laboratory Control Sample (LCS). Method blanks and instrument calibration blanks were analyzed. Laboratory control samples were not created in the sample preparation laboratory; no assessment of overall laboratory performance can be made without these data. The requirements for the analysis of an LCS are specified in ES/ER/TM-16. Several transcription errors were discovered and corrected against raw data. Several raw data outputs were illegible, possibly because of copy machine difficulties. No matrix spike samples were analyzed for Round 2. No laboratory duplicate samples were analyzed for gamma analyses in Round 2.

Samples were analyzed for ^{3}H and ^{90}Sr by ORISE at a level of 10% of the total number of samples in Rounds 1 and 2 in an effort to confirm radiological data for similar samples analyzed at WAG 2. In addition to the confirmation analyses, ORISE also analyzed gross alpha and gross beta, which was not analyzed by the WAG 2 laboratories.

ORISE Laboratory Data. Table 6.7 summarizes the analytical data validation results of radionuclide analyses conducted by ORISE.

Table 6.7. Summary of data validation results for radionuclide analyses performed by ORISE Laboratory

Nuclide	J	UJ	R	Number of samples	Qualifier sum	Percent usable at Level C
^{3}H	6		1	7	7	86
^{90}Sr	19			19	19	100
Gross alpha	80			80	80	100
Gross beta	48		12	60	60	80

Tritium. All tritium data have been qualified J at QC Level C because of deficiencies in quality control, except for the sample qualified R, listed below. No record of dark adaption was provided. Count times were inadequate. NIST certificates for standards were not included in the data package, so standard traceability could not be assured. Date discrepancies precluded verification that the most recent efficiency curve was used for quantitation of samples.

Sample 3098 (Batch 415, Round 1) has been qualified R because concentrations were less than five times the amount in the method blank, in addition to the deficiencies listed above.

Strontium-90. All ^{90}Sr data have been qualified J at QC Level C because of deficiencies in quality control. No laboratory control samples were analyzed. Continuing calibration was not performed when necessary. Instrument background counts were not performed when necessary.

Gross Alpha and Beta. All data for gross alpha and beta have been qualified J at QC Level C because of deficiencies in quality control, except for the samples qualified R, listed below. Count times were inadequate. Sample dry weights exceeded the 100 mg limit for all samples except the blank and standard. In some cases, the daily blank showed high activity, but no corrective action was taken or documented. In some cases, the matrix spike percent recoveries were out of criteria, as noted in the laboratory notes, but no corrective action was taken or documented. In one case, no laboratory control sample was run for a batch of analytical samples; laboratory control charts of LCS were not provided in the package. Changes were made to raw data without signatures or dates and without justification for the changes. For Batch 498, gross alpha values were reported in place of gross beta values; however, this problem was corrected in the analytical validation procedure.

The following samples analyzed for gross beta have been qualified R because of the presence of unsigned, undated handwritten corrections/changes on the instrument printout, originating at the laboratory. No explanation is provided for these changes. The results cannot be supported by these raw data. All samples listed are in Batch 409, for the Round 1 sampling event.

3023
3031
3106
3021
3022
3023

3024
3025
3026
3027
3028
3029

6.6.2 Chemical Analytical Data Validation Summary

Analytical validation of the inorganic and anions data was done by Analytical Environmental Support Group; 20% of the total samples collected were validated, including all critical samples.

Metals. Table 6.8 summarizes the analytical data validation results for metals. The analysis of inorganic species was performed according to SW-846 methods. However, the data were reported on Contract Laboratory Program (CLP) forms.

A qualifier of R was placed on sample results for silver in Batch 3280-2 because of low matrix spike percent recovery (9.9%). A qualifier of R was placed on all sample results in Batch 13827 arising from atomic absorption analysis for potassium, arsenic, cadmium, lead, mercury, nickel, and selenium because of failure of the laboratory to include initial calibration on the run log. A qualifier of R was placed on all mercury results for Batch 14666 because of failure of the laboratory to provide a run log, which would include that the instrument was initially calibrated properly with four standards and a blank.

Anions. Anion analysis of was performed according to EPA Method 300.0. At the time of sample analysis, the laboratory was not archiving data, and the initial calibration data was unavailable for review. Initial and continuing calibration verification results were performed, but without the initial calibration information, verification that instruments were calibrated properly is impossible. All data have been qualified R because of inability of the laboratory to provide initial calibration data. Results for all samples analyzed for anions for the seeps and tributaries task Rounds 1 and 2 could be qualified R, as the analyses were all done by a similar laboratory, and no initial or continuing calibration data is available.

6.7 DATA INTERPRETATION

6.7.1 Data Usability

As stated earlier, the primary objective of the WAG 2 RI Seep and Tributary Task is to identify seeps and tributaries that are responsible for the contaminant fluxes to the main channels of WAG 2 and to quantify their input to the total contaminant flux. The quality objectives for this first screening survey were not as rigorous as those would be for a baseline risk assessment. The goal was to gather data needed to prioritize seeps and source areas for future monitoring, for directing focused corrective actions, and for longer term monitoring to evaluate the effectiveness of remedial actions. Data collected from the initial screening survey is not meant to stand alone but to help confirm and supplement previous investigations and continuing compliance monitoring.

The previous sections (6.5 and 6.6) provide an assessment of each parameter in terms of the data quality indicators (precision, accuracy, representativeness, comparability, and completeness) and give summaries of the validity of the data. In general, >80% of the radionuclide and metal results had RPD values <20%, indicating that the precision of the data is adequate. Calculated RPDs which were >20%, were typically associated with lower

Table 6.8. Summary distribution of analytical data validation results for metals

Metal	J	UJ	R	U	Number of samples validated	Qualifier sum	Percent usable at Level C
Al					59		100
Sb					59		100
Ar		1	23		59	24	61
Ba				2	59	2	100
Be				16	59	16	100
Bo				10	20	10	100
Cd			23		30	23	23
Ca					59		100
Cr					59		100
Co					59		100
Cu					59		100
Fe					59		100
Pb			23		30	23	23
Mg					30		100
Mn					59		100
Mo					30		100
Hg			37		57	37	35
Ni					59		100
K			27		59	27	54
Se			23		30	24	23
Si	1				30		100
Ag		15	15		59	30	75
Sr					30		100
Na					30		100
Tl					59		100
V	7			3	59	10	100
Zn		3			59	3	100
CN					7		100

concentrations. Accuracy as assessed for laboratory observations was within acceptable ranges for those analyses (^{3}H and metals) for which accuracy could be estimated, with the exception of gross alpha and gross beta analyses. Results from these measures included the absence of contamination in >98% of the blanks and rinsates analyzed. Comparability was ensured by the use of EPA-approved methods for most analytes. Tritium and ^{90}Sr data generated by ESD were compared in an intralaboratory performance evaluation and found to be comparable (RPDs <20%), with the exception of samples with low concentrations. An overall completeness of >95% was obtained for sampling and analyses. Of all samples validated, 89% are usable at levels B and C. Some of the gross beta and metals results and all of the anion results were rejected (see Sect. 6.6).

Although most of the radionuclide results were validated with the qualifier J (considered to be an estimated value), these estimates are sufficient to identify contaminant sources and to begin to prioritize seeps and tributaries because of the large range of concentrations present (particularly for ^{3}H and ^{90}Sr) throughout the watershed (see Figs. 6.3 through 6.7). However, additional interpretation is needed to use the gross alpha results. Beta cross talk, false counts occurring in the alpha channel, can significantly affect the reported alpha concentration for those samples that have high beta concentrations. Beta cross talk is about 1% (i.e., gross alpha counts are overestimated by 1% of the gross beta counts). Gross alpha values reported in Appendix B have not been corrected for beta cross talk.

Based on the overall QC assessment of the radionuclide analyses, ^{3}H results are adequate for contaminant flux estimates. Strontium-90 results are mostly adequate for flux calculations; however, the method used—Cerenkov Radiation Counting—is not as sensitive as needed for lower concentrations. This becomes critical primarily in WOC where ^{90}Sr concentrations may be less than 100 pCi/L. Because stream flow is relatively large, the ^{90}Sr flux becomes important, but has a larger associate error. In addition, changes in concentrations (potential ^{90}Sr source inputs) along the WOC stream reach are not easily identifiable because of the insufficient sensitivity of the analytical method. As seen later in Sect. 6.7.4, these estimates are still useful for prioritizing contaminant source areas.

Based on the overall QC assessment of the metal analyses, results exceeding ARARs should be considered as potential contaminants of concern. Additional data are needed before conclusions are made about whether a particular metal is a contaminant of concern.

6.7.2 Comparison with Historic Seep Data

Results from the seep survey can be compared with historic seep data to gain an understanding of the temporal dynamics of contaminant transport.

WAG 7 Area: Duguid (1975) identified and sampled eight seeps in WAG 7 in 1973 (Table 6.9). During the WAG 2 survey, only two of these eight had markers with identification tags; however, seeps were found in the same vicinity as the other six historic seeps. Although one seep was tagged as RS 3, it is suspected that this may really be the historic RS 2, based on locations indicated on a map (Duguid 1975). Comparisons of ^{60}Co (the primary contaminant) were made and suggest that there has been a significant decrease in ^{60}Co release from this area over the last 20 years (Table 6.9). This decrease may partially be a result of radioactive decay, because the half-life of ^{60}Co is only 5.3 years. Over 17 years (1975–92) ^{60}Co was reduced to radioactive decay.

WAG 5 Area. Duguid (1975) identified and sampled 16 seeps in WAG 5 in 1973 and 1974 (Table 6.1). None of these were positively identified during the WAG 2 survey; however, a few of the seeps found during the WAG 2 survey probably correspond with the historic seeps. The WAG 2 seep SW5-7, which had the highest ^{3}H concentrations (100 and 127 µCi/L), may correspond with the historic seep S-15 which had a ^{3}H concentration of 432 µCi/L. The high ^{90}Sr seep, SW5-4 (with 485 and 573 nCi/L ^{90}Sr) probably corresponds with Duguid's seep S-5 (with 158 nCi/L ^{90}Sr) and Spalding and Munro's T-2 (with a yearly average ^{90}Sr concentration of 208 nCi/L) (Spalding and Munro 1984). Spalding and Munro (1984) also report a discharge rate, averaged from October 1980 to October 1981, of 0.8 L/min for T-2 (which compares well with the wet-season and dry-season discharges of 1.2 and 0.07 L/min, respectively for the seep). Tritium and ^{90}Sr continue to be the primary contaminants of concern in WAG 5 seeps.

Table 6.9. Comparison of historic seeps data

Historic seep location[a]	Corresponding WAG[b] 2 location	Cobalt-60 pCi/L in March 1973[c]	Cobalt-60 pCi/L in March 1972[b]
RS 1	RS-1	<90	15
RS 2	RS-3	17342	667
RS 3	SW7-2	46847	1029
RS 4	EAST SEEP	5180	135
RS 5	SW7-3	25450	495
RS 6	SW7-7	6036	85
RS 7	SW7-5	215766	1412
RS 8	SW7-6	<225 (1712 pCi/L ^{137}Cs)	<9 (306 pCi/L ^{137}Cs)

[a] Duguid (1975).
[b] WAG = Waste Area Group.
[c] Particulate and dissolved concentrations were combined to report the total cobalt-60 present.

WAG 4 Area. None of the WAG 4 seeps identified by Duguid (1975) in 1973 and 1974 or by Huff et al. (1982) in 1979 and 1980 were positively identified during the WAG 2 survey. Results from the WAG 2 sampling are consistent with the historic data, in that elevated ^{90}Sr concentrations continue to be found in WAG 4 seeps.

6.7.3 Stream Transect Sampling

White Oak Creek. Results from the stream transect sampling indicated that there were no significant ^{3}H or ^{90}Sr inputs into the WOC reach below WC7500 other than stream discharges from the WAG 4 tributary, Melton Branch, and a potential tritiated groundwater discharge near WCWEIR. During the dry-season baseflow, there was some increase in ^{3}H concentrations just below WCWEIR, suggesting that there may be an input of contaminated groundwater in this reach; however, this input was not evident during the wet-season sampling round.

Melton Branch. Transect sampling along Melton Branch identified four areas of discernable contaminated groundwater input. These areas are referred to as Areas A, B, C, and D by the WAG 5 RI efforts (Newsome et al. 1993). Contaminated groundwater inputs are apparent in these areas from the increases in ^{3}H and ^{90}Sr concentrations that occur at the downstream locations (Figs. 6.8 and 6.9). One of these four areas is where a fairly discrete seep (SW5-7) discharges highly tritiated groundwater to the Melton Branch tributary between HRT-2 and HRT-3 (Fig. 6.8). Another significant ^{3}H input appears to be a more diffuse area along the southeastern boundary of WAG 5 (Fig. 6.8). Sharp increases of ^{90}Sr in Melton Branch occur as a result of input from seep SW5-4 on the southern edge of WAG 5 (Fig. 6.9). This seep is a major source of ^{90}Sr to the watershed. Results from the first round of stream transect sampling along Melton Branch also revealed another significant ^{90}Sr input below MBWEIR and above the confluence with WOC (Fig. 6.9). This seep, SW2-5, was later visually identified, and samples were collected from it during the second round of sampling.

WAG 4 Tributary. Contaminated groundwater discharge into the WAG 4 tributary is apparent from the high ^{3}H and ^{90}Sr concentrations; however, large discrete increases in ^{3}H and ^{90}Sr concentrations along the tributary were not evident in the transect sampling results (Figs. 6.10 and 6.11). Both ^{3}H and ^{90}Sr concentrations and fluxes change very little between the upper flume location, WAG4 MS1, and the downstream flume location, WAG4 T2A (see Fig. 6.1), indicating that most of the contaminated groundwater seepage occurs above WAG4 MS1. Most of the ^{3}H appears to be entering the tributary in the upper reach above W4TRIB-6. Decreasing ^{3}H concentrations after W4TRIB-6 indicate that groundwater with lower

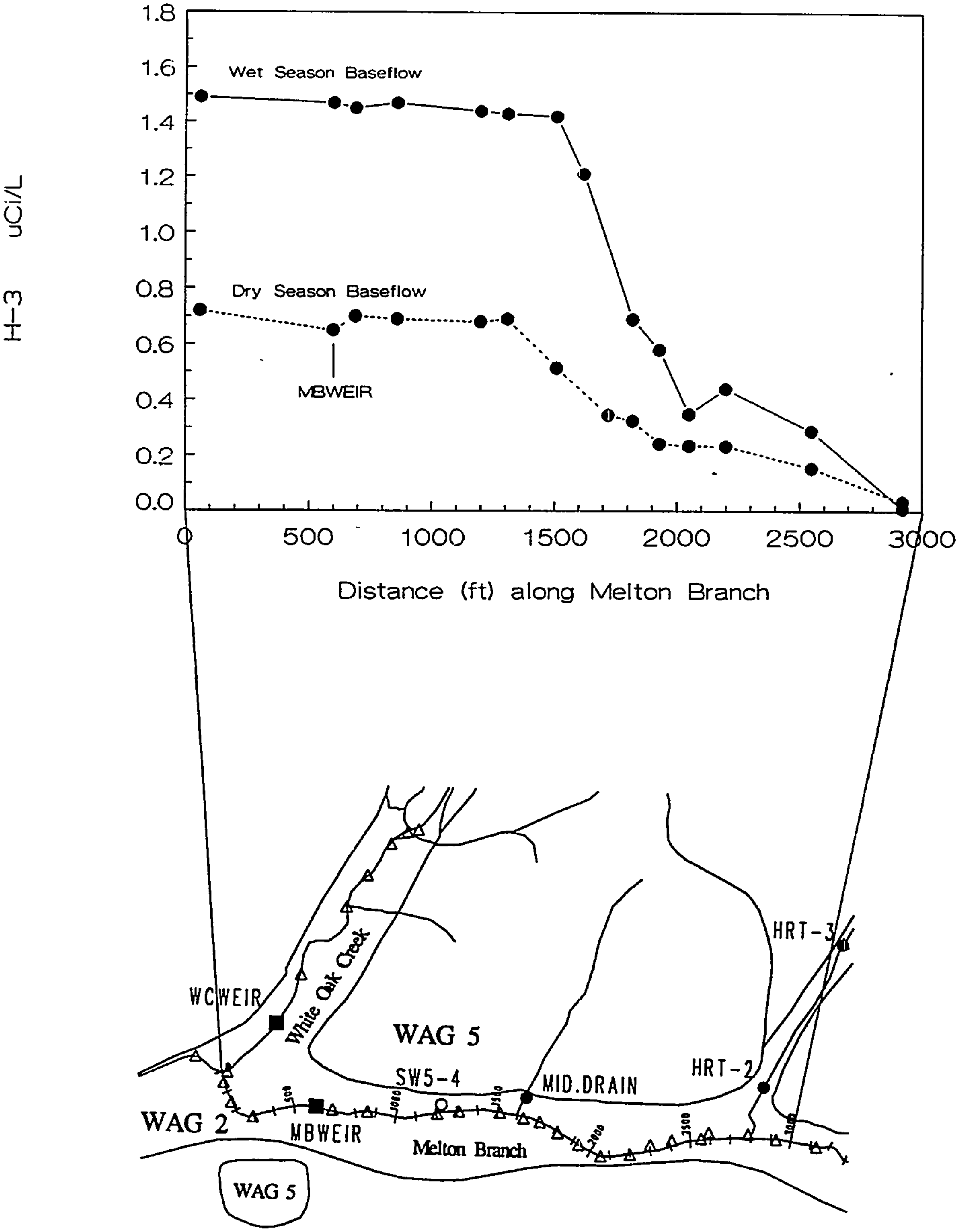

Fig. 6.8. Tritium concentrations at transect locations along Melton Branch.

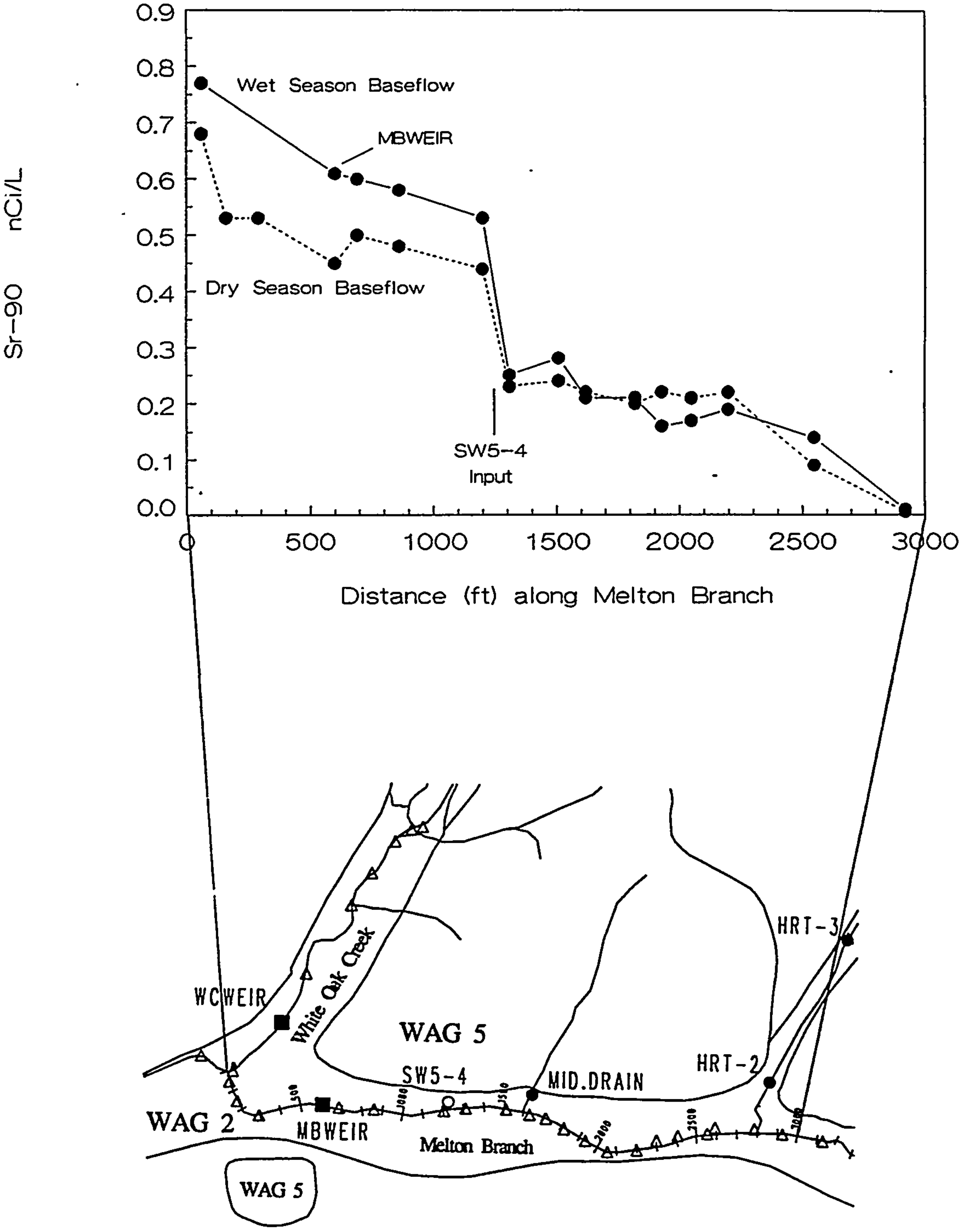

Fig. 6.9. Strontium-90 concentrations at transect locations along Melton Branch.

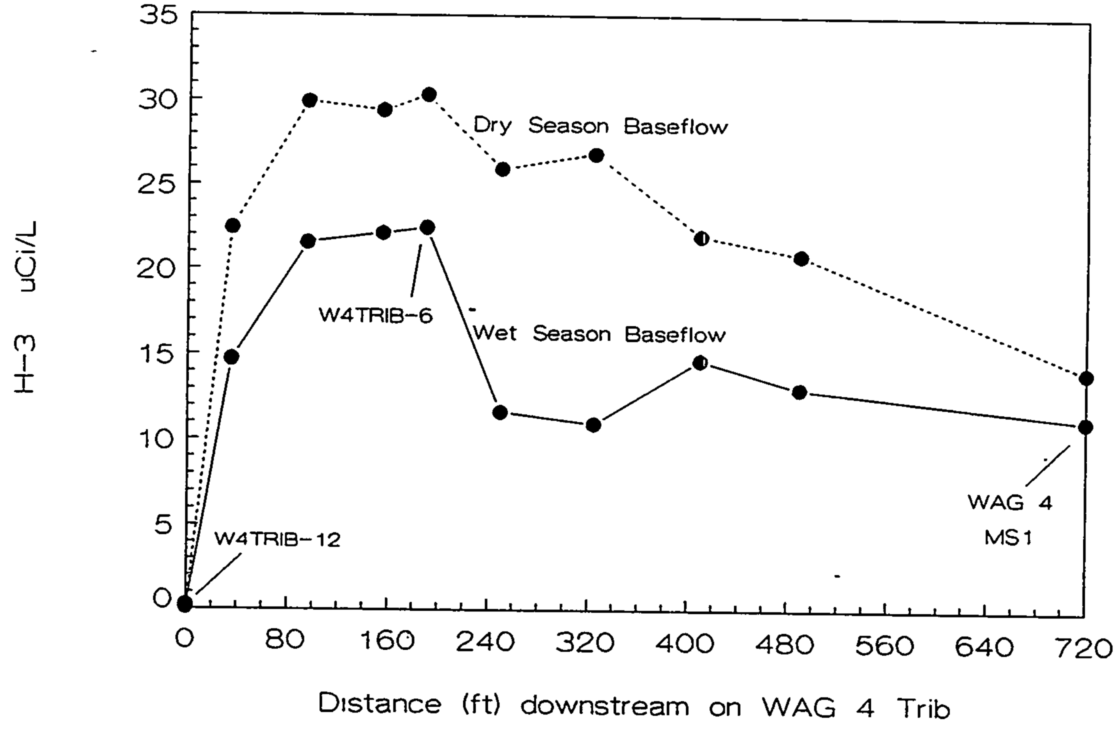

Fig. 6.10. Tritium concentrations at transect locations along the WAG 4 tributary.

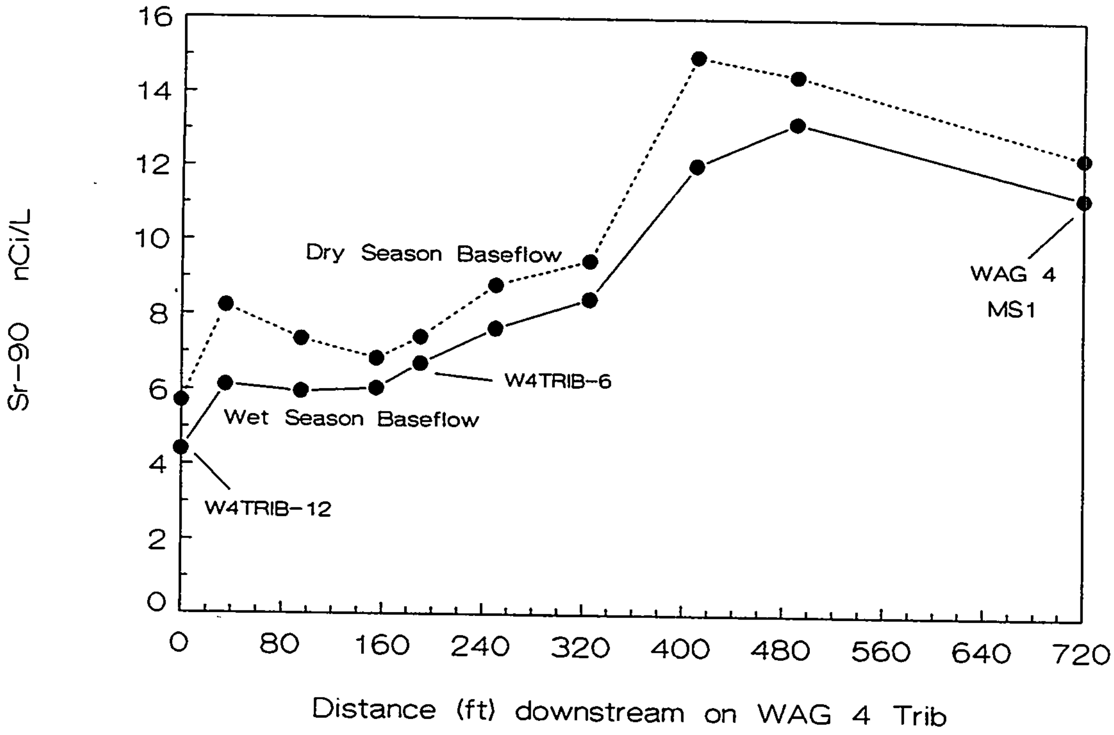

Fig. 6.11. Strontium-90 concentrations at transect locations along the WAG 4 tributary.

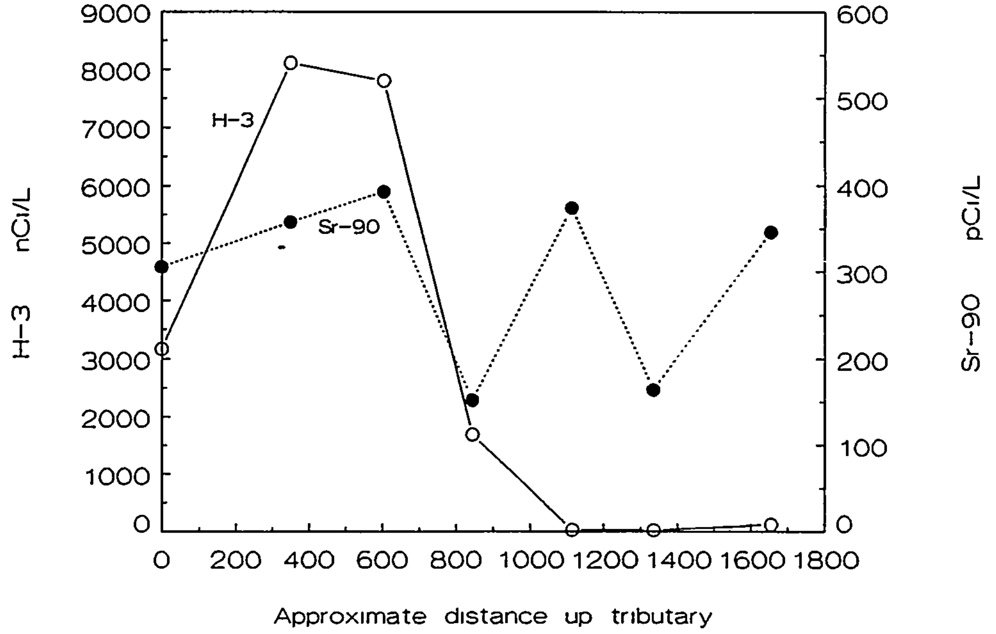

Fig. 6.12. Tritium and strontium-90 concentrations at transect locations along the WAG 6 MS3B tributary.

^{3}H levels discharges into the tributary below this area. The ^{90}Sr release from WAG 4 into the tributary is even more diffuse, as seen in the gradual ^{90}Sr concentration increases in Fig. 6.11, with the greatest increase between locations W4TRIB-3 and W4TRIB-2.

WAG 6 Tributaries. WAG 6 tributary MS3B has the highest ^{3}H and ^{90}Sr concentrations of the tributaries in WAG 6. A few transect samples were collected up this tributary to identify where these contaminants may be entering the stream. Tritium results suggest that groundwater high in ^{3}H discharges primarily to the upper reach of the stream (Fig. 6.12). Strontium-90 concentrations are also high in the upper reach but are more erratic in the lower reach. Additional transect sampling at smaller intervals could define the contaminated groundwater discharge areas more precisely.

6.7.4 Contaminant Fluxes

Contaminant flux is the product of contaminant concentration and instantaneous stream flow measurements. Contaminant fluxes were estimated for those locations where stream flow measurements can be made (Fig. 6.13). Collection and processing of discharge data used for flux calculations followed standard operating procedures and guidelines as described in Clapp and Borders (1992). A mass balance approach was used to estimate the flux values at these locations as a percent of the total flux at WOD (Table 6.10). These data provide snapshot pictures of the contaminant source and their contribution to risk, during two different hydrological conditions (wet-season and dry-season baseflow). These snapshot flux percentages compare well with the March and September monthly results from the Compliance Monitoring Program which collects flow-proportional samples at the major weir locations (Mark Tardiff personal communication, Appendix E).

Results from both sampling rounds indicate that WAG 5 is the source for over half (~70-75%) of the ^{3}H flux in the watershed, with WAG 4 being the other major contributor (~15%) primarily during the wet season (Table 6.10). WAGs 1 and 5 are the main sources of ^{90}Sr (~36% each), with WAG 4 being a significant contributor during the wet season. Relative to other seeps, Seep SW5-4 in WAG 5 has a higher discharge volume combined with the high ^{90}Sr concentrations makes it a major source (~16-25%) of ^{90}Sr to the watershed (Table 6.10).

Though not shown in Table 6.10, results from the WAG 2 sampling efforts indicate that WAG 1 is the primary source of ^{137}Cs. During baseflow conditions, WAG 2 appears to be a sink for ^{137}Cs. For example, during the wet-season baseflow sampling, the ^{137}Cs flux decreased approximately 20% from WC7500 to WCWEIR and an additional 50% from WCWEIR to WOD (Fig. 6.13).

Colbalt-60 concentrations were below detection at both WC7500 and WCWEIR during both baseflow sampling rounds. The primary source area for ^{60}Co is WAG 7. Two locations in WAG 7, SW7-5 and East Seep (Fig. 6.1), probably contribute most of the ^{60}Co flux at WOD. Both of these locations were essentially dry during the second round, and the ^{60}Co concentration at WOD was below detection. This is consistent with the 1991 Compliance Monitoring results from flow-proportional sampling (Clapp et al. 1992). The results from the monthly composite samples also identified the lower reach of WOC as a source area (primarily during the wetter months) for the ^{60}Co discharge at WOD.

Because of the errors associated with both analytical results and flow measurements (5% assumed), small inputs of contaminants may be overlooked; however, flux data used with the stream transect sampling can identify key areas of contaminant releases to the WOC watershed. The ability to quantify contaminant releases hinges on reliable stream discharge measurements.

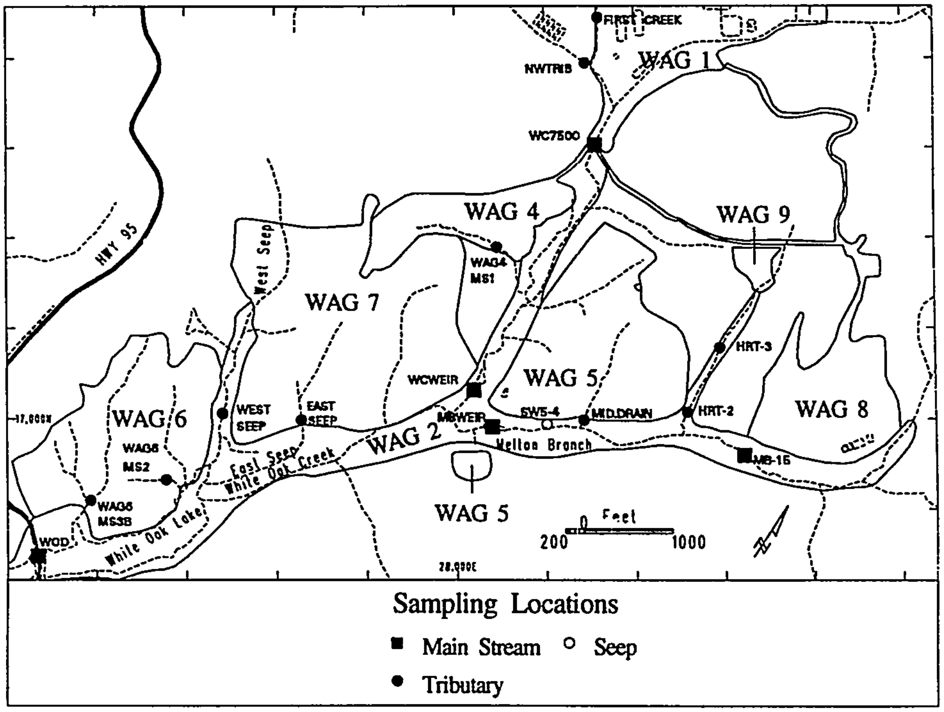

Fig. 6.13. Locations of seep and stream flow measurements.

Weirs, flumes, and sampling stations existing on some of the streams are in need of upgrading. A critical location is MBWEIR, at which much of the ^{3}H and ^{90}Sr release in WAG 2 is measured. Inaccurate measurements could overestimate or underestimate the flux from WAGs 5, 8, and 9, potentially leading to incorrect prioritization of source areas and difficulties in monitoring the effectiveness of remedial actions.

6.7.5 Seasonal Differences

Contaminant concentrations and fluxes may vary at a location because of the effect of different hydrologic conditions on contaminant transport pathways, transport processes, and source areas. Contaminant fluxes through the WOC watershed are greatly dependent on flow (i.e., with the decreasing trend of flow, there is a decrease in contaminant flux). The ^{3}H and ^{90}Sr fluxes at WOD during the wet-season baseflow sampling were about 9 and 3 times greater, respectively, than the fluxes during the dry-season baseflow sampling (Table 6.10). While fluxes usually decrease during the dry months, contaminant concentrations can often increase as a result of the decrease in rainwater recharge to the groundwater system. Specific conductance values and many metals and anion concentrations in seeps were higher during the dry-season baseflow sampling. Contaminant concentrations in the seeps and streams varied throughout the watershed; some areas had higher concentrations and others lower concentrations. Lower concentrations in a seep during dry conditions may indicate that the primary source of contamination is within the trenches or upper soil horizons and that the water table is no longer in contact with the waste.

Differences between wet-season and dry-season concentrations were evident in the transect sampling results; however, more data are needed to interpret the different responses and how they relate to contaminant transport processes and source areas. There was an almost-50% decrease in the ^{3}H concentrations along Melton Branch and approximately a 15% decrease in ^{90}Sr concentrations along the lower reach of Melton Branch (Figs. 6.8 and 6.9). In contrast, there was an almost-50% increase in the ^{3}H concentrations in the WAG 4 tributary and slightly less of an increase in ^{90}Sr concentrations (Figs. 6.10 and 6.11). As more data are gathered differences like these may provide important information about contaminant sources and responses to future remedial efforts.

Results from the transect sampling along Melton Branch near SW5-4 (Fig. 6.9) indicate that flow measurements from seeps may not represent total groundwater discharge in an area. During the wet season, ^{90}Sr flux estimates from timed volumetric measurements compared well with the amount of ^{90}Sr increase observed in Melton Branch just downstream from SW5-4. However, during the dry season, little surface runoff from SW5-4 was present, and ^{90}Sr flux estimates from timed volumetric measurements did not account for the large ^{90}Sr increase still observed just downstream from SW5-4. For some seeps and areas of contaminated groundwater discharge, it may be best to monitor contaminants in adjacent stream reaches rather than trying to install a weir or flume to intercept the discharge on the surface.

The following presents the methodology used in calculating the risk values presented in Table 6.10 and includes the assumptions, exposure factors, and equations used to quantify contaminant intakes and indicates the reference where this data was obtained.

The following risk assessment equation for drinking water (rad) was used:

*Risk=Concentration (pCi/L*Ingestion Rate (2L/d)*Exp frequency (350 d/y)*Exp duration (30y)*Slope factor (HEAST Risk/pCi)*

These results were then flux weighted using the data from one wet and one dry-season seep and tributary sampling round and calculated using the equation below. The flux data for each of the sources are used with WOD flux data to rank the relative importance of the different sources within the context of the WOD integration point. Given the generalized cancer risk equation for multiple substances:

$$\mathrm{Risk}_T=\sum_i \mathrm{Risk},$$

where,

Risk_T=the total cancer risk, expressed as a unitless probability, and
Risk_i=the risk estimate for the i^{th} substance.

The equation for calculation of carcinogenic effects for the flux-based risk assessments at each of the sources is

$$\mathrm{Risk}_{sf}(\%) = (\{\sum[\mathrm{Risk}_i\ (\mathrm{Flux}_{is}/\mathrm{Flux}_{ip})]\}/\mathrm{Risk}_T)^*100,$$

where,

Risk_{sf}=percentage of risk at the integration point which originates at the identified source,
Flux_{is}=flux of the i^{th} substance originating from the identified source, and
Flux_{ip}=flux of the i^{th} substance identified at the integration point.

6.8 SUMMARY AND PLANNED ACTIVITIES

Results from these two rounds of sampling have identified key seeps and areas that contribute significantly to the total contaminant flux in WAG 2 and that are major contributors to the risk at WOD. The results are already being used in directing focused investigations and potential removal actions on specific source areas in WAG 5 (Newsom et al. 1993).

To clarify the distribution of contaminant fluxes and sources in WAG 2, two more extensive baseflow sampling rounds will be completed in 1993. A different analytical method for ^{90}Sr, with a lower analytical error, will be used for samples from locations that are critical for flux estimates. An extensive round of samples was collected in the spring of 1993, following a large rain event when subsurface stormflow was active, to estimate the variability of source areas during different hydrologic conditions. Key seeps and contaminant source areas will be monitored bimonthly (every other month) to assess seasonal variability in contaminant releases. All these data will be combined with the initial 1992 baseflow sampling results. As key seeps and source areas continue to be identified and prioritized based on risk, more extensive sampling will be conducted to identify specific contaminant pathways and sources. A tributary monitoring program for WAG 2 was initiated in 1993 and focuses on four of the key tributaries that contribute contaminants to the WOC watershed. Storm samples will be collected from these four tributaries and two or three key seeps to define contaminant variabilities and chemical characteristics that will aid in identifying groundwater pathways and contaminant sources.

Table 6.10. Tritium and strontium-90 fluxes at WOD and associated human health risk from water ingestion.[a]

Sampling location	Wet-season baseflow[b]			Dry-season baseflow[c]		
	% ^{3}H	% ^{90}Sr	% Risk[d]	% ^{3}H	% ^{90}Sr	% Risk
WCWEIR	22 ± 2	48 ± 10	31	6 ± 4	48 ± 11	32
NWTRIB	<1	2 ± 1	1	<1	<1	<1
FIRST CREEK	No sample	No sample		<1	7 ± 1	4
WC7500	4 ± 3	32 ± 6	14	2 ± 8	37 ± 10	24
WAG4 MS1	15 ± 5	10 ± 1	13	1 ± 1	<1	<1
MBWEIR	75 ± 5	43 ± 6	64	70 ± 5	32 ± 5	47
SW5-4	<1	25 ± 3	9	<1	16 ± 3[e]	10
MID DRAIN	10 ± 1	3 ± 1	8	3 ± 1	<1	1
HRT-2	13 ± 1	9 ± 1	12	17 ± 1	10 ± 1	13
HRT-3	<1	8 ± 1	3	<1	9 ± 1	6
MB-15	<1	<2	<2	<1	<2	<2
EAST SEEP	<1	<1	<1	<1	<1	<1
WEST SEEP	<1	3 ± 1	1	<1	<1	<1
WAG6 MS2	1 ± 1	<1	<1	2 ± 1	<1	1
WAG6 MS3B	4 ± 1	<1	3	1 ± 1	<1	<1

[a] Percentages are reported with an asymptotic approximation of the standard error of the ratio, calculated from the associated analytical counting error and an assumed 5% error or flow measurements.

[b] Tritium-3 flux at WOD = 104 μCi/s with a corresponding risk of 3.01×10^{-4}. Strontium-90 flux at WOD = 86 nCi/s with a corresponding risk of 1.66×10^{-4}.

[c] Tritium-3 flux at WOD = 11.6 μCi/s with a corresponding risk of 9.19×10^{-5}. Strontium-90 flux at WOD = 28 nCi/s with a corresponding risk of 1.47×10^{-4}.

[d] Percentages of total human health risk at WOD from water ingestion.

[e] Value inferred from concentration changes along stream transect.

7. WAG 2 FLOODPLAIN RADIATION WALKOVER

7.1 INTRODUCTION

A radiation walkover survey was conducted in the spring of 1992 to map the distribution of gamma-emitting radionuclides in the sediments of the WOC floodplain. The results of this survey are being used to (1) estimate the extent of sediment contamination, (2) locate and define hot spots, and (3) guide soil sampling efforts in support of future remedial actions. As reported in the annual report of the Environmental Restoration Monitoring and Assessment Program at ORNL (Clapp 1992), a preliminary risk assessment (Blaylock et al. 1992) indicated that direct exposure of on-site workers to gamma radiation is the primary threat to human health from WAG 2. Soils and sediments contaminated with ^{137}Cs are the main source of gamma radiation in WAG 2. Characterizing the distribution of radionuclides in the WOC floodplain is a key objective of the WAG 2 RI. Without screening information, analysis of a prohibitively large number of soil samples would be required to map the distribution of contaminants in WAG 2. However, because ^{137}Cs is a strong gamma emitter, and because the contaminated sediments are near the surface, the contaminated areas can be mapped using a handheld gamma scintillometer.

7.2 METHODS

From April 6 to May 26, 1993, personnel from the Chemrad Tennessee Corporation traversed the WAG 2 site recording both the total gamma radiation levels at the ground surface and the dose rate at a height of 1 m. The Ultrasonic Ranging and Data System (USRADS[1]) was used to provide automatic data collection. This system was developed at ORNL and licensed for marketing to Chemrad Tennessee. A backpack with a radio transmitter is carried in a systematic pattern over the WAG 2 area. The distance between passes was generally 1.5–3 m. The backpack transmitter instantly relays the scintillometer readings for storage in a portable computer. The *x-y* position at the time of the measurement is determined from the travel time of an ultrasonic pulse emitted by a transmitter in the backpack to microphones mounted on tripods in the survey area. Both position and instrument readings are recorded automatically once each second. Over 300,000 measurements were collected, providing a detailed map of the distribution of radionuclide contamination within WAG 2. The computed position and incoming data are monitored in real time on a computer display at the base station. If any areas are missed, the computer operator can direct the backpack operator to re-walk the area. Some gaps will remain in the coverage, either because of water, swamp, or impenetrable brush. Refer to Nyquist and Blair (1991) for additional information about USRADS.

7.2.1 Survey Instrumentation

Measurements were made using two NaI crystal instruments, a Ludlum Model 3 ratemeter equipped a with Model 44-1, 0.25-cm NaI scintillation crystal probe which was swung in an arc about 0.15 m above the ground (reported in counts per minute), and a Ludlum Model 19 Micro-R meter positioned at a height of 1 m to simulate dose rate to a human (reported in μR/h). For areas where the radiation levels were high enough to saturate the NaI-based detectors, Chemrad Tennessee personnel used a Ludlum Model 3 ratemeter connected to a

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[1] USRADS is a registered trademark of the Chemrad Tennessee Corporation.

Model 44-38 Energy Compensated Geiger Mueller detector (reported in mR/h) in addition to the other two instruments.

7.2.2 Quality Assurance

USRADS calibration is designed into the system operation. Prior to the radiation survey, civil survey methods were used to place control points on a 200-ft grid spacing over all of WAG 2. Variations in the local speed of sound (a function of temperature and barometric pressure) that could affect USRADS are corrected for at the start of the survey for each 200- by 200-ft cell using these control points. USRADS positioning errors relative to the control points are typically better than ±10 cm. In hilly terrain, the accuracy can be reduced slightly, because USRADS only computes the *x-y* position and cannot be used to determine elevation.

The radiation instrumentation was calibrated by the manufacturer immediately before the start of the walkover with records retained at Chemrad Tennessee's Oak Ridge office. The instruments were checked daily for consistency and background response at the Bechtel Field Operations Facility and recorded in the Chemrad Instrument Response Check Log. As a further check, all instruments used in the survey were tested at the Oak Ridge National Laboratory's Radiation Calibration Facility. All instruments were reading within 10% of the correct value (Table 7.1).

Table 7.1. Instrument test at the ORNL Radiation Calibration Facility

Instrument	Reading	Serial number	Probe[a]	CAL date	Source setting (μR/h) 1.0	 2.5	 4.0[a]
Bicron RSO-5	mR/h	ORNL 1505-01	NA	09-30-92	1.0	2.4	3.9
Ludlum M19	μR/h	89493	NA	03-31-92	1,000	2,250	3.6
Ludlum M3	CPM	92036	088933/ 44-2	03-31-92	170,000	400,000	NA
Ludlum M3	mR/h	93115	089281/ 44-38	04-16-92	1.1	3.0	4.5
Ludlum M3	CPM	92036	088933/ 44-2	03-31-92	180,000	400,000	NA
Ludlum M19	μR/h	89493	NA	03-31-92	1,100	2,400	3.8

[a] NA = not available.

7.3 DISCUSSION

7.3.1 Data Organization

The USRADS data are collected using 200- by 200-ft grid blocks. Each block represents a separate USRADS setup and data file. The blocks are identified in the computer data base using an alphanumeric grid (Fig. 7.1). For example, Block E26 refers to the block bounded in the lower left by the coordinates E29600, N16600 and in the upper right by the coordinates

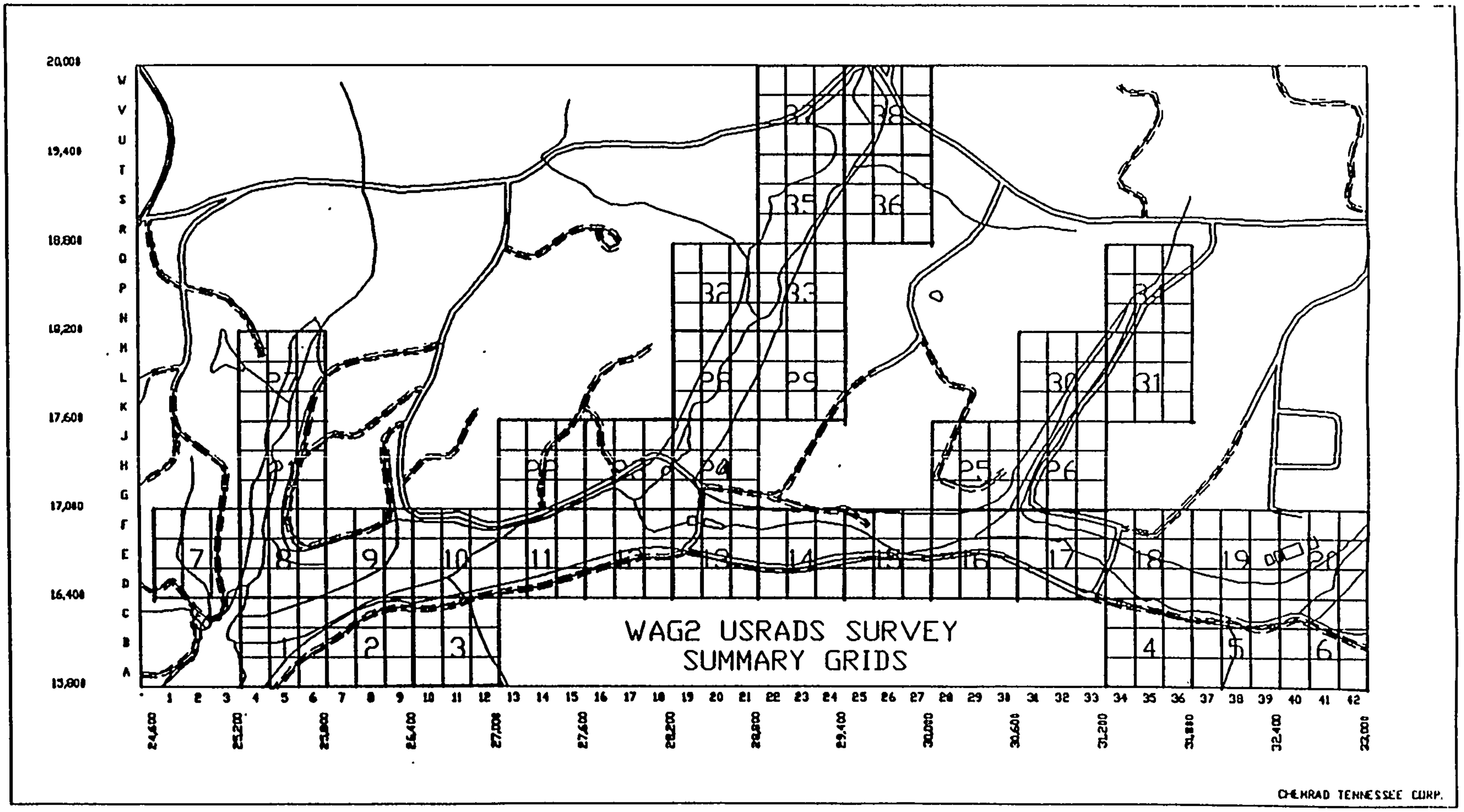

Fig. 7.1. WAG 2 USRADS survey summary grids.

E29800, N16800. For the Chemrad Tennessee final report, these blocks were then grouped into summary grids each containing nine blocks arranged in a square 600 ft on each side. The aforementioned Block E34 is the center block of Summary Grid 15 (Fig. 7.2), which includes Blocks D25–D27, E25–E27, and F25–F27. There were a total of 38 summary grids. The walking path (track maps) and color contour maps of the surface and dose rate measurements for each summary grid were published in Chemrad Tennessee's final report (Chemrad Tennessee 1992).

7.3.2 Summary of Findings

A preliminary plot of the WAG 2 data (Fig. 7.3) was prepared by averaging the data collected in contiguous 10- by 10-ft squares. In the figure, gamma radiation levels are expressed in millirems per hour as measured with an NaI detector near the ground surface, the WAG 2 boundaries are marked with a thick black line, the WOC system is marked with a thin black line. Clearly the large areas of high gamma radiation are associated with the sediments and soils adjacent to WOC between the 7500 bridge and WOL, as expected. Radiation levels tend to decrease away from the creek, as one moves toward the hillsides where sediments cannot accumulate. The largest area of high gamma radiation is the Intermediate Holding Pond Site just downstream from the 7500 bridge. During the 1940s, an earthen dam across WOC was used to retain contamination from ORNL. The earthen dam at this site was the original retention structure for what was the Intermediate Holding Pond. In 1944, that dam was breached during a storm and sediments moved downstream. Radiation levels along Melton Branch are much lower, which supports the observation that gamma-emitting radionuclides are not as abundant as in the main branch of the White Oak Creek system.

Plots at this scale mask the wealth of detail available in the original data. A plot of the data points for Summary Grid 15 (Fig. 7.2), for example, shows the dense data coverage. Each dot represents a separate measurement point. The contoured data (Fig. 7.4) show that, even in Melton Branch, the general course of the stream (solid black line) is evident in the radiation data. Also evident in this figure is a known seep emerging from WAG 5 to the north, which is discussed in the previous section.

7.3.3 Limitations of the Data

Because both instruments were calibrated using a ^{137}Cs source, the reported dose rate at 1 m assumes that ^{137}Cs is the only gamma emitter. If other sources of gamma radiation are present, particularly low-energy X-ray or gamma rays, then the translation from CPM to μR/h will be affected. The NaI detectors are more efficient at detecting low-energy gamma radiation. Therefore, if low-energy gamma radiation or X-ray sources are present, the dose rate and subsequent radiation hazard will be overestimated because of (1) the higher capture efficiency (i.e., increased counts per minute) and (2) the assumption that the counts were caused by the higher energy ^{137}Cs gamma radiation.

Comparison of readings made with the gamma scintillometer (Ludlum 19) and a recently developed energy-independent detector (Bicron) suggest that the dose rate may be overestimated by up to a factor of 9 for some parts of WAG 2 (Table 7.2). Some initial tests with a field-portable gamma spectrometer support the hypothesis that low-energy gamma rays are the cause of the discrepancy, but the source of this low-energy radiation has not yet been identified. Analysis of recently collected sediment cores may provide the answer. Until the elevated dose rates are better understood, the dose rate information collected during the walkover survey should be viewed as an upper bound on the true dose rate.

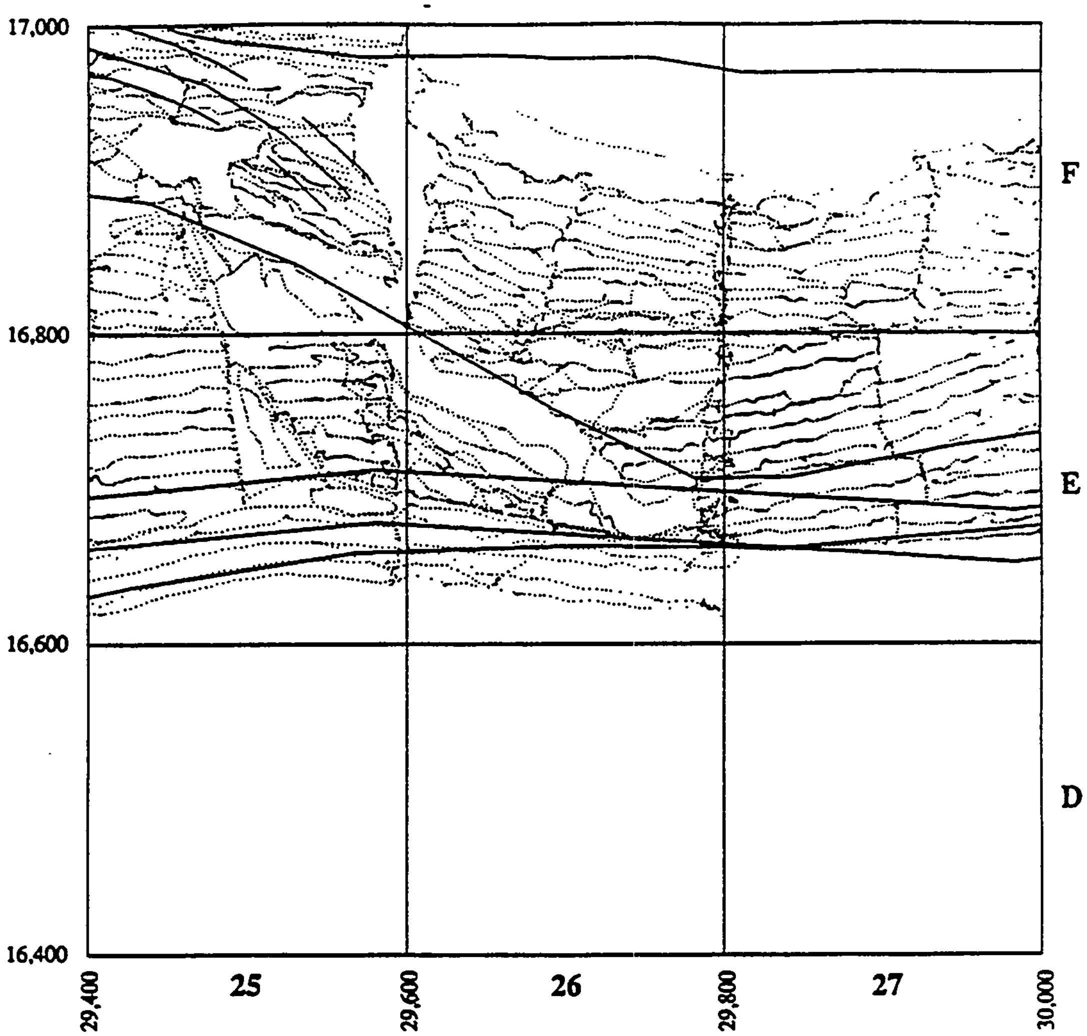

Fig. 7.2. WAG 2 USRADS summary grid 15.

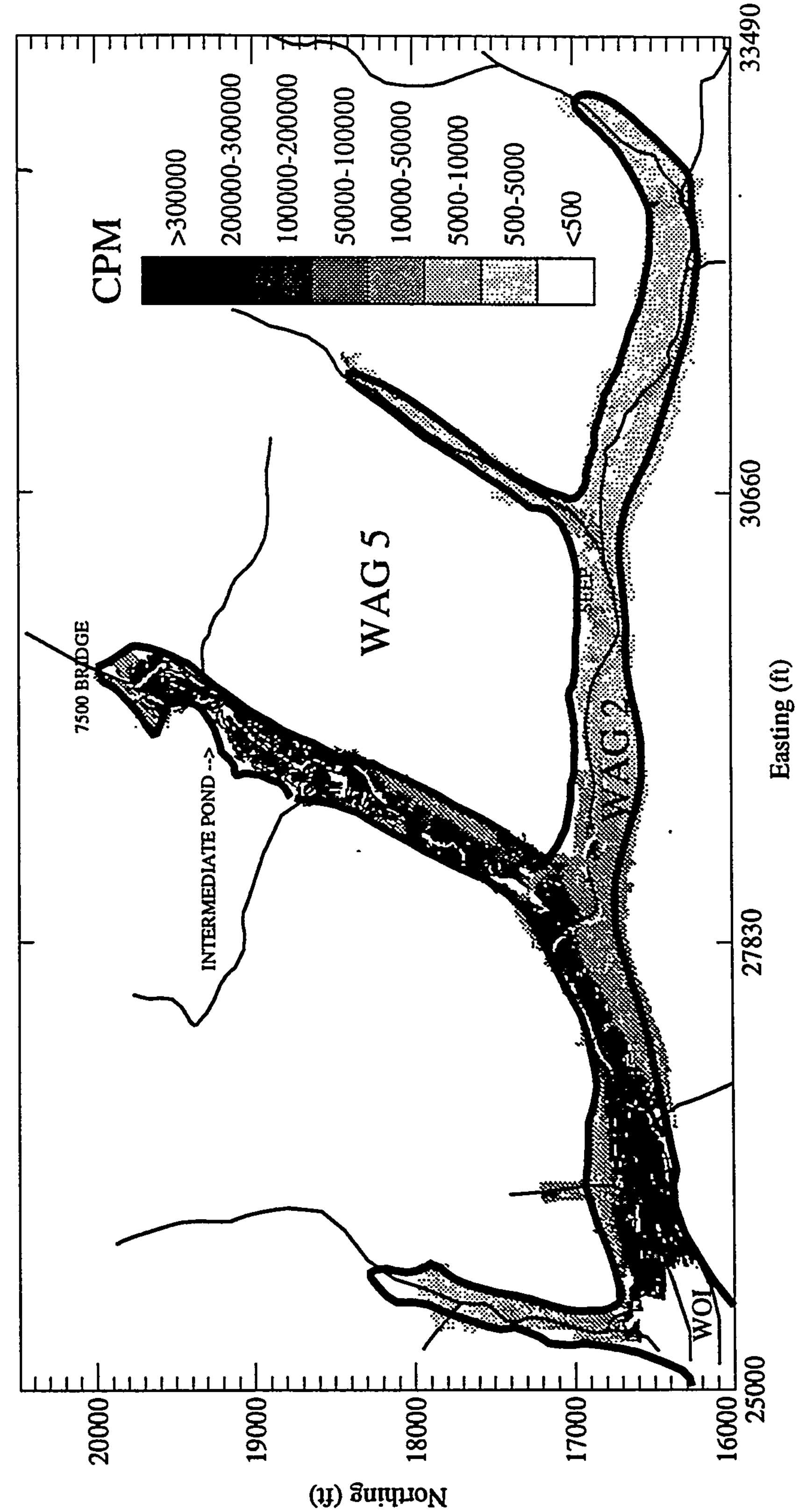

Fig. 7.3. WAG 2 USRADS counts-per-minute summary map.

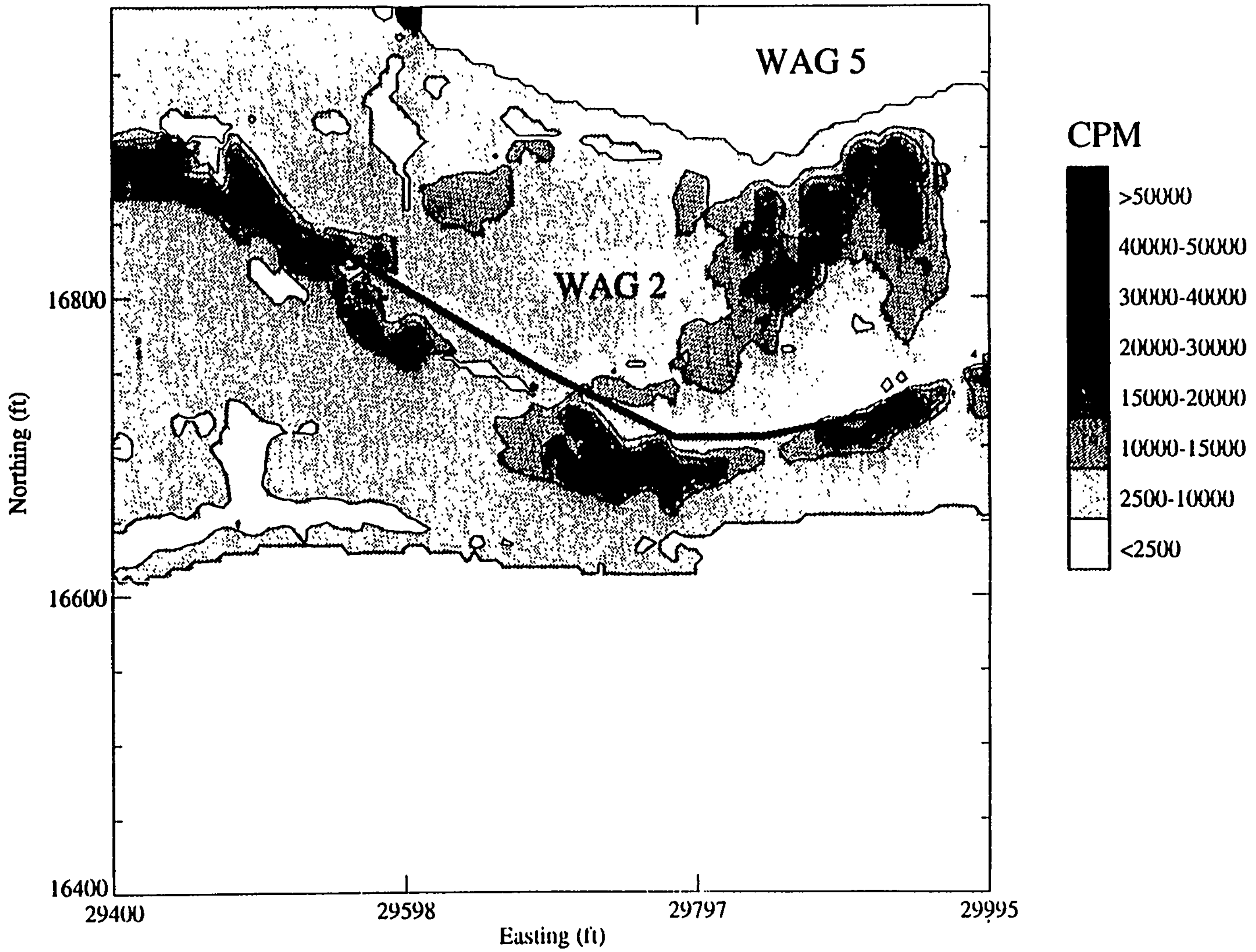

Fig. 7.4. WAG 2 USRADS Summary Grid 15 contour map.

Table 7.2. Comparison showing the inflated reading reported by the NaI detector caused by low-energy gamma radiation at WAG 2

Location (Easting/northing)	Ludlum 19 (μR/h)	Bicron (μR/h)	Ratio M19/Bicron
26,000/16,000	2800	1000	2.8
25,800/16,600	1200	200	6.0
27,800/17,200[a]	1000	350	2.9
28,900/17,200[b]	700	<100	~7.0
28,900/17,200[c]	3800	1400	2.7
28,900/17,200	4900	900	5.4
28,600/17,400	900	<100	~9.0
29,000/18,400	500	<100	~5.0
28,800/18,600	1800	300	6.0
28,800/18,400	500	<100	~5.0

[a] Readings taken at the edge of tributary ~4 m south of stake.

[b] Readings taken in back of the green building between WOC and M weir (~200 ft east of Bldg. 7871).

[c] Readings taken by hydrofracture pond in the middle of the road.

The gamma walkover methodology is useful in measuring the gamma radiation and dose rate at the soil surface; however, no inferences can be made about the vertical distribution of gamma contamination from these data. Because the intensity of gamma radiation measured at the surface depends on the specific radionuclides and the thickness and shielding properties of the overlying sediments, it is impossible to distinguish between deep, high-level contamination and near-surface, low-level contamination with gamma scintillometer measurements made at the surface. Plans exist to collect and analyze sediment cores to discover the variation in burial depth and radionuclide inventories over the floodplain and to use the results to improve our interpretation of the radiation walkover data.

7.3.4 Summary

The largest area of high gamma radiation is the Intermediate Holding Pond Site just downstream from the 7500 bridge. Radiation levels tend to decrease away from the creek as one moves toward the hillsides, which are not typically sediment deposition areas. The WAG 2 radiation walkover data set contains a wealth of information that may be used to estimate gamma exposure levels for risk assessment scenarios, guide interim corrective measures, investigate correlations with soil type and biotic data; locate seeps near burial grounds, estimate (in conjunction with stormflow models) contaminant mobilization during flooding; and form the basis of geostatistical studies. In the past year, these data have been used by several WAG 2 researchers to guide their planning and sampling efforts.

Additional sampling is currently being conducted to resolve some of the limitations of this screening methodology. Sediment and soil cores will be collected in Phase II and analyzed to (1) determine the distribution of radionuclides with depth; (2) calculate the theoretical gamma radiation field at the surface to compare with the measured values; and (3) test whether the distribution of co-contaminants, such as metals, correlates well with the distribution of radionuclides. If the radionuclide levels are well correlated with metal and organic contamination levels, then the radiation data may be used to guide soil sampling for these co-contaminants. Additionally, we plan to merge the WAG 2 USRADS walkover data set with the walkover data collected for WAG 5 and WAG 1 (Fig. 1.1).

All walkover data have been loaded into the Geographical Information System and are readily available for graphical comparison. The effort to integrate walkover data from several WAGs will direct additional characterization efforts and guide the implementation of remedial actions.

8. PRELIMINARY REMEDIAL ACTION GOALS

The process of establishing remedial action goals for the WAG 2 site is ongoing and is determined by (1) future land-use scenarios and associated clean-up criteria, (2) available remedial technologies, and (3) remediation of upgradient WAGs. Future remedial actions in WAG 2 will be based in part on iterative human health and ecological risk screenings and site-specific contaminants of concern. The ensuing preliminary remedial action goals will be established by (1) health-based criteria for carcinogenic effects or for systemic toxic effects, (2) the lowest chemical specific ARARs, or (3) ecologically based criteria. Implementation of final remediation of WAG 2 will occur after contaminant inputs from upgradient WAG 2 have ceased and secondary contaminant source inputs are minimized.

Currently, there are no interim remedial actions scheduled for WAG 2 in the immediate future, and final remediation will follow the completion of remediation of upgradient WAGs. The principal WAG 2 remedial action goals are to reduce potential off-site risk by identifying and supporting source control remediation efforts in upgradient WAGs and within WAG 2. Remediation of surface water will not likely occur in WAG 2 because WAG 2 is not the source of contaminants in surface water. Likewise, groundwater will not likely be remediated in WAG 2. WAG 2 serves as a conduit for contaminated groundwater from contaminated source areas that primarily discharges to surface water within WAG 2 via seeps and springs. Therefore, remediation efforts will focus on supporting remedial actions in upgradient source areas that are identified as key contributors to groundwater and surface water contamination. The groundwater OU will support environmental assessments of source WAGs based on groundwater data, analyses, and predictions regarding contaminated groundwater movement and will serve as the programmatic mechanism for implementation of any required groundwater remedial actions.

Interim corrective measures are, however, likely to be implemented for WAG 2 soils and sediments. Soils and sediments in WAG 2 have been contaminated primarily with ^{137}Cs and ^{60}Co from upgradient sources and are currently high priority for immediate consideration for remediation. Unlike surface water or groundwater, WAG 2 soils and sediments are relatively stationary and do represent a significant potential contaminant source area for particle-bound contaminants. Preliminary remedial action goals for WAG 2 soils and sediments are to (1) reduce on-site risk from external exposure and (2) minimize potential off-site contaminant flux and associated potential risks. On-site risks are minimized by institutional controls. Off-site risks are continually assessed as part of the WAG 2 environmental monitoring program. The sediment and soils and sediment transport modeling components of the environmental monitoring program specifically address two key issues in reducing off-site risk: where are current hot spots and sources of contaminant flux into WAG 2, and where are potential contaminant sources likely to occur under future conditions. There are several interim corrective-action or removal-action strategies possible for contaminated WAG 2 soil and sediment: stabilization, isolation, or removal. Stabilization options under consideration for future implementation include capping and simple erosion barriers (i.e., revetment mats or berms), while isolation efforts may involve soil solidification techniques (in situ vitrification).

The intermediate pond area has the highest gamma values of the WAG 2 floodplain area and is under consideration for a stabilization early action. The objective of this action is to minimize the migration of sediment-bound contaminants to off-site areas during high flow events. Prior to determining specific preliminary remedial action objectives for this area, however, more site characterization data are needed. Phase II sampling activities are currently evaluating the vertical extent of floodplain soil contamination in the intermediate pond area and are assessing the extent of contamination and the erosion rate of contaminated sediment from contiguous stream banks and channels. Results from these Phase II sampling efforts will provide data necessary to guide future remedial actions. The development of specific remedial action goals will be reported in later RI Implementation Reports.

9. SUMMARY

This report presents the activities and findings of the first phase of a three-phased RI of WAG 2 at ORNL located in Oak Ridge, Tennessee, and updates the scope and strategy for WAG 2-related efforts. WAG 2 consists of WOC and its tributaries downstream of the ORNL main plant area, WOL, WOCE on the Clinch River, and the associated floodplain and subsurface environment. The remediation of WAG 2 logically follows the cessation of contaminant input from hydrologically upgradient WAGs. Remedial investigations and remedial actions are under way or planned for contaminated areas upgradient of WAG 2. While upgradient areas are being remediated, the strategy for WAG 2 is to conduct a long-term monitoring and investigation program that takes full advantage of WAG 2's role as an integrator of contaminant fluxes from other ORNL WAGs.

Phase I of the WAG 2 RI consisted of submission of the final components of the RI work plan and implementation of the field component of the RI (scoping surveys of the site to determine the need for interim corrective measures, preliminary identification of remedial alternatives, and initiation of the monitoring and investigation efforts). Much of the effort during Phase I focused on sediment, seep, and tributary screening efforts. This report includes field and RI support activities completed through October 1992.

The WAG 2 RI consists of a short-term component conducted while upgradient WAGs are being investigated and remediated, and a long-term component that completes the WAG 2 RI. Because WAG 2 is not a prototypic RI, it is necessary to update support plans to the RI Plan as new data become available. During Phase I, the Sampling and Analysis Plan and Quality Assurance Plan were issued and the Health and Safety Plan and Waste Management Plan were developed (although these were not issued during Phase I).

NEPA documentation was prepared and supporting reconnaissances were conducted during Phase I to consider the effects of proposed WAG 2 sampling activities on the environment. A wetlands delineation and threatened and endangered species and archeological and historic sites surveillances were conducted to comply with NEPA and to determine ARARs. The results of the NEPA documentation process and reconnaissances are listed here.

- Approximately one-third of the WAG 2 area is composed of wetlands as defined by the U.S. Army Corps of Engineers Wetland Delineation Manual.
- Two state-listed plant species, lesser ladies tresses and butternut, were found in the survey area.
- No threatened or endangered animal species (aquatic and terrestrial invertebrates and vertebrates) or critical habitat listed was found to be present on the WAG 2 site.
- No impact on any archeological or historic property will be imposed by WAG 2 activities.
- A Notice of Involvement for floodplains and wetlands was submitted to DOE-HQ in November 1992 and is pending publication in the federal register.
- A Statement of Findings was prepared and will be published after publication of the NOI.

During Phase I, a human health and ecological risk screening analysis was conducted for contaminants found in WAG 2. The results of this screening were published in Blaylock et al. 1992. The conclusions of the screening risk assessment follow.

- External exposure from radionuclides (^{137}Cs and ^{60}Co) in sediments is a high priority for further evaluation (i.e., potential excess lifetime cancer risk $>10^{-4}$).
- Tritium, ^{90}Sr, and PCBs are concerns for human health from the surface water ingestion pathway.
- Additional data are needed for ^{152}Eu, ^{154}Eu, ^{137}Cs, ^{235}U, arsenic, and thallium.
- Tritium, ^{90}Sr, and lead in groundwater are of concern for human health.
- Some evidence exists that fish reproduction and benthic invertebrate community composition are being effected by watershed contaminants.
- Although toxic effects are not severe, additional work including surveys of biotic communities and toxicity testing are needed.

A monitoring program for tributaries and seeps was initiated as part of the WAG 2 surface water program, because surface water is the primary transport pathway for contaminants through and out of the WOC watershed. Conclusions of the seeps and tributary screening survey follow.

- Results from a wet and dry baseflow sampling identified key seeps that contribute significantly to the contaminant flux at White Oak Dam.
- The highest ^{3}H concentrations were found emerging from WAG 5.
- The highest ^{90}Sr concentrations were found in seeps and tributaries in and around WAGs 4 and 5.
- Elevated levels of ^{137}Cs are not as prevalent as ^{3}H or ^{90}Sr; fewer than one-half the locations sampled have ^{137}Cs activities above detection.
- Elevated levels of ^{60}Co were almost exclusively found in seeps and springs around WAG 7.

- Although variable, the highest concentration of gross alpha was in seeps in WAGs 5 and 7.
- Gross beta values generally corresponded to ^{90}Sr concentrations and were also associated with areas with elevated ^{60}Co.
- Thallium, arsenic, mercury, chromium, antimony, nickel, copper, and zinc exceeded at least one federal or state ARARs for at least one site.

A radiation walkover survey was conducted to map the distribution of gamma-emitting radionuclides in the sediments of the WOC floodplain. Blaylock et al. (1992) reported that direct exposure of on-site workers to gamma-radiation soils is the primary risk to human health. The results of this survey are being used to (1) estimate the extent of sediment contamination, (2) locate and define hot spots, and (3) guide soil sampling efforts in support of future remedial actions. Conclusions of the radiation walkover follow.

- The largest area of high gamma radiation is the Intermediate Holding Pond.
- Radiation levels tend to decrease away from sediment deposition areas.
- Low-energy X rays or gamma rays may have caused an overestimation of calculated dose rates.
- Additional sampling is needed to determine the vertical distribution of gamma radiation and possible co-contaminates such as metals or organics.

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Appendix A

INTERNAL ENVIRONMENT ASSESSMENT AND NATIONAL ENVIRONMENTAL POLICY ACT STATUS

MARTIN MARIETT
Internal Correspondence
MARTIN MARIETTA ENERGY SYSTEMS, INC.

January 6, 1992

L. D. Bates, K1330, MS 7298 (4-9042)
H. L. Boston, 1504, MS 6351 (4-7840)

Internal Environmental Assessment (IEA) and National Environmental Policy Act (NEPA) Status: FY 1992 Environmental Restoration Program Project, RI/FS ORNL WAG 2 Site Characterization, 1470X

Attached is a copy of the completed IEA for the FY 1992 Environmental Restoration Program Project, RI/FS ORNL WAG 2 Site Characterization, 1470X. This document contains the data obtained in the project NEPA compliance screening and, as such, represents a current profile of the planned or ongoing activity. The data in the IEA have been entered into the ORNL Environmental Coordinator's data base, which constitutes a permanent repository of auditable ORNL actions screened under NEPA. A field review of this action may be conducted in the future to verify that activities comply with the description in this IEA. Therefore please retain pertinent ES&H information in your files including documentation of contact with ES&H personnel. A NEPA certificate is also included. NEPA certification supports ORNL's policy to conduct all work in a manner that protects the environment, the public, and the health and safety of personnel. **PLEASE DISPLAY THE NEPA CERTIFICATE IN THE WORK AREA.**

Please note below the status of your activity:

Work on this project may proceed as scheduled. [X]

Work on this project may not proceed because [ ]

1. A NEPA determination has been requested, but no response from DOE has been received. [ ]
2. A CX must be completed and approved by DOE prior to proceeding. [ ]
3. An EA must be completed and approved by DOE prior to proceeding. [ ]
4. A CX has been transmitted, but it has not been signed by DOE. [ ]
5. An EA has been transmitted, but a FONSI has not been issued by DOE. [ ]
6. Other reason [ ]

If you have any questions, please contact Helen Braunstein (4-5774), James Hall (6-1293), or me.

F. C. Korne

F. C. Kornegay, 4500N, MS 6198 (4-5776)
ORNL Environmental Coordinator

FCK:JAH:1470X:RIWAG2S.IEA

Attachments (2)

cc: Attached

ornl
OAK RIDGE NATIONAL LABORATORY
Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy

Appendix B

SEEP AND TRIBUTARY DATA TABLES—RADIONUCLIDES

Table B.1 Radionuclide results for seep and stream samples collected during wet–season baseflow conditions

LOCATION	SAMPLE ID	DATE SAMPLED	$^{3}H^{a}$ nCi/L	$^{90}Sr^{a}$ pCi/L	^{137}Cs Dissolved pCi/L	$^{137}Cs^{b}$ Particulate pCi/L	^{60}Co Dissolved pCi/L	$^{60}Co^{b}$ Particulate pCi/L	Gross Alpha^{a} pCi/L	Gross Beta^{a} pCi/L
WOD	3001	25–Mar–92	265	219	4.8	36.5	2.3	< 3.4		
WCWEIR	3002	25–Mar–92	72	127	42.4	60.2	< 7.4	< 2.1		
WCWEIR	3002	25–Mar–92	72	134	55.1		< 7.4			
MBWEIR	3003	25–Mar–92	1100	518	< 6.4	< 3.2	< 12.7	< 3.2		
WAG6 MS1	3004	25–Mar–92	383	3	< 8	< 1.1	< 7.4	< 3.4		
WAG6 MS2	3005	25–Mar–92	1917	3	< 2.1	< 2.2	< 2	< 2.2		
WAG6 MS3A	3006	25–Mar–92	160	14	< 7.6	< 1.8	< 0	< 2.6		
WAG6 MS3B	3007	25–Mar–92	3901	484	< 2.1	< 1.6	< 2.5	< 2.0		
WESTSEEP	3008	25–Mar–92	7	219	< 8.3	< 1.4	< 17.2	< 3.1		
EASTSEEP	3009	25–Mar–92	16	2	< 7.6	< 1.8	135.	< 3.3		
WCWEIR	3010	02–Apr–92	68	191	46.4	36.5	< 7.3	< 3.4		
WC7500	3011	02–Apr–92	30	143	83.2	28.2	< 6.4	< 2.6		
WCHEAD	3012	02–Apr–92	0.5	7	< 6.3	< 1.6	< 5.2	< 2.6		
WAG4 MS1	3013	02–Apr–92	11178	11227	< 8.2	< 1.9	< 5.6	< 2.2	545	22395
WAG4 T2A	3014	02–Apr–92	8537	8115	10.5	146.5	< 7.3	< 2.8		
WAG4 T2A	3014	02–Apr–92	8494	8066	< 13.2	134.7	< 7.3	< 2.6		
5NNT	3015	02–Apr–92	1	−12	< 8	< 2.1	< 3.7	< 3.2		
5NST	3016	02–Apr–92	77	59	< 2.5	< 1.7	< 2	< 1.2		
NWTRIB	3017	02–Apr–92	1	85	< 7.2	< 2.2	< 5.2	< 2.6		
MBWEIR	3018	09–Apr–92	1472	607	< 7.2	< 2.0	< 7.3	< 2.6		
MB–15	3019	09–Apr–92	7	18	< 6.4	< 2.4	< 9	< 3.1		
WCTRIB–1	3021	25–Mar–92	6	15	< 6.8	< 2.5	24.4	< 2.8	9.2	246
WSTRIB–1	3022	25–Mar–92	13	214	< 6.6	4.6	12.4	7.6	84	446
RS–1	3023	25–Mar–92	17	124	< 3.4		15.3		8.0	333
RS–1	3023	25–Mar–92	17	109	< 1.8		14.8		10	370
RS–3	3024	25–Mar–92	34	295	< 10.5	< 8.7	613	54.0	11840	7800
SW7–1	3025	25–Mar–92	10	44	< 7.6	< 1.1	< 7	< 2.4	3.0	95
SW7–2	3026	25–Mar–92	7	3	< 14.6	< 2.6	953	76.3	38	886
SW7–3	3027	25–Mar–92	22	30	< 13.2	< 2.8	487	7.8	1423	775
SW7–4	3028	25–Mar–92	14	50	< 8	< 1.5	136	5.4	75	395
SW7–5	3029	25–Mar–92	26	−8	< 17.5	< 2.0	1387	25.3	124	3066
SW7–6	3030	25–Mar–92	3	1043	< 15	305.5	< 6.4	< 2.3	29	2085

Table B.1 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	$^{3}H^{a}$ nCi/L	$^{90}Sr^{a}$ pCi/L	^{137}Cs Dissolved pCi/L	$^{137}Cs^{b}$ Particulate pCi/L	$^{60}Co^{b}$ Dissolved pCi/L	^{60}Co Particulate pCi/L	Gross Alpha^{a} pCi/L	Gross Beta^{a} pCi/L
SW7-7	3031	25-Mar-92	12	6	< 6.8	22.2	69.8	208.0	78	302
SW7-7	3031	25-Mar-92	12	12	< 5.2	< 2.8	76.6	7.5	85	241
SW7-8	3032	25-Mar-92	7	2	< 8.3	< 2.1	< 12.9	< 2.8	99	58
SW2-1	3033	25-Mar-92	11	365	< 8.3	3.2	< 6.4	< 2.0	19	761
SW6-1	3034	25-Mar-92	221	10	< 3.7	< 2.0	32.3	< 2.5	3.4	54
WCTRIB-2	3035	02-Apr-92	3	-4	< 7.6	< 1.1	< 7.3	< 1.5	-0.3	1.2
WCTRIB-3	3036	02-Apr-92	241	1607	< 3.7	10.1	< 3.6	< 1.5	145	2990
WCTRIB-4	3037	02-Apr-92	1	40	< 7.5	2.1	< 7.2	< 2.4	0.2	86
SW2-2	3038	02-Apr-92	5	742	< 9.3	3.6	< 9.7	< 2.3	41	1506
SW2-3	3039	02-Apr-92	7	10	< 8.3	< 2.1	< 8.2	< 2.9	-0.2	31
SW4-1	3040	03-Apr-92	23	4738	< 7.2	< 1.4	< 8.2	< 1.5	262	8253
SW4-2	3041	02-Apr-92	25	15039	90.1	1.9	< 12.1	< 1.2	715	29209
BTT	3042	03-Apr-92	28	23460	216.	22.7	< 3.7	< 2.2	1673	46978
5NW-1	3043	03-Apr-92	4	18	< 3.3	< 1.4	< 9.5	< 2.0	6.9	39
5NW-2	3044	02-Apr-92	5	7	< 8.3	0.6	< 3.7	< 1.1	-0.3	0.7
SW5-1	3045	02-Apr-92	425	115	< 7.6	< 1.7	< 8.2	< 1.5	15	196
SW5-2	3046	03-Apr-92	32	242	29.8	< 1.6	4.4	18.4	8.7	304
SW5-2	3046	03-Apr-92	32	260		< 2.0		8.6	19	395
MID.DRAIN.	3047	09-Apr-92	8703	2115	< 8	< 1.9	< 6.3	< 2.3	144	4575
SW5-3	3048	09-Apr-92	9140	1981	< 6.4	2.2	< 9	< 2.3	166	5357
SW5-3	3048	09-Apr-92	9065	1996	< 6.8	< 1.9	< 8.2	< 1.1	180	5988
SW5-4	3049	09-Apr-92	7012	485037	< 16	< 2.7	< 9.6	< 2.0	10220	1149600
SW5-5	3050	09-Apr-92	11318	1279	< 7.2	< 1.6	< 8.5	< 2.6	83	2851
SW5-6	3051	09-Apr-92	10700	33182	< 6.4	< 2.1	< 10.4	< 2.0	1307	69128
SW5-7	3052	09-Apr-92	100020	3253	< 2.2	43.2	< 2.7	< 1.9	253	7599
SW5-8	3053	09-Apr-92	35725	294	3.5	7.6	< 2.4	< 1.6	31	865
SW5-9	3054	09-Apr-92	26895	563	2.1	1.9	< 2.4	< 2.3	90	2477
HRT-2A	3055	09-Apr-92	208	1063						
SW5-11	3056	09-Apr-92	97348	1181395	< 2.2	< 1.1	< 7.4	< 1.6	28570	2816200
WC-1	3057	25-Mar-92	251	212						
WC-2	3058	25-Mar-92	249	204						
WC-3	3059	25-Mar-92	250	208						

Table B.1 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	$^{3}H^{a}$ nCi/L	$^{90}Sr^{a}$ pCi/L	^{137}Cs Dissolved pCi/L	$^{137}Cs^{b}$ Particulate pCi/L	^{60}Co Dissolved pCi/L	$^{60}Co^{b}$ Particulate pCi/L	Gross Alpha^{a} pCi/L	Gross Beta^{a} pCi/L
WC–4	3060	25–Mar–92	256	264						
WC–5	3061	25–Mar–92	259	227						
WC–6	3062	25–Mar–92	241	208						
WC–6	3062	25–Mar–92	238	238						
WC–7	3063	25–Mar–92	262	227						
WC–8	3064	25–Mar–92	266	223						
WC–9	3065	25–Mar–92	195	201						
WC–10	3066	25–Mar–92	78	145						
WC–11	3067	06–Apr–92	47	186						
WC–12	3068	06–Apr–92	49	238						
WC–13	3069	06–Apr–92	40	216						
WC–14	3070	06–Apr–92	47	216						
WC–15	3071	06–Apr–92	24	193						
WC–16	3072	06–Apr–92	4	152						
WC–17	3073	06–Apr–92	6	160						
WC–17	3073	06–Apr–92	7	145						
WC–18	3074	06–Apr–92	3	175						
WC–19	3075	06–Apr–92	3	152						
MB–1	3076	09–Apr–92	1493	753						
MB–1	3076	09–Apr–92	1484	787						
MB–2	3077	09–Apr–92	1454	596						
MB–3	3078	09–Apr–92	1472	581						
MB–4	3079	09–Apr–92	1442	533						
MB–5	3080	09–Apr–92	1425	249						
MB–6	3081	09–Apr–92	1421	258						
MB–7	3082	09–Apr–92	1207	175						
MB–7	3082	09–Apr–92	883	212						
MB–8	3083	09–Apr–92	687	204						
MB–9	3084	09–Apr–92	577	160						
MB–10	3085	09–Apr–92	348	171						
MB–11	3086	09–Apr–92	442	193						
MB–12	3087	09–Apr–92	292	137						

Table B.1 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	^{3}H[a] nCi/L	^{90}Sr[a] pCi/L	^{137}Cs Dissolved pCi/L	^{137}Cs[b] Particulate pCi/L	^{60}Co Dissolved pCi/L	^{60}Co[b] Particulate pCi/L	Gross Alpha[a] pCi/L	Gross Beta[a] pCi/L
MB–13	3088	09–Apr–92	9	10						
MB–14	3089	09–Apr–92	7	–1						
MB–16	3090	09–Apr–92	7	22						
MB–17	3091	09–Apr–92	7	–6						
MB–18	3092	09–Apr–92	10	–4						
MB–19	3093	09–Apr–92	1	2						
HRT–1A	3094	09–Apr–92	2157	1152						
HRT–1B	3095	09–Apr–92	1618	488						
HRT–1C	3096	09–Apr–92	2727	1443						
HRT–1C	3096	09–Apr–92	2260	1469						
HRT–1D	3097	09–Apr–92	7924	757						
HRT–2	3098	09–Apr–92	2376	1208						
HRT–3	3099	09–Apr–92	–0.2	1100	< 8	< 2.4	< 11	< 2.6		
HRT–4	3100	09–Apr–92	–0.2	1193						
MBTRIB–1	3101	09–Apr–92	–0.1	22						
MBTRIB–2A	3102	09–Apr–92	8	25						
MBTRIB–2B	3103	09–Apr–92	–0.1	7						
W4TRIB–1	3117	03–Apr–92	13010	13209						
W4TRIB–2	3118	03–Apr–92	14664	12048						
W4TRIB–3	3119	03–Apr–92	10949	8443						
W4TRIB–4	3120	03–Apr–92	11635	7660						
W4TRIB–5	3121	03–Apr–92	17243	9387						
W4TRIB–6	3122	03–Apr–92	22428	6716						
W4TRIB–7	3123	03–Apr–92	34276	19966						
W4TRIB–8	3124	03–Apr–92	22098	6055						
W4TRIB–9	3125	03–Apr–92	21540	5966						
W4TRIB–10	3126	03–Apr–92	14698	6137						
W4TRIB–11	3127	03–Apr–92	15730	10447						
W4TRIB–12	3128	03–Apr–92	101	4413						
WCWEIR	3129	06–Apr–92	50	204						
WAG4 T2A	3130	06–Apr–92	8384	7943						
WC7500	3131	06–Apr–92	3	145						
SW2–4	3132	11–May–92	1237	316	< 2.4	3.7	5	< 0.8	41	637

[a] All values are for dissolved radionuclides except where noted for ^{137}Cs and ^{60}Co.

[b] Particulate concentrations are reported as activity per liter to facilitate flux calculations.

Table B.2 Radionuclide results for seep and stream samples collected during dry–season baseflow conditions

LOCATION	SAMPLE ID	DATE SAMPLED	$^{3}H^{a}$ nCi/L	$^{90}Sr^{a}$ pCi/L	^{137}Cs Dissolved pCi/L	$^{137}Cs^{b}$ Particulate pCi/L	^{60}Co Dissolved pCi/L	$^{60}Co^{b}$ Particulate pCi/L	Gross Alpha^{a} pCi/L	Gross Beta^{a} pCi/L
WCTRIB–1	3280	16–Sep–92	12	41	< 1.0	< 0.5	8.1	< 0.7		
RS–3	3281	16–Sep–92	50	924	< 6.4	< 0.6	1222	40.6	39350	10429
SW7–2	3282	16–Sep–92	7	19	< 6.1	< 0.4	1880	44.9	66	1947
SW7–2	3282	16–Sep–92	8	40	< 6.7		1786		54	1844
SW6–1	3283	16–Sep–92	59	10	10.8	13.7	< 3.1	2.3	1.9	53
WSTRIB–1	3284	16–Sep–92	53	170	< 1.9	< 0.3	47.0	< 0.6	1194	613
SW2–4	3285	17–Sep–92	927	255	6.4	35.3	< 2.7	< 0.6	5.8	5.8
SW5–1	3287	17–Sep–92	709	97	< 2.4	< 0.5	< 2.6	< 0.5	3.7	138
5NW–2	3288	17–Sep–92	19	14	< 2.3	< 0.5	< 2.5	< 0.6	–0.8	–0.8
SW5–4	3289	01–Oct–92	7348	573166	< 5.5	< 0.5	< 3.4	< 0.5	18595	1281450
MID. DRAIN.	3290	01–Oct–92	10207	2637	< 0.7	0.7	< 0.8	< 0.5	140	5250
MBTRIB–3	3291	01–Oct–92	3	57	4.7	< 0.3	< 2.9	< 0.4	8.4	109
SW7–3	3292	16–Sep–92	31	63	< 4.8	< 0.5	644	2.6	4505	4505
SW7–4	3293	16–Sep–92	47	18	< 2.6	< 0.3	119	< 0.5	32	487
SW7–7	3294	16–Sep–92	34	48	< 3.2	< 0.5	249	4.2	73	73
WCTRIB–4	3295	17–Sep–92	1	57	9.4	< 0.5	< 2.8	< 0.5	0.6	109
5NNT	3296	17–Sep–92	2	18	< 2.4	< 0.3	< 3.0	< 0.2		
SW4–1	3297	17–Sep–92	1345	5678	< 3.0	< 0.8	< 2.9	< 0.9	201	10354
SW5–7	3298	01–Oct–92	126696	4659	< 3.2	14.9	< 3.1	< 0.6	10	10540
RS–1	3299	16–Sep–92	23	184	< 3.2	2.5	< 5.1	1.9	3.5	312
MBWEIR	3300	01–Oct–92	649	480	< 2.9	< 0.5	< 3.6	< 0.6		
WOD	3301	16–Sep–92	81	195	9.6	26.2	< 3.8	< 0.8		
WAG6 MS1	3302	16–Sep–92	168	66	< 2.3	< 0.6	< 2.7	< 0.6	5.0	14
WAG6 MS2	3303	16–Sep–92	1479	137	< 2.5	< 0.7	< 3.4	< 0.9	0.4	4.2
WAG6 MS3A	3304	16–Sep–92	56	6	< 2.6	1.8	< 2.9	< 0.8	–0.1	6.1
WAG6 MS3B	3305	16–Sep–92	3175	306	< 4.4	< 0.6	< 4.7	< 1.0	13	633
WEST SEEP	3306	16–Sep–92	17	144	< 2.9	0.8	40.9	< 1.0		
WCWEIR	3307	16–Sep–92	5	99	37.9	7.8	< 2.9	< 0.4	3.6	126
WCWEIR	3307	16–Sep–92	5	91	35.3	39.5	< 2.8	< 0.3		
MBWEIR	3309	16–Sep–92	509	551	< 2.2	0.1	< 2.9	< 0.3		
EAST SEEP	3310	16–Sep–92	42	12	< 3.7	1.2	210	8.1		
WCWEIR	3311	17–Sep–92	4	91	41.0	8.1	< 3.0	< 0.7		

Table B.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	^{3}H^{a} nCi/L	^{90}Sr^{a} pCi/L	^{137}Cs Dissolved pCi/L	^{137}Cs^{b} Particulate pCi/L	^{60}Co Dissolved pCi/L	^{60}Co^{b} Particulate pCi/L	Gross Alpha^{a} pCi/L	Gross Beta^{a} pCi/L
5NST	3312	17–Sep–92	65	77	< 2.1	< 0.4	< 3.0	< 0.6		
WCHEAD	3313	17–Sep–92	–1	10	< 0.8	< 0.4	< 1.0	< 0.7		
NWTRIB	3314	17–Sep–92	1	14	< 2.0	< 0.7	< 3.4	< 0.8		
WC7500	3315	17–Sep–92	2	82	71.5	4.5	< 1.1	< 0.2		
WAG4 MS1	3316	17–Sep–92	14053	12305	< 3.4	< 0.8	< 3.5	< 0.7		
MB–15	3317	01–Oct–92	31	26	< 1.4	< 0.5	< 2.2	< 0.6		
HRT–3	3318	01–Oct–92	0.2	1069	< 0.8	< 0.7	< 0.8	< 0.8		
MB–1	3319	01–Oct–92	718	721						
WC–1	3320	16–Sep–92	54	160						
WC–2	3321	16–Sep–92	55	152						
WC–2	3321	16–Sep–92	69	156						
WC–3	3322	16–Sep–92	57	152						
WC–4	3323	16–Sep–92	59	160						
WC–5	3324	16–Sep–92	60	172						
WC–6	3325	16–Sep–92	59	149						
WC–7	3326	16–Sep–92	73	156						
WC–8	3327	16–Sep–92	59	149						
WC–9	3328	16–Sep–92	36	117						
WC–10	3329	16–Sep–92	20	89						
WC–11	3330	17–Sep–92	3	77						
WC–12	3331	17–Sep–92	3	58						
WC–13	3332	17–Sep–92	1	89						
WC–14	3333	17–Sep–92	3	101						
WC–15	3334	17–Sep–92	11	89						
WC–16	3335	17–Sep–92	2	89						
WC–17	3336	17–Sep–92	1	73						
WC–18	3337	17–Sep–92	2	93						
WC–19	3338	17–Sep–92	0.3	77						
W4TRIB–1	3339	17–Sep–92	20836	14481						
W4TRIB–2	3340	17–Sep–92	21959	14979						
W4TRIB–3	3341	17–Sep–92	26849	9465						
W4TRIB–4	3342	17–Sep–92	25950	8806						

Table B.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	$^{3}H^{a}$ nCi/L	$^{90}Sr^{a}$ pCi/L	^{137}Cs Dissolved pCi/L	$^{137}Cs^{b}$ Particulate pCi/L	^{60}Co Dissolved pCi/L	$^{60}Co^{b}$ Particulate pCi/L	Gross Alpha^{a} pCi/L	Gross Beta^{a} pCi/L
W4TRIB-6	3344	17-Sep-92	30274	7423						
W4TRIB-8	3346	17-Sep-92	29357	6851						
W4TRIB-9	3347	17-Sep-92	29864	7360						
W4TRIB-10	3348	17-Sep-92	22438	8225						
W4TRIB-11	3349	17-Sep-92	32754	11649						
W4TRIB-12	3350	17-Sep-92	254	5713						
MB-1A	3351	01-Oct-92	700	555						
MB-1B	3352	01-Oct-92	700	583						
MB-1B	3352	01-Oct-92	707	539						
MB-2	3353	01-Oct-92	701	524						
MB-3	3354	01-Oct-92	693	504						
MB-3	3354	01-Oct-92	689	508						
MB-4	3355	01-Oct-92	681	464						
MB-5	3356	01-Oct-92	691	239						
MB-6	3357	01-Oct-92	514	255						
MB-7	3358	01-Oct-92	774	227						
MB-8	3359	01-Oct-92	325	216						
MB-9	3360	01-Oct-92	243	231						
MB-10	3361	01-Oct-92	236	224						
MB-11	3362	01-Oct-92	234	227						
MB-12	3363	01-Oct-92	155	97						
MB-13	3364	01-Oct-92	34	6						
MB-14	3365	01-Oct-92	32	-9						
MB-16	3366	01-Oct-92	41	26						
MB-17	3367	01-Oct-92	32	2						
MB-18	3368	01-Oct-92	40	6						
MB-18	3368	01-Oct-92	40	22						
MB-19	3369	01-Oct-92	4	26						
HRT-1A	3370	01-Oct-92	1131	1112						
HRT-1B	3371	01-Oct-92	1175	563						
HRT-1C	3372	01-Oct-92	1174	1223						
HRT-1D	3373	01-Oct-92	4613	1930						

Table B.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	$^{3}H^{a}$ nCi/L	$^{90}Sr^{a}$ pCi/L	^{137}Cs Dissolved pCi/L	$^{137}Cs^{b}$ Particulate pCi/L	^{60}Co Dissolved pCi/L	$^{60}Co^{b}$ Particulate pCi/L	Gross Alpha^{a} pCi/L	Gross Beta^{a} pCi/L
HRT−2	3374	01−Oct−92	1157	1183						
HRT−4	3376	01−Oct−92	1	1065						
MBTRIB−1	3377	01−Oct−92	2	18						
MBTRIB−2A	3378	01−Oct−92	34	34						
MBTRIB−2B	3379	01−Oct−92	2	−2						
WAG6 MS3A−1	3380	16−Sep−92	64	26	< 2.0	< 0.2	< 2.1	< 0.4	−0.7	5.4
WAG6 MS3A−1	3380	16−Sep−92	61	−2	< 2.5	< 0.4	< 3.2	< 0.6	−2.2	−2.2
WAG6 MS3B−6	3381	16−Sep−92	125	346	< 2.9	< 0.3	< 3.3	< 0.4	9.4	9.4
WAG6 MS1−1	3382	16−Sep−92	485	22	< 2.5	< 0.5	< 3.3	< 0.8	−1.4	27
FRENCH DR S	3384	16−Sep−92	5836	6	< 3.3	< 0.3	< 2.2	< 0.4	−2.8	−2.8
SW6−2	3385	16−Sep−92	1635	−9	< 2.6	< 1.7	< 4.0	< 0.6	−3.3	−3.3
FIRST CREEK	3387	17−Sep−92	1	587	< 2.4	< 0.5	< 2.5	< 0.5		
FIFTH CREEK	3388	17−Sep−92	7	97	< 3.2	2.3	< 4.3	< 0.9		
WAG6 MS3B−1	3389	16−Sep−92	8112	358						
WAG6 MS3B−2	3390	16−Sep−92	7804	393						
WAG6 MS3B−3	3391	16−Sep−92	1684	152						
WAG6 MS3B−4	3392	16−Sep−92	33	374						
WAG6 MS3B−5	3393	16−Sep−92	25	164						
WAG6 MS3A−3	3394	16−Sep−92	351	26						
WAG6 MS3A−3	3394	16−Sep−92	472	14						
SW2−5	3395	01−Oct−92	12038	143344	< 2.8	< 0.3	< 3.3	< 0.5	3190	258973
WAG6 MS3A−2	3396	16−Sep−92	2	10						
HRT−2A	3399	01−Oct−92	284	1013						
SW5−6	3410	01−Oct−92	9737	42554	< 2.8	0.7	< 2.5	< 0.6	885	77036
SW5−8	3411	01−Oct−92	16368	239	< 1.7	< 0.3	< 1.9	< 0.5	17	486
SW5−9	3412	01−Oct−92	24641	701	< 3.0	< 0.4	< 3.8	< 0.5	29	1318
MB−7A SIDE	3417	01−Oct−92	1305	247						
MB−7B	3418	01−Oct−92	346	208						

[a] All values are for dissolved radionuclides except where noted for ^{137}Cs and ^{60}Co.

[b] Particulate concentrations are reported as activity per liter to facilitate flux calculations.

Appendix C

SEEP AND TRIBUTARY DATA TABLES— INORGANIC AND FIELD MEASUREMENTS

LABORATORY DATA QUALIFIER DEFINITIONS

The following contract laboratory data qualifiers are used in this project.

Qualifier	Explanation
U	Indicates compound was analyzed for but not detected.
J	Indicates an estimated value.
N	Spiked sample recovery not within control limits.
E	Reported value estimated because of the presence of interference.
M	Duplicate injection precision not met.
B	Reported value was obtained from a reading that was less than the CRDL, but greater than or equal to the instrument detection limit (IDL).
S	Reported value was determined by the method of standard additions (MSA).
W	Post-digestion spike for furnace atomic absorption is out of control limits, while sample absorbance is less than 50% of spike absorbance.
*	Duplicate analysis not within control limits.
+	Correlation coefficient for the MSA is less than 0.995.

Table C.1 Metal analysis results (μg/L) for seep and stream samples collected during wet–season baseflow conditions

LOCATION	SAMPLE ID	DATE SAMPLED	Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe
WOD	3001	25–Mar–92	< 10	< 30		< 20	37.4	0.5	46800		< 7	< 5	< 2	< 20
WCWEIR	3002	25–Mar–92	< 10	31.9		20.4	36	0.4	49300		< 7	< 5	3	< 20
WCWEIR	3002	25–Mar–92	< 10	33		< 20	35.9	0.5	49000		< 7	< 5	< 2	< 20
MBWEIR	3003	25–Mar–92	< 10	< 30		< 20	42	0.5	50200		< 7	< 5	< 2	< 20
WAG6–MS1	3004	25–Mar–92	< 10	< 30	< 10	56.1	52.7	0.6	80900	< 5	< 7	< 5	< 2	< 20
WAG6–MS2	3005	25–Mar–92	< 10	< 30	< 10	41.3	58	0.5	42700	< 5	< 7	< 5	< 2	< 20
WAG6–MS3A	3006	25–Mar–92	< 10	< 30	< 10	< 20	38.7	0.5	50500	< 5	< 7	< 5	< 2	117
WAG6–MS3B	3007	25–Mar–92	< 10	< 30	< 10	32.6	43.4	0.4	65500	< 5	< 7	< 5	< 2	< 20
WEST SEEP	3008	25–Mar–92	11.4	< 30		< 20	39.7	0.4	23900		< 7	< 5	< 2	26.1
EAST SEEP	3009	25–Mar–92	< 10	< 30		< 20	24.4	0.5	47800		< 7	< 5	< 2	< 20
WCWEIR	3010	02–Apr–92	< 10	45.6	< 10	26.3	35.8	0.5	53500	< 5	< 7	< 5	3	< 20
WC7500	3011	02–Apr–92	< 10	39.8		25.5	35.7	0.5	53600		< 7	< 5	< 2	< 20
WCHEAD	3012	02–Apr–92	< 10	< 30		< 20	49.2	0.5	23000		< 7	< 5	< 2	< 20
WAG4 MS1	3013	02–Apr–92	< 10	< 30	< 10	105	142	0.5	84300	< 5	< 7	< 5	< 2	31.3
WAG4 T2A	3014	02–Apr–92	< 10	< 30	< 10	111	102	0.5	82800	< 5	< 7	< 5	< 2	< 20
WAG4 T2A	3014	02–Apr–92	< 10	< 30	< 10	117	103	0.5	84200	< 5	< 7	< 5	< 2	< 20
5NNT	3015	02–Apr–92	< 10	< 30	< 10	< 20	48	0.4	29800	< 5	< 7	< 5	< 2	< 20
5NST	3016	02–Apr–92	< 10	< 30	< 10	38.9	48.3	0.6	66300	< 5	< 7	< 5	< 2	< 20
NWTRIB	3017	02–Apr–92	< 10	31	< 10	39.3	27.1	0.5	64300	< 5	< 7	< 5	< 2	< 20
MBWEIR	3018	09–Apr–92	< 10	< 30		39.3	72.3	0.3	86200		< 7	< 5	< 2	30.5
MB–15	3019	09–Apr–92	< 10	35.5	< 10	37.1	67.3	0.4	90500	< 5	< 7	< 5	2.1	22.7
WCTRIB–1	3021	25–Mar–92	< 10	< 30	< 10	< 20	44.3	0.5	37800	< 5	< 7	< 5	< 2	< 20
WSTRIB–1	3022	25–Mar–92	< 10	< 30	< 10	< 20	37.9	0.3	23700	< 5	< 7	< 5	< 2	23
RS–1	3023	25–Mar–92	< 10	< 30	< 10	< 20	42	0.4	39400	< 5	< 7	< 5	< 2	156
RS–1	3023	25–Mar–92	< 10	< 30	14	< 20	40.7	< 0.2	37700	< 5	< 7	< 5	< 2	139
RS–3	3024	25–Mar–92	< 10	149	< 10	37.4	15.4	0.4	15600	< 5	18	36.3	6.2	101
SW7–1	3025	25–Mar–92	< 10	< 30	< 10	< 20	61.4	0.4	49500	< 5	< 7	< 5	< 2	4420
SW7–2	3026	25–Mar–92	< 10	< 30	< 10	< 20	28.1	0.4	12600	< 5	81	< 5	< 2	79.2
SW7–3	3027	25–Mar–92	< 10	< 30	< 10	38.7	17.4	0.5	20200	< 5	< 7	55.8	3.2	< 20
SW7–4	3028	25–Mar–92	< 10	< 30	< 10	< 20	21.6	0.5	44300	< 5	< 7	< 5	< 2	30.4

Table C.1 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Hg	K	Mn	Mo	Ni	Pb	Sb	Se	Sr	Tl	V	Zn
WOD	3001	25-Mar-92		1220	77.6	< 10	< 9		< 50		82.7	< 40	23.5	< 2
WCWEIR	3002	25-Mar-92		1530	39	< 10	< 9		< 50		83.4	< 40	23.9	14.2
WCWEIR	3002	25-Mar-92		1550	37.6	< 10	< 9		< 50		83.1	< 40	23.2	13.4
MBWEIR	3003	25-Mar-92		1110	115	< 10	< 9		< 50		94.1	< 40	22.4	< 2
WAG6-MS1	3004	25-Mar-92	< 0.1	1270	545	< 10	< 9	< 3	< 50	< 5	129	< 40	27.4	< 2
WAG6-MS2	3005	25-Mar-92	< 0.1	1270	50.3	< 10	< 9	< 3	< 50	< 5	87.3	< 40	22.8	< 2
WAG6-MS3A	3006	25-Mar-92	< 0.1	1410	666	< 10	< 9	< 3	< 50	< 5	105	< 40	23.6	< 2
WAG6-MS3B	3007	25-Mar-92	< 0.1	1170	106	< 10	< 9	< 3	< 50	< 5	122	< 40	17.2	< 2
WEST SEEP	3008	25-Mar-92		1380	61.7	< 10	< 9		< 50		53.5	< 40	25	< 2
EAST SEEP	3009	25-Mar-92		1070	68.9	< 10	11		< 50		89.6	< 40	26.2	2.2
WCWEIR	3010	02-Apr-92	< 0.1	1640	42.8	< 10	< 9	< 3	< 50	< 5	89.5	< 40	29.9	16.4
WC7500	3011	02-Apr-92		1580	31.1	< 10	< 9		< 50		89.7	< 40	29.2	21.3
WCHEAD	3012	02-Apr-92		550	12.2	< 10	< 9		< 50		23.6	< 40	30	< 2
WAG4 MS1	3013	02-Apr-92	< 0.1	5560	327	< 10	11.2	< 3	< 50	< 5	183	< 40	27.3	3.1
WAG4 T2A	3014	02-Apr-92	< 0.1	4010	78.3	< 10	< 9	< 3	< 50	< 5	185	< 40	25.1	2.8
WAG4 T2A	3014	02-Apr-92	< 0.1	4000	78.8	< 10	< 9	< 3	< 50	< 5	188	< 40	25.4	2.3
5NNT	3015	02-Apr-92	< 0.1	1330	7.8	< 10	< 9	< 3	< 50	< 5	67.3	< 40	24.2	< 2
5NST	3016	02-Apr-92	< 0.1	1310	55.9	< 10	< 9	< 3	< 50	< 5	138	< 40	32.2	< 2
NWTRIB	3017	02-Apr-92	< 0.1	910	15.1	< 10	< 9	< 3	< 50	< 5	105	< 40	28.6	3.9
MBWEIR	3018	09-Apr-92		2400	143	< 10	< 9		< 50		176	< 40	13.6	17.3
MB-15	3019	09-Apr-92	< 0.1	2800	46.6	< 10	< 9	< 3	< 50	< 5	186	< 40	16.9	42.3
WCTRIB-1	3021	25-Mar-92	< 0.1	940	42	< 10	< 9	< 3	< 50	< 5	77.1	< 40	23.7	< 2
WSTRIB-1	3022	25-Mar-92	< 0.1	1380	117	< 10	< 9	< 3	< 50	< 5	53.5	< 40	12.3	2.1
RS-1	3023	25-Mar-92	< 0.1	1330	1180	< 10	9.4	< 3	< 50	< 5	72	< 40	17	< 2
RS-1	3023	25-Mar-92	< 0.1	1290	1070	< 10	12.4	< 3	< 50	< 5	70.2	< 40	12.1	< 2
RS-3	3024	25-Mar-92	0.2	1280	35.4	31.	72.9	< 3	< 50	< 5	26	< 40	25.3	< 2
SW7-1	3025	25-Mar-92	< 0.1	780	6070	< 10	< 9	< 3	< 50	< 5	92	< 40	14.5	< 2
SW7-2	3026	25-Mar-92	< 0.1	790	255	< 10	< 9	< 3	< 50	< 5	26.4	< 40	24.8	< 2
SW7-3	3027	25-Mar-92	< 0.1	1120	4.8	10.	14.4	< 3	< 50	< 5	30.2	< 40	27.8	9.9
SW7-4	3028	25-Mar-92	< 0.1	910	100	< 10	< 9	< 3	< 50	< 5	78.1	< 40	24.8	< 2

Table C.1 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe
SW7-5	3029	25-Mar-92	< 10	< 30	< 10	21.3	33.2	0.6	43800	< 5	< 7	< 5	< 2	< 20
SW7-6	3030	25-Mar-92	< 10	< 30	< 10	< 20	50.4	0.2	2510	< 5	< 7	< 5	< 2	< 20
SW7-7	3031	25-Mar-92	< 10	< 30	< 10	< 20	26.7	0.2	41000	< 5	< 7	< 5	< 2	< 20
SW7-7	3031	25-Mar-92	< 10	< 30	< 10	< 20	27	0.2	41100	< 5	< 7	< 5	< 2	21.9
SW7-8	3032	25-Mar-92	< 10	< 30	< 10	< 20	34.2	0.2	37800	< 5	< 7	< 5	< 2	< 20
SW2-1	3033	25-Mar-92	< 10	< 30	< 10	29.6	201	0.4	99800	< 5	< 7	< 5	< 2	5750
SW6-1	3034	25-Mar-92	< 10	< 30	< 10	< 20	79.2	0.2	72000	< 5	< 7	< 5	< 2	3420
WCTRIB-2	3035	02-Apr-92	< 10	< 30	< 10	< 20	42.3	0.5	38600	< 5	< 7	< 5	< 2	< 20
WCTRIB-3	3036	02-Apr-92	< 10	< 30	< 10	197	74.2	0.6	105000	< 5	< 7	< 5	< 2	146
WCTRIB-4	3037	02-Apr-92	< 10	< 30	< 10	< 20	66.6	0.5	47500	< 5	< 7	< 5	< 2	< 20
SW2-2	3038	02-Apr-92	< 10	< 30	< 10	25	116	0.6	73500	< 5	8.2	< 5	< 2	393
SW2-3	3039	02-Apr-92	< 10	< 30	< 10	< 20	40.9	0.5	33800	< 5	< 7	< 5	< 2	28.8
SW4-1	3040	03-Apr-92	< 10	< 30	< 10	134	350	0.8	144000	< 5	< 7	< 5	< 2	2500
SW4-2	3041	02-Apr-92	< 10	< 30	< 10	162	465	0.8	128000	< 5	< 7	< 5	< 2	2080
BTT	3042	03-Apr-92	< 10	< 30	< 10	76.9	327	0.8	144000	< 5	< 7	< 5	< 2	97.7
5NW-1	3043	03-Apr-92	< 10	< 30	< 10	20.7	62	0.5	40100	< 5	< 7	< 5	< 2	751
5NW-2	3044	02-Apr-92	< 10	< 30	< 10	< 20	59.1	0.5	19100	< 5	< 7	< 5	< 2	70
SW5-1	3045	02-Apr-92	< 10	< 30	< 10	75.6	110	0.8	128000	< 5	< 7	< 5	< 2	< 20
SW5-2	3046	03-Apr-92	< 10	< 30	< 10	129	84.7	0.7	136000	< 5	< 7	< 5	< 2	< 20
SW5-2	3046	02-Apr-92	< 10	< 30	< 10	127	84.9	0.7	137000	< 5	< 7	< 5	< 2	< 20
MID.DRAIN.	3047	09-Apr-92	< 10	< 30	< 10	184	65.2	0.3	110000	< 5	< 7	< 5	< 2	331
SW5-3	3048	09-Apr-92	< 10	< 30	< 10	80.6	145	0.4	103000	< 5	< 7	< 5	< 2	1990
SW5-4	3049	09-Apr-92	< 10	< 30	< 10	138	118	0.4	105000	< 5	< 7	< 5	< 2	437
SW5-5	3050	09-Apr-92	< 10	< 30	< 10	175	75.6	< 0.2	96700	< 5	< 7	< 5	< 2	4140
SW5-6	3051	09-Apr-92	< 10	< 30	< 10	514	93.6	0.3	162000	< 5	< 7	< 5	< 2	158
SW5-7	3052	09-Apr-92	< 10	< 30	< 10	405	169	0.3	115000	< 5	9.2	< 5	< 2	5640
SW5-8	3053	09-Apr-92	< 10	< 30	< 10	598	175	< 0.2	107000	< 5	< 7	< 5	< 2	2570
SW5-9	3054	09-Apr-92	< 10	< 30	< 10	781	105	0.4	143000	< 5	8.3	< 5	< 2	26.4
SW5-11	3056	09-Apr-92	10.4	< 30	< 10	74.3	60.2	0.4	105000	< 5	< 7	< 5	< 2	< 20
HRT-3	3099	09-Apr-92	< 10	< 30	< 10	25.9	58.7	< 0.2	44300	< 5	< 7	< 5	< 2	< 20

Table C.1 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Hg	K	Mn	Mo	Ni	Pb	Sb	Se	Sr	Tl	V	Zn
SW7-5	3029	25-Mar-92	< 0.1	630	12.3	< 10	< 9	< 3	< 50	< 5	56	< 40	27.5	< 2
SW7-6	3030	25-Mar-92	< 0.1	790	13.9	< 10	< 9	< 3	< 50	< 5	13.9	< 40	12.3	< 2
SW7-7	3031	25-Mar-92	< 0.1	1000	141	< 10	10.3	< 3	< 50	< 5	78.3	< 40	12.7	< 2
SW7-7	3031	25-Mar-92	< 0.1	940	166	< 10	11.1	< 3	< 50	< 5	77.6	43.	14.1	< 2
SW7-8	3032	25-Mar-92	< 0.1	1020	105	< 10	< 9	< 3	< 50	< 5	75.2	< 40	14	< 2
SW2-1	3033	25-Mar-92	< 0.1	1640	2010	< 10	< 9	< 3	< 50	< 5	266	< 40	16.9	< 2
SW6-1	3034	25-Mar-92	< 0.1	870	3000	< 10	< 9	< 3	< 50	< 5	125	< 40	10.9	< 2
WCTRIB-2	3035	02-Apr-92	< 0.1	1000	27.1	< 10	< 9	< 3	< 50	< 5	68.1	< 40	25.4	< 2
WCTRIB-3	3036	02-Apr-92	< 0.1	2630	872	< 10	11.1	< 3	< 50	< 5	229	< 40	27.9	< 2
WCTRIB-4	3037	02-Apr-92	< 0.1	1330	30	< 10	< 9	< 3	< 50	< 5	80.3	< 40	28.6	< 2
SW2-2	3038	02-Apr-92	< 0.1	1520	986	< 10	< 9	< 3	< 50	< 5	137	< 40	30.2	2.6
SW2-3	3039	02-Apr-92	< 0.1	870	88.2	< 10	< 9	< 3	< 50	< 5	57.7	< 40	25.1	< 2
SW4-1	3040	03-Apr-92	< 0.1	5000	877	< 10	< 9	< 3	< 50	< 5	313	< 40	26.1	3.4
SW4-2	3041	02-Apr-92	< 0.1	3480	901	< 10	3310	< 3	< 50	< 5	289	< 40	31.1	< 2
BTT	3042	03-Apr-92	< 0.1	2810	70.6	10.	33.4	< 3	< 50	< 5	259	< 40	30.2	6.2
5NW-1	3043	03-Apr-92	< 0.1	750	922	< 10	< 9	< 3	< 50	< 5	73.1	< 40	27.1	< 2
5NW-2	3044	02-Apr-92	< 0.1	1460	952	< 10	< 9	< 3	< 50	< 5	45.4	< 40	25.3	< 2
SW5-1	3045	02-Apr-92	< 0.1	1630	134	< 10	< 9	< 3	< 50	< 5	204	< 40	28.7	< 2
SW5-2	3046	03-Apr-92	< 0.1	1540	8.6	< 10	< 9	< 3	< 50	< 5	257	< 40	31.3	< 2
SW5-2	3046	02-Apr-92	< 0.1	1540	8.2	< 10	< 9	< 3	< 50	< 5	259	< 40	29.1	< 2
MID.DRAIN.	3047	09-Apr-92	< 0.1	1700	470	< 10	< 9	< 3	< 50	< 5	192	< 40	12.2	3.3
SW5-3	3048	09-Apr-92	< 0.1	1400	291	< 10	< 9	< 3	< 50	< 5	197	< 40	18.9	< 2
SW5-4	3049	09-Apr-92	< 0.1	2800	547	< 10	< 9	< 3	< 50	< 5	201	< 40	17.9	2.1
SW5-5	3050	09-Apr-92	< 0.1	2800	3260	< 10	< 9	< 3	< 50	< 5	187	< 40	13	< 2
SW5-6	3051	09-Apr-92	< 0.1	1400	7140	< 10	22.9	< 3	< 50	< 5	265	< 40	13.8	< 2
SW5-7	3052	09-Apr-92	< 0.1	1200	6360	< 10	< 9	< 3	< 50	< 5	195	< 40	18.7	< 2
SW5-8	3053	09-Apr-92	< 0.1	1300	4630	< 10	19.3	< 3	< 50	< 5	215	< 40	13.2	< 2
SW5-9	3054	09-Apr-92	< 0.1	1300	2500	< 10	< 9	< 3	< 50	< 5	250	< 40	15.8	< 2
SW5-11	3056	09-Apr-92	< 0.1	1300	259	< 10	< 9	< 3	< 50	< 5	174	< 40	15.9	< 2
HRT-3	3099	09-Apr-92	< 0.1	1800	40.3	< 10	< 9	< 3	< 50	< 5	93.1	< 40	9.9	< 2

Table C.2 Metal analysis results (μg/L) for seep and stream samples collected during dry–season baseflow conditions

LOCATION	SAMPLE ID	DATE SAMPLED	Ag	Al	As	B	Ba	Be	Ca	Cd	Cn
WCTRIB–1	3280	16–Sep–92	UN 10	U 30	UW 2	U 50	B 75	U 2	84200	UN 0	
RS–3	3281	16–Sep–92	UN 10	BE 1570	22	281	B 17	U 2	5840	UW 0	
SW7–2	3282	16–Sep–92	UN 10	BE 48	U 2	143	B 26	U 2	B 3460	U 0	
SW7–2	3282	16–Sep–92	UN 10	BE 52	U 2	142	B 25	U 2	B 3340	U 0	
SW6–1	3283	16–Sep–92	UN 10	B 51	U 2	U 50	B 141	U 2	91300	UWN 0	
WSTRIB–1	3284	16–Sep–92	UN 10	B 52	U 2	60	B 48	U 2	54900	UWN 0	
SW2–4	3285	17–Sep–92	UN 10	U 30	B 3	52	B 184	U 2	158000	UW 0	
SW5–1	3287	17–Sep–92	UN 10	U 30	U 2	61	B 90	U 2	122000	UW 0	
5NW–2	3288	17–Sep–92	UN 10	B 54	U 2	56	B 31	U 2	20300	UWN 0	
SW5–4	3289	01–Oct–92	UN 10	U 30	BW 3	174	231	U 2	59800	UEN 2	
MID. DRAIN.	3290	01–Oct–92	UN 10	B 43	U 2	218	B 141	U 2	127000	UWN 0	
MBTRIB–3	3291	01–Oct–92	UN 10	U 30	U 2	61	B 72	U 2	90300	UN 0	
SW7–3	3292	16–Sep–92	UN 10	U 30	B 4	178	B 20	U 2	16400	UWN 0	
SW7–4	3293	16–Sep–92	UN 10	B 59	U 2	107	B 59	U 2	75200	UWN 0	
SW7–7	3294	16–Sep–92	UN 10	U 30	UW 2	135	B 37	U 2	60100	UWN 0	
WCTRIB–4	3295	17–Sep–92	UN 10	U 30	U 2	75	B 144	U 2	63500	UW 0	
5NNT	3296	17–Sep–92	UN 10	U 30	U 2	U 50	B 113	U 2	54900	UW 0	
SW4–1	3297	17–Sep–92	UN 10	U 30	B 3	171	570	U 2	123000	U 0	
SW5–7	3298	01–Oct–92	UN 10	B 116	B 3	538	275	U 2	134000	UEN 2	
SW5–7	3298	01–Oct–92	U 10	B 113	B 2	549	274	U 2	134951	U 2	
RS–1	3299	16–Sep–92	UN 10	BE 60	UW 2	89	B 70	U 2	62100	UW 0	
MBWEIR	3300	01–Oct–92	UN 10	U 30	B 2	429	B 87	U 2	121000	UWN 0	U 10
WOD	3301	16–Sep–92	UN 10	U 30		76	B 40	U 2	52600		U 10
WAG6 MS1	3302	16–Sep–92	UN 10	B 45	UW 2	83	B 76	U 2	108000	UWN 0	
WAG6 MS1 [a]	3302	16–Sep–92	UN 10	BE 91	U 2	112	B 75	U 2	107000	U 0	
WAG6 MS2	3303	16–Sep–92	U 10	BE 51	U 2	77	B 54	U 2	37000	UW 2	
WAG6 MS2 [a]	3303	16–Sep–92	UN 10	E 212	U 2	130	B 56	U 2	37100	U 0	

Table C.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Co	Cr	Cu	Fe	Hg	K	Mg	Mn	Mo	Na
WCTRIB−1	3280	16−Sep−92	U 10	U 10	U 10	B 57	U 0.2	B 1380	9950	1260	U 20	8230
RS−3	3281	16−Sep−92	B 18	64	U 10	692	0.5	B 2820	B 1110	69	41	616000
SW7−2	3282	16−Sep−92	142	U 10	U 10	U 20	U 0.2	B 1050	B 1750	142	U 20	119000
SW7−2	3282	16−Sep−92	142	U 10	U 10	U 20	U 0.2	B 1030	B 1700	141	U 20	117000
SW6−1	3283	16−Sep−92	U 10	U 10	U 10	14700	U 0.2	B 1640	8290	2560	U 20	U 5010
WSTRIB−1	3284	16−Sep−92	U 10	U 10	U 10	U 20	U 0.2	B 2850	11800	443	U 20	47500
SW2−4	3285	17−Sep−92	U 10	U 10	U 10	983	U 0.2	B 3930	18100	10600	U 20	21300
SW5−1	3287	17−Sep−92	U 10	U 10	U 10	B 78	U 0.2	B 2760	13600	5410	U 20	6610
5NW−2	3288	17−Sep−92	U 10	U 10	U 10	148	U 0.2	B 2370	6790	5330	U 20	B 4060
SW5−4	3289	01−Oct−92	U 10	U 10	U 10	3580		B 2770	10200	5760	U 20	17800
MID. DRAIN.	3290	01−Oct−92	U 10	U 10	U 10	4110		B 2400	18200	6180	U 20	17900
MBTRIB−3	3291	01−Oct−92	U 10	U 10	U 10	U 20		B 1990	11400	505	U 20	B 4720
SW7−3	3292	16−Sep−92	14	50	U 10	U 20	0.4		B 2200	U 10	U 20	260000
SW7−4	3293	16−Sep−92	U 10	U 10	U 10	463	U 0.2	B 909	10100	7400	U 20	102000
SW7−7	3294	16−Sep−92	U 10	U 10	U 10	U 20	U 0.2	B 2270	9880	757	U 20	106000
WCTRIB−4	3295	17−Sep−92	U 10	U 10	U 10	450	U 0.2	B 2860	12800	679	U 20	13900
5NNT	3296	17−Sep−92	U 10	U 10	U 10	U 20	U 0.2	B 2670	10100	123	U 20	B 4650
SW4−1	3297	17−Sep−92	U 10	U 10	U 10	9580	U 0.2	8550	22100	2380	U 20	15600
SW5−7	3298	01−Oct−92	U 10	U 10	U 10	7110		B 2360	17200	8760	U 20	23900
SW5−7	3298	01−Oct−92	U 10	U 10	U 10	7146		B 2361	17250	8827	U 20	23867
RS−1	3299	16−Sep−92	U 10	U 10	U 10	1270	U 0.2	B 2660	11000	7330	U 20	41300
MBWEIR	3300	01−Oct−92	U 10	U 10	B 11	B 45	U 0.2	B 4970	31200	188	U 20	21100
WOD	3301	16−Sep−92	U 10	U 10	U 10	U 20	U 0.2	B 3200	12900	131	U 20	17700
WAG6 MS1	3302	16−Sep−92	U 10	U 10	U 10	U 20	U 0.2	B 2620	13000	3930	U 20	B 4620
WAG6 MS1 [a]	3302	16−Sep−92	U 10	U 10	U 10	135	U 0.2	B 2150	12500	3730	U 20	B 4470
WAG6 MS2	3303	16−Sep−92	U 10	U 10	U 10	U 20	U 0.2	B 2450	5680	152	U 20	B 3430
WAG6 MS2 [a]	3303	16−Sep−92	U 10	U 10	U 10	167	U 0.2	B 2250	5610	151	U 20	B 3580

Table C.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Ni		Pb		Sb		Se		Si		Sr		Tl		V		Zn	
WCTRIB−1	3280	16−Sep−92	U	20	U	2	B	6	U	2		4380		165	B	268	U	10	U	5
RS−3	3281	16−Sep−92		91	U	2	B	8	U	2		5060		17	U	150	U	10	B	8
SW7−2	3282	16−Sep−92	U	20	UW	2	U	5	U	2		5970		14	U	150	U	10	U	5
SW7−2	3282	16−Sep−92	U	20	U	2	U	5	U	2		5990		14	U	150	U	10	U	5
SW6−1	3283	16−Sep−92	U	20	*	6	U	5	U	2		6330		168		450	U	10		28
WSTRIB−1	3284	16−Sep−92	U	20	U*	2	B	6	UW	2		4970		145		345	U	10	U	5
SW2−4	3285	17−Sep−92	U	20	U	2	U	5	U	2		5920		288		417	U	10	U	5
SW5−1	3287	17−Sep−92	U	20	U	2	U	5	U	2		5530		206		420	U	10	U	5
5NW−2	3288	17−Sep−92	U	20	U*	2	U	5	UW	2		3390		56	U	150	U	10	U	5
SW5−4	3289	01−Oct−92	U	20	U	2	B	10	U	2	U	3090	U	120	U	150	U	10	U	5
MID. DRAIN.	3290	01−Oct−92	U	20	U*	2	U	5	UW	2		6510		252		398	U	10	U	5
MBTRIB−3	3291	01−Oct−92	U	20	U	2	U	5	U	2		3830		175		332	U	10	U	5
SW7−3	3292	16−Sep−92		25	U	2	U	5	B	4		3370		28	U	150	U	10		22
SW7−4	3293	16−Sep−92		43	U*	2	U	5	UW	2		3500		126	B	290	U	10	B	9
SW7−7	3294	16−Sep−92		46	U	2	U	5	U	2		3540		113	B	161	U	10		23
WCTRIB−4	3295	17−Sep−92	U	20	U	2	U	5	U	2		3890		124	B	272	U	10	U	5
5NNT	3296	17−Sep−92	U	20	U	2	U	5	U	2		3170		125	U	150	U	10	U	5
SW4−1	3297	17−Sep−92	U	20	U	2	U	5	U	2		4570		308		331	U	10	U	5
SW5−7	3298	01−Oct−92	U	20	U	2	U	5	U	2		6360		239	U	150	U	10	U	5
SW5−7	3298	01−Oct−92	U	20	U	2	U	5	U	2		6383		240	U	150	U	10	U	5
RS−1	3299	16−Sep−92	U	20	U	2	U	5	U	2		3940		116	B	257	U	10	U	5
MBWEIR	3300	01−Oct−92	U	20	U	2	U	5	U	2		7740		285		324	U	10		63
WOD	3301	16−Sep−92	U	20								2350		116	B	231	U	10	U	5
WAG6 MS1	3302	16−Sep−92	U	20	U*	2	U	5	U	2		4140		179		384	U	10	U	5
WAG6 MS1 [a]	3302	16−Sep−92	U	20	U	2	U	5	U	2		3820		175	B	241	U	10	B	10
WAG6 MS2	3303	16−Sep−92	U	20	U	2	B	5	U	2		3210		79	B	162	U	10	U	5
WAG6 MS2 [a]	3303	16−Sep−92	U	20	U	2	U	5	U	2		3150		78	U	150	U	10		32

Table C.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Ag		Al		As		B		Ba		Be		Ca	Cd		Cn	
WAG6 MS3A	3304	16-Sep-92	U	10	BE	56	U	2	U	50	B	73	U	2	88100	UW	2		
WAG6 MS3A	3304	16-Sep-92	UN	10	BE	75	U	2		83	B	77	U	2	87500	U	0		
WAG6 MS3B	3305	16-Sep-92	UN	10	BE	61	U	2		62	B	47	U	2	88400	UW	0		
WAG6 MS3B	3305	16-Sep-92	UN	10	BE	197	U	2		129	B	47	U	2	82900	U	0		
WEST SEEP	3306	16-Sep-92	UN	10	B	54	U	2		59	B	50	U	2	48300	UWN	0		
WCWEIR	3307	16-Sep-92	UN	10	B	45	B	3		75	B	34	U	2	40800	UN	0	U	10
WCWEIR	3307	16-Sep-92	UN	10	B	38	U	2		74	B	34	U	2	40100	UWN	0	U	10
MBWEIR	3309	16-Sep-92	UN	10	B	53	UW	2		399	B	76	U	2	120000	UN	0	U	10
EAST SEEP	3310	16-Sep-92	UN	10	B	44	U	2		145	B	33	U	2	62300	UWN	0		
WCWEIR	3311	17-Sep-92	UN	10	B	68	B	2		80	B	34	U	2	42500	UWN	0		
5NST	3312	17-Sep-92	UN	10	U	30	U	2	U	50	B	61	U	2	76200	U	0		
WCHEAD	3313	17-Sep-92	UN	10	U	30	U	2	U	50	B	108	U	2	34100	U	0		
NWTRIB	3314	17-Sep-92	UN	10	U	30			U	50	B	50	U	2	38900				
WC7500	3315	17-Sep-92	UN	10	B	86	U	2		63	B	30	U	2	39800	UWN	0	U	10
WAG4 MS1	3316	17-Sep-92	UN	10	U	30	U	2		156		346	U	2	98600	U	0		
MB-15	3317	01-Oct-92	UN	10	U	30	B	4		487	B	89	U	2	129000	UWN	0	U	10
HRT-3	3318	01-Oct-92	UN	10	U	30				60	B	61	U	2	47200				
WAG6 MS3A-1	3380	16-Sep-92	UN	10	U	30	B	3	U	50	B	82	U	2	62900	UWN	0		
WAG6 MS3A-1	3380	16-Sep-92	UN	10	U	30	UW	2	U	50	B	83	U	2	62000	UWN	0		
WAG6 MS3B-6	3381	16-Sep-92	UN	10	B	44	U	2		132	B	70	U	2	85500	UWN	0		
WAG6 MS1-1	3382	16-Sep-92	UN	10	U	30	B	4		81	B	148	U	2	117000	UWN	0		
FRENCH DR S	3384	16-Sep-92	UN	10	U	30	U	2		130	B	189	U	2	90800	UN	0		
SW6-2	3385	16-Sep-92	UN	10	U	30	B	2		62	B	137	U	2	135000	UN	0		
FIRST CREEK	3387	17-Sep-92	UN	10	U	30	U	2	U	50	B	34	U	2	49900	U	0		
FIFTH CREEK	3388	17-Sep-92	UN	10	U	30	U	2	U	50	B	53	U	2	42500	U	0		
WAG6 MS3B-4	3392	16-Sep-92	U	10	U	30	B	5		182	B	20	U	2	16520	U	0		
SW2-5	3395	01-Oct-92	UN	10	U	30	U	2		231		332	U	2	146000	UWN	0		
SW5-6	3410	01-Oct-92	UN	10	U	30	U	2		522		213	U	2	147000	U	0		
SW5-8	3411	01-Oct-92	UN	10	U	30	U	2		699		275	U	2	143000	UW	0		
SW5-9	3412	01-Oct-92	UN	10	U	30	B	3		938		271	U	2	146000	UW	0		

Table C.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Co	Cr	Cu	Fe	Hg	K	Mg	Mn	Mo	Na
WAG6 MS3A	3304	16–Sep–92	U 10	U 10	U 10	653	U 0.2	B 2040	12000	4300	U 20	B 4910
WAG6 MS3A	3304	16–Sep–92	U 10	U 10	U 10	1420	U 0.2	B 1750	12000	4720	U 20	B 4910
WAG6 MS3B	3305	16–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 2500	11900	1020	U 20	5250
WAG6 MS3B	3305	16–Sep–92	U 10	U 10	U 10	207	U 0.2	B 2150	11100	985	U 20	5060
WEST SEEP	3306	16–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 3070	12000	386	U 20	384000
WCWEIR	3307	16–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 2650	10600	B 15	U 20	20600
WCWEIR	3307	16–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 2580	10300	15	U 20	20100
MBWEIR	3309	16–Sep–92	U 10	U 10	U 40	U 109	U 0.2	B 4900	309000	289	U 20	19700
EAST SEEP	3310	16–Sep–92	U 10	12	U 10	U 20	U 0.2	B 2420	10500	283	U 20	159000
WCWEIR	3311	17–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 2740	10800	U 23	U 20	21100
5NST	3312	17–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 2810	13900	165	U 20	5360
WCHEAD	3313	17–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 1100	17700	U 10	U 20	B 318
NWTRIB	3314	17–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 1540	12300	26	U 20	B 3810
WC7500	3315	17–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 2770	10400	20	U 20	19500
WAG4 MS1	3316	17–Sep–92	U 10	U 10	U 10	1520	0.2	6930	18000	6470	U 20	11400
MB–15	3317	01–Oct–92	U 10	U 10	29	134		5740	35000	100	U 20	24000
HRT–3	3318	01–Oct–92	U 10	U 10	U 10	U 20		B 2210	10700	37	U 20	5750
WAG6 MS3A–1	3380	16–Sep–92	U 10	U 10	U 10	1700	U 0.2	B 2640	8620	5730	U 20	B 3500
WAG6 MS3A–1	3380	16–Sep–92	U 10	U 10	U 10	U 1840	U 0.2	B 2610	8550	5940	U 20	B 3490
WAG6 MS3B–6	3381	16–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 1900	13000	2760	U 20	5530
WAG6 MS1–1	3382	16–Sep–92	U 10	U 10	U 10	1650	U 0.2	B 2230	17000	12200	28	B 4400
FRENCH DR S	3384	16–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 1760	13400	U 10	U 20	5840
SW6–2	3385	16–Sep–92	U 10	U 10	U 10	1550	U 0.2	B 1860	19800	1760	U 20	12300
FIRST CREEK	3387	17–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 1970	9930	B 15	U 20	6200
FIFTH CREEK	3388	17–Sep–92	U 10	U 10	U 10	U 20	U 0.2	B 1430	13400	U 10	U 20	B 3450
WAG6 MS3B–4	3392	16–Sep–92	B 12	51	U 10	U 20		B 1994	B 2213	U 10	U 20	260530
SW2–5	3395	01–Oct–92	U 10	U 10	U 10	U 20		B 2020	16100	414	U 20	19600
SW5–6	3410	01–Oct–92	U 10	U 10	U 10	115		B 2820	17300	3740	U 20	24800
SW5–8	3411	01–Oct–92	U 10	U 10	U 10	721		B 1990	U 16800	4910	U 20	22400
SW5–9	3412	01–Oct–92	U 10	U 10	U 10	9030		B 2150	15500	5020	U 20	21900

Table C.2 (continued)

LOCATION	SAMPLE ID	DATE SAMPLED	Ni		Pb		Sb		Se		Si	Sr	Tl		V		Zn	
WAG6 MS3A	3304	16–Sep–92	U	20	U	2	U	5	U	2	5480	203		312	U	10	U	5
WAG6 MS3A	3304	16–Sep–92	U	20	U	2	U	5	U	2	5130	202	B	185	U	10	U	5
WAG6 MS3B	3305	16–Sep–92	U	20	U	2	U	5	UW	2	4790	164		310	U	10	U	5
WAG6 MS3B	3305	16–Sep–92	U	20	U	2	U	5	U	2	4510	156	B	291	U	10	B	7
WEST SEEP	3306	16–Sep–92	U	20	U*	2	B	5	UW	2	4880	142	U	150	U	10	U	5
WCWEIR	3307	16–Sep–92	U	20	U	2	U	5	U	2	2620	96	B	207	U	10	U	5
WCWEIR	3307	16–Sep–92	U	20	U	2	B	8	U	2	2570	94	B	165	U	10	U	5
MBWEIR	3309	16–Sep–92	U	20	U*	2	UW	5	U	2	7750	303		422	U	10		115
EAST SEEP	3310	16–Sep–92	B	31	U*	2	U	5	UW	2	3680	153	B	155	U	10	U	5
WCWEIR	3311	17–Sep–92	U	20	U*	2	U	5	U	2	2870	105	B	156	U	10		38
5NST	3312	17–Sep–92	U	20	U	2	U	5	U	2	3750	168	B	272	U	10	U	5
WCHEAD	3313	17–Sep–92	U	20	U	2	U	5	U	2	3990	39	B	185	U	10	U	5
NWTRIB	3314	17–Sep–92	U	20							2180	85	U	150	U	10	U	5
WC7500	3315	17–Sep–92	U	20	UW*	2	U	5	U	2	2970	97	B	169	U	10		34
WAG4 MS1	3316	17–Sep–92	B	34	U	2	U	5	U	2	4810	236		334	U	10	U	5
MB–15	3317	01–Oct–92	U	20	U	2	UW	5	U	2	8740	314		410	U	10		157
HRT–3	3318	01–Oct–92	U	20							3030	99	B	168	U	10	U	5
WAG6 MS3A–1	3380	16–Sep–92	U	20	U	2	U	5	U	2	4960	141	B	174	U	10	U	5
WAG6 MS3A–1	3380	16–Sep–92	U	20	U	2	U	5	U	2	4970	140	U	150	U	10	U	5
WAG6 MS3B–6	3381	16–Sep–92	U	20	U*	2	U	5	U	2	4450	155	B	297	U	10		26
WAG6 MS1–1	3382	16–Sep–92	U	20	U	2	B	6	U	2	4760	187		305	U	10	U	5
FRENCH DR S	3384	16–Sep–92	U	20	U	2	U	5	U	2	6590	184	B	214	U	10	B	6
SW6–2	3385	16–Sep–92	U	20	U	2	B	6	U	2	7430	230		311	U	10	U	5
FIRST CREEK	3387	17–Sep–92	U	20	U	2	U	5	U	2	2750	109	B	250	U	10	B	19
FIFTH CREEK	3388	17–Sep–92	U	20	U	2	U	5	U	2	3260	81	U	150	U	10	B	14
WAG6 MS3B–4	3392	16–Sep–92	B	25	U	2	U	5	B	4	3433	28	U	150	U	10		22
SW2–5	3395	01–Oct–92	U	20	U	2	U	5	U	2	10100	318		512	U	10	U	5
SW5–6	3410	01–Oct–92	B	32	U	2	U	5	U	2	9580	250		505	U	10	U	5
SW5–8	3411	01–Oct–92	B	24	U	2	U	5	U	2	9960	264	U	439	U	10	U	5
SW5–9	3412	01–Oct–92	B	38	U	2	U	5	U	2	9160	267		438	U	10	U	5

[a] Results are for total metals. Samples were not filtered.

Table C.3 Anion results and field measurements for seep and stream locations.

Location	Sample Id	Date Sampled	Chloride mg/L	Fluoride mg/L	Nitrate mg/L	Phosphate mg/L	Sulphate mg/L	Flow L/s	pH	Specific Conductance uS/cm	Temp °C	Alkalinity mg/L of $CaCO_3$
WOD	3001	25–Mar–92	6	0.4	1.5	0.3	24	393	7.9	216	13	72
WCWEIR	3002	25–Mar–92	6	0.3	2.3	<3	23	323				60
WCWEIR	3002	25–Mar–92	8	0.5	3	<1	31					72
MBWEIR	3003	25–Mar–92	2.2	0.2	<1	<3	15	71				60
WAG6–MS1	3004	25–Mar–92	4.6	0.1	<1	<3	14	0.34				
WAG6–MS2	3005	25–Mar–92	3.6	<1	<1	<3	11	0.76	7.2	167	9	
WAG6–MS3A	3006	25–Mar–92	3.4	0.3	<1	<3	11	0.6	7.6	178	9	72
WAG6–MS3B	3007	25–Mar–92	5.8	0.2	<1	<3	18	1.05	7.6	240	8	156
WEST SEEP	3008	25–Mar–92	2	<1	<1	<3	21	12.4	7.5	112	8	66
EAST SEEP	3009	25–Mar–92	3.6	0.3	12	3	33	1.47				108
WCWEIR	3010	02–Apr–92	9.7	1	3.79	0.7	36	231	7.8	254	12	81
WC7500	3011	02–Apr–92	9.8	1	3.69	<3	36	217	7.9	261	14	67
WCHEAD	3012	02–Apr–92	<1	<1	0.15	<3	2.8	4.9	7.4	103	11	33
WAG4 MS1	3013	02–Apr–92	0.8	0.13	<0.1	0.08	1.5	0.8	8.2	371	11	63
WAG4 T2A	3014	02–Apr–92	10.1	1	<1	<3	16.1	1.2	7.5	325	8	162
WAG4 T2A	3014	02–Apr–92	10.1	1	<1	<3	16					168
5NNT	3015	02–Apr–92	3.6	0.4	<1	0.6	25	1.06	7.4	127	10	48
5NST	3016	02–Apr–92	13	<1	0.27	<3	32		7.5	239	7	90
NWTRIB	3017	02–Apr–92	4.5	0.5	<1	<3	14.2	16.1	8.1	220	11	121
MBWEIR	3018	09–Apr–92	13	0.9	2	1	132	37		406	15	102
MB–15	3019	09–Apr–92	14	1	3	1	153	48		474	18	86
WCTRIB–1	3021	25–Mar–92	1.5	<1	<1	<3	25					90
WSTRIB–1	3022	25–Mar–92	1.6	<1	<1	<3	17		7.2	125	10	78
RS–1	3023	25–Mar–92	1	<1	1.4	<3	33		6.8	236	9	118
RS–1	3023	25–Mar–92	<1	<1	1.3	<3	29					78
RS–3	3024	25–Mar–92	2.7	4.7	41	7.4	131		9.1	860	9	115
SW7–1	3025	25–Mar–92	1.2	0.2	<1	<3	9		7.0	219	8	84
SW7–2	3026	25–Mar–92	1.8	0.2	15	<3	78		6.4	286	10	108
SW7–3	3027	25–Mar–92	29	2.3	13.5	3.6	62					210
SW7–4	3028	25–Mar–92	2.3	0.16	12.0	<3	45	0.09				84

Table C.3 (continued)

Location	Sample Id	Date Sampled	Chloride mg/L	Fluoride mg/L	Nitrate mg/L	Phosphate mg/L	Sulphate mg/L	Flow L/s	pH	Specific Conductance uS/cm	Temp °C	Alkalinity mg/L of $CaCO_3$
SW7–5	3029	25–Mar–92	1.9	<1	26	<3	59	0.29				96
SW7–6	3030	25–Mar–92	1.4	<1	<1	<3	2			29	10	3
SW7–7	3031	25–Mar–92	1.8	0.2	14	<3	37		7.5	239	9	78
SW7–8	3032	25–Mar–92	1.8	<1	4.7	<3	29			178	9	60
SW2–1	3033	25–Mar–92	2.7	0.2	1	<3	6.2		7.2	384	9	180
SW6–1	3034	25–Mar–92	3.4	0.2	<1	<3	3.4				9	174
WCTRIB–2	3035	02–Apr–92	0.26	<1	<1	<3	2		7.7	143	10	96
WCTRIB–3	3036	02–Apr–92	11.8	0.93	<1	0.8	30					210
WCTRIB–4	3037	02–Apr–92	3.4	0.28	<1	<3	12		6.6	172	9	86
SW2–2	3038	02–Apr–92	3.5	0.28	<1	<3	22		6.9	273	11	133
SW2–3	3039	02–Apr–92	2.6	<1	<1	<3	23		7.1	126	7	78
SW4–1	3040	03–Apr–92	0.9	15.7	<1	<3	14		7.0	569	12.8	280
SW4–2	3041	03–Apr–92	1.0	0.04	<0.1	<0.3	0.06		7.3	516	13	148
BTT	3042	03–Apr–92	7	0.26	<1	<3	5.8	0.02				74
5NW–1	3043	02–Apr–92	4.3	<1	<1	<3	19					82
5NW–2	3044	02–Apr–92	3.0	<1	<1	0.69	27					3
SW5–1	3045	02–Apr–92	14.2	0.32	3.7	0.83	21					210
SW5–2	3046	02–Apr–92	7.9	0.1	<1	<3	19		6.6	403	10	261
SW5–2	3046	02–Apr–92	8.2	0.12	<1	<3	19					264
MID. DRAIN.	3047	09–Apr–92	19	<0.1	<1	<1	8	0.80		491	16	264
SW5–3	3048	09–Apr–92	16	<0.1	<1	<1	12			413	12	236
SW5–3	3048	09–Apr–92	0.3	16	<1	<1	13					234
SW5–4	3049	09–Apr–92	12	0.1	<1	<1	8	0.03				260
SW5–5	3050	09–Apr–92	17	0.1	<1	<1	8					241
SW5–6	3051	09–Apr–92	18	<0.1	<1	<1	4					390
SW5–7	3052	09–Apr–92	16	<0.1	<1	<1	8			482	12	281
SW5–8	3053	09–Apr–92	27	<0.1	<1	<1	8			510	16	252
SW5–9	3054	09–Apr–92	24	<0.1	<1	<1	10			575	15	345
SW5–11	3056	09–Apr–92	7	<0.1	<1	<1	9		0.7		2	321
HRT–3	3099	09–Apr–92	5	0.5	2	<1	22	3.7		226	16	115

Table C.3 (continued)

Location	Sample Id	Date Sampled	Chloride mg/L	Fluoride mg/L	Nitrate mg/L	Phosphate mg/L	Sulphate mg/L	Flow L/s	pH	Specific Conductance uS/cm	Temp °C	Alkalinity mg/L of $CaCO_3$
WCWEIR	3129	06–Apr–92						187				
WAG4 T2A	3130	06–Apr–92						1				
WC7500	3131	06–Apr–92						171				
WCTRIB–1	3280	16–Sep–92	2.5	<1	<1	<3	14			192	23	141
RS–3	3281	16–Sep–92	1.3	11	77	28	190			616	23.9	1016
SW7–2	3282	16–Sep–92	1.4	<1	27	<3	130			230	24	96
SW7–2	3282	16–Sep–92	1.5	<1	27	<3	130					96
SW6–1	3283	16–Sep–92	3.6	<1	<1	<3	2.9			266	30	220
WSTRIB–1	3284	16–Sep–92	3.1	<1	4.7	<3	30					195
SW2–4	3285	17–Sep–92	14	<1	<1	<3	5.5		6.2	950	23	446
SW5–1	3287	17–Sep–92	18	<1	<1	<3	10		6.2	610	22	260
5NW–2	3288	17–Sep–92	2.6	<1	<1	<3	29		5.4	170	24	58
SW5–4	3289	01–Oct–92	14	<1	<1	<3	4.9	0.001	6.8	449	18	345
MID. DRAIN.	3290	01–Oct–92	24	<1	<1	<3	4.8	0.06	7.3	448	18	319
MBTRIB–3	3291	01–Oct–92	5.2	<1	1.6	<3	35		7.3	314	19	218
SW7–3	3292	16–Sep–92	44	3.5	20	14	96	0.007		342	21	333
SW7–4	3293	16–Sep–92	5.5	<1	4.7	<3	69			266	22	310
SW7–7	3294	16–Sep–92	4.5	<1	25	<3	86			254	22	296
WCTRIB–4	3295	17–Sep–92	16	<1	<1	<3	77				19	141
5NNT	3296	17–Sep–92	4.9	<1	<1	<3	24		7.0		19	134
SW4–1	3297	17–Sep–92	28	1.4	<1	<3	7		6.8		22	366
SW5–7	3298	01–Oct–92	20	<1	<1	<3	7.2		6.5	485	18	354
RS–1	3299	16–Sep–92	1.8	<1	<1	<3	47			312	33	220
MBWEIR	3300	01–Oct–92	23	1.3	18	<3	324	19	8.0	449	18	74
WOD	3301	16–Sep–92	14	<1	2.4	<3	80	143	7.9	430	25	102
WAG6 MS1	3302	16–Sep–92	5.6	<1	1	<3	19					
WAG6 MS1 [a]	3302	16–Sep–92	5.2	<1	<1	<3	9.4	0.14	7.4	580	21	297
WAG6 MS2	3303	16–Sep–92	5.6	<1	1	<3	19		7.8	190	22	64
WAG6 MS2 [a]	3303	16–Sep–92	5.8	<1	<1	<3	20	0.06				

Table C.3 (continued)

Location	Sample Id	Date Sampled	Chloride mg/L	Fluoride mg/L	Nitrate mg/L	Phosphate mg/L	Sulphate mg/L	Flow L/s	pH	Specific Conductance uS/cm	Temp °C	Alkalinity mg/L of $CaCO_3$
WAG6 MS3A	3304	16–Sep–92	4.7	<1	<1	<3	2.5		7.1	430	23	230
WAG6 MS3A [a]	3304	16–Sep–92	4.5	<1	<1	<3	2.6	0.04				
WAG6 MS3B	3305	16–Sep–92	6.8	<1	<1	<3	18		7.7	420	24	207
WAG6 MS3B [a]	3305	16–Sep–92	6.9	<1	<1	<3	18					
WEST SEEP	3306	16–Sep–92	2.2	<1	5.9	<3	29	0.01		358	34	189
WCWEIR	3307	16–Sep–92	11	<1	6.9	5.1	47	132		274	35	98
WCWEIR	3307	16–Sep–92	10	<1	8.4	<3	49					98
MBWEIR	3309	16–Sep–92	19	<1	12	26	343	16		440	37	
EAST SEEP	3310	16–Sep–92	24	1.2	19	<3	93		15.5	474	36	318
WCWEIR	3311	17–Sep–92	9.5	<1	8.2	<3	52	126	7.4	300	21	107
5NST	3312	17–Sep–92	10	<1	<1	<3	16		4.2	320	21	212
WCHEAD	3313	17–Sep–92	10	<1	7.8	5.1	40	3.1	8.3		20	143
NWTRIB	3314	17–Sep–92	5.2	<1	1.2	<3	14	8.7	7.8		23	121
WC7500	3315	17–Sep–92	11	<1	8.3	5.1	42	111	7.9		22	96
WAG4 MS1	3316	17–Sep–92	15	<1	<1	<3	8	0.007	7.1		20	312
MB–15	3317	01–Oct–92	27	1.8	20	<3	403	11.9				61
HRT–3	3318	01–Oct–92	7.3	<1	4.3	<3	24	2.4	7.8	215	15	115
WAG6 MS3A–1	3380	16–Sep–92	4.6	<1	<1	<3	4.2		7.0	300	22	182
WAG6 MS3B–6	3381	16–Sep–92	4.6	<1	<1	<3	10		7.5	430	21	251
WAG6 MS1–1	3382	16–Sep–92	6	<1	<1	<3	6.3		6.9	640	21	342
FRENCH DR S	3384	16–Sep–92	8.9	<1	8.5	<3	30				25	215
SW6–2	3385	16–Sep–92	9.9	<1	<1	<3	28					401
FIRST CREEK	3387	17–Sep–92	8.1	1	4.6	<3	24	2.8	8.3		26	110
FIFTH CREEK	3388	17–Sep–92	4.7	<1	2.6	<3	13		8.2		24	115
SW2–5	3395	01–Oct–92	19	<1	3.1	6	25		6.8	466	17	387
SW5–6	3410	01–Oct–92	17.8	<1	<1	<3	10					403
SW5–8	3411	01–Oct–92	23	<1	<1	<3	7.2					496
SW5–9	3412	01–Oct–92	24	<1	<1	<3	15					324

[a] Results are for total anions. Samples were not filtered.

Appendix D

METAL RESULTS EXCEEDING ARARs

Table D.1. Metals results, from Round 1 seep sampling, exceeding current Federal or state criteria. (All values are in μg/L.)

Analyte	Location	Qualifier	Result μg/L	Human Health			Freshwater Organisms
				Safe Drinking Water Act MCLs/MCLGs	Federal Recreation Criteria	Tennessee Recreation Criteria	Federal and State Maximum Concentrations
Antimony	All sites	<	50	6	4308	4310	—
Arsenic	RS-1		14	50	0.14	—	360[a]
	All others	<	10				
Cadmium	All sites	<	5	5			4[b]
Chromium	RS-3		36.3	100	670,000[a]		16[a]
	SW7-3		55.8				
Nickle	SW4-2		3310	100	4584	4600	1418[b]
Mercury	RS-3		0.20	2	0.15	0.15	2.4
Thallium	SW7-7		43.4	2/0.5	6.3	—	—
	All others	<	40				

Note: Method Detection Limits for Arsenic and Cadmium are the best available and meet or exceed CLP Contract Required Detection Limits. The drinking water limits for Antimony and Thallium are not effective until January 17, 1994, and the recreation limit for Thallium was 48 μg/L at the time of sampling.

[a] Limits exist for only certain elemental species. Concentration presented is the most restrictive.

[b] Water hardness dependent criteria (100 mg/L $CaCO_3$). 1991 hardness at WCWIER and MBWEIR ranged from 128 to 259 mg/L (ORNL 1992).

Table D.2. Metals results, from Round 2 seep sampling, exceeding current Federal or state criteria. (All values are in $\mu g/L$.)

Analyte	Location	Qualifier[a]	Result (µg/L)	Human Health			Freshwater Organisms
				Safe Drinking Water Act MCLs/MCLGs	Federal Recreation Criteria	Tennessee Recreation Criteria	Federal and State Maximum Concentration
Antimony	RS-3	B	8.00	6/6	4,308	4,310	—
	SW5-4	B	10.00				
	SW6-2	B	6.00				
	WAG6 MS1-1	B	6.00				
	WCTRIB-1	B	6.00				
	WCWEIR	B	8.00				
	WSTRIB-1	B	6.00				
Arsenic	MB-15	B	4.00	50	0.14	—	360[b]
	RS-3		22.00				
	SW2-4	B	3.00				
	SW4-1	BW	3.00				
	SW5-4	B	3.00				
	SW5-7	B	3.00				
	SW5-9	B	3.00				
	SW7-3	B	4.00				
	WAG6 MS1-1	B	4.00				
	WAG6 MS3A-1	B	3.00				

Table D.2 (continued)

Analyte	Location	Qualifier[a]	Result (μg/L)	Human Health			Freshwater Organisms
				Safe Drinking Water Act MCLs/MCLGs	Federal Recreation Criteria	Tennessee Recreation Criteria	Federal and State Maximum Concentration
Arsenic (Cont.)	WAG6 MS3B-4	B	5.00	50	0.14	—	360[b]
	WCWEIR	B	3.00				
	ALL OTHERS	U	2.00				
Chromium	RS-3		64.00	100/100	670,000[b]	—	16[b]
	SW7-3		50.00				
	WAG6 MS3B-4		51.00				
Copper	MB-15		29.00	1300	—	—	17.7[c]
	MBWEIR	U	40.00				
Mercury	RS-3		0.54	2/2	0.15	0.15	2.4
	SW7-3		0.43				
	ALL OTHERS	U	0.20				
Thallium	5NST	B	272.00	2/0.5	6.3	—	—
	EAST SEEP	B	155.00				
	FIRST CREEK	B	250.00				
	FRENCH DR S	B	214.00				
	HRT-3	B	168.00				
	MB-15		410.00				
	MBTRIB-3		332.00				

Table D.2 (continued)

Analyte	Location	Qualifier[a]	Result (µg/L)	Human Health			Freshwater Organisms
				Safe Drinking Water Act MCLs/MCLGs	Federal Recreation Criteria	Tennessee Recreation Criteria	Federal and State Maximum Concentration
Thallium (cont.)	MBWEIR		324.00	2/0.5	6.3	—	—
	MBWEIR		422.00				
	MID. DRAIN.		398.00				
	RS-1	B	257.00				
	RS-3	B	220.00				
	SW2-4		417.00				
	SW2-5		512.00				
	SW4-1		331.00				
	SW5-1		420.00				
	SW5-6		505.00				
	SW5-8	B	439.00				
	SW5-9		438.00				
	SW6-1		450.00				
	SW6-1		329.00				
	SW6-2		311.00				
	SW7-4	B	290.00				
	SW7-7	B	161.00				
	WAG4 MS1		334.00				

Table D.2 (continued)

Analyte	Location	Qualifier[a]	Result (µg/L)	Human Health			Freshwater Organisms
				Safe Drinking Water Act MCLs/MCLGs	Federal Recreation Criteria	Tennessee Recreation Criteria	Federal and State Maximum Concentration
Thallium (cont.)	WAG6 MS1		384.00	2/0.5	6.3	—	—
	WAG6 MS1	B	241.00				
	WAG6 MS1-1		305.00				
	WAG6 MS2	B	162.00				
	WAG6 MS3A		312.00				
	WAG6 MS3A	B	185.00				
	WAG6 MS3A-1	B	174.00				
	WAG6 MS3B		310.00				
	WAG6 MS3B	B	291.00				
	WAG6 MS3B-6	B	297.00				
	WC7500	B	169.00				
	WCHEAD	B	185.00				
	WCTRIB-1	B	268.00				
	WCTRIB-4	B	272.00				
	WCWEIR	B	207.00				
	WCWEIR	B	165.00				
	WCWEIR	B	156.00				
	WOD	B	231.00				

Table D.2 (continued)

Analyte	Location	Qualifier[a]	Result (µg/L)	Human Health			Freshwater Organisms
				Safe Drinking Water Act MCLs/MCLGs	Federal Recreation Criteria	Tennessee Recreation Criteria	Federal and State Maximum Concentration
Thallium (cont.)	WSTRIB-1		345.00	2/0.5	6.3	—	—
	ALL OTHERS	U	150.00				
Zinc	MB-15		157.00	—	—	—	117[c]

Note: Method Detection Limits for Arsenic, Cadmium, and Mercury are the best available and meet or exceed CLP Contract Required Detection Limits. The drinking water limits for Antimony and Thallium are not effective until January 17, 1994, and the recreation limit for Thallium was 48 µg/L at the time of sampling.

[a] Qualifiers:

U	Indicates compound was analyzed for but not detected.
B	The reported value is less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).
E	The reported value is estimated because of the presence of interference.
N	Spiked sample recovery not within control limits.
W	Post-digestion spike for Furnace AA analysis is out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.

[b] Limits exist for only certain elemental species. Concentration presented is the most restrictive.

[c] Water hardness dependent criteria (100 mg/L as $CaCO_3$). 1991 hardness at WCWIER and MBWEIR ranged from 128 to 259 mg/L (ORNL 1992).

Appendix E

M. TARDIFF PERSONAL COMMUNICATION TO D. HICKS

Diana,

Here are the compliance monitoring results for comparison to your seep sampling program results. We used the March '92 data and the September '92 data since these months correspond to your sampling months.

WOD	March	September
Sr, nCi/s	102	21
H-3, uCi/s	112	11
WOC	%[1]	%
Sr	nCi/s → 45 (44)	8.4 (41)
H-3	29 (26)	0.56 (4.9)
MB1		
Sr	58 (57)	10 (49)
H-3	110 (98)	14 (119)

[1] The % is the percent of the value at WOD; I assumed those were the % in your table.

I think that the correlation among the data from the two programs is pretty good, given the differences in how the samples were collected.

Any questions? Don't be bashful.

Mark 4-4055

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To DIANA HICKS	From MARC TARDIFF
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Dept.	Phone #
Fax #	Fax #

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