PUBLIC HEALTH ASSESSMENT
Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation (USDOE)

Oak Ridge, Anderson County, Tennessee

EPA FACILITY ID: TN1890090003

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Prepared by:
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Foreword

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and cleanup of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations—the structure may vary from site to site. Whatever the form of the public health assessment, the process is not considered complete until the public health issues at the site are addressed.

Exposure

As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects

If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances than adults. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high-risk groups within the community (such as the elderly, chronically ill, and people engaging in high-risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic, and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When it touches on cases in which this is so, this report suggests what further public health actions are needed.

Conclusions

This report presents conclusions about the public health threat, if any, posed by a site. Any health threats that have been determined for high-risk groups (such as children, the elderly, chronically ill people, and people engaging in high-risk practices) are summarized in the Conclusions section of the report. Ways to stop or reduce exposure are recommended in the Public Health Action Plan section.

ATSDR is primarily an advisory agency, so its reports usually identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community

ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments

If, after reading this report, you have questions or comments, we encourage you to send them to us. Letters should be addressed as follows:

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Acronyms

ALARA	as low as reasonably achievable
ALI	annual limits on intake
ALS	amyotrophic lateral sclerosis
AOEC	Association of Occupational and Environmental Clinics
ATSDR	Agency for Toxic Substances and Disease Registry
Bq	becquerel
BSCP	Background Soil Characterization Project
CDC	Centers for Disease Control and Prevention
Ce 144	cerium 144
CED	committed effective dose
CEDR	Comprehensive Epidemiologic Data Resource
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFRF	consolidated fuel recycling facility
Ci	curie
cm	centimeter
Co 60	cobalt 60
COC	contaminant of concern
COPD	chronic obstructive pulmonary disease
CRM	Clinch River mile
Cs 137	cesium 137
D&D	decontaminating and decommissioning
DCF	dose conversion factor
DDREF	dose and dose rate effectiveness factor
DOE	U.S. Department of Energy
EDE	effective dose equivalent
EE/CA	Engineering Evaluation/Cost Analysis
EEVOC	East End Volatile Organic Compound (plume)
EFPC	East Fork Poplar Creek
EMEG	Environmental media Evaluation Guides
EPA	U.S. Environmental Protection Agency
ERAMS	Environmental Radiation Ambient Monitoring System
ETTP	East Tennessee Technology Park
FACA	Federal Advisory Committee Act
FAMU	Florida Agriculture and Mechanical University
FDA	Food and Drug Administration
FFA	Federal Facility Agreement
FFAB	Federal Facilities Assessment Branch
GAAT	gunite and associated tanks
GAO	General Accounting Office
Gy	gray
H3	tritium
HF	hydrofracture facility
HFIR	high flux isotope reactor
Hg	mercury

Acronyms (continued)

HRE	homogeneous reactor experiment
HRSA	Health Resources Services Administration
IAG	interagency agreement
ICRP	International Commission on Radiological Protection
IHP	intermediate holding pond
IROD	Interim Record of Decision
I 131	iodine 131
ISV	in situ vitrification
IWMF	interim waste management facility
JEM	Johnson-Ettinger Model
LEFPC	Lower East Fork Poplar Creek
LET	Linear Energy Transfer
LLLW	liquid low-level waste
LNT	linear no-threshold
LTHA	lifetime health advisory
LWBR	Lower Watts Bar Reservoir
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MEPAS	Multimedia Environmental Pollutant Assessment System
MeV	million electron volts
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mGy	milligray
mrem	millirem
µCi/mL	microcuries per milliliter
µg/L	micrograms per liter
µR/hr	microroentgen per hour
MRL	minimal risk level
MS	multiple sclerosis
MSRE	molten salt reactor experiment
mSv	millisievert
MVST	Melton Valley storage tanks
mya	million years ago
Nb 95	niobium 95
NCEH	National Center for Environmental Health
NCRP	National Council on Radiation Protection and Measurements
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHF	new hydrofracture facility
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
OHF	Old Hydrofracture Facility
OREIS	Oak Ridge Environmental Information System

Acronyms (continued)

ORGDP	Oak Ridge Gaseous Diffusion Plant
ORHASP	Oak Ridge Health Agreement Steering Panel
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
P&A	plugging and abandonment
PAG	FDA protective action guide
PCB	polychlorinated biphenyl
pCi	picocurie
pCi/L	picocurie per liter
PCM	Poplar Creek mile
PDF	portable document format
PHAP	Public Health Action Plan
PHAWG	Public Health Assessment Work Group
ppb	parts per billion
ppm	parts per million
PWSB	process waste sludge basin
PWTP	Process Waste Treatment Plant
rad	radiation absorbed dose
RAR	Remedial Action Report
RBC	Risk Based Concentration
RCRA	Resource Conservation and Recovery Act
RER	remediation effectiveness report
RfC	reference concentration
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
RMEG	Reference Dose Media Evaluation Guides
ROD	Record of Decision
Ru 106	ruthenium 106
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SNF	spent nuclear fuel
SRS	sediment retention structure
Sr 90	strontium 90
Sv	sievert
SWSA	solid waste storage area
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TRM	Tennessee River Mile
TRU	transuranic waste
TSCA	Toxic Substances Control Act
TSF	tower shielding facility
TVA	Tennessee Valley Authority

Acronyms (continued)

TWRA	Tennessee Wildlife Resources Agency
U 233	uranium 233
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound
WAC	waste acceptance criteria
WAG	waste area grouping
WBRIWG	Watts Bar Reservoir Interagency Work Group
WIPP	waste isolation pilot plant
WOC	White Oak Creek
WOCE	White Oak Creek Embayment
W_R	radiation weighting factor
W_T	tissue weighting factor
Zr 95	zirconium 95

I. Summary

In 1942, the federal government established the Oak Ridge Reservation (ORR) in Anderson and Roane Counties in Tennessee as part of the Manhattan Project to research, develop, and produce special radioactive materials for nuclear weapons. Four facilities were built at that time. The Y-12 Complex, the K-25 site, and the S-50 site were created to enrich uranium. The X-10 site was created to demonstrate processes for producing and separating plutonium. Since the end of World War II, the role of the ORR (Y-12 Complex, K-25 site, and X-10 site) broadened widely to include a variety of nuclear research and production projects vital to national security.

In 1989, the ORR was added to the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL) because, over the years, the ORR operations have generated a variety of radioactive and nonradioactive wastes that a portion of which remain in old waste sites and some pollutants have been released into the environment. The U.S. Department of Energy (DOE) is conducting clean up activities at the ORR under a Federal Facility Agreement (FFA) with EPA and the Tennessee Department of Environment and Conservation (TDEC). These agencies are working together to investigate and take remedial action on hazardous waste from past and present activities at the site.

ATSDR is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. Prior to this public health assessment, ATSDR addressed current public health issues related to off-site areas, including the East Fork Poplar Creek area and the Watts Bar Reservoir area.

I.A. Scope of this Public Health Assessment

This public health assessment is focused solely on evaluating the potential off-site exposures to contaminated groundwater emanating from ORR. Exposures to groundwater within the ORR boundaries are not considered in this document. Likewise, exposures to contaminated surface water will not be evaluated in this document – even though this contamination may be a result of discharge from contaminated groundwater. Exposure to contamination in surface water and other media is addressed in other ATSDR public health assessments including: Current & Future Chemical Exposure Evaluation (1990-2003), White Oak Creek Radionuclide Releases, and Y-12 Mercury Releases PHA's.

The overall goal of this PHA is to determine the potential public health hazard posed by historical releases of contaminants to groundwater. It will accomplish this goal by evaluating all currently available groundwater monitoring data as well as demographic and current and historical land and groundwater use information. This information will be used to determine whether members of the community are being exposed to contaminated groundwater emanating from ORR. Another goal of this PHA is to fully address specific community concerns solicited by ATSDR as part of the public health assessment process about site-related public health issues relating to exposure to off-site groundwater.

I.B. ATSDR's Evaluation of Exposure to Contaminated Off-Site Groundwater

Based on available data, off-site contamination has only occurred in monitoring wells and seeps/springs in Union Valley, and residential wells have been unaffected by contamination resulting from ORR activities. Since nearly all groundwater beneath the ORR ends up as surface water before leaving the site, community exposure to contamination via off-site groundwater is unlikely.

The east end volatile organic compound (EEVOC) groundwater contaminant plume, extending east-northeast from the Y-12 Complex, is the only confirmed off-site contaminant plume migrating across the ORR boundary. This carbon-tetrachloride dominated plume is actually several contaminant plumes that have commingled and have migrated east-northeast off-site into Union Valley. Institutional controls are set forth in the Interim Record of Decision for Union Valley (Jacobs EM Team, 1997), in which, DOE requires license agreements with property owners whereby DOE will notify them of the potential of contamination and requiring property owners to inform DOE 90 days prior to any changes in groundwater use. It also requires appropriate verification by DOE of compliance with the agreements and notification of state and local agencies. While this selected action does not provide for reduction in toxicity, mobility or volume of contaminants of concern, ATSDR scientists conclude that it is protective of public health to the extent that it limits or prevents community exposure to contaminated groundwater in Union Valley.

ATSDR scientists have concluded that there is no exposure to contaminated groundwater emanating from ORR. Therefore, the groundwater does not pose a public health hazard. Sufficient evidence exists that no human exposures to off-site contaminated groundwater have occurred, no exposures are currently occurring, and exposures are not likely to occur in the future (ATSDR 2005). ATSDR also examined the possibility of vapor intrusion of VOCs into an office building which partially overlies the EEVOC plume. Conservative modeling results estimate indoor vapor concentrations several orders of magnitude below Occupational Safety and Health Administration and National Institutes for Occupational Safety and Health guidelines. ATSDR scientists have concluded that exposure via vapor intrusion does not represent a health threat.

II. Background

II.A. Site Description

In 1942, during World War II, the U.S. government developed the Oak Ridge Reservation (ORR) under the Manhattan Project initiative to produce and study nuclear material needed to make nuclear weapons (ChemRisk 1993b). The ORR is located in eastern Tennessee, in the city of Oak Ridge, approximately 15 miles west of Knoxville; it is situated in both Roane and Anderson Counties. The southern and western borders of the ORR are formed by the Clinch River, and most of the reservation lies within the Oak Ridge city limits. The ORR plants are isolated from the city's populated areas. Figure 1 shows the location of the ORR.

When the federal government acquired the ORR in 1942, the reservation consisted of 58,575 acres (91.5 square miles). Since that time, the federal government has transferred 24,340 (38.0

square miles) of the original 58,575 acres to other parties (e.g., City of Oak Ridge, Tennessee Valley Authority [TVA]); the U.S. Department of Energy (DOE) continues to control the remaining 34,235 acres (53.5 square miles) (Jacobs Engineering Group Inc. 1996; ORNL 2002).

Under the Manhattan Project, the government constructed four facilities at the ORR. The X-10 site (formerly known as the Clinton Laboratories and is now part of what is referred to as the Oak Ridge National Laboratory [ORNL]) was built to produce and separate plutonium. The K-25 site (formerly known as the Oak Ridge Gaseous Diffusion Plant [ORGDP] and now referred to as the East Tennessee Technology Park [ETTP]), the Y-12 plant (now known as the Y-12 National Security Complex), and the former S-50 site (now part of the ETTP) were developed to enrich or process uranium (ChemRisk 1993b; Jacobs Engineering Group Inc. 1996; TDEC 2002; TDOH 2000).

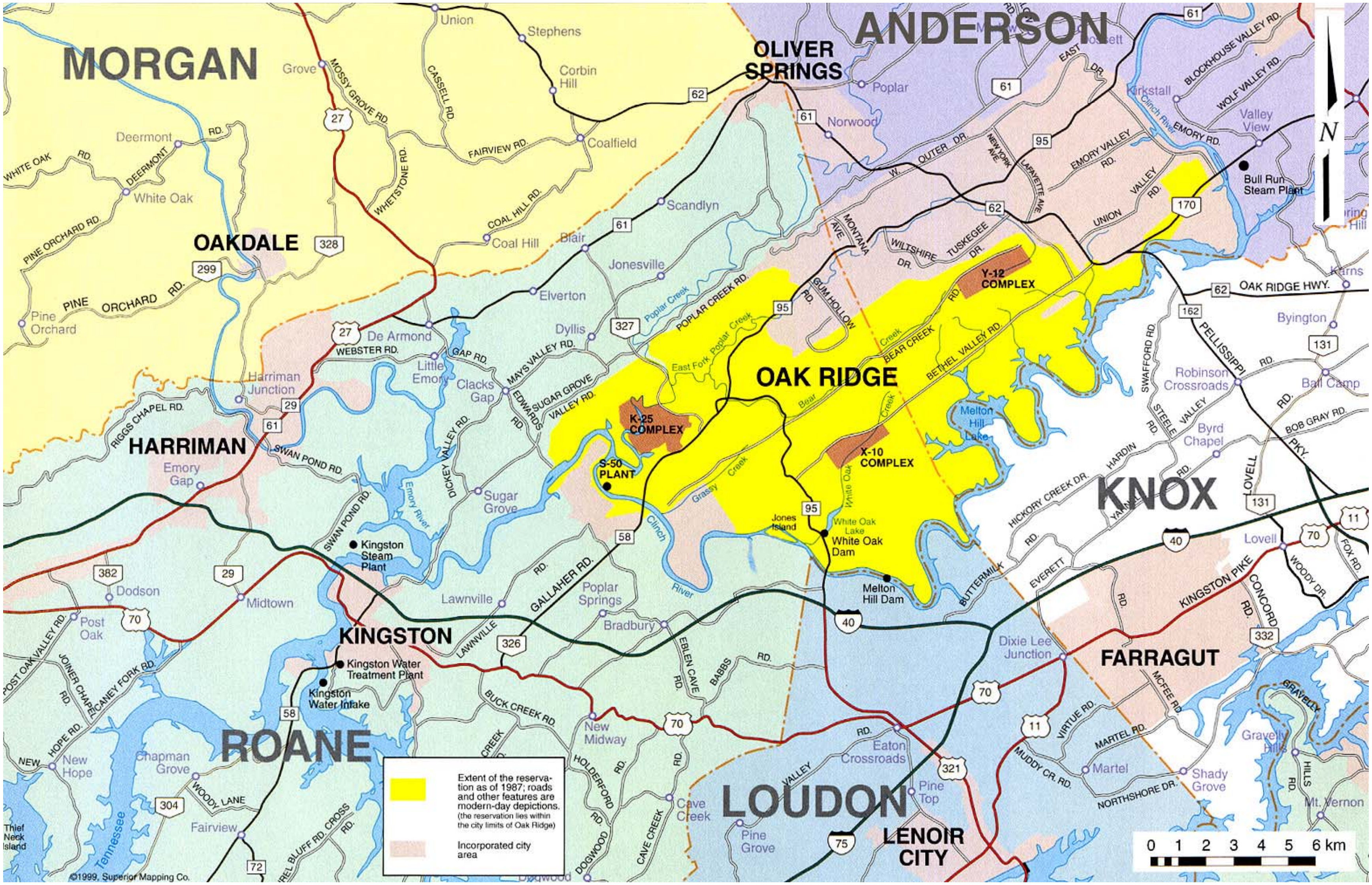


Figure 1: Location of the Oak Ridge Reservation

II.B. Site Geology/Hydrogeology

ORR is located in the East Tennessee Valley, which is part of the Valley and Ridge Province of the Appalachian Mountains. The East Tennessee Valley is bound to the west by the Cumberland Mountains of the Appalachian Plateau Province and to the east by the Smokey Mountains of the Blue Ridge Province. The defining characteristics of the Valley and Ridge Province are the southwest trending series of ridges and valleys caused by crustal folding and faulting due to compressive tectonic forces as well as the differential weathering of the various formations underlying the area.

The contaminated areas on the ORR were separated into large tracts of land that are typically associated with the major hydrologic watersheds (EUWG 1998). These watersheds are:

1. East Tennessee Technology Park (ETTP) Watershed
2. Bethel Valley Watershed
3. Melton Valley Watershed
4. Bear Creek Valley Watershed
5. Upper East Fork Poplar Creek (UEFPC) Watershed

For the purposes of this health assessment, the ETTP Watershed will be discussed independently, but the Bethel Valley and Melton Valley Watersheds will be discussed together, as will the Bear Creek Valley and UEFPC Watersheds. These groupings were made based on the similar hydrogeology of watersheds as well as the similarity of the nature of ORR operations in each watershed.

The vast majority of information available concerning the geology and hydrogeology of the site indicates that groundwater occurs as shallow flow with short flow paths to surface water (ORNL 1982, MMES 1986, USGS 1986b, USGS 1988, USGS 1989, USDOE 2004, SAIC 2004). The fractures and solution cavities, which are common in this karst region, occur in shallow (0-100 ft. deep) bedrock and significantly decrease at depth (>100 ft. deep). In the aquitard formations (see Table B-1) as much as 95% of all groundwater occurs in the shallow zone and discharges into local streams and eventually into the Clinch River. In the aquifer formations, the Knox Aquifer being the most important, solution conduits can make flow paths much deeper and longer along strike; however, there is no evidence of deep regional flow off of the ORR or between basins (USDOE 2004). Please refer to Appendix B for a discussion of ORR geology and general groundwater flow principles relative to the area.

It is important to note that conclusions reached in this Public Health Assessment are based upon currently available data and are limited by the uncertainties inherent in both the data and the general nature of karst groundwater systems. Please refer to Appendix B for a discussion of karst systems on and around the ORR and their impact on groundwater flow.

Groundwater beneath the ORR is typically very shallow and approximately 95% ends up as surface water before leaving the site boundary (USDOE 2004).

It is unlikely that contaminated groundwater at the ORR will flow beneath, and continue to flow away from, streams and rivers that surround the site. There is an extensive interconnection between groundwater and surface water and groundwater contamination sources on the ORR are primarily in the shallow subsurface (with the exception of deep-well injection conducted at ORNL, which will be discussed in the Melton Valley Watershed section of this document). Furthermore, core samples have shown that beneath the alluvium at the bottom of the stream beds in this area is a silty-clay horizon that likely impedes downward groundwater movement (USGS 1989). The incised meander (see Appendix A) of the Clinch River in bedrock also represents a major topographic feature that prevents groundwater from passing beneath the river (ORNL 1982). ATSDR scientists conclude that on-site contaminated groundwater does not likely migrate beneath and away from streams and rivers either as slug-flow or in fractures, solution channels, or other conduits in the bedrock.

II.C. Off-Site Groundwater Data

ATSDR scientists queried the Oak Ridge Environmental Information System (OREIS) Database for all groundwater sampling data from residential wells, monitoring wells, and from seeps and springs. The query resulted in over 2150 on-site sampling locations and over 120 off-site sampling locations with hundreds of thousands of data points with dates ranging from the mid 1980's to 2004. The specific sources of data are:

- ORNL Groundwater Monitoring Data (1991-2004)
- ORNL Bethel Valley Watershed RI 1997
- ORNL White Oak Creek Watershed RI 1996
- Y-12 Upper East Fork Poplar Creek RI 1997
- Y-12 Groundwater Protection Program (Ongoing)
- ORR Integrated Water Quality Program 1998
- ORR Water Resources Restoration Program (Ongoing)
- ORR Remediation Effectiveness Reports (2000-2005)
- K-25, K-1070-A Burial Ground – Brashears Creek
- Lower East Fork Poplar Creek Operable Unit
- Atomic City Auto Parts Site Characterization
- TDEC Environmental Monitoring Reports (through 2003)

In 1996, TDEC initiated a residential well sampling program. Seventy-one (71) residential wells were identified for sampling. Most were situated southwest and within 2 miles of ORR boundaries because, based on the hydrology and geomorphology of the area, these were the areas most likely affected by contaminated groundwater from ORR. In conjunction with the residential well sampling program, TDEC conducted a house-to-house survey of homeowners about their concerns with groundwater. The results of this survey revealed that there were no anecdotal problems with groundwater quality. The analytical results of the residential well sampling program indicated that there was no "discernable" impact on residential wells from activities on the ORR (TDEC 2004).

These sampling locations were first separated into on- and off-site locations. Since this health assessment focuses on off-site (outside ORR boundaries) exposure to groundwater contamination, only off-site sampling data were evaluated. Next, the sampling locations were differentiated based whether they came from residential wells, monitoring wells, or from seeps and springs. A further distinction was made based upon proximity of the sampling locations to the main facilities of ORR: near ETTP, near ORNL, or near the Y-12 Complex. Maps are included (Figure 4, Figure 8, and Figure 14) and sampling results will be discussed for each area in the respective sections.

The only data gaps that were identified during the data evaluation process were the relative irregularity of residential well sampling. These wells are not regularly and systematically sampled in the same way that monitoring wells are. In TDEC's 2005 Environmental Monitoring Plan (TDEC 2005), "older" residential wells are typically only sampled when there is a specific request or other justification to do so. In the mid-1990's, when the majority of available data in the OREIS database was collected, TDEC conducted a sweeping residential well sampling as part of their 1996 Residential Well Sampling Program. Newly installed residential wells are included in the current (2005) sampling plan.

It should be noted that TDEC's residential well sampling program was never intended to be a comprehensive characterization of off-site well contamination. So, we include the lack of residential well sampling data as a "data gap" not to criticize the efforts of TDEC but to highlight an area where sufficient data is unavailable.

II.D. East Tennessee Technology Park (ETTP) Watershed

The 1,700-acre K-25 site, which includes the former S-50 plant (37 acres), is now called the East Tennessee Technology Park (ETTP). The K-25 site is close to the ORR's western border (Figure 2); it is situated along Poplar Creek, near the creek's confluence with the Clinch River in Roane County, approximately 10 miles west of downtown Oak Ridge (ChemRisk 1999a; U.S. DOE 1996).

Operational History

In October 1944, the S-50 plant started separating uranium by liquid thermal diffusion; the plant closed in September 1945. The K-25 site was used from 1945 to 1964 to enrich weapons-grade uranium through gaseous diffusion. From 1965 to 1985, the site used uranium hexafluoride in the gaseous diffusion process to manufacture commercial-grade uranium. All gaseous diffusion operations ceased at the site in 1985, and the site was closed in 1987. Since 1996, reindustrialization has been the focus of the K-25 site, which now houses two business centers—the Heritage Center and the Horizon Center. The site also maintains the Toxic Substances and Control Act (TSCA) incinerator; it is the only facility in the country authorized to incinerate wastes with radioactive and hazardous contaminants that contain PCBs.

Geology/Hydrogeology

The ETTP was constructed almost entirely on the limestone bedrock of the Chickamauga Group (see Figure B-1). The Chickamauga Group is between 450 and 600 meters thick in the Oak Ridge area. Although the formation is predominantly limestone in composition, it resists dissolution and large cavities are rare. Consequently, water storage remains near the surface in the unconsolidated zone because of the low hydraulic conductivity of the bedrock. Cracks and fissures do occur in the Chickamauga Group and, therefore, prevent any prediction of groundwater flow direction and rate in the bedrock (MMES 1986, USGS 1986B, USGS 1988, USGS 1989, SAIC 2004). However, since these cracks and fissures decrease with depth, deep groundwater flow is very limited. The Chickamauga Group is considered a flow-limiting aquitard (ORNL 1982, MMES 1985, USGS 1997). The lithology of the Rome Formation, which underlies the southeastern portion of the ETTP, consists of shales and siltstones which have typically low hydraulic conductivities; however, due to the complex fractures and fissures in this formation, it is also nearly impossible to accurately predict a flow path for groundwater in this formation (Figure 3).

Because the local water table occurs just below the surface in the unconsolidated zone, groundwater flow is generally consistent with the surface topography. However, the rate and direction of groundwater flow in the ORR vary, and are often affected by fluctuations in precipitation as well as flood control operations both up and down stream. Groundwater recharge comes from diffuse rainwater infiltration through the permeable, well-drained silty soils typical of the area. However, during high precipitation events, the clay content in the soil can prevent rapid infiltration and may result in significant surface run-off. Groundwater discharge occurs through evapotranspiration during the spring and summer months, but is predominantly discharged into surface water via seeps and springs. Most groundwater at ORR ultimately ends up in the Clinch River serving as base flow for small streams and tributaries, including Mitchell Branch and Poplar Creek near the ETTP area (MMES 1985, SAIC 2004).

Contamination at ETTP

The primary contaminants in sediments at ETTP are inorganic elements, radionuclides, and polychlorinated biphenyls (PCBs). In soils, the contaminants of concern include inorganic elements, radionuclides, semi-volatile organic compounds (SVOCs), polyaromatic hydrocarbons (PAHs), and VOCs. However, the primary contaminants of concern in groundwater at ETTP are VOCs. Dye tracing has been used to identify exit points for groundwater discharge to surface waters around the ETTP. Monitoring wells have been installed at each of these exit points to evaluate contaminant concentrations in these areas and to monitor the migration of known contaminant plumes. As of FY 2003 sampling, volatile organic compound (VOC) concentrations have shown a general decreasing trend at exit point monitoring wells. Results from monitoring of the bedrock well (BRW-083) and the unconsolidated zone well (UNW-107) near the confluence of Mitchell Branch and Poplar Creek, have shown no detectable levels of VOCs (Figure 2). These wells are considered a significant exit point for several commingling groundwater plumes emanating from the eastern portions of ETTP, including the K-1070-C/D burial grounds and the K-1401 area.

Testing at exit point monitoring wells BRW-035 and BRW-068, between the K-901 holding pond and the Clinch River, have occasionally shown low concentrations of TCE and 1,2-DCE, chloroform, gross alpha and gross beta activity; all below the respective MCLs. VOC contaminated groundwater does, however, discharge to surface water from several seeps and springs north of the K-901 holding pond including Spring 21-002.

Another significant contaminant source area for the ETTP is the K-27 building. VOC concentrations in the groundwater in this area range from 20 μg/L (UNW-096) to 130 μg/L (UNW-038). Both of these unconsolidated zone monitoring wells are southwest of K-27 along Poplar Creek. Monitoring wells (BRW-016) north of K-27 along Poplar Creek typically reveal TCE degradation products such as *cis*-1,2-DCE and vinyl chloride. FY 2003 sampling from BRW-016 revealed vinyl chloride concentrations slightly above the MCL of 2 μg/L.

As is the case north of K-27, the distal portions of the commingled VOC plumes near the Mitchell Branch are largely composed of TCE degradation products *cis*-1,2-DCE and vinyl chloride. In both cases, this can indicate that the source of contamination is significantly upgradient or the source of contamination has been eliminated. It could also be a result of increased biodegradation in those particular areas. Based on monitoring data from FY 2003 collected from known and suspected exit point locations, contaminant (largely VOC) concentrations have either remained constant or have decreased from previous years. These steady or decreasing groundwater concentrations have also resulted in decreased impact on ETTP perimeter surface waters. VOC concentrations from the Mitchell Brach weir (K-1700 – see Figure 3 inset) have decreased from 1997-98 (SAIC 2004).

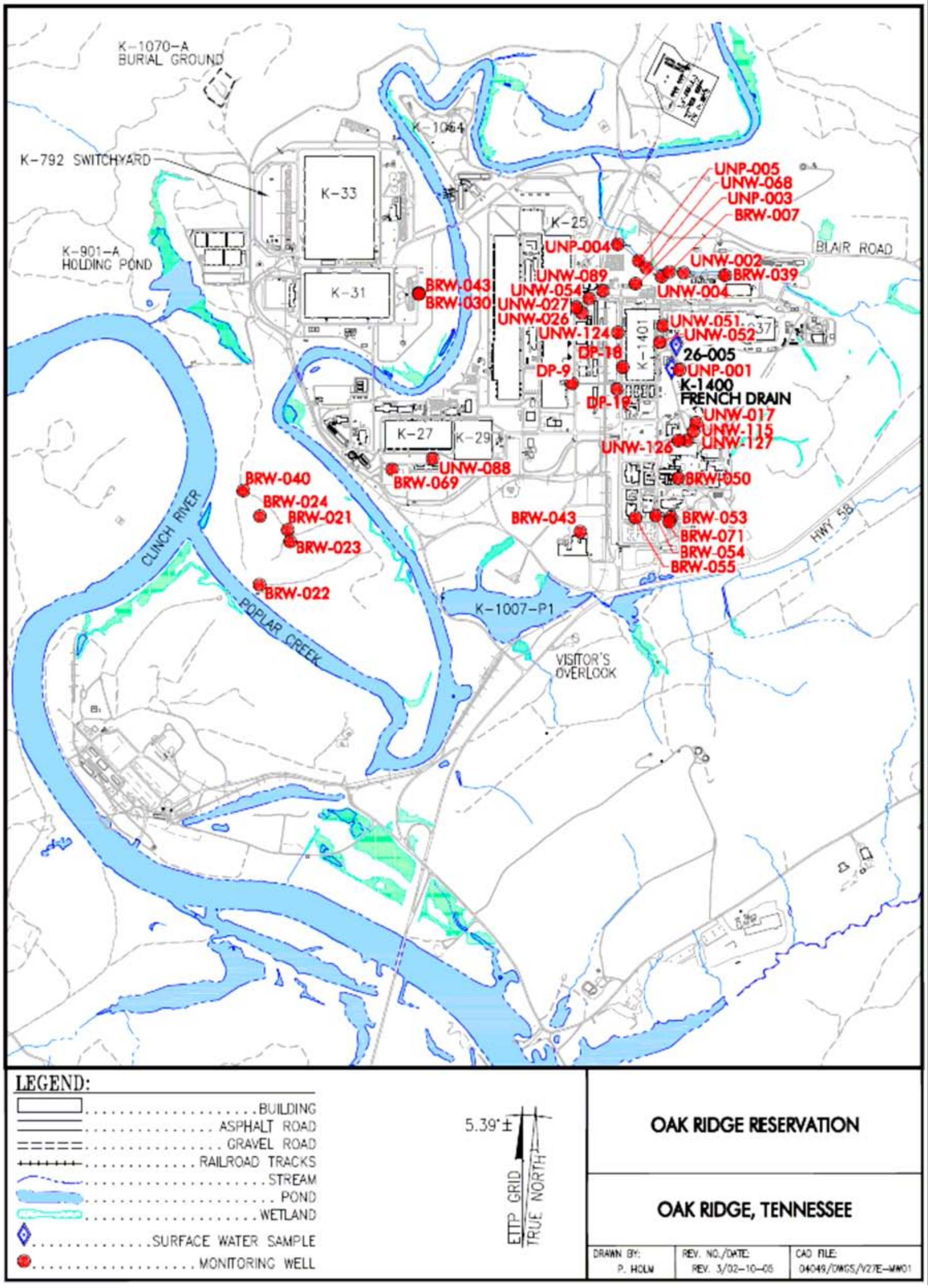


Figure 2: On-Site Groundwater Monitoring Locations at ETTP

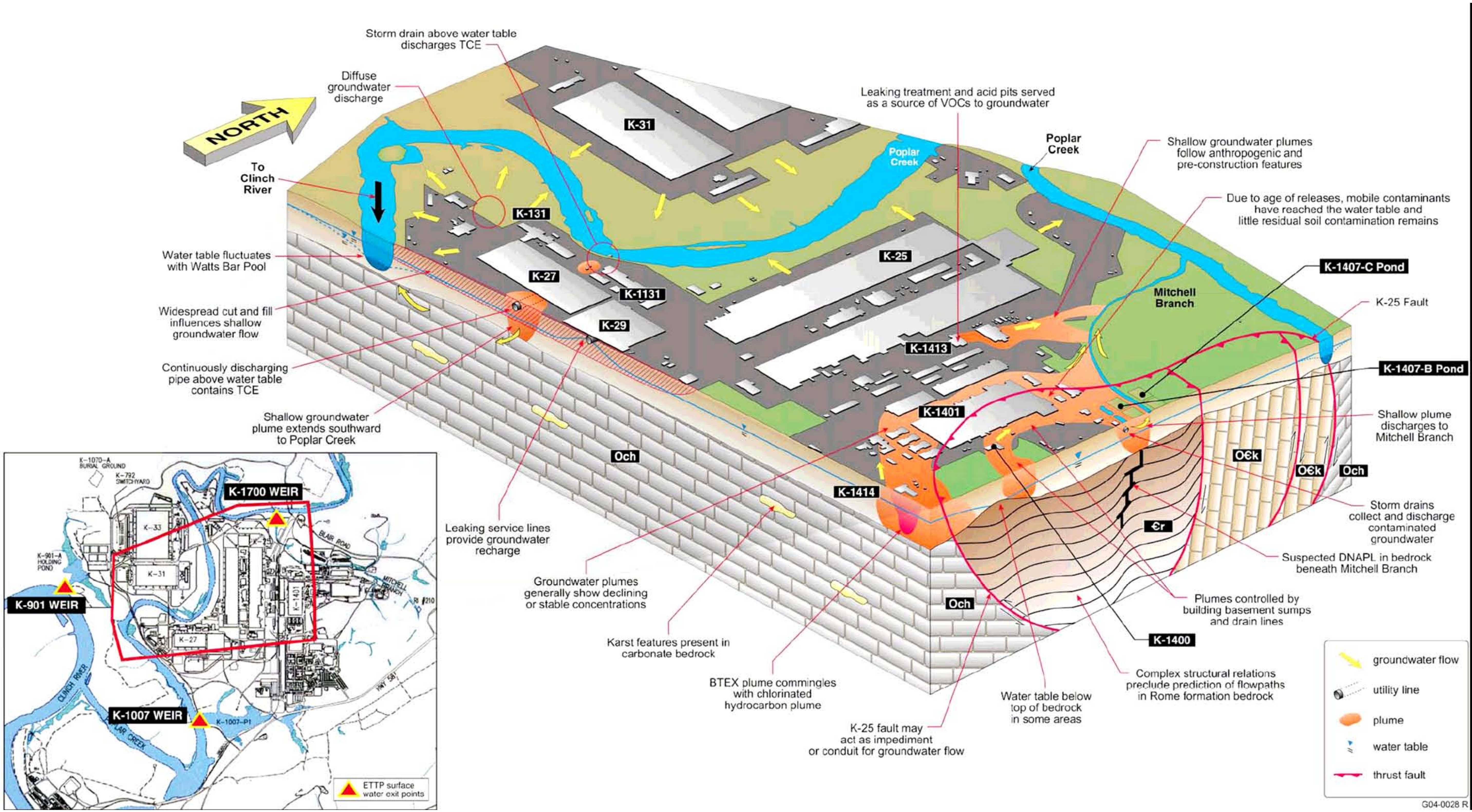


Figure 3: Conceptual Model of Groundwater Flow and Contaminant Transport at ETTP

Off-Site Groundwater Monitoring Data

Seeps and Springs

Comparison values are doses or substance concentrations set well below levels that are known or anticipated to result in adverse heath effects (ATSDR 2005) — see Appendix A.

Lead and manganese were the only substances detected above comparison values (CVs) in seeps and springs near ETTP. Lead was only detected in five samples out of 28. Three out of those were above the 15 ppb MCL for lead. Of the 12 detected samples of manganese, only one sample was above the 500 ppb CV for manganese. For both substances, all samples that were detected above the respective CVs were taken from the CCC Well #2 (See Figure 4). Samples taken from an adjacent location (CCC Well #1) on the same day(s) were below detection limits for both substances.

Table 1: Contaminants Detected Above Comparison Values in Seeps or Springs Near ETTP

Substance	*Detects / Samples*	*Samples Detected Above CVs*	*CV (ppb)*	*Max Conc. (ppb)*	*Max Location*	*Max Conc. Date*
Lead	5 / 28	3	15	95.4	CCC Well #2	3/5/1996
Manganese	12 / 15	1	500	995	CCC Well #2	9/8/1995

Monitoring Wells

There were no contaminants detected above CVs in monitoring wells outside of the ORR boundaries near the ETTP.

Residential Wells

The only contaminant detected above CV in residential wells near ETTP is boron. Boron has been detected in four samples from four different wells collected on September 22, 1998. Only one of these samples was detected above the 100 ppb CV. This sample was taken from RW-A-15 and yielded a boron concentration of 154 ppb. No subsequent sampling has been conducted at these wells.

ATSDR Conclusion for the ETTP Watershed

Lead, manganese and boron are naturally occurring elements. Lead and manganese were both detected above CVs in seeps outside the ORR. Because neither lead nor manganese could be detected in samples collected concurrently at adjacent sampling locations, it is unlikely that these substances are associated with groundwater contamination. Likewise, boron was only detected above it's CV in one sample. Concurrent sampling at adjacent wells revealed concentrations well below the CV. Exit pathway monitoring wells are being continually monitored as part of the Water Resources Restoration Program for ETTP. Groundwater contamination at ETTP does not migrate off-site; rather, it is discharged into surface water. The ETTP Environmental Monitoring Plan includes surface water surveillance (ORNL 2004). ATSDR scientists conclude that the public (community) is not being exposed to groundwater contamination from ETTP.

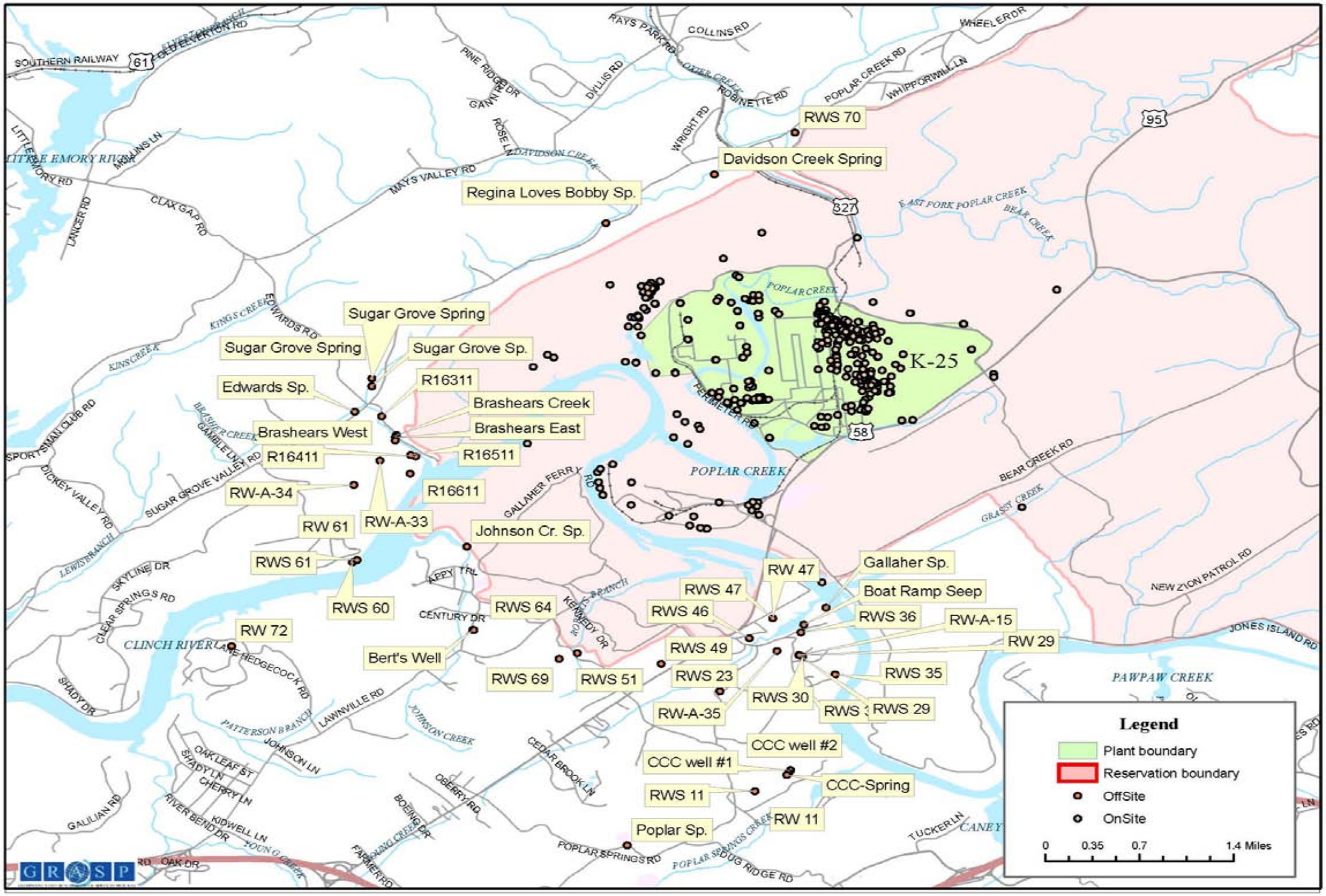


Figure 4: Off-Site Groundwater Sampling Locations Near ETTP

II.E. Bethel Valley Watershed and Melton Valley Watersheds

The X-10 site, now known at the Oak Ridge National Laboratory (ORNL) is about 10 miles southwest of the city center of Oak Ridge in Roane County, and encompasses approximately 26,580 acres. It is surrounded by heavily forested ridges that include Chestnut Ridge, Haw Ridge, and Copper Ridge (ChemRisk 1999a; TDOH 2000). The X-10 Site is situated within two watersheds – Bethel Valley and Melton Valley (ORNL et al. 1999). The main laboratory at X-10 is located along Bethel Valley Road, within Bethel Valley (ChemRisk 1999a; ORNL et al. 1999). The X-10 site also contains remote facilities and waste storage areas in Melton Valley (ORNL et al. 1999). White Oak Creek begins in Bethel Valley and flows south along the eastern border of the plant and travels through a gap in Haw Ridge before entering Melton Valley. From Melton Valley, White Oak Creek joins the Clinch River below Melton Hill Dam (ChemRisk 1999a). See Figure 1 for the location of White Oak Creek and the relationship between X-10, White Oak Dam, the Clinch River, and the Watts Bar Reservoir.

Operational History

Beginning in the early 1940s, radioactive material was used on the ORR for various processes, such as uranium enrichment, plutonium production, plutonium separation, and the development of separation processes for additional radionuclides (ChemRisk 1993b; Jacobs Engineering Group Inc. 1996). The X-10 site was built in 1943 as a "pilot plant" to demonstrate plutonium production and chemical separation. The government had intended to operate the facility for only one year. However, this initial time period was extended indefinitely as operations were continued and expanded at X-10 (ChemRisk 1999a; TDOH 2000). After World War II, the facility's focus was broadened to include non-weapons related activities, such as the physical and chemical separation of nuclear products, the creation and assessment of nuclear reactors, and the production of a range of radionuclides for global use in the medicinal, industrial, and research disciplines (ChemRisk 1993b). In the 1950s and 1960s, the X-10 site became a worldwide research center to study nuclear energy and to investigate the physical and life sciences that are related to nuclear energy. From 1958 to 1987, the Oak Ridge Research Reactor operated to support various scientific experiments at X-10. For a long period of time, this reactor was the main radionuclide supplier to the "free world" for medical, research, and industrial purposes (Johnson & Schaffer 1992, Stapleton 1992, and Thompson 1963 as cited in ChemRisk 1993b).

Geology/Hydrogeology

The entire X-10 site was built on the Chickamauga Group (see Figure B-1). This aquifer formation is a flow limiting strata that has a relatively low hydraulic conductivity. This formation is subject to upper-level fracturing, but these cracks and fissures are typically only a few centimeters wide and serve more as groundwater storage as opposed to facilitating the spatial movement of groundwater (MMES 1985). Haw Ridge separates Bethel Valley from Melton Valley. This ridge was formed partially from thrust faulting by compressive tectonic forces millions of years ago. It is also a result of differential weathering. Underlying Haw Ridge is the Rome Formation. This siliciclastic formation is composed primarily of siltstone, sandstone and shale (USGS 2004). The Rome formation is more resistant to weathering than the Chickamauga Group, which underlies the Bethel Valley to the north, and the Conasauga Group, which underlies Melton Valley to the south.

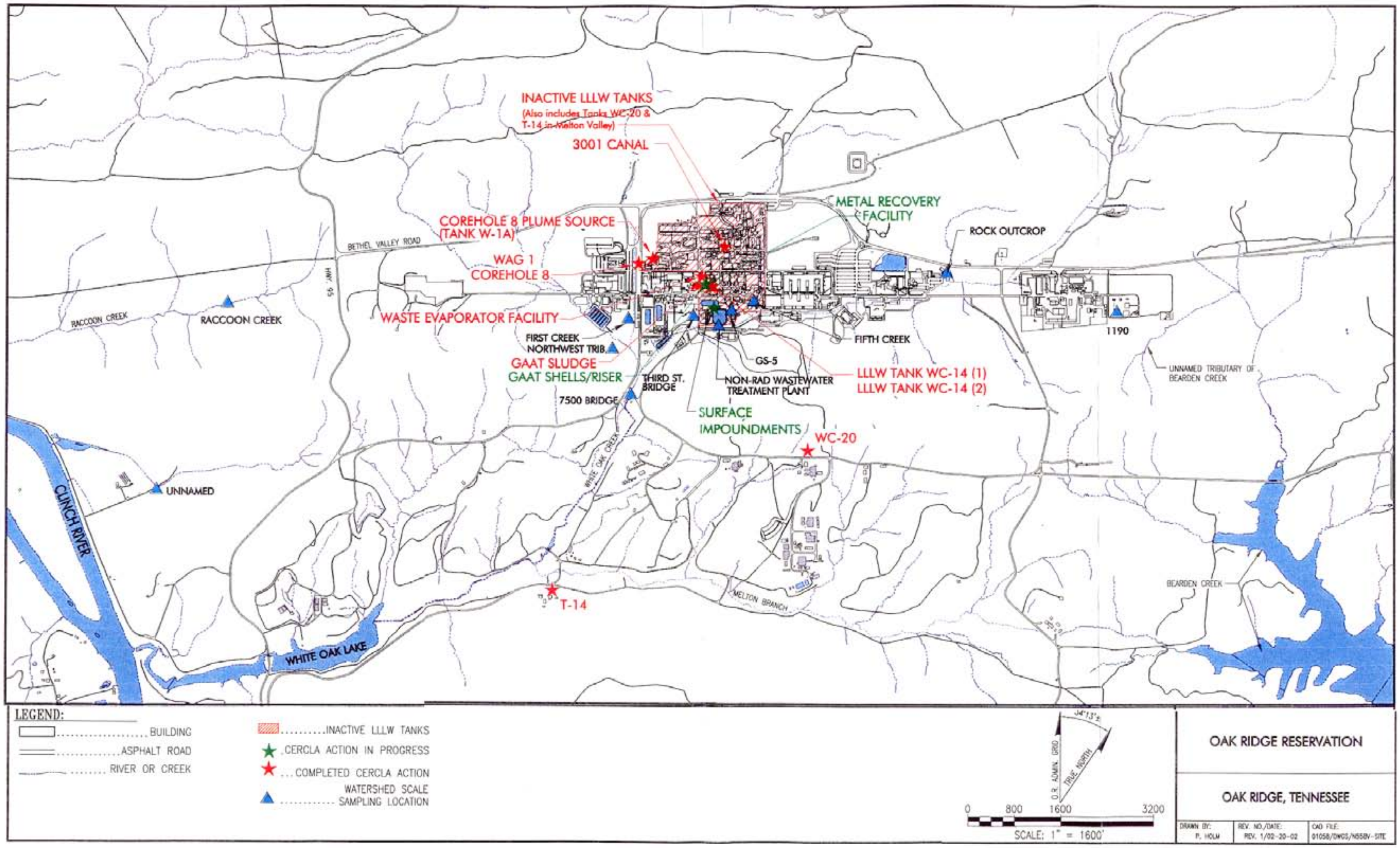


Figure 5: Major Remedial Activities in Bethel Valley

Groundwater in the ORR area generally occurs in the unconsolidated zone. Depth to the water table, depending on seasonal variability, in the Bethel Valley ranges from 1 to 35 feet and from 1 to 67 feet in Melton Valley. Groundwater flow paths most often mirror the surface topography with diffuse discharge to surface waters or as discharge via springs and seeps (Figure 7). In the Bethel Valley, there is a hydrologic divide separating surface water flow in the western third of the watershed. West of the divide, surface water and groundwater flow west to Raccoon Creek (Figure 6) and eventually into the Clinch River. East of the divide, waters flow east to White Oak Creek. Groundwater flow generally follows these topographic trends and flow paths to surface water are relatively short (ORNL 2004).

White Oak Creek flows through a gap in Haw Ridge from Bethel Valley to Melton Valley. Soils in the Melton Valley area, overlying the Conasauga Shale, have a low primary porosity and therefore, have a low storage capacity. The common concept of contaminated groundwater plume migration is not appropriate in this area because of the shallow active zone and the interaction with surface water. The water that infiltrates into the upper weathered zone eventually discharges into streams via the "bathtub effect" – where water collects in a low area, or trench, causing an overflow at the down gradient end (MMES 1985). This overflow occurs as springs or seeps from which water flows downhill to creeks and streams (Figure 7).

Contamination in Bethel Valley and Melton Valley

The major operations at X-10 take place within the Bethel Valley Watershed. The main plant, key research facilities, primary administrative offices, as well as various forms of waste sites, are situated in Bethel Valley. Over the past 60 years, X-10 releases have contaminated the Bethel Valley Watershed. Mobile contaminants primarily leave the Bethel Valley Watershed via White Oak Creek. These contaminants travel from the Bethel Valley Watershed to the Melton Valley Watershed, where further contaminants enter White Oak Creek. Then, the contaminants that have been discharged to White Oak Creek are released over White Oak Dam and into the Clinch River (U.S. DOE 2001d).

Bethel Valley Contamination

For the purpose of environmental investigation and remediation, the Bethel Valley area was subdivided into four regions. The regions are; Raccoon Creek, West Bethel Valley, Central Bethel Valley, and East Bethel Valley (Figure 6). The Raccoon Creek area lies on the western most portion of the valley west of Highway 95. West Bethel Valley lies east of Highway 95 and west of the ORNL main plant area. While the Raccoon Creek area does not have any known contaminant source areas, West Bethel Valley contains a burial ground (SWSA 3) and adjacent landfills, which have resulted in soil and groundwater contamination in both West Bethel Valley as well as Raccoon Creek. Radiological wastes were stored in SWSA 3 from 1946 to 1951 from DOE facilities all over the country. The SWSA 3 and the adjacent landfills cover approximately 18 acres in Bethel Valley. Over the years, seasonal surface water infiltration and heavy rain events have resulted in contaminant leaching from SWSA 3 and the adjacent landfills. Subsurface contaminant movement was short, flowing to Raccoon Creek to the southwest, and northeast to the Northwest Tributary (SAIC 2004).

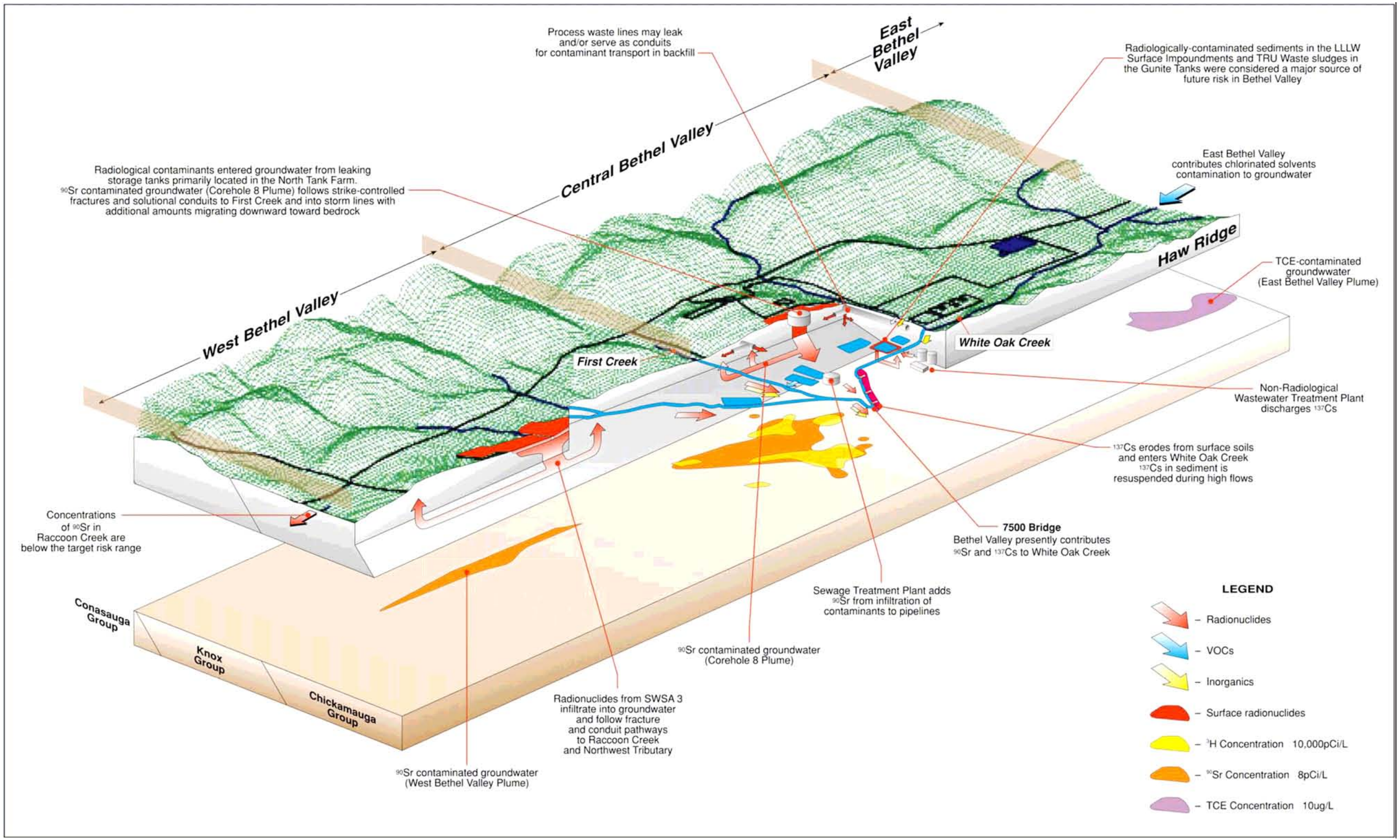


Figure 6: Conceptual Model of Groundwater Flow and Contaminant Transport in Bethel Valley

While the Raccoon Creek and the West Bethel Valley areas have relatively small defined contaminant release areas, the Central and East Bethel Valley areas have extensive soil and groundwater contamination. The Central Bethel Valley contains the main ORNL plant site and has over 150 sites that have been identified for environmental restoration (SAIC 2004). The leading areas of concern in terms of groundwater contamination in the Central Bethel Valley are the Corehole 8 plume and in some building sumps which have tested positive for mercury contamination (Figure 5). However, the only groundwater plume that is regularly monitored on a watershed scale is the Corehole 8 plume (SAIC 2004).

The Corehole 8 Plume, which was identified at X-10 in 1991, is a plume of groundwater that is contaminated with Sr 90 (SAIC 2002, U.S. EPA 2002a). In 1994, a removal site evaluation revealed that contaminated groundwater was leaching into X-10's storm drain system and was being released into First Creek. First Creek is a stream that feeds into White Oak Creek and ultimately flows into the Clinch River. Additional evaluation indicated that the contaminated groundwater was seeping into the storm drain system via three catch basins on the western portion of X-10 (SAIC 2002). In November 1994, an action memorandum was approved; by March 1995, a groundwater collection and transmission system was being used at the Corehole 8 Plume to prevent groundwater infiltration (SAIC 2002, U.S. EPA 2002a). Through this system, groundwater is treated by X-10's Process Waste Treatment Plant (PWTP) and then released through a National Pollutant Discharge Elimination System (NPDES) outfall.

In August 1995, DOE prepared a removal action report that required monthly monitoring of the storm drain outfall close to the joining of First Creek and the Northwest Tributary (Figure 5). In addition, based on suggestions from the 1997 remediation effectiveness report (RER), monthly composite samples are taken at this area, as well as at the Corehole 8 sump (SAIC 2002). Surface water monitoring in October 1997 revealed elevated levels of Sr 90 and uranium 233 (U 233) in First Creek. In December 1997, further investigation indicated that this contamination was entering the area through two unlined storm drain manholes. As a result, in March 1998, DOE established another interceptor trench that linked to one of the plume's collection sumps. An addendum to the original action memorandum was approved in September 1999. This addendum, which was intended to increase the effectiveness of the initial remedial action, endorsed more groundwater extraction and treatment activities at the Corehole 8 Plume (SAIC 2002, SAIC 2004). The source of the Corehole 8 plume is the W-1A tank in the North Tank Farm. This tank was commissioned in 1951 to receive LLLW from Buildings 3019, 3019B, and 2026, but use of the tank was discontinued in 1986 because of leaks in the transfer lines. Grab samples of soil around the W-1A tank revealed extremely high levels of transuranic waste (TRU). The tank is still in place because it was determined that removal of the tanks would result in a high dose rate to the workers (SAIC 2004).

Melton Valley Contamination

In the late 1950's, scientists at ORNL began experimenting with injecting low-level radioactive waste mixed with a Portland cement into induced fractures of the underlying bedrock. The geologic formation involved was a low-permeability formation of the Conasauga Group called the Pumpkin Valley Shale. Two experimental sites were developed for testing of this disposal method. The first was Hydrofracture-1 (HF-1) and the other was HF-2. At each site twenty-four observation and monitoring wells were installed. Various experiments revealed that the Pumpkin

Valley Formation could effectively and safely contain the contaminated grout. Continued experimental and, later, successful operational waste disposal was performed at two other injection sites (Old Hydrofracture Facility and New Hydrofracture Facitily – OHF and NHF) until operations were halted in 1982. The Underground Injection Control regulations promulgated by the USEPA effectively eliminated hydrofracture waste injections at ORNL (SAIC 1997, ORNL 2000). In 2000, Bechtel Jacobs Company LLC (BJC) contracted Tetra Tech NUS, Inc and their sub-contractor Texas World Operations, Inc. to perform the plugging and abandonment (P&A) of 111 wells in Melton Valley (Whiteside et al. 2002). As of FY 2002, demolition and deconstruction activities at OHF were completed and 110 of 111 hydrofracture wells have been plugged and abandoned (P&A) exceeding ALARA principles on the project (SAIC 2004, Whiteside et al. 2002). Contaminated grout is expected to remain in the induced hydrofractures in the Pumpkin Valley Shale or within boreholes or wells penetrated by grout. There is no known contribution to surface water contamination from hydrofracture waste (SAIC 1997).

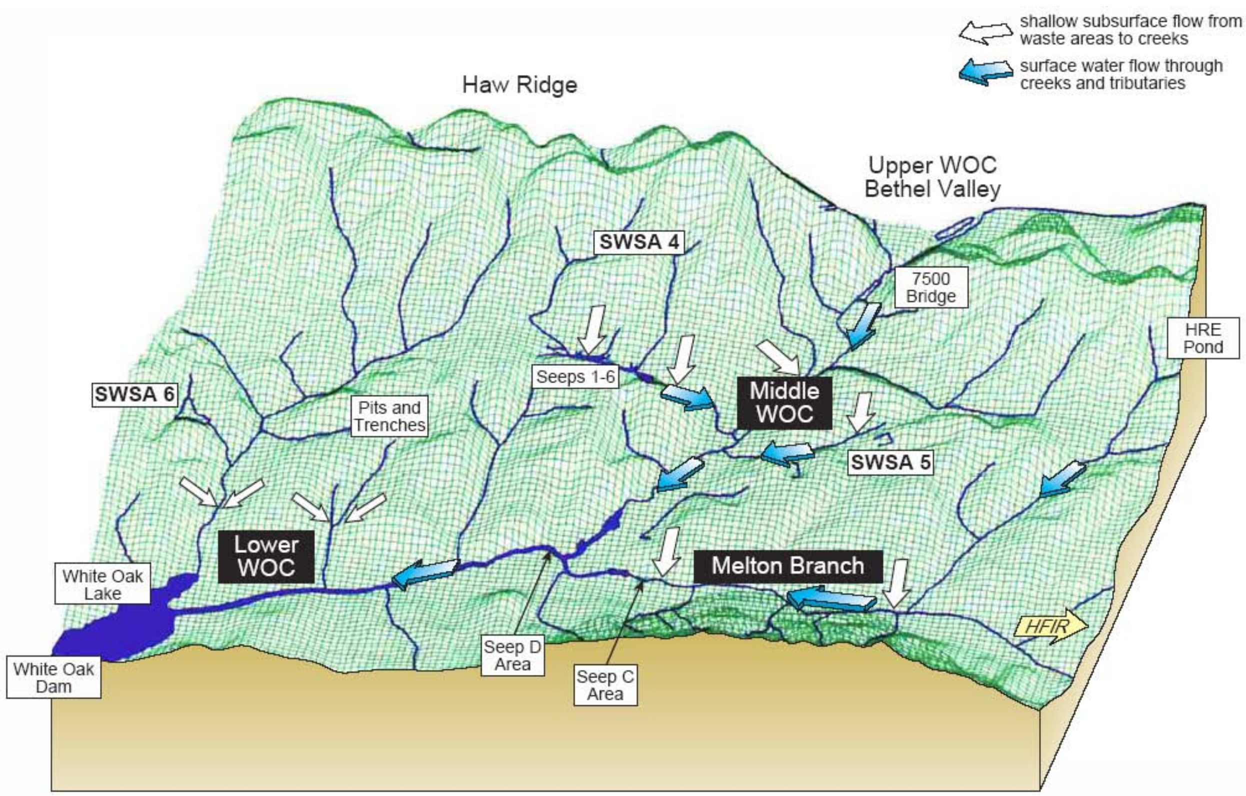


Figure 7: Surface Water and Shallow Groundwater Flow in Melton Valley

Melton Valley served as the U. S. Atomic Energy Commission's (AEC's) Southern Regional Burial Ground for wastes for ORNL and over 50 other facilities. X-10 disposed of its radioactive wastes (liquid and solid) in Melton Valley, and also operated its experimental facilities within this watershed (U.S. DOE 2002a, 2002b). The major burial grounds are SWSA's 4, 5, and 6. Wastes were buried predominantly in unlined trenches and auger holes. Consequently, discharges from Melton Valley's waste areas have produced secondary contamination sources that include sediment, groundwater, and soil contamination. Furthermore, contaminants that are discharged from Melton Valley travel off the reservation through surface water and flow into the

Clinch River (SAIC 2002, USGS 1988). As a result, the greatest impact to off-site receptors is from strontium 90 (^{90}Sr), tritium (^{3}H), and cesium 137 (^{137}Cs) contaminated surface water flowing across the White Oak Dam (WOD). The three primary release areas in Melton Valley are the SWSA 4 seep areas, and SWSA 5 Seeps C and D (SAIC 2004).

The SWSA 4 seeps area is located at the X-10 site (U.S. DOE 2001e). Data collected at the ORR suggest that releases from SWSA 4 have contributed to approximately 25% of the overall ^{90}Sr that is discharged over White Oak Dam (SAIC 2002). SWSA 4 consists of 23 acres that were used between 1951 and 1974 for industrial and radioactive waste burial (SAIC 2002). DOE's investigation revealed that two seeps produced about 70% of the overall ^{90}Sr that was discharged from SWSA 4 (SAIC 2002; U.S. DOE 2001e). Because contaminants from these waste trenches migrated into White Oak Creek, grouting techniques were used to reduce the releases of ^{90}Sr from these trenches; these activities were completed in October 1996. Surface water monitoring revealed that, as of 2001, these efforts had resulted in the ^{90}Sr releases being reduced by about 33% (SAIC 2002).

In 1994, DOE conducted an assessment and remedial activities at SWSA 5 Seeps C and D. The assessment found that ^{90}Sr was discharged from the X-10 site, and that Seeps C and D were major sources of off-site releases. Seeps C and D are located in the southern portion of WAG 5, which consists of a burial site used for radioactive waste disposal between 1951 and 1959 (SAIC 2002; U.S. DOE 2001f). Since ^{90}Sr could potentially constitute a significant threat to off-site populations, one of DOE's main goals was to minimize these discharges from SWSA 5 into the White Oak Creek system (SAIC 2002; U.S. DOE 2001f; U.S. EPA 2002a). The objective of these remedial activities was to reduce the quantity of ^{90}Sr in collected groundwater by at least 90% (SAIC 2002; U.S. DOE 2001f).

DOE's investigation in 1994 showed that Seep C was a major source of ^{90}Sr releases to White Oak Creek (SAIC 2002). Of the strontium detected at White Oak Dam between 1993 and 1994, 20% to 30% was released from Seep C. In March 1994, an action memorandum was accepted, and by November 1994, a "French" drain had been installed at Seep C. The French drain collects the groundwater and directs it to a unit for treatment; this treatment unit consists of drums filled with minerals that filter the ^{90}Sr. Once the groundwater is treated, it is released into Melton Branch. Thus, the primary goal of these remediation activities is to lower the amount of ^{90}Sr that is released to Melton Branch, and therefore, to off-site locations (SAIC 2002; U.S. DOE 2001f). According to samples taken in 2000 and 2001, the treatment unit has prevented over 99% of the ^{90}Sr at Seep C from entering Melton Branch (SAIC 2002). The amount of ^{90}Sr is greater downstream from Seep C than upstream, which suggests that a portion of the ^{90}Sr from WAG 5 bypasses the treatment unit (SAIC 2002; U.S. DOE 2001f). Currently, there are bimonthly sampling and weekly inspections of the treatment unit at Seep C (SAIC 2002).

Seep D was also a major source of ^{90}Sr to the White Oak Creek watershed (SAIC 2002). Of the ^{90}Sr detected at White Oak Dam between 1993 and 1994, 7% was released from Seep D. An action memorandum was passed in July 1994, and a groundwater treatment unit was installed and functioning at Seep D by November 1994. Once the groundwater has been treated, it is released to Melton Branch (SAIC 2002; U.S. DOE 2001f). Data collected in 2000 and 2001 showed that this treatment unit has prevented over 99% of the ^{90}Sr at Seep D from entering Melton Branch (SAIC 2002). However, the amount of ^{90}Sr is greater downstream at Seep D than upstream. This suggests that small quantities of ^{90}Sr going into Melton Branch did not originate from the Seep D pumping location (SAIC 2002; U.S. DOE 2001f). Daily inspections are conducted at Seep D and monthly sampling is performed on the treatment unit, as well as upstream and downstream of Melton Branch (SAIC 2002).

All of the waste areas in the Melton valley are in the aquitard formations of the Conasauga Group, where permeability, and consequently, groundwater migration, is limited (USGS 1988). As is the case in much of the ORR, groundwater flow is very shallow is closely coupled with surface water. Greater than 95% of the rainwater that infiltrates the soil ends up as surface water in White Oak Creek and eventually in to the Clinch River (ORNL 1982, SAIC 2004). As a result, most of the monitoring that is performed in Melton Valley concerns surface water with emphasis on the WOD. Surface water contamination in this area is addressed in the White Oak Creek Public Health Assessment.

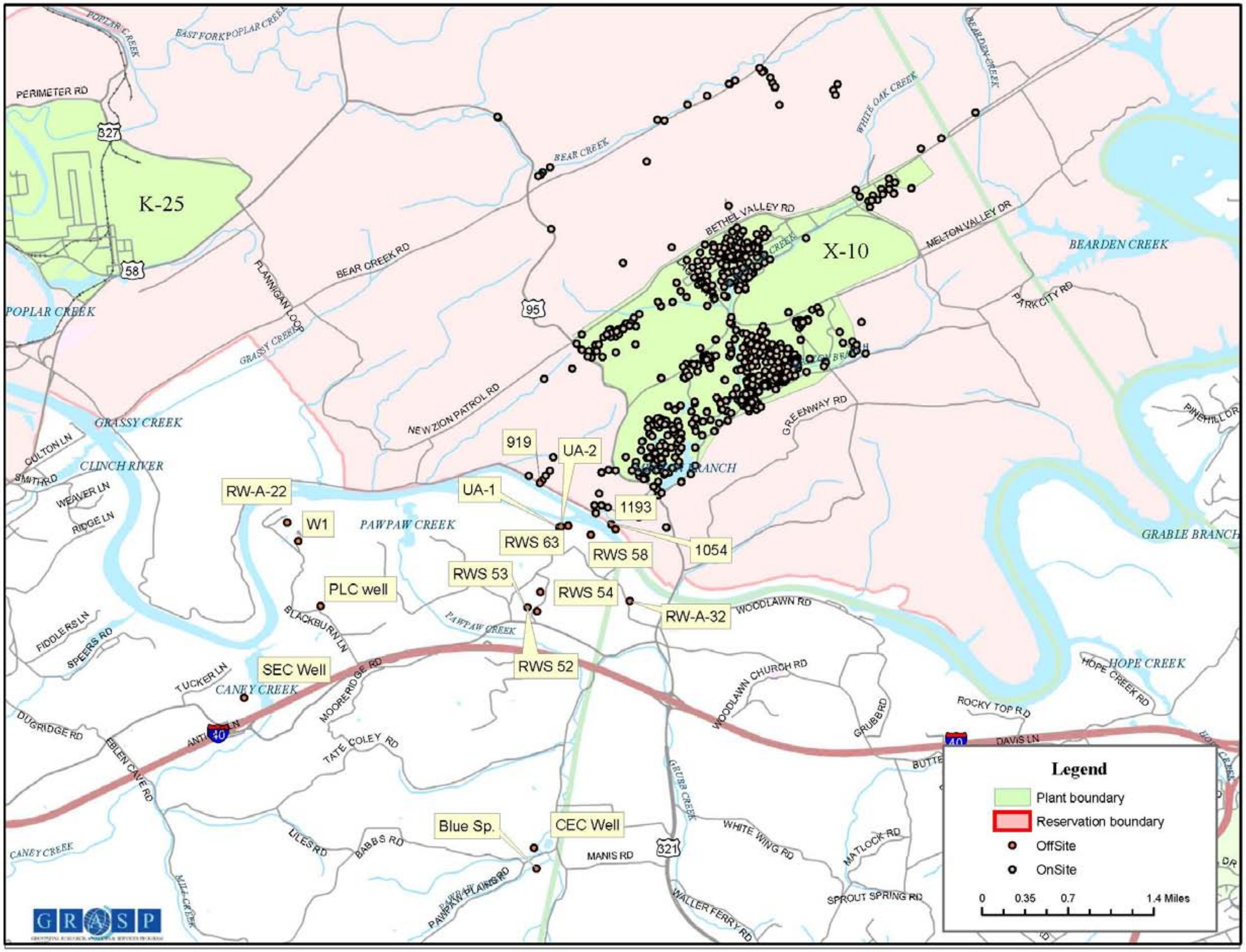


Figure 8: Off-Site Groundwater Sampling Locations Near ORNL

Off-Site Groundwater Monitoring Data

Seeps and Springs

Thallium was detected in one of seven samples from seeps and springs off-site near ORNL. The detected sample was taken from the SEC Well on March 4, 1996 and revealed a concentration of 2.4 ppb, which is slightly above the 2 ppb MCL for thallium. Thallium was not detected in a sample collected from the same location six months earlier. Subsequent sampling at that location has not been conducted.

Monitoring Wells

Table 2: Contaminants Detected Above Comparison Values in Monitoring Wells in the Bethel Valley and Melton Valley Watersheds

Substance	*Detects / Samples*	*Samples Detected Above CVs*	*CV (ppb)*	*CV Source*	*Max Conc. (ppb)*	*Max Location*	*Max Conc. Date*
Boron	8 / 9	8	100	EMEG	243	1193	5/13/1994
Iron	6 / 11	1	10950	RBC for tap water	16200	PLC Well	9/7/1995
Thallium	2 / 11	2	2	MCL	2.4	PLC Well	3/4/1996

Boron was only detected in one well – well #1193. Boron was not detected in the most recent sample from this well, which occurred on April 3, 1996. Iron was only detected above the 10950 ppb CV in one sample. This sample was taken from the PLC Well in September of 1995. A subsequent sample, six months later, from the same well yielded a concentration of 2550 ppb – well below the CV. Both samples with elevated thallium concentrations were taken from the PLC Well. No subsequent sampling has taken place for thallium at the PLC Well.

Residential Wells

There have been no contaminants detected above comparison values in residential wells near the ORNL.

ATSDR Conclusion for Bethel Valley and Melton Valley Watersheds

Groundwater in Bethel Valley and Melton Valley has short flow-paths to surface water, namely, First Creek, Raccoon Creek, the Northwest Tributary and White Oak Creek. Contaminated groundwater has not migrated to the ORR boundary. Remediation of groundwater in Bethel Valley is ongoing as it is in Melton Valley. Contaminant concentrations in general are either decreasing or are steady. There is no site-related groundwater contamination beyond the ORR boundaries from operations in Bethel or Melton Valleys. Thallium has been detected sporadically in seeps/springs and monitoring wells near ORNL. While subsequent sampling has not been conducted at the specific locations (SEC Well and PLC Well), concurrent sampling from adjacent locations have not been able to detect thallium. Iron and boron were not detected in subsequent sampling events. No contamination has been detected in residential wells near

ORNL. For these reasons, ATSDR concludes that there is no public (community) exposure to groundwater contamination emanating from the ORNL.

II.F. Bear Creek and Upper East Fork Poplar Creek Watersheds

The Bear Creek watershed and the Upper East Fork Poplar Creek (UEFPC) watershed comprise a large portion of Bear Creek Valley on the ORR. Bear Creek Valley is bordered by Chestnut Ridge and Pine Ridge. The 825-acre Y-12 plant, now called the Y-12 National Security Complex, is located in Bear Creek Valley and lies predominantly in the UEFPC watershed.

Operational History

From 1944 to 1947, the Y-12 Complex was used to electromagnetically enrich uranium. In 1952, the facility was converted to enrich lithium-6 using a column-exchange process and to fabricate components for thermo-nuclear weapons using high-precision machining and other specialized processes. In 1992, after the Cold War ended, Y-12's mission was curtailed, and the plant is currently used for weapons disassembly and weapon renovation operations. The National Nuclear Security Administration currently uses the Y-12 National Security Complex as the primary storage site for highly enriched uranium. While operational levels have increased since 1992, the total operations have not approached the levels experienced before the 1990's.

Geology/Hydrogeology

The Y-12 Complex is located in the eastern end of Bear Creek Valley. It is bordered on the south by Chestnut Ridge and on the north by Bear Creek Road and Pine Ridge (ChemRisk 1999). The main Y-12 production area is about 0.6 miles wide and 3.2 miles long; the area contains roughly 240 principal buildings, of which about 18 were directly involved with processing and/or storage of uranium compounds (Patton 1963; UCC-ND 1983 as cited in ChemRisk 1999). The Y-12 Complex is located within the corporate limits of the city of Oak Ridge, about 2 miles south of downtown (ChemRisk 1999). It is less than a half mile from the Scarboro community, but Pine Ridge (which rises to about 300 feet above the valley floor) separates the Y-12 Complex from the main residential areas of Oak Ridge (TDOH 2000). Figure 9 illustrates how groundwater flows along strike in Pine Ridge and Chestnut Ridge. Indeed, the southward sloping orientation of the bed planes beneath Pine Ridge prevents groundwater from flowing north toward Scarboro.

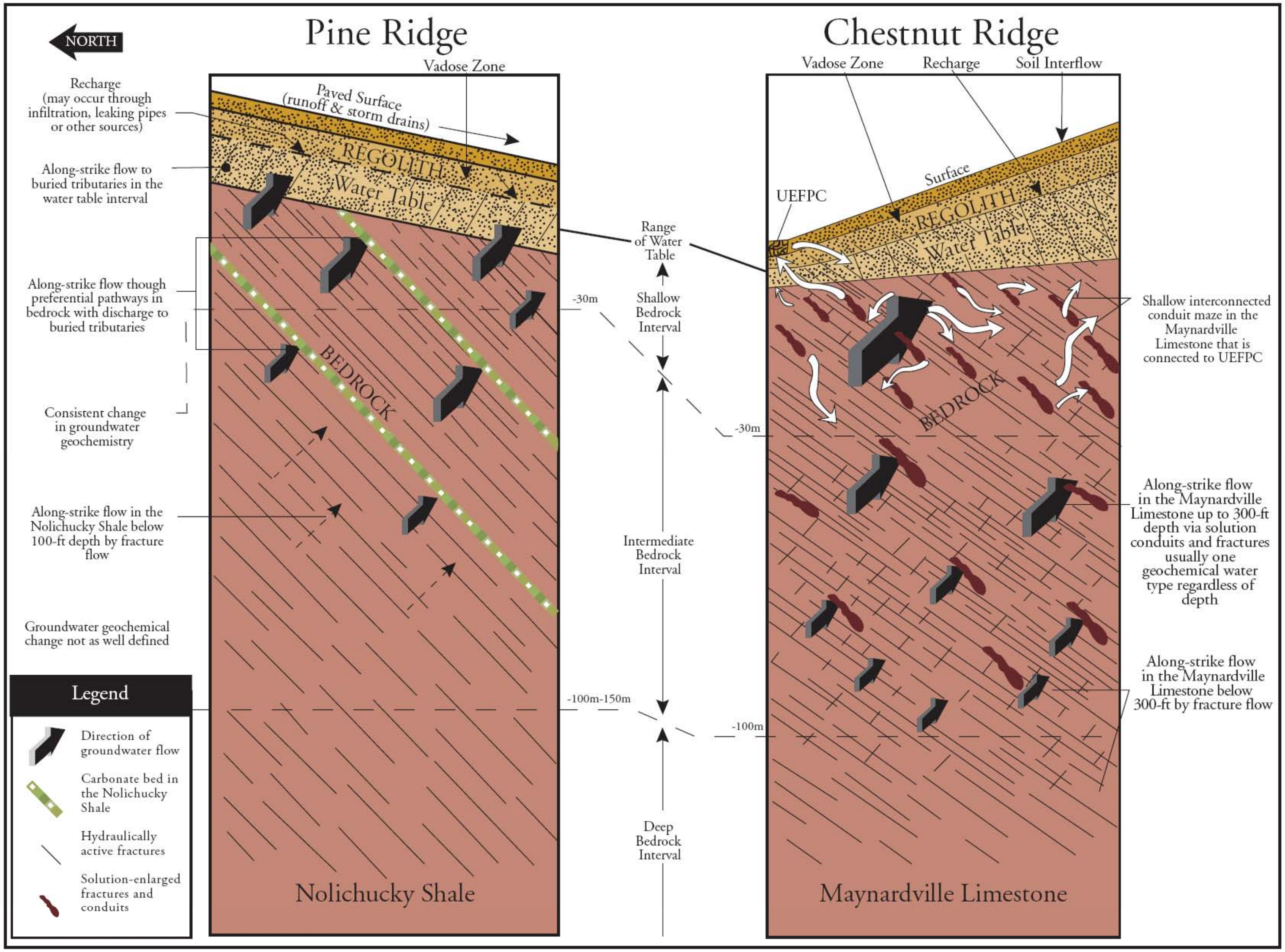


Figure 9: Cross-sectional Diagram of Pine Ridge and Chestnut Ridge in the Y-12 Vicinity

Contamination at Bear Creek Valley and UEFPC Watersheds

Bear Creek Valley Watershed

In the June 2000 *Record of Decision* (ROD) *for the Phase I Activities in Bear Creek Valley and the Oak Ridge Y-12 Plant*, Bear Creek Valley was divided into three Zones for the purposes of establishing and evaluating performance standards for each zone in terms of resulting land and resource uses and residential risks following remediation (Figure 10).

Zone 1 is the area of Bear Creek Valley Watershed west of surface water monitoring location BCK 7.87. The pre-ROD situation for this zone was that there was no unacceptable risk to residential or recreational users of the land or resources in this area of the valley. The agreed upon goal for this zone was to maintain the "unrestricted use" classification. Monitoring locations, scheduling of sampling and parameters to be monitored were established throughout this zone to ensure that the goals of the ROD would be achieved (SAIC 2004).

Groundwater sampling in FY 2003 revealed that there was no uranium detected above MCLs in Zone 1. Uranium that was detected in Zone 1 was only found in GW-715 at a concentration substantially lower than results from FY 2002 sampling. These data indicate that uranium concentrations may be going down overall after peaking following a five year increase in this well from 1998. Since 1998, GW-715 has also yielded detectable concentrations of nitrate, ^{99}Tc, gross alpha, and gross beta. At 43 feet deep, GW-715 is the shallowest well in Zone 1 and represents the close relationship with the surface water in Bear Creek. The contaminants detected in groundwater are also typically detected at surface water sampling locations along Bear Creek. In fact, losing reaches of Bear Creek contribute to groundwater recharge between Northern Tributary #9 (NT-9) and surface water sampling station #6 (SS-6) (SAIC 2004). In FY 2003, there were anomalously high exceedences of AWQCs due to high-flow conditions. These levels are expected to decrease markedly thus reducing groundwater contamination in Zone 1.

Zone 2 is the area of Bear Creek Valley between Bear Creek surface water stations BCK 7.87 and BCK 9.47. The short-term land use goals for this zone are recreational and the long-term goal is to attain unrestricted use classification. The ROD identifies the comparative criteria for groundwater in Zone 2 to be MCLs. The remedial action objective (RAO) for cleanup levels in Zone 2 is risk to potential residents to the area be below 1×10^{-5}. The RAO applies as the performance criterion at BCK 9.47. BCK 9.47 is the eastern, upgradient extent of Bear Creek in Zone 2 and the integration point (IP) for contaminants in Bear Creek Valley.

In FY 2003, samples collected at the IP exceeded secondary MCLs for aluminum and manganese. Uranium was detected in the August 2003 sampling event but levels remained in the background range, so over the past 10 years the slight downward trend continues. According to these results, as of FY 2003, Zone 2 continues to meet criteria for the remediation goal of recreational land use.

The total flux of contaminants from all sources exiting the watershed in surface water and groundwater is evaluated at the IP. In the 1994 remedial investigation, mass balance equations and calculations were performed and determined that of the total amount of water passing through the IP only 3% was groundwater – measured at the Maynardville Limestone picket A.

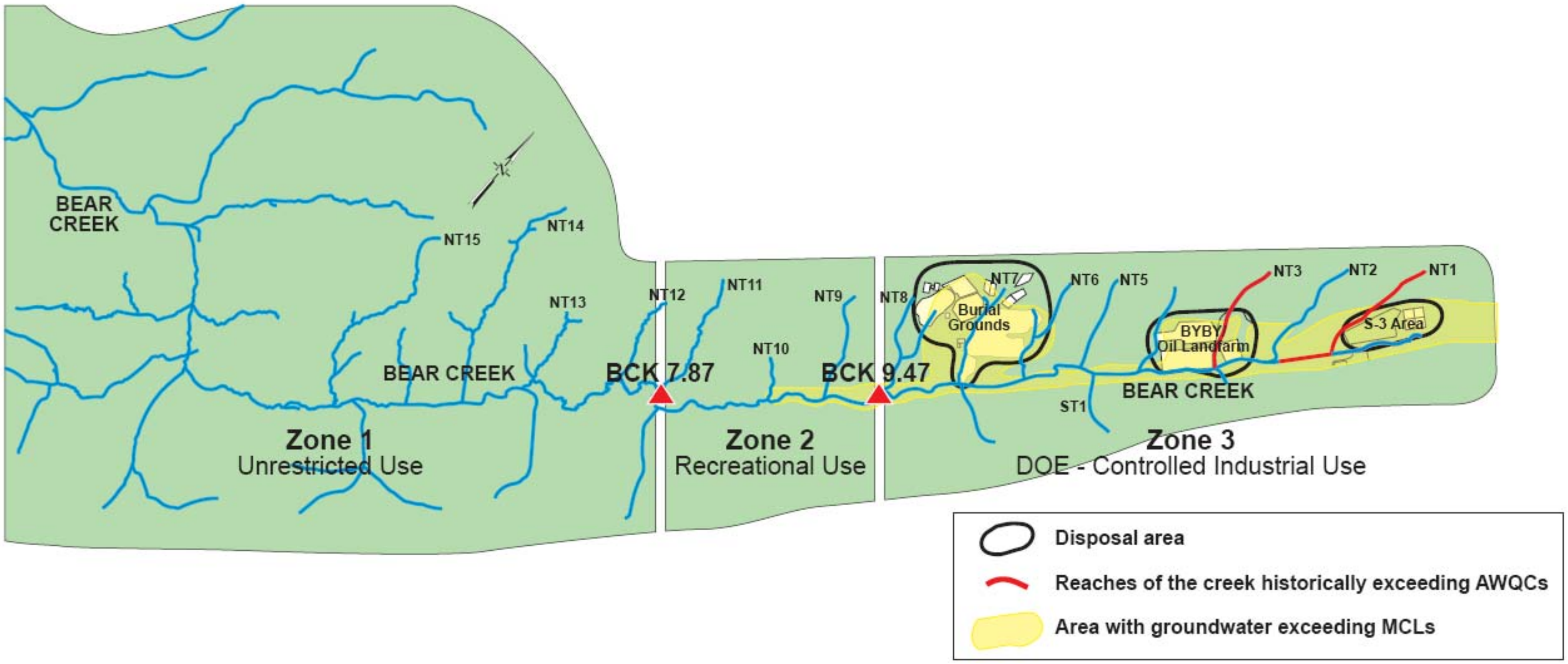


Figure 10: Bear Creek Valley Zones 1, 2, and 3

Up to 99% of contaminants exiting the former waste disposal sites in Bear Creek Valley are intercepted at the IP.

Zone 3 is the area of Bear Creek Valley that lies east of the IP (BCK 9.47). The BYBY, the S-3 Site and the BCBG are located in Zone 3. The remediation goal for Zone 3 is to reduce contaminant levels to be consistent with long-term industrial land use. Groundwater cleanup criteria in Zone 3 have not been determined but contaminant concentrations are being monitored and compared to MCLs for evaluation. Uranium, nitrate, manganese, and several VOCs have exceeded MCLs in Zone 3 for many years following previously observed trends. For example, nitrate concentrations in GW-526 have been historically increasing as a result of the plume's center of mass migrating along strike, but have remained relatively stable since 1995; the closure of the S-3 Site has resulted in decreasing concentrations of uranium, nitrate, and ^{99}Tc in GW-276; and stable to slightly decreasing concentrations of uranium, nitrate and TCE have been observed at exit pathway picket B.

As is the case throughout much of the ORR, there is a very high interconnectivity between surface and groundwater. There are gaining and losing reaches of Bear Creek along the entire Bear Creek Valley and often the contamination of surface water results in increasing contaminant concentrations in the shallow ground water and vice versa. Indeed, there are several large solution cavities beneath Bear Creek which (along certain reaches) serve as a hydraulic drain to the Maynardville Limestone (Lemiski 1994, SAIC 1996). However, completion of remedial actions in Bear Creek Valley has resulted in substantial reductions in contaminants in general. The short and long-term goals set forth in the ROD, in terms of land use and risk to residents, are being met.

UEFPC Watershed

Groundwater contamination occurs beneath the entire UEFPC watershed and continues east, across the ORR boundary, into Union Valley (Figure 13). This contaminated plume is made up of several commingling plumes from a variety of sources (Figure 11). The contaminants that were detected in one of the six monitoring wells in the Maynardville Limestone and in two springs feeding Scarboro Creek were consistent with those found in the carbon tetrachloride plume emanating from the Y-12 Complex (U.S. DOE 1997). Although the sources of most of these contaminants can not be confirmed, they are likely a result of various leaks and spills throughout the Y-12 facility. The east end of the Y-12 complex has been used primarily for maintenance and as a shipping and receiving area. Carbon tetrachloride, the primary VOC in the east end VOC (EEVOC) contaminant plume, was used extensively in the 1940s in the electromagnetic uranium separation process. The high historical on-site concentrations of carbon tetrachloride (>8000µg/L) indicate that there are probably DNAPLs present.

> Groundwater in adjacent formations flows toward the Maynardville Limestone because of the formation's relatively high hydraulic conductivity and well-developed karst system.

Groundwater in the UEFPC watershed typically flows along strike from west to east in the Maynardville Formation between 100ft and 400ft below ground. Groundwater flow direction in this area is also influenced by anthropogenic structures such as pipes, drains and other underground structures which have created preferential flow paths for contaminated groundwater (SAIC 2005). However, the

Maynardville Limestone is the primary pathway for contaminant migration off-site from Y-12 (Figure 12). Groundwater from adjacent formations tends to flow toward the Maynardville Limestone because of its well developed karst-system (U.S. DOE 1997). Because of the high interconnectivity with surface water, groundwater discharges at seeps and springs constitutes much of the base flow of Scarboro Creek and UEFPC. Depth to groundwater in this area is between 1 and 4 feet below ground during the winter and between 2 and 7 feet below ground in the summer (USGS 1989).

Groundwater in this area responds quickly to storms and can exhibit high flow rates with rapid dilution. A silty-clay glei horizon exists beneath EFPC and impedes downward groundwater migration (USGS 1989).

The Interim Record of Decision (ROD) for Union Valley was published in 1997 in accordance with the requirements of CERCLA (Figure 13). It presents the selected interim remedial action for Union Valley. Two interim actions were considered: Alternative 1 – no action, and Alternative 2 – institutional controls. The selected action was Alternative 2, which consisted of the following institutional controls: 1) DOE obtains license agreements with property owners notifying them of the potential contamination and requiring them to notify DOE of any changes in use of groundwater or surface water in certain areas and, 2) there will be appropriate verification by DOE of compliance with the agreements and notification of state and local agencies. This remedy is not the final remedy for Union Valley and, thus, it does not have provisions to reduce toxicity, mobility or volume of contaminants of concern. The purposes of this interim action are to 1) ensure that public health is protected while final actions are being developed and implemented and, 2) identify and, if necessary, prohibit future activities with a potential to accelerate the rate of contaminant migration from the characterization area or increase the extent of the contaminant plume (U.S. DOE 1997). In October 2000, a VOC treatment system began full-scale operation. The treatment system, which removes groundwater and treats it using filters and air strippers, is located near the ORR boundary with Union Valley.

The EEVOC plume is the only confirmed off-site contamination of groundwater at the ORR (USDOE 2004). While it is important to understand the sources and magnitudes of on-site contamination, especially as they relate to contamination off-site, the purpose of this health assessment is to determine the extent of off-site groundwater contamination using existing information and the effect, if any, this contamination will have on the public health. The Tennessee Department of Environment and Conservation (TDEC) conducts groundwater sampling at locations on the ORR and at off-site locations. In CY 2003, six residential wells and 17 exit pathway springs were sampled. In the 2003 Environmental Monitoring Report (TDEC 2003a), TDEC reports findings from three off-site springs (Bootlegger, Cattail and SS-7) and one groundwater well (GW-919). While traces of VOCs from the EEVOC plume have historically been detected in the Bootlegger spring, early in CY 2003, dilution, as a result of higher than average rainfall events, resulted in non-detects in this spring. There are no residential wells in Union Valley (Figure 14).

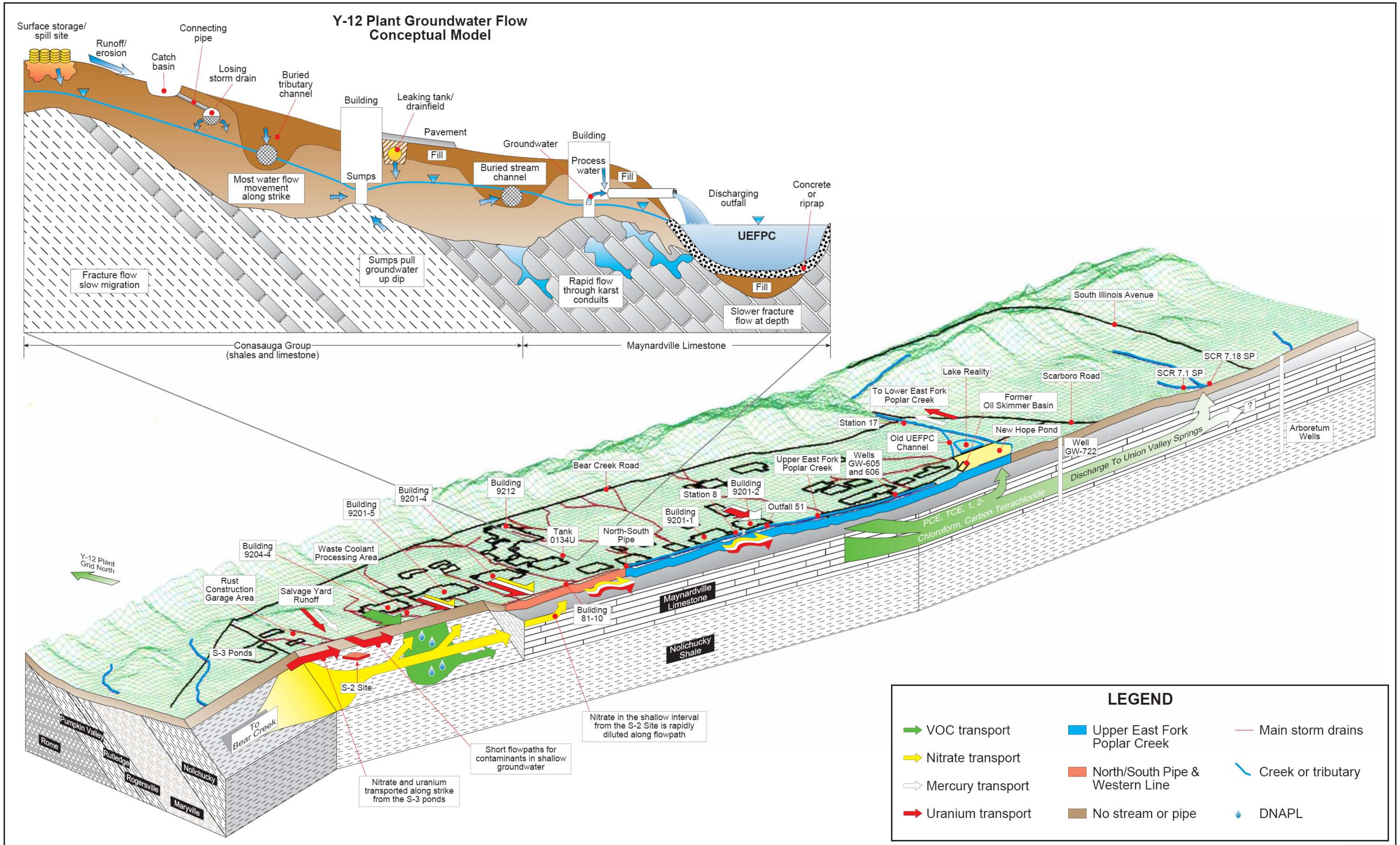


Figure 11: Conceptual Model of Groundwater Flow and Contaminant Transport at the Y-12 Complex

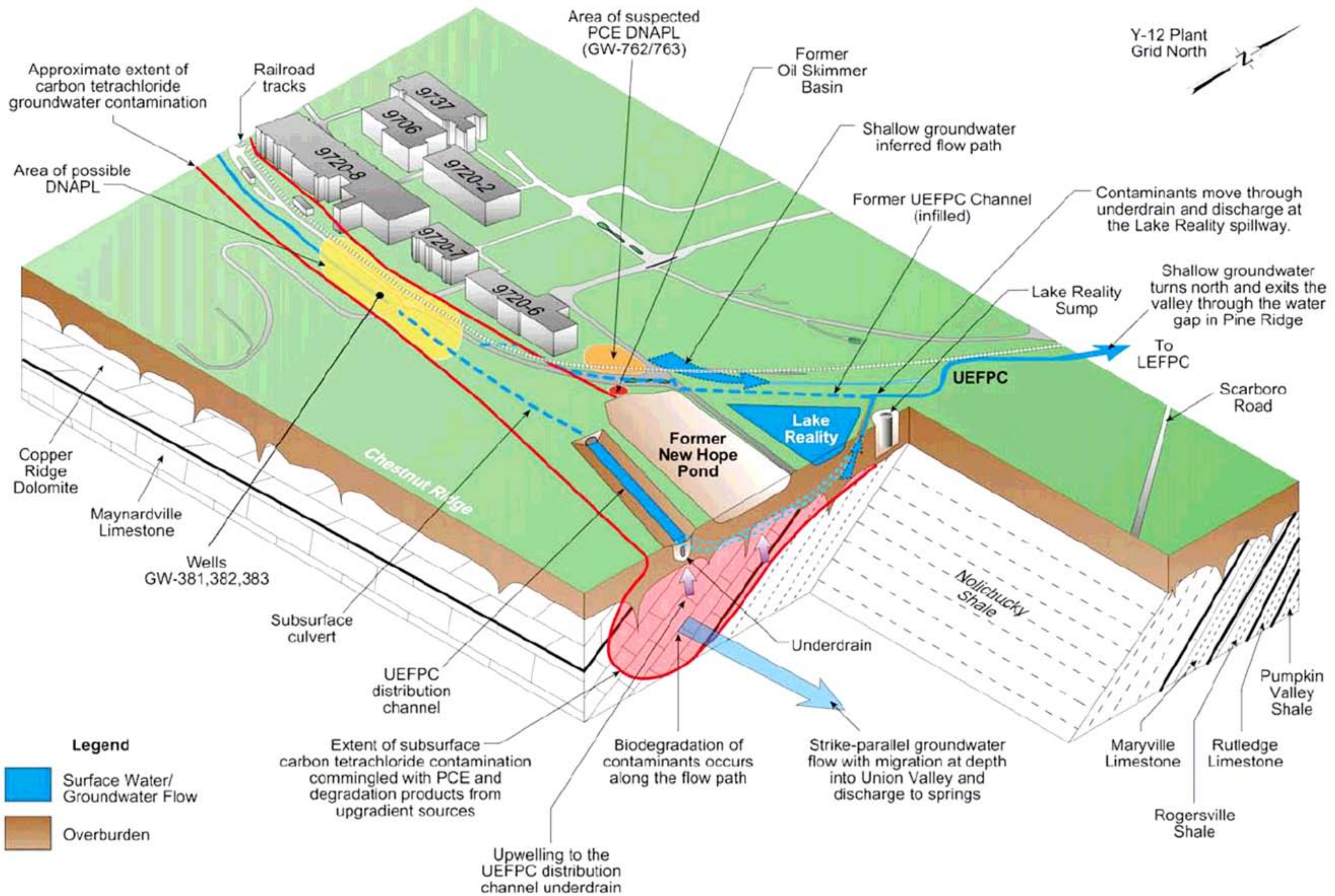


Figure 12: East End VOC Plume Conceptual Model

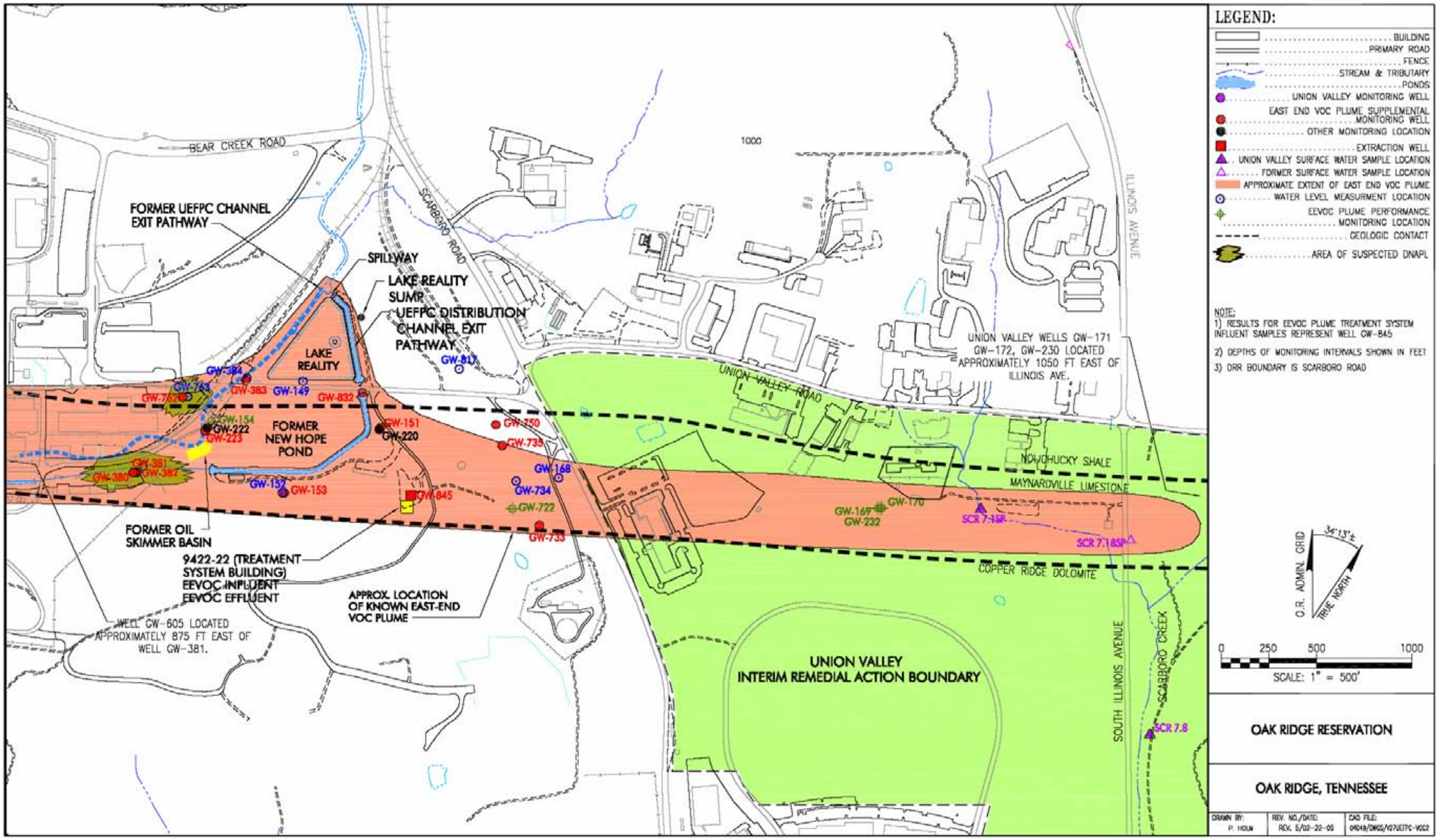


Figure 13: Estimated Extent of the EEVOC Plume in Union Valley

Off-Site Groundwater Monitoring Data

Seeps and Springs

Not surprisingly, the samples which contained concentrations of substances above CVs came from springs just east of the ORR boundary near the Y-12 Complex. These springs are within the known extent of the EEVOC plume (Figure 13). These results are from a one-time sampling event on March 21, 1996. Samples were collected from each sampling location and then they were split and were assigned separate sample identification numbers. Of the 15 'Samples Detected Above CVs' listed in Table 3, 13 of them are from two split samples from SCR7.14SP and SCR7.16SP. There were two other samples (from SCR7.1SP and SCR7.18SP) with elevated levels of manganese. There has been no subsequent sampling of these springs.

Table 3: Substances Detected Above CVs in Seeps or Springs Near the Y-12 Complex

Substance	Detects / Samples	Samples Detected Above CVs	CV (ppb)	CV Source	Max Conc. (ppb)	Max Location	Max Conc. Date
Benzene	1 / 8	1	5	MCL	7	SCR7.14SP	3/21/1996
Boron	16 / 16	4	100	EMEG	880	SCR7.14SP	3/21/1996
Iron	13 / 16	3	10950	RBC for Tap Water	44000	SCR7.14SP	3/21/1996
Manganese	15 / 16	6	500	RMEG	2900	SCR7.16SP	3/21/1996
Selenium	1 / 1	1	50	MCL	69	SCR7.16SP	3/21/1996

Residential Wells

There were no contaminants detected above CVs in off-site residential wells near the Y-12 Complex. The nearest residential well (RWS 67) is over 2 miles from the Y-12 Complex.

Monitoring Wells

Thirty chemical contaminants and twelve radionuclides were detected above comparison values in off-site monitoring wells near the Y-12 Complex. Nine chemicals (indicated by superscript 3 in Table 4) were detected above CVs only in wells in the EFPC floodplain. Wells in the EFPC floodplain include WDANE4, NOAND1, WFANE1, BRAND7, and others with similar naming convention as shown on Figure 14. As previously mentioned, groundwater does not migrate from Union Valley beneath Pine Ridge (see ATSDR's response to Public Comment #2 in Table 10); therefore, it is unlikely that any contamination in the EFPC floodplain is a direct result of groundwater contamination emanating from the Y-12 Complex. The groundwater contamination in the EFPC Floodplain results from contaminated surface water (EFPC) infiltrating into the groundwater. In 1993, ATSDR conducted a Health Consultation for this area and concluded that there is a possible health threat to people consuming groundwater in this area; however, based on available data, all residences in the area were using water from the municipal water system. Fourteen of the thirty chemicals (indicated by superscript 4 in Table 4) were either detected below CVs or not detected at all in concurrent or subsequent samples taken from wells in Union

Valley. Additional comments regarding the monitoring for each substance are included in Table 4.

Of the twelve radionuclides detected above CVs (Table 5), seven were not detected above CVs, or not detected at all in subsequent samples. Five of the radionuclides were only detected above CVs in the EFPC floodplain (except radium in one sample in GW-169). Concurrent sampling of gross beta from GW-169 (the only radium exceedance) yielded a concentration 10 times lower than the CV.

Table 4: Contaminants Detected in Monitoring Wells Near the Y-12 Complex

Substance	Detects / Samples	Samples Detected Above CVs	CV (ppb)	CV Source	Max Conc. (ppb)	Max Location	Max Conc. Date[2]	Comments
2,4-Dinitro phenol [3]	15 / 103	15	20	RMEG	50	EFPC Floodplain[1]	3/12/1991	All samples detected above CVs were taken from wells in the EFPC Floodplain.
2-Nitroaniline [3]	15 / 113	15	3.3	RBC for Tap Water	50	EFPC Floodplain[1]	3/12/1991	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Acetone [3]	81 / 247	1	9000	RMEG	14000	WDANE4	11/19/1990	The only sample detected above the CV was taken from a well in the EFPC Floodplain.
Aluminum [4]	188 / 347	33	20000	EMEG	140000	GW-169	9/28/1995	Aluminum has not been detected in subsequent samples in GW-169. Several wells in the EFPC Floodplain yielded aluminum concentrations above the CV.
Arochlor-1260 [3]	4 / 82	4	0.033	RBC for Tap Water	1	EFPC Floodplain[1]	3/12/1991	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Arsenic [4]	39 / 310	7	10	MCL	83	GW-169	9/28/1995	Arsenic has not been detected in subsequent samples.
Barium [4]	350 / 354	1	2000	MCL	3150	NOAND1	6/14/1991	Another sample on the same day (6/14/1991) from the same well yielded a concentration of only 412 ppb.
Benzene[3]	15 / 237	3	5	MCL	7	NOAND1	11/08/1990	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Beryllium	36 / 196	20	4	MCL	28.1	NOAND5	6/18/1991	Elevated levels of beryllium have only been found in GW-169 in Union Valley; however, several wells in the EFPC floodplain have shown concentrations above the CV.
Boron	183 / 184	75	100	EMEG	2900	GW-232	3/12/1991	All samples detected above the CV have come from wells located within the known extent of the EEVOC.
Carbon tetrachloride	45 / 244	26	7	RMEG	200	GW-170	11/17/1994	All samples detected above the CV have come from one well, GW-170, located within the known extent of the EEVOC.
Chloroform [4]	52 / 249	1	100	EMEG	134	GW-170	2/2/1994	Samples collected on the same day from the same well were below the CV. Subsequent samples were also below the CV.
Chromium [4]	88 / 354	13	100	LTHA	720	GW-169	4/27/1992	Subsequent samples were well below the CV for chromium.
Cobalt [4]	74 / 354	3	100	EMEG	144	WFANE1	11/19/1990	In two of the three wells where samples exceeded the CV, subsequent samples were below the CV.
Copper [4]	139 / 354	10	100	EMEG	6320	WFANE1	11/19/1990	Most samples detected above CVs were taken from wells in the EFPC Floodplain.

Substance	Detects / Samples	Samples Detected Above CVs	CV (ppb)	CV Source	Max Conc. (ppb)	Max Location	Max Conc. Date[2]	Comments
Dibenzo(a,h) anthracene [3]	11 / 113	11	0.009	RBC for Tap Water	11	BRAND7	11/2/1990	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Flouride [4]	124 / 198	1	4000	MCL	4900	GW-169	5/18/2000	Only one sample exceeded the CV. Concurrent and subsequent samples from adjacent wells were below the CV.
Ideno(1,2,3-cd)pyrene [3]	15 / 113	15	0.092	RBC for Tap Water	12	WAANE12	3/14/1991	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Iron [4]	300 / 354	78	10950	RBC for Tap Water	200000	GW-169	9/28/1995	The only well in Union Valley with elevated iron levels was GW-169. All other samples exceeding the CV were in the EFPC Floodplain.
Lead	93 / 296	38	15	MCLG	1200	GW-169	4/27/1992	Samples from both Union Valley and the EFPC floodplain exceeded the CV.
Manganese	309 / 354	193	500	RMEG	27600	NOAND3	6/18/1991	Samples from both Union Valley and the EFPC floodplain exceeded the CV.
Mercury [3]	41 / 119	22	2	MCL	280	WFANE1	11/19/1990	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Methylene chloride [3]	130 / 250	4	600	EMEG	4200	BRAND7	11/2/1990	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Nickel [4]	100 / 358	16	100	LTHA	657	WFANE1	11/19/1990	Samples from both Union Valley and the EFPC floodplain exceeded the CV.
Selenium [4]	37 / 259	4	50	EMEG	72	GW-230	9/20/1995	All samples detected above the CV have come from wells located within the known extent of the EEVOC.
Tetrachloro-ethylene [4]	77 / 259	23	5	MCL	11	GW-170	11/17/1994	All samples detected above the CV have come from wells located within the known extent of the EEVOC.
Thallium	38 / 88	38	2	MCL	7	GW-170	2/2/1994	All but one sample detected above CVs were taken from wells in the EFPC Floodplain. Only one sample was detected above the CV in GW-170 in 1994. Thallium was never detected in adjacent wells. Subsequent sampling for thallium in GW-170 has not been conducted.
Trichloro-ethylene [4]	67 / 261	3	5	MCL	6	GW-169	3/1/1991	All samples detected above the CV have come from wells located within the known extent of the EEVOC.
Vanadium [4]	80 / 366	37	30	EMEG	300	GW-169	9/28/1995	The only well in Union Valley with elevated vanadium levels was GW-169. All other samples exceeding the CV were in the EFPC Floodplain.
Zinc	272 / 354	7	3000	EMEG	12000	GW-230	6/18/1996	All samples detected above the CV have come from wells located within the known extent of the EEVOC.

PLEASE SEE APPENDIX A FOR DEFINITIONS OF TERMS USED IN THIS TABLE

[1]Several locations reported the same maximum concentration. All locations were in the EFPC Floodplain.
[2]Where more than one sampling location yielded the same maximum concentration, the most recent sample date is reported.
[3]Contaminants detected above CVs only in the EFPC Floodplain.
[4]In all subsequent samples from wells in Union Valley, contaminants were either detected below CVs or not detected at all.

Table 5: Radionuclides Detected Above CVs in Monitoring Wells Near the Y-12 Complex

Radionuclide	*Detects / Samples*	*Samples Detected Above CVs*	*CV (pCi/L)*[1]	*Max Conc. (pCi/L)*	*Max Location*	*Max Date*	*Comments*
Alpha radiation	122 / 177	9	15	81.3	GW-232	11/7/2001	Subsequent samples in all wells have been below detection limit.
Am-241	70 / 72	38	7.25	110	NOAND1	3/8/1991	All samples above the CV were from the EFPC Floodplain.
Beta radiation	164 / 189	5	50	2560	GW-230	8/7/2002	Subsequent samples in all wells have been either below detection limit or below the CV.
Gross beta	41 / 41	1	50	57.5	GW-169	9/28/1995	Concurrent sampling from this well yielded 4.9 pCi/L.
Iodine-129	27 / 27	2	14	21.6	GW-170	3/22/1995	Subsequent samples in all wells have been below the CV.
Neptunium-237	52 / 53	29	13.8	239	WEANE3	3/8/1991	All samples above the CV were from the EFPC Floodplain.
Radium	109 / 109	14	5	26.3	NOAND2	11/8/1990	All samples above the CV were from the EFPC Floodplain except one from GW-169. Subsequent samples from GW-169 were below the CV.
Radium-228	5 / 8	1	2	2.11	GW-230	12/13/1995	Subsequent samples have been either below detection limit or below the CV.
Thorium-234	13 / 13	3	435	655	GW-172	9/26/1994	Subsequent sampling has not occurred.
Uranium-234	111 / 113	8	30	109	WFANE1	11/19/1990	All samples above the CV were from the EFPC Floodplain.
Uranium-235	87 / 114	2	30	54.9	GW-230	9/28/1994	Subsequent samples have been either below detection limit or below the CV.
Uranium-238	119/ 124	7	30	115	WFANE1	11/19/1990	All samples above the CV were from the EFPC Floodplain.

[1]Based on Federal Guidance 13, two liters water/day

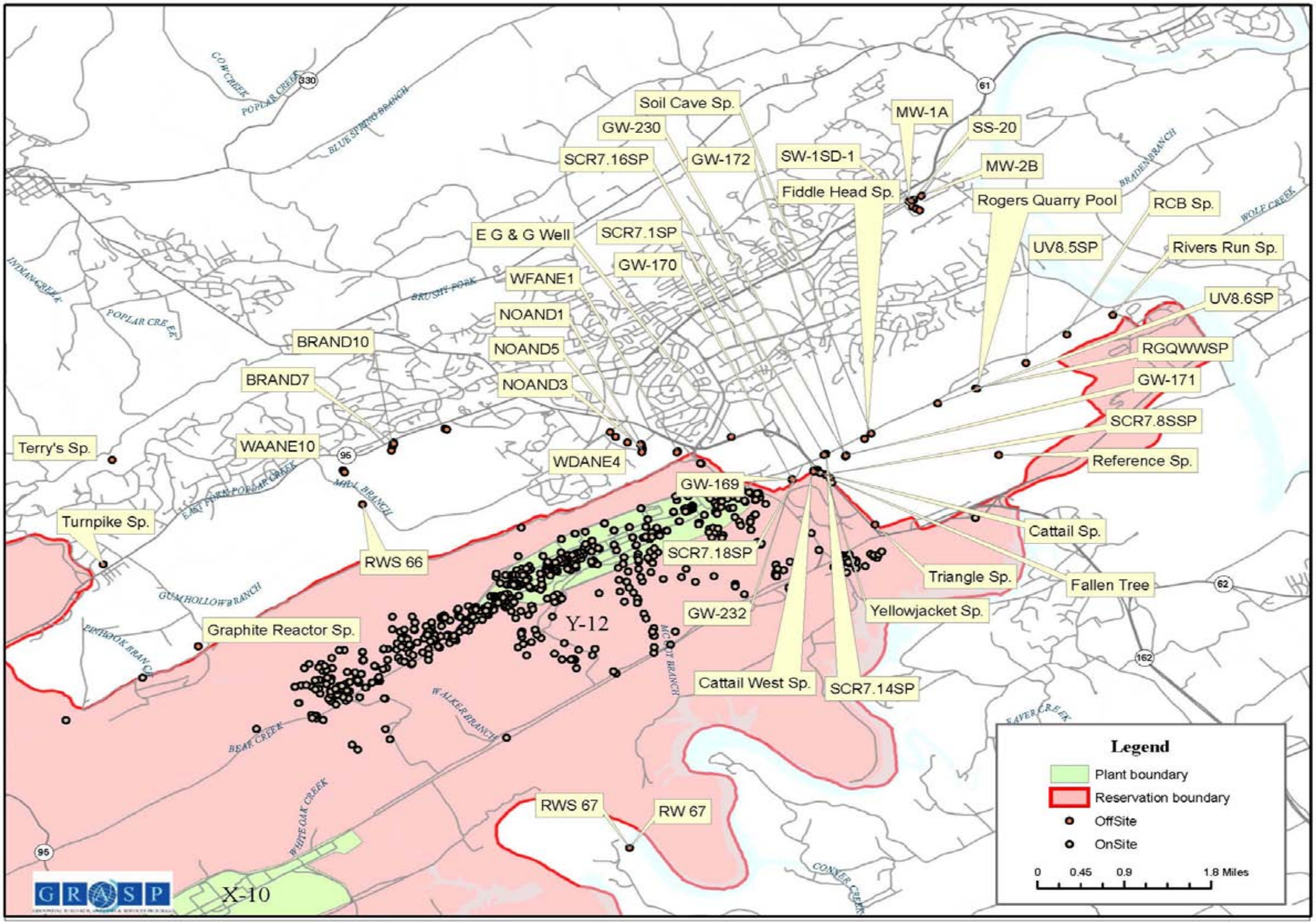


Figure 14: Off-Site Groundwater Sampling Locations Near the Y-12 Complex

ATSDR's Conclusion for Bear Creek Valley and UEFPC Watersheds

The most successful remediation efforts in FY 2002 and FY 2003 occurred in Bear Creek Valley. The uranium flux throughout the watershed decreased markedly. The EEVOC plume in the UEFPC Watershed has been subject to aggressive pump and treat remedial efforts since August of 1999 when an action memorandum was issued to begin installation and testing of a groundwater extraction well. Actual pumping of the plume commenced in June of 2000. Administrative controls set forth in the 1997 Interim ROD for Union Valley are deemed protective of public health. Since the EEVOC groundwater plume extends off-site into Union Valley, ATSDR scientists will evaluate possible exposure scenarios for this area in the *Evaluation of Environmental Contamination and Potential Exposure Pathways* section of this document.

II.G. Land Use and Natural Resources

When the ORR was acquired in 1942, the government reserved a section of the reservation (about 14,000 acres out of the total of approximately 58,575) for housing, businesses, and support services (ChemRisk 1993d; ORNL 2002). In 1959, that section of the ORR was turned into the independently governed city of Oak Ridge. This self-governing area has parks, homes, stores, schools, offices, and industrial areas (ChemRisk 1993d).

The majority of residences in Oak Ridge are located along the northern and eastern borders of the ORR (Bechtel Jacobs Company LLC et al. 1999). However, since the 1950s, the urban population of Oak Ridge has grown toward the west. As a result of this expansion, the property lines of many homes in the city's western section border the ORR property (Faust 1993 as cited in ChemRisk 1993d). Apart from these urban sections, the areas close to the ORR continue to be mainly rural, as they have historically been (Bechtel Jacobs Company LLC et al. 1999; ChemRisk 1993d). The closest homes to X-10 are located near Jones Island, about 2.5 to 3.0 miles southwest of the main facility (ChemRisk 1993d).

In 2002, the ORR measured 34,235 acres, which includes the three main DOE facilities: Y-12, X-10, and K-25 (ORNL 2002). The majority of the ORR is situated within the city limits of Oak Ridge. These DOE facilities constitute approximately 30% of the reservation; the remaining 70% of the reservation was turned into the National Environmental Research Park in 1980. This park was created so that protected land could be used for environmental education and research, and to show that the development of energy technology could be compatible with a quality environment (EUWG 1998). A large amount of land at the ORR that was formerly cleared for farmland has grown into full forests over the past several decades. Sections of this land contain areas called "deep forest" that include flora and fauna considered ecologically significant, and portions of the reservation are regarded as biologically rich (SAIC 2002).

Historically, forestry and agriculture (beef and dairy cattle) have constituted the primary uses of land in the area around the reservation. However, these uses of land are both declining. For several years, milk produced in the area was bottled for local distribution, whereas beef cattle from the area were sold, slaughtered, and nationally distributed. In addition, tobacco, soybeans, corn, and wheat were the primary crops grown in the area. Also, small game and waterfowl were hunted on a regular basis in the ORR area, but deer were hunted during specific time periods

(ChemRisk 1993d). Waterfowl and small game hunting regularly occurs within the ORR area, while deer hunting occurs annually on the ORR (ChemRisk 1993d). During the annual deer hunts, radiological monitoring is conducted on all deer prior to their release to the hunters. Monitoring is conducted to ensure that none of the animals contain quantities of radionuclides that could cause "significant internal exposure" to the consumer (Teasley 1995).

The southern and western boundaries of the ORR are formed by the Clinch River; Poplar Creek and East Fork Poplar Creek drain the ORR to the north and west (Jacobs EM Team 1997b). White Oak Creek, which travels south along the eastern border of the X-10 site, flows into White Oak Lake, over White Oak Dam, and into the White Oak Creek Embayment before meeting the Clinch River at CRM 20.8 (ChemRisk 1993b, 1999a; TDOH 2000; U.S. DOE 2002a). Ultimately, every surface water system on the reservation drains into the Clinch River (ChemRisk 19993b). The Lower Watts Bar Reservoir is situated downstream of the ORR, extending from the confluence of the Clinch and Tennessee Rivers to the Watts Bar Dam (U.S. DOE 1995a as cited in ATSDR 1996). As a result, the Clinch River and the Lower Watts Bar Reservoir have received contaminants associated with X-10 operations (Jacobs EM Team 1997b; U.S. DOE 1995a; U.S. DOE 2001a). Please see Figure 1 for these relative water systems.

The majority of land around the Clinch River and the Lower Watts Bar Reservoir is undeveloped and wooded. Other than activities at the ORR, there is minimal industrial development in these surrounding areas, and there is a fair amount of residential growth. The public has access to the Clinch River and to the Lower Watts Bar Reservoir, which it uses for recreational purposes such as boating, swimming, fishing, water skiing, and shoreline activities (U.S. DOE 1996d, 2001b, 2003b).

Land use in Union Valley, just east of the Y-12 complex, is zoned by the City of Oak Ridge primarily as "Forestry, Agriculture, Industry, and Research District". The land over the presumed extent of the off-site contaminant plume is zoned as "Industrial District 2". None of the current landowners in Union Valley extract groundwater for residential use. Extracted groundwater from dewatering of the quarry on lot Excess (613) by Rogers Group, Inc. is discharged to surface water. No contamination has been found in the quarry water. The closest "One-Family Residential District" is 2.25 miles east of the known extent of the EEVOC plume (DOE 1997).

> None of the current landowners in Union Valley extract groundwater for residential use. The nearest residential well is over 2 miles from the EEVOC groundwater plume.

II.H. Demographics

Demographic data provide information on the size and characteristics of a given population. ATSDR examined demographic data to determine the number of people living in the vicinity of the ORR and to determine the presence of sensitive populations, such as children (age 6 years and younger), women of childbearing age (age 15 to 44 years), and the elderly (age 65 years and older). According to the 2000 U.S. Census, 153 children, 403 women of childbearing age, and 423 elderly persons live within a quarter mile from the ORR; and 778 children, 1,935 women of childbearing age, and 1,681 elderly persons live within a mile of the ORR (see Figure 15).

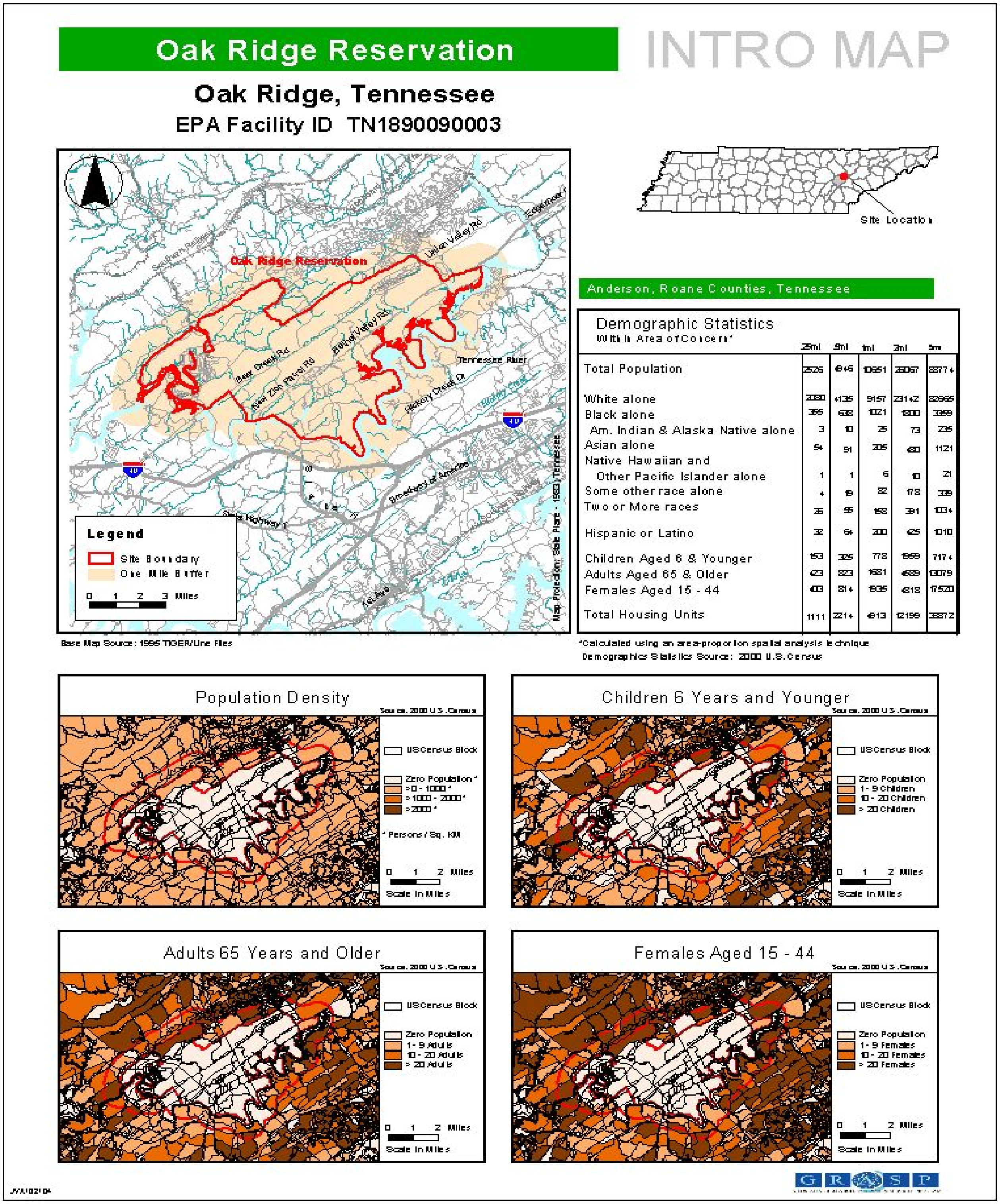
Demographics also provide details on population mobility and residential history in a particular area. This information helps ATSDR evaluate how long residents might have been exposed to environmental contaminants. The number of people living in the counties surrounding the ORR from 1940 to 2000, are listed in Table 6.

Table 6: Population of Surrounding Counties from 1940 to 2000

County	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Anderson County	26,504	59,407	60,032	60,300	67,346	68,250	71,330
Blount County	41,116	54,691	57,525	63,744	77,770	85,969	105,823
Knox County	178,468	223,007	250,523	276,293	319,694	335,749	382,032
Loudon County	19,838	23,182	23,757	24,266	28,553	31,255	39,086
Meigs County	6,393	6,080	5,160	5,219	7,431	8,033	11,086
Morgan County	15,242	15,727	14,304	13,619	16,604	17,300	19,757
Rhea County	16,353	16,041	15,863	17,202	24,235	24,344	28,400
Roane County	27,795	31,665	39,133	38,881	48,425	47,227	51,910

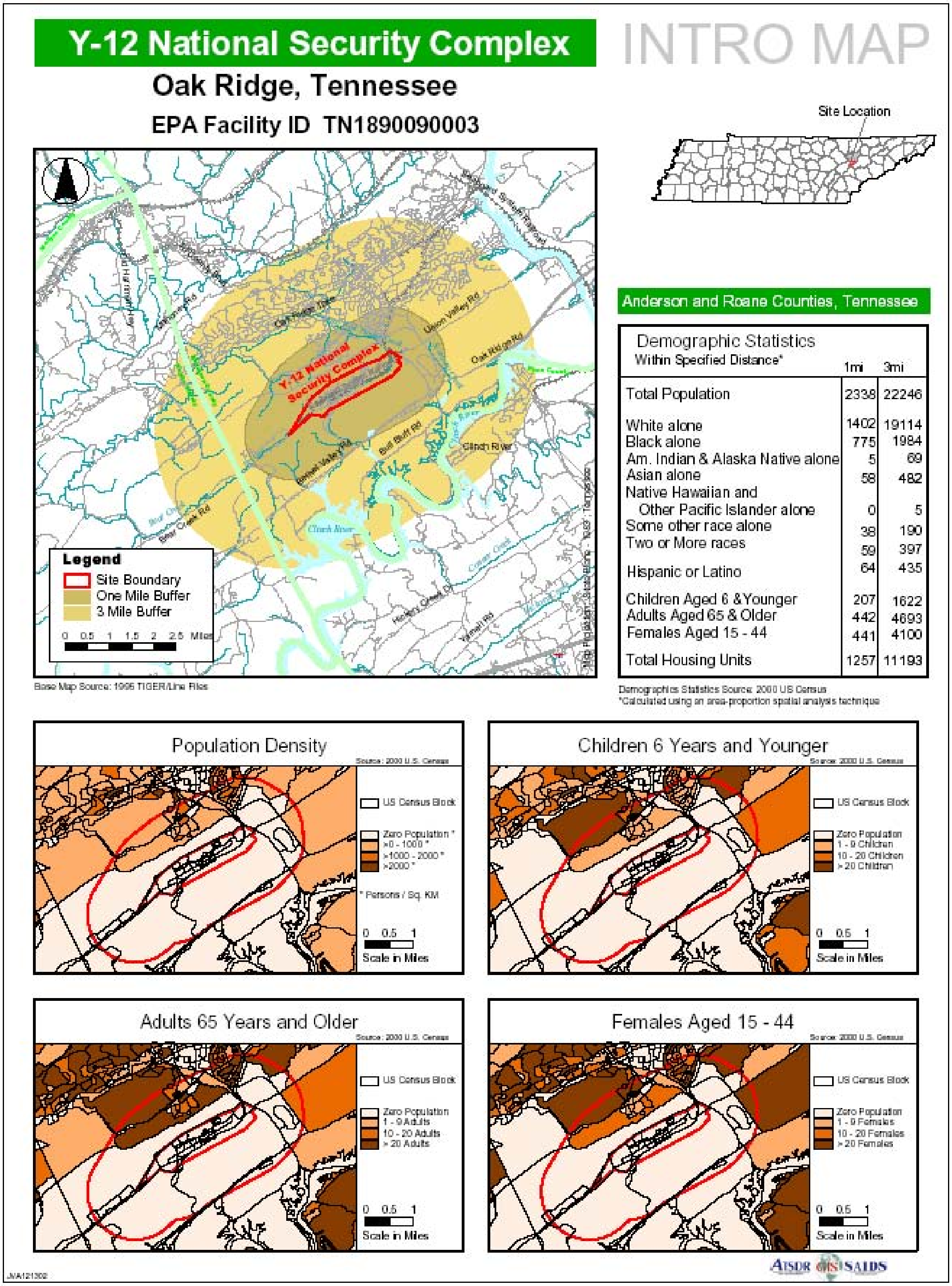
Sources: U.S. Bureau of the Census 1900–1990, 2000

Figure 15 shows the demographics within a 5 mile radius of the ORR boundary. As previously mentioned, most of the residents of the Oak Ridge and surrounding communities, live along the northern and northeastern borders of the site. Figure 16 shows the population distribution within a one and 3 mile radius of the Y-12 complex – the only area where groundwater contamination has migrated off-site. Surrounding the area of known off-site EEVOC plume, along Union Valley Road to the east-northeast of the Y-12 complex, there are no residences. For more information concerning the demographics of the surrounding towns please refer to the following Public Health Assessments: Former K-25 and S-50 Sites Air Releases, Y-12 Uranium Releases, and White Oak Creek Radionuclide Releases.



Demographic Statistics Within Area of Concern*	.25mi	.5mi	1mi	2mi	5mi
Total Population	2526	4945	10651	25067	58774
White alone	2080	4135	9157	23142	52965
Black alone	395	638	1021	1800	3359
Am. Indian & Alaska Native alone	3	10	25	73	235
Asian alone	54	91	205	480	1121
Native Hawaiian and Other Pacific Islander alone	1	1	6	10	21
Some other race alone	4	19	32	178	339
Two or More races	25	55	158	391	1034
Hispanic or Latino	32	64	200	425	1010
Children Aged 6 & Younger	153	325	778	1969	7174
Adults Aged 65 & Older	423	823	1681	4589	13079
Females Aged 15 - 44	403	814	1935	4818	17520
Total Housing Units	1111	2214	4813	12199	33872

Figure 15: Demographics Within 5 Miles of ORR



Demographic Statistics Within Specified Distance*	1mi	3mi
Total Population	2338	22246
White alone	1402	19114
Black alone	775	1984
Am. Indian & Alaska Native alone	5	69
Asian alone	58	482
Native Hawaiian and Other Pacific Islander alone	0	5
Some other race alone	38	190
Two or More races	59	397
Hispanic or Latino	64	435
Children Aged 6 & Younger	207	1622
Adults Aged 65 & Older	442	4693
Females Aged 15 - 44	441	4100
Total Housing Units	1257	11193

Figure 16: Demographics within 1 and 3 miles of the Y-12 Complex

III. Evaluation of Environmental Contamination and Potential Exposure Pathways

A release of a contaminant from a site does not always mean that the substance will have a negative impact on a member of the off-site community. For a substance to pose a potential health problem, exposure must first occur. Human exposure to a substance depends on whether a person comes in contact with the contaminant, for example by breathing, eating, drinking, or touching a substance containing it. If no one comes into contact with a contaminant, then no exposure occurs—and thus no health effects can occur. Even if the site is inaccessible to the public, contaminants can move through the environment to locations where people could come into contact with them.

ATSDR evaluates site conditions to determine if people could have been or could be exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation. ATSDR also identifies an exposure pathway as *completed* or *potential,* or *eliminates the pathway from further evaluation*. Completed exposure pathways exist if all elements of a human exposure are present. A release of a chemical or radioactive material into the environment does not always result in *human exposure*. For an exposure to occur, a *completed exposure pathway* must exist. A *completed exposure pathway* exists when all of the following five elements are present:

1. a source of contamination,
2. an environmental medium through which the contaminant is transported,
3. a point of human exposure,
4. a route of human exposure, and
5. an exposed population.

A *potential exposure pathway* exists when one or more of the elements are missing but available information indicates possible human exposure. An *incomplete exposure pathway* exists when one or more of the elements are missing and available information indicates that human exposure is unlikely to occur (ATSDR 2001). In addition, for each exposure pathway ATSDR scientists identify whether releases of contaminants and exposures are likely to have occurred in the past, are currently occurring, or could potentially occur in the future.

In preparing this PHA, ATSDR reviewed and evaluated environmental data provided to ATSDR scientists directly from the Department of Energy or in various reports prepared by the Environmental Protection Agency Region IV, the Tennessee Department of Environment and Conservation (TDEC) DOE Oversight Division, or their contractors. ATSDRs evaluation included the identification of inconsistencies and data gaps. The validity of analyses and conclusions drawn in this PHA are based on the reliability of the information referenced in reports related to the Oak Ridge Reservation (ORR). In our assessment, the quality of environmental data available in these documents is sufficient for public health decisions.

This public health assessment is exclusively focused on human exposure to off-site groundwater. Exposure to other media is discussed in other health assessments of ORR performed by ATSDR.

Since off-site groundwater contamination only occurs in the area immediately east of Y-12, in Union Valley, this is the only area where exposure scenarios are evaluated. ATSDR scientists have identified three possible exposure scenarios to the EEVOC plume (Table 9). The first exposure scenario involves withdrawal of groundwater for personal use from private groundwater wells. This exposure pathway was eliminated because there is no point of exposure, and there is no receptor population. No groundwater contaminant has been detected above CVs in residential wells, except one sample collected near ETTP in 1998 where boron was detected at a concentration slightly higher than the CV. As previously mentioned, the closest residential well to the EEVOC plume is approximately 2.25 miles away. There is no groundwater being withdrawn for personal use in Union Valley. Institutional controls implemented in accordance with the Interim ROD for Union Valley (DOE 1997) serve to help ensure that no one is drinking contaminated groundwater now or in the future. Residents near ORR who are consuming groundwater are not being exposed to contamination emanating from ORR.

Site-related contaminants have not been detected beyond the ORR boundaries near either the ETTP or the ORNL.

The second exposure scenario evaluated was the possibility of someone coming in direct contact with groundwater at seeps or springs in Union Valley. Since the land overlying the known extent of the contaminant plume is zoned as "Industrial District 2", it is unlikely that individuals will come in contact with springs or seeps in this area. Also, most groundwater surfaces as diffuse discharge directly into Scarboro Creek. Indeed, groundwater constitutes the baseflow for Scarboro Creek in Union Valley (Figure 11). So, it is unlikely that individuals will come into direct contact with groundwater in seeps and springs before dilution with surface water occurs. Exposures to ORR related contaminants in surface waters are excluded in this PHA but are addressed in various other PHAs including: the White Oak Creek PHA, Y-12 Uranium PHA, and the Current and Future Chemical PHAs.

Based upon currently available data, there are no *completed exposure pathways* for ingestion or direct contact with off-site groundwater. Because of the shallow water table at ORR and the high interconnectivity of the groundwater with the surface water, contaminated groundwater transport is typically along short flow-paths to surface water. The EEVOC plume, east of the Y-12 complex, is the only confirmed off-site groundwater plume. This area is zoned for industrial purposes; therefore, there are no residential areas and, consequently, there are no private wells in use in this area. In fact, the only groundwater withdrawal occurring is from the dewatering operations of the quarry at lot Excess (613) near the eastern end of Union Valley. Contamination has never been detected in the quarry groundwater (DOE 1997). For these reasons, and because there is no point of exposure or receptor population for contaminated groundwater, ATSDR has determined that there are no *completed exposure pathways* for ingestion or direct contact with off-site groundwater.

Vapor Intrusion as a Potential Exposure Pathway

Vapor intrusion is the migration of volatile chemicals from subsurface soil or groundwater into overlying buildings (USEPA 2002c). Volatile organic compounds (VOCs) present in buried wastes in soil and/or in groundwater can emit vapors that may migrate through subsurface soils and into indoor air spaces of overlying buildings (NJDEP 2005). Often, the vapor concentrations in residences or occupied buildings are low and vapors may not be present at detectable levels, based on the specific conditions of the site. In extreme cases, the vapors may accumulate to levels that may pose safety hazards, acute and/or chronic health effects, or aesthetic issues (USEPA 2002c). As such, vapor intrusion has evolved as a potential exposure pathway of consideration in the investigation of contaminated sites.

Three off-site monitoring wells (GW-169, GW-170, and GW-232) near the Y-12 Complex and within the known extent of the EEVOC groundwater contaminant plume contained twelve contaminants with at least one sample above CVs. The contaminants included the following: aluminum, arsenic, boron, carbon tetrachloride, chloroform, chromium, fluoride, iron, lead, tetrachloroethylene, thallium, and trichloroethylene (Table 4). Of the above-mentioned contaminants detected, only carbon tetrachloride, chloroform, tetrachloroethylene, and trichloroethylene are VOCs. The following VOCs were either absent or detected at concentrations below the CVs in all subsequent samples: chloroform, tetrachloroethylene, and trichloroethylene. In addition, sampling of off-site residential wells near the Y-12 Complex, including the nearest residential well (RWS 67) approximately 2.25 miles east of the known extent of the EEVOC plume, found no contaminants above CVs.

In evaluating potential exposure to groundwater contaminants via vapor intrusion, ATSDR considered the ORR groundwater hydrology. Nearly all groundwater beneath the ORR migrates to surface water before leaving the ORR boundaries. Therefore, additional migration of groundwater contamination off site is unlikely, due to the widespread diffuse discharge of groundwater into the surface water bordering the site.

No residences exist over the EEVOC groundwater contaminant plume. In addition, areas in Union Valley overlying the known extent of the contaminant plume are zoned as "Industrial District 2." There is, however, a portion of an office building overlying the mapped extent of the EEVOC plume in Union Valley (Figure 13). This office building is on Scarboro Rd. just east of the Y-12 Complex. The building is currently used by DOE contractors. Because the apparent extent of the EEVOC plume is beneath this building, it is necessary to evaluate the possibility of vapor intrusion into the workspaces within this building.

The EEVOC groundwater contaminant plume contains carbon tetrachloride, a contaminant of sufficient volatility to be of concern for vapor intrusion. In order to estimate the transport of contaminant vapors from a subsurface source into indoor air spaces, the Johnson-Ettinger Model (JEM) was developed as a screening level model (available at http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm). Since the JEM is a screening tool, it is based on several conservative assumptions regarding contaminant distribution and occurrence, subsurface characteristics, transport mechanisms, and building construction (USEPA 2004).

Since most of the required JEM input data are not collected during a typical site characterization, conservative inputs were estimated or inferred from available data and other non-site specific sources of information. A groundwater screening model was utilized to estimate the carbon tetrachloride vapor concentration in the building that overlays the EEVOC groundwater contaminant plume.

Table 7 outlines the conservative default parameters and assumptions used in the JEM. The JEM was used to consider carbon tetrachloride vapor intrusion into the building that overlays the EEVOC plume through two soil types (silt and silt clay). Because it is unknown whether the building has a basement or slab-on-grade, the JEM was used to consider both possibilities.

Table 7: JEM Groundwater Screening Model Variables for Vapor Intrusion of Carbon Tetrachloride1 into the Building that Overlays the Off-Site EEVOC Groundwater Plume

JEM Variable	*Silt Value*	*Silty Clay Value*	*Notes*
Depth below grade to bottom of enclosed space floor	200 cm (B) [2] 15 cm (S) [2]	200 cm (B) 15 cm (S)	Default parameters were used to consider a building constructed with a basement or on a slab.
Depth below grade to water table	364 cm (B) 179 cm (S)	393 cm (B) 208 cm (S)	Regardless of the depth to water, the JEM requires a minimum depth to account for capillary fringe. The capillary fringe is 164 cm for buildings that overlay silt and 193 cm for buildings that overlay silty clay. The shallowest depth allowed by the model was utilized for both the basement and slab scenarios.
Soil type directly above the water table	Silt (B) Silt (S)	Silty Clay (B) Silty Clay (S)	JEM was utilized to consider vapor intrusion into an occupational building with either a basement or a slab, which overlays two types of soil (silt and silty clay). Both types of soil are found in the area of the building.
Average groundwater temperature	15ºC (B) 15ºC (S)	15ºC (B) 15ºC (S)	Average shallow groundwater temperature for Tennessee was calculated by taking the average of the shallow groundwater zones north (14ºC) and south (16ºC) of the state of Tennessee (Figure 8; USEPA 2004).
Vadose zone soil type	Silt (B) Silt (S)	Silty Clay (B) Silty Clay (S)	JEM was utilized to consider vapor intrusion into an occupational building with either a basement or a slab, which overlays two types of soil (silt and silty clay). Both types of soil are found in the area of the building.
Vadose zone soil dry bulk density	1.50 g/cm^3 (B) 1.50 g/cm^3 (S)	1.50 g/cm^3 (B) 1.50 g/cm^3 (S)	The universal default parameter which is consistent with USEPA (1996a and b) for subsurface soils.
Vadose zone soil total porosity	0.43 (B) 0.43 (S)	0.43 (B) 0.43 (S)	The universal default parameter which is consistent with USEPA (1996a and b) for subsurface soils.
Vadose zone soil water-filled porosity	0.05 cm^3/cm^3 (B) 0.05 cm^3/cm^3 (S)	0.11 cm^3/cm^3 (B) 0.11 cm^3/cm^3 (S)	Conservative default parameters for the vadose zone silt and silty clay water-filled porosity (Table 10; USEPA 2004).

[1] The predominant VOC in the EEVOC groundwater contaminant plume is carbon tetrachloride. The maximum concentration (200 ppb) of carbon tetrachloride was detected (11/17/1994) above the CV from well GW-170, which is located within the known extent of the EEVOC.

[2] B = building with a basement; S= building built on a slab

Irrespective of the type of soil that underlies the building (silt or silty-clay), the carbon tetrachloride concentration was estimated to be slightly higher in a building with a basement, as opposed to a building with slab-on-grade construction (Table 8). To evaluate whether workers in this office building are being exposed to levels of VOCs that could potentially result in adverse health effects, ATSDR compared the JEM estimated carbon tetrachloride vapor concentrations to ATSDR's CVs, as well as to occupational exposure guidelines from the Occupational Health and Safety Administration (OSHA) and from the National Institute for Occupational Health and Safety (NIOSH) (Table 8).

Table 8: Estimated Vapor Concentration of Carbon Tetrachloride in the Office Building that Overlays the Off-Site EEVOC Groundwater Plume

Building	*Silt*	*Silty Clay*	*ATSDR CREG*[1]	*ATSDR EMEG*[2]	*OSHA PEL*[3]	*NIOSH REL*[4]
Basement	2.13 ppb	0.26 ppb	0.01 ppb	30 ppb	TWA = 10,000 ppb C = 25,000 ppb 200,000 ppb peak	ST = 2,000 ppb (60-minute)
Slab	1.80 ppb	0.22 ppb				

C = ceiling
ppb = part per billion
ST = short-term exposure limit
TWA = time-weighted average

[1] The cancer risk evaluation guide (CREG) is a highly conservative value that would be expected to cause no more than one excess cancer in a million persons exposed over time.
[2] The environmental media evaluation guide (EMEG) is a media-specific comparison value that is used to select contaminants of concern. Levels below the EMEG are not expected to cause adverse non-carcinogenic health effects.
[3] Occupational Safety and Health Administration (OSHA) permissible exposure levels (PELs) are regulatory limits on the amount or concentration of a substance in the air one may be exposed to over an 8-hour workday during a 40-hour workweek.

- TWA concentrations for OSHA PELs must not be exceeded during any 8-hour work shift of a 40-hour workweek.
- OSHA ceiling concentrations (C) must not be exceeded during any part of the workday; if instantaneous monitoring is not feasible, the ceiling must be assessed as a 15-minute TWA exposure.
- There is also a 200,000 ppb peak, which means that a 5-minute exposure above the ceiling value, but never above the maximum peak, is allowed in any 4 hours during an 8-hour workday.

[4] The National Institute of Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) indicates a time-weighted average (TWA) concentration for up to a 10-hour workday during a 40-hour workweek. Specifically, the short-term exposure limit (ST) is a 15-minute TWA exposure that should not be exceeded at any time during a workday.

It is important to note that this evaluation was conservative for the following reasons:

* The maximum carbon tetrachloride concentration (200 ppb), rather than an average, from an off-site groundwater monitoring well in the EEVOC plume was used in the calculations. Further, carbon tetrachloride was only detected in 45 of 244 samples, and only 26 of these detections were higher than 7 ppb.

* Default parameters and assumption variables were entered into the model, due to the lack of information regarding the building characteristics and specific depth of the

EEVOC groundwater plume in this area. In general, using the default parameters for input variables will result in higher indoor air concentrations (USEPA 2004).

* ATSDR assumed that the EEVOC plume exists in the shallow, transient groundwater zone (between 1 and 7 feet below ground; USGS 1989). The depth below grade to water table variable was the smallest depth one could assume, given the inherent capillary fringe requirement.

In all instances, the estimated vapor concentrations of carbon tetrachloride in the office building are much less than ATSDR's environmental media evaluation guide (EMEG) and the OSHA and NIOSH regulatory limits. Even though the estimated vapor concentrations are above the cancer risk evaluation guide (CREG), ATSDR does not expect vapor intrusion to be a concern for the people who work in the building that overlays the EEVOC plume, especially given the conservative nature of the evaluation. The CREG is a highly conservative CV that is based on exposure in a residential setting 24 hours/day, every day of the year. Occupational (i.e., 8 hours/day, 40 hours/week) exposure would be much lower.

Based on currently available data and the results of the JEM, ATSDR concludes that groundwater *does not pose a public health hazard* via a vapor intrusion exposure pathway. Although the EEVOC groundwater contaminant plume emanating from the Y-12 complex has migrated off site, no residences overlay the plume. The nearest residence is approximately 2.25 miles east of the known extent of the EEVOC plume. One office building partially overlies the plume; however, conservative modeling indicates that estimated VOC concentrations are well below the EMEG and several orders of magnitude below the regulatory limits for occupational exposure.

Table 9: Exposure Pathways

Pathway	*1. Source of Contamination*	*2. Fate and Transport*	*3. Point of Exposure*	*4. Route of Exposure*	*5. Receptor Population*	*Time Frame*	*Conclusion for Pathway*
	Five Components of a **Completed** *Exposure Pathway*						
Contacting GW from Private wells in Union Valley	EEVOC Plume from the Y-12 Complex	Plume is migrating east along strike in the Maynardville Limestone Formation. It extends off-site into Union Valley.	**None.** There are no residences deriving drinking water from private wells in this area.			Past, Present, Future	**Incomplete**
Contacting groundwater from seeps and springs in Union Valley	EEVOC Plume from the Y-12 Complex	EEVOC plume has migrated off-site and discharges at various seeps and springs throughout Union Valley	**Potential** use of, or contact with, spring water from Union Valley.	Ingestion, dermal contact, inhalation	**None likely.** Seeps and springs feed Scarboro creek so isolated contact with groundwater from seeps and springs before dilution in surface water is unlikely.	Past, Present, Future	**Incomplete**
Inhaling VOCs via vapor intrusion into buildings in Union Valley	EEVOC Plume from the Y-12 Complex	EEVOC plume has migrated off-site under	**Working in the office building immediately east of Y-12.**	Inhalation	**Individuals working in the building**	Past, present, future	**Potentially Complete**

IV. Public Health Implications

ATSDR scientists have determined that there are no *completed exposure pathways* for ingestion or direct contact with off-site groundwater at ORR. The only confirmed contamination to have migrated off-site was from EEVOC contaminated groundwater plume originating in the Y-12 Complex. There has been no site-related groundwater contamination detected off-site either at the ETTP (former K-25 and S-10), or the ORNL (former X-10) facilities. This is likely due to the widespread diffuse discharge of groundwater into the surface water bordering the site. Groundwater is a known contributor to surface water contamination throughout the ORR. However, this PHA only addresses human exposure to off-site groundwater.

Y-12

The exposure investigation of this document addressed three possible exposure scenarios for contacting contaminated groundwater emanating from the Y-12 complex, two were eliminated because there are no points of exposure (i.e., contaminants have not been detected above CVs in private wells and there is no ready access to springs and seeps) and there is no receptor population. Exposure to the contaminated groundwater is unlikely to occur because there are no private wells and no residences near the EEVOC plume in Union Valley. The third possible exposure pathway – vapor intrusion into an office building overlying the EEVOC plume – has been conservatively modeled with results indicating estimated VOC concentrations well below occupational regulatory guidelines. ATSDR scientists have determined that there are *no public health implications* associated with contaminants from the Y-12 Complex.

ETTP and ORNL

A discussion of how the groundwater of the ORR typically flows has been presented in this document in the *Site Geology/Hydrogeology* section. There, it is illustrated that groundwater movement beneath streams and rivers in this area is limited at best. While it is true that water does occur beneath the stream beds, most is actually taken up into the stream flow (gaining stream system) through diffuse discharge from the groundwater. Some groundwater can be retained in the alluvium beneath and adjacent to the stream beds in the hyporheic zone, but core samples near the UEFPC indicate that there is a glei horizon beneath the stream bed which limits downward groundwater migration (USGS1989). Cracks and fissures in the karst rock formations underlying ORR significantly decrease with depth, thereby further limiting migration of contaminants to shallow plumes intercepted by surface water either by seeps and springs, which are common throughout the ORR, or as baseflow for creeks and streams. Also, site-related contaminants have not been detected beyond the ORR boundaries near either ETTP or ORNL in seeps/springs, monitoring wells or residential wells. For these reasons, ATSDR scientists have determined that there are *no public health implications* related to exposure to contaminated groundwater from either ETTP or ORNL.

V. Health Outcome Data Evaluation

Health outcome data are measures of disease occurrence in a population. Common sources of health outcome data are existing databases (cancer registries, birth defects registries, death certificates) that measure morbidity (disease) or mortality (death). Health outcome data can provide information on the general health status of a community—where, when, and what types of disease occurs and to whom it occurs. Public health officials use health outcome data to look for unusual patterns or trends in disease occurrence by comparing disease occurrences in different populations over periods of years. These health outcome data evaluations are descriptive epidemiologic analyses. They are exploratory as they may provide additional information about human health effects and they are useful to help identify the need for public health intervention activities (for example, community health education). However, health outcome data cannot—and are not meant to—establish cause and effect between environmental exposures to hazardous materials and adverse health effects in a community.

ATSDR scientists generally consider health outcome data to evaluate the possible health effects in a population known to have been exposed to enough environmental contamination to experience health effects. In this pubic health assessment on off-site groundwater at ORR, ATSDR scientists determined that people were not and are not using private groundwater wells and were not exposed to ORR related contaminants from groundwater exposure. For these reasons, health outcome data will not be evaluated in this public health assessment.

VI. Community Health Concerns

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. ATSDR actively gathers comments and other information from the people who live or work near the ORR. ATSDR is particularly interested in hearing from residents of the area, civic leaders, health professionals, and community groups.

To improve the documentation and organization of community health concerns at the ORR, ATSDR developed a *Community Health Concerns Database* that is specifically designed to compile and track community health concerns related to the site. The database allows ATSDR to record, track, and respond appropriately to all community concerns, and also to document ATSDR's responses to these concerns. From 2001 to 2003, ATSDR compiled more than 2,500 community health concerns obtained from the ATSDR/ORRHES community health concerns comment sheets, written correspondence, phone calls, newspapers, comments made at public meetings (ORRHES and work group meetings), and surveys conducted by other agencies and organizations. These concerns were organized in a consistent and uniform format and imported into the database.

The community health concerns addressed in this public health assessment are those concerns in the ATSDR Community Health Concerns Database that are directly related to issues associated with groundwater contamination on-site and movement of the contaminant plume off-site. Table 10 contains the actual comments and ATSDR's responses.

Table 10: Community Health Concerns from the Oak Ridge Reservation Community Health Concerns Database and ATSDR Responses

#	*Comment*	*ATSDR Response*
1	Is the groundwater helping to contribute to kidney cancer? -and, Past exposures to arsenic from groundwater may have resulted in high levels of arsenic in my body.	Since ATSDR scientists have concluded that there is no exposure to contaminated groundwater from ORR (see the *Evaluation of Environmental Contamination and Potential Exposure Pathways* section of this document), it is unlikely that any incidence of kidney cancer or elevated levels of arsenic in the body of citizens in the surrounding area is attributable to consumption of groundwater.
2	Groundwater flows from the Y-12 plant to Scarboro.	The East End Volatile Organic Compound (EEVOC) plume flows east-northeast along strike, paralleling the underlying geology. Current DOE plume mapping indicates that the EEVOC is entirely in the Maynardville Limestone (part of the Conasauga Group – See Figure B-1), an aquifer formation with relatively high hydraulic conductivity. The Scarboro community is located on the Rome formation that consists of low-conductivity shales and siltstones. It is unlikely that water will migrate from areas with higher hydraulic conductivity to those with less.
3	What effect do the solid waste storage areas have on groundwater?	Solid waste storage areas (SWSA) are discussed in the *Melton Valley Watershed* section of this document.
4	Concern that communities that share a limestone slab with a burial ground or dumping ground might have contaminated groundwater.	A thorough investigation of the underlying geology of the ORR and surrounding areas, as well as the contaminated groundwater from ORR, with respect to the communities nearby is the focus of this public health assessment. We hope that the specific information we have presented in this PHA about each of the facilities at ORR has answered this general question about public contact with contaminated groundwater. For specific information regarding the geology and hydrology of the ORR, please refer to Appendix B.

VII. Conclusions

It is important for the reader to understand that ATSDR scientists acknowledge the fact that karst systems are notoriously difficult to fully characterize with respect to groundwater flow direction and rate. We have based our conclusions on currently available data concerning groundwater flow and specific contaminant fate and transport from well monitoring data. There are large solution cavities beneath ORR and the surrounding area which are often interconnected and have high flow rates. Some have been encountered in various well drilling activities or by casual observation, and some have yet to be discovered. Our conclusions are based upon well supported information of groundwater flow and contaminant transport. While much is unknown or fully understood about karst systems in general, it is our intention to assess the currently available data, and to arrive at a conclusion of whether the community has had (or is currently having) an exposure to contaminants in off-site groundwater.

Another point of consideration is that of the possibility of the over-pumping of groundwater wells creating a negative hydraulic gradient which could draw contaminants against the normal flow of groundwater. It is true that heavy well pumping can create a negative hydraulic gradient and cause groundwater to flow toward the well in all directions. Also, the theoretical potential exists for contaminated water to be drawn from surface water sources. However, based on available data, we do not believe this is occurring in residential wells or monitoring wells surrounding the reservation.

This public health assessment addresses off-site (community) exposures to contaminated substances released to the groundwater from the Oak Ridge Reservation. Having thoroughly evaluated past public health activities and available current environmental information, ATSDR has reached the following conclusions:

- Although extensive groundwater contamination exists throughout the ORR, ATSDR scientists have concluded that there is ***No Public Health Hazard*** from exposure to contaminated groundwater emanating from ORR. This conclusion category is used for sites that, because of the absence of exposure, do not pose a public health hazard. Sufficient evidence exists that no human exposures to contaminated groundwater have occurred, no exposures are currently occurring, and exposures are not likely to occur in the future (ATSDR 2005). The EEVOC plume emanating from the Y-12 complex is the only confirmed off-site groundwater plume. Table 9 illustrates the three exposure scenarios that were considered for this public health assessment: 1) contacting groundwater from private wells in Union Valley, 2) contacting groundwater from seeps and springs in Union Valley, and 3) vapor intrusion in to the off-site office building east of Y-12. Based on the fact that groundwater has short flow paths to surface water in this area and that there are no private wells pumping groundwater in this area, ATSDR scientists concluded that there were *no completed exposure pathways* for ingestion or direct contact with off-site groundwater. Also, extremely conservative modeling indicates that estimated VOC concentrations in the office building are much less than ATSDR's EMEG and the OSHA and NIOSH regulatory limits. Even though the estimated vapor concentrations are above the extremely conservative CREG, ATSDR does not expect vapor intrusion to be a concern for the people who work in the building that overlays the EEVOC plume.

- Groundwater and surface water are highly interconnected throughout the ORR. Groundwater flow in this area (ORR) is influenced largely on the extent of fractures in the bedrock which create preferential flow paths. In the regional aquifers of East Tennessee, including those underlying the ORR, fractures in bedrock are typically limited to the upper extents of the bedrock formations and significantly decrease with depth (MMES 1986, USGS 1986b, USGS 1988, USGS 1989, SAIC 2004). The numerous springs and seeps in the area support the notion of a very active shallow groundwater system in the ORR. Also, groundwater will flow along bedding planes and along strike, especially in areas where carbonate units have well-developed conduit systems (ORNL 1982, USGS 1997). Therefore, groundwater constitutes much of the baseflow of many streams and tributaries in the area, including East Fork Poplar Creek (USGS 1989, SAIC 2004). It is unlikely that contaminated groundwater at the ORR will flow beneath, and continue to flow away from, streams and rivers that surround the site. Indeed, the incised meander (see Appendix A) of the Clinch River in bedrock represents a major topographic feature that prevents groundwater from passing beneath the river (ORNL 1982).

VIII. Recommendations

Having evaluated past public health activities and the available environmental information, ATSDR recommends that the community be informed that ATSDR has evaluated off-site groundwater contamination from the Oak Ridge Reservation and has concluded that there is *no public health hazard* associated with past and current releases.

In this PHA, ATSDR scientists used every data source available to compile a database of off-site groundwater sampling results, albeit from monitoring wells, residential wells, or from seeps and springs nearby. While CERCLA requires groundwater monitoring, residential well sampling is not regularly conducted by either the State of Tennessee or by DOE. Therefore, we recommend that a regular periodic residential well-sampling program be initiated in order to assure that these wells remain free of ORR site-related contaminants.

ATSDR also recommends that institutional controls set forth in the Interim Record of Decision for Union Valley (Jacobs EM Team 1997a) remain in place to prevent exposure to contaminated groundwater. These controls should remain in place until all off-site contamination in Union Valley is reduced to below levels of health concern.

IX. Public Health Action Plan

The public health action plan for the Oak Ridge Reservation (ORR) contains a description of actions taken at the site and those to be taken at the site following the completion of this public health assessment. The purpose of the public health action plan is to ensure that this public health assessment not only identifies potential and ongoing public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to harmful substances in the environment. The following public health actions at the ORR are completed, ongoing, or planned:

Completed Actions

- In 1991, the Tennessee Department of Health (TDOH) began a two-phase research project to determine whether environmental releases from ORR harmed people who lived nearby. Phase I focused on assessing the feasibility of doing historical dose reconstruction and identifying contaminants that were most likely to have effects on public health. Phase II efforts included full dose reconstruction analyses of iodine 131, mercury, polychlorinated biphenyls (PCBs), and radionuclides, as well as a more detailed health effects screening analysis for releases of uranium and other toxic substances (a summary can be found in the *Oak Ridge Dose Reconstruction Project Summary Report, Volume 7*). Phase II was completed in January 2000. All of the final reports from Phase I and Phase II of the Oak Ridge Environmental Dose Reconstruction Project are accessible from the DOE public use database called Comprehensive Epidemiologic Data Resource (CEDR). This database contains information pertinent to health-related studies performed at Oak Ridge Reservation and other DOE sites. The URL for the Phase I and Phase II Dose Reconstruction Project is – http://cedr.lbl.gov/DR/dror.html.

- In 1992, the U.S. Department of Energy (DOE) conducted a *Background Soil Characterization Project* in the area around Oak Ridge (DOE 1993).

- In 1993, ATSDR evaluated public health issues related to past and present releases into the creek from the Y-12 Complex in a health consultation, *Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek* (ATSDR 1993).

- In 1996, ATSDR evaluated the current public health issues related to the past and present releases into the Lower Watts Bar Reservoir from the ORR in a *Health Consultation on the Lower Watts Bar Reservoir* (ATSDR 1996).

- In 1998, the Environmental Sciences Institute at Florida Agricultural and Mechanical University (FAMU), along with its contractual partners at the Environmental Radioactivity Measurement Facility at Florida State University, and the Bureau of Laboratories of the Florida Department of Environmental Protections, as well as DOE subcontractors in the Neutron Activation Analysis Group at Oak Ridge National Laboratory and the Jacobs Engineering Environmental Management Team, sampled soil, sediment, and surface water from Scarboro to address community concerns about environmental monitoring in the neighborhood (FAMU 1998).

- In 2001, the U.S. Environmental Protection Agency (EPA) collected samples of soil, sediment, and surface water from the Scarboro community to address community concerns and verify the results of the 1998 sampling conducted by FAMU (EPA 2003).

- In 2004, the Agency for Toxic Substances and Disease Registry (ATSDR) released the final ORR Public Health Assessment for Y-12 Uranium Releases.

Ongoing Actions

- ATSDR will continue to evaluate contaminants and pathways of concern to the community surrounding the reservation. In addition to this evaluation of groundwater, ATSDR is evaluating uranium from the Y-12 Complex, uranium and fluorides from the K-25 facility, iodine 131, mercury, White Oak Creek releases in the 1950s, PCBs, and the TSCA incinerator.

- In 1999, the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) was created under the guidelines and rules of the Federal Advisory Committee Act to provide a forum for communication and collaboration between citizens and the agencies that are evaluating public health issues and conducting public health activities at the ORR. The ORRHES serves as a citizen advisory group to CDC and ATSDR and provides recommendations on matters related to public health activities and research at the reservation. It also provides an opportunity for citizens to collaborate with agency staff members, to learn more about the public health assessment process and other public health activities, and to help prioritize public health issues and community concerns to be evaluated by ATSDR.

- DOE has developed a Groundwater Strategy document (USDOE 2004) that lays out a plan for making future decisions on groundwater remediation on the ORR on a watershed scale. Previously, groundwater contamination had been dealt with on a site-by-site basis. The goal is to evaluate various groundwater remediation technologies for that areas within the same water transport system (watershed) and have similar contamination problems and land uses in an effort to increase cost-effectiveness.

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XI. References

Alley W.M., Healy R.W., LaBaugh J.W., Reilly T.E. 2002. Flow and Storage in Groundwater Systems. *Science*. Vol 296, Issue 5575. June 14, 2002.

ATSDR (Agency for Toxic Substances and Disease Registry). 1993. Health Consultation for U.S. DOE Oak Ridge Reservation: Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek, Oak Ridge, Tennessee. April 5, 1993.

ATSDR. 1996a. Health consultation for U.S. DOE Oak Ridge Reservation: Lower Watts Bar Reservoir Operable Unit. Oak Ridge, Anderson County, Tennessee. Atlanta, Georgia: U.S. Department of Health and Human Services. February 1996.

ATSDR. 1996b. Health consultation for U.S. DOE Oak Ridge Reservation: proposed mercury clean-up level for the East Fork Poplar Creek floodplain soil, Oak Ridge, Anderson County, Tennessee. Atlanta: U.S. Department of Health and Human Services.

ATSDR, National Center for Environmental Health, National Institute for Occupational Safety and Health, Tennessee Department of Health, Tennessee Department of Environment and Conservation, U.S. Department of Energy. 2000. Compendium of public health activities at the U.S. Department of Energy. November 2000. Available from URL: http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

ATSDR. 2004. Public Health Assessment, Y-12 Uranium Releases, Oak Ridge Reservation. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Atlanta, GA, January 30, 2004.

ATSDR. 2005. Public Health Assessment Guidance Manual (Update). U.S. Department Of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA. Available from URL: http://www.atsdr.cdc.gov/HAC/PHAManual/index.html

Bechtel Jacobs Company LLC, Lockheed Martin Energy Research Corporation, and Lockheed Martin Energy Systems, Inc. 1999. Comprehensive integrated planning process for the Oak Ridge operations sites. Prepared for the U.S. Department of Energy. September 1999. Available from URL: http:www.ornl.gov/~dmsi/cip/cip4.htm.

Benfield R. 2002. ORRHES meeting minutes. TDEC groundwater geologist presentation. October 22, 2002. Available from URL: http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m10_02.pdf.

Benson M, W Lyons, JM Scheb. 1994. Report of knowledge, attitudes and beliefs survey of residents of an eight-county area surrounding Oak Ridge, Tennessee. Prepared for the Tennessee Department of Health, Division of Epidemiology, the Oak Ridge Health Agreement Steering Panel (ORHASP), and the Oak Ridge Reservation Local Oversight Committee (LOC). University of Tennessee, Knoxville. August 12, 1994.

Census Bureau see U.S. Census Bureau.

ChemRisk. 1993a.Oak Ridge health studies, phase I report. Volume I—Oak Ridge health studies phase I overview. Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. September 1993. Available from URL: http://cedr.lbl.gov/DR/OAKPDF/overviewphase1.pdf

ChemRisk. 1993b. Oak Ridge health studies, phase I report. Volume II—part A—dose reconstruction feasibility study. Tasks 1 & 2: A summary of historical activities on the Oak Ridge Reservation with emphasis on information concerning off-site emissions of hazardous materials. Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. September 1993. Available from URL: http://cedr.lbl.gov/DR/OAKPDF/historicalops.pdf

ChemRisk. 1993c. Oak Ridge health studies, phase I report. Volume II—part B—dose reconstruction feasibility study. Tasks 3 & 4: Identification of important environmental pathways for materials released from Oak Ridge Reservation. Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. September 1993. Available from URL: http://cedr.lbl.gov/DR/OAKPDF/importexposure.pdf

ChemRisk. 1993d. Oak Ridge health studies, phase 1 report. Volume II—part C—dose reconstruction feasibility study. Task 5: A summary of information concerning historical locations and activities of populations potentially affected by releases from the Oak Ridge Reservation. Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel. September 1993. Available from URL: http://cedr.lbl.gov/DR/OAKPDF/historicalocations.pdf

ChemRisk. 1993e. Oak Ridge health studies, phase 1 report. Volume II—part D—dose reconstruction feasibility study. Task 6: Hazard summaries for important materials at the Oak Ridge Reservation. Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel. September 1993. Available from URL: http://cedr.lbl.gov/DR/OAKPDF/hazardsumm.pdf

ChemRisk. 1999a. Radionuclide releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an assessment of historical quantities released, off-site radiation doses, and health risks, task 4. Reports of the Oak Ridge dose reconstruction, volume 4. Tennessee Department of Health. July 1999. Available from URL: http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf.

ChemRisk. 1999b. Screening-level evaluation of additional potential materials of concern, task 7. Reports of the Oak Ridge dose reconstruction, volume 6. Tennessee Department of Health. July 1999. Available from URL: http://www2.state.tn.us/health/CEDS/OakRidge/Screen.pdf.

ChemRisk. 1999c. Uranium releases from the Oak Ridge Reservation – a review of the quality of historical effluent monitoring data and a screening evaluation of potential off-site exposures, task 6. Report of the Oak Ridge Dose Reconstruction, Volume 5. Oak Ridge: Tennessee Department of Health. Available from URL: http://cedr.lbl.gov/DR/OAKPDF/task6report.pdf

ChemRisk. 2000. Oak Ridge dose reconstruction project summary report. Reports of the Oak Ridge dose reconstruction, volume 7. Tennessee Department of Health. March 2000. Available from URL: http://www2.state.tn.us/health/CEDS/OakRidge/ProjSumm.pdf.

City of Oak Ridge. 2002. City of Oak Ridge water treatment web site. Available from URL: http://www.cortn.org/PW-html/water_treatment.htm.

C.J. Enterprises, Inc. 2001. Public involvement plan for CERCLA activities at the U.S. Department of Energy Oak Ridge Reservation. U.S. Department of Energy.

DOE see U.S. Department of Energy.

East Tennessee Development District. 1995. 1990 census summary report for Roane County. December 1995.

EPA see U.S. Environmental Protection Agency.

EUWG (End Use Working Group). 1998. Final report of the Oak Ridge Reservation.

Florida Agricultural and Mechanical University (FAMU). 1998. Scarboro Community Environmental Study.

Friday JC, RL Turner. 2001. Scarboro community assessment report. Joint Center for Political and Economic Studies. August 2001.

Hutson SS and AJ Morris. 1992. Public water-supply systems and water use in Tennessee, 1988. Water-resources investigations report 91-4195. Prepared by the U.S. Geological Survey (USGS) in cooperation with the Tennessee Department of Environment and Conservation, Division of Water Supply.

Jacobs EM Team. 1997a. Record of Decision for an Interim Action for Union Valley, Upper East Fork Poplar Creek Characterization Area, Oak Ridge, TN. Prepared for the U.S. Department of Energy, Office of Environmental Management. April 1997.

Jacobs EM Team. 1997b. Record of decision for the Clinch River/Poplar Creek operable unit, Oak Ridge, Tennessee. Prepared for the U.S. Department of Energy, Office of Environmental Management. September 1997. Available from URL: http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf.

Jacobs Engineering Group Inc. 1996. Remedial investigation/feasibility study of the Clinch River/Poplar Creek operable unit. Prepared for the U.S. Department of Energy, Office of Environmental Management. March 1996. Available from URL: http://www.osti.gov/dublincore/gpo/servlets/purl/226399-5omhIT/webviewable/226399.pdf.

Lemiski, PJ. 1994. Geological Mapping of the Oak Ridge K-25 Site, Oak Ridge, TN. Environmental Sciences Division, Oak Ridge National Laboratory and Department of Geological Sciences, University of Tennessee, Knoxville, TN. January 1994.

Lockheed Martin Energy Systems, Inc. 1998. Draft Accelerating Cleanup: Paths to Closure Oak Ridge Operations Office. Prepared for the U.S. Department of Energy, Office of Environmental Management Program. February 1998. Available from URL: http://web.em.doe.gov/ftplink/closure/04exec1.pdf.

MapQuest. 2003. Driving directions for North America. Available from URL: http://www.mapquest.com.

MMES. 1986. Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985. Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee. ORNL-6271. April 1986.

NIOSH 2005. NIOSH Pocket Guide to Chemical Hazards. (NIOSH Publication No. 2005-151). Available from URL: http://www.cdc.gov/niosh/npg/npgd0107.html.

NJDEP. 2005. Main Vapor Intrusion Guidance Document. Available from URL: http://www.nj.gov/dep/srp/guidance/vaporintrusion/vig_main.pdf.

ORHASP (Oak Ridge Health Agreement Steering Panel). 1999. Releases of contaminants from Oak Ridge facilities and risks to public health. Final report of the ORHASP. December 1999.

ORNL (Oak Ridge National Laboratory). 1982. Environmental Analysis of the Operation of Oak Ridge National Laboratory (X-10 Site). Prepared for the U.S. Department of Energy. ORNL-5870. November 1982.

ORNL. 1997. Effective porosity and density of carbonate rocks (Maynardville Limestone and Copper Ridge Dolomite) within Bear Creek Valley on the Oak Ridge Reservation based on modern petrophysical techniques. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. ORNL/GWPO-026. February 1997.

ORNL, Oak Ridge Y-12 Plant, and East Tennessee Technology Park. 1999. Oak Ridge Reservation annual site environmental report for 1998. Prepared for the U.S. Department of Energy. December 1999. Available from URL: http://www.ornl.gov/Env_Rpt/aser98/xfront.pdf.

ORNL. 2000. Oak Ridge National Laboratory old hydrofracture facility tank-closure plan and grout-development status report for FY1999. Prepared for the U.S. Department of Energy. ORNL/TM-2000/7. April 2000.

ORNL. 2002. Oak Ridge National Laboratory land and facilities plan. Prepared for the U.S. Department of Energy. August 2002. Available from URL: http://www.ornl.gov/~dmsi/landUse/.

Prothero and Schwab. 1996. Sedimentary Geology. WH Freeman and Company. New York, NY.

Reidy C. and Clinton S. 2004. Down Under: Hyporheic zones and their function. Center for Water and Watershed Studies, University of Washington, Seattle, WA. Available from URL: http://depts.washington.edu/cwws/Outreach/FactSheets/hypo.pdf.

SAIC (Science Applications International Corporation). 1996. White Oak Creek Watershed: Melton Valley Area Remedial Investigation Report, at Oak Ridge National Laboratory, Oak Ridge, TN. Volume I: Main Text. Prepared for the U.S. Department of Energy. DOE/OR/01-1546/V1&D1. November 1996.

SAIC. 1996b. Report on the remedial investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, TN. Volume 2: Appendix A – Waste sites, source terms, and waste inventory report; Appendix B – Description of the field activities and report database; Appendix C – Characterization of hydrogeologic setting report. September 1996.

SAIC. 1997. Remedial Investigation Report on the Melton Valley Watershed at Oak Ridge National Laboratory, Oak Ridge, TN. Volume I: Evaluation, Interpretation, and Data Summary. Prepared for the U.S. Department of Energy. DOE/OR/01-1546/V1&D2. May 1997.

SAIC. 2002a. 2002 remediation effectiveness report for the U.S. Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee. Science Applications International Corporation.

SAIC. 2002b. Land use technical report. Science Applications International Corporation. September 2002. Prepared for the U.S. Department of Energy, Office of Environmental Management. March 2002.

SAIC. 2004. Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, TN. Science Applications International Corporation. Prepared for the U.S. Department of Energy, Office of Environmental Management. March 2004.

SAIC. 2005. Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, TN. Science Applications International Corporation. Prepared for the U.S. Department of Energy, Office of Environmental Management. March 2005.

TDEC (Tennessee Department of Environment and Conservation) 2005. Environmental Monitoring Plan: January through December 2005. Tennessee Department of Environment and Conservation, DOE Oversight Division. January 2005.

TDEC 2004. Environmental Monitoring Report: January through December 2003. Tennessee Department of Environment and Conservation, DOE Oversight Division. March 2004.

TDEC. 2002. Status report to the public. TDEC, DOE Oversight Division. March 2002. Available from URL: http://www.local-oversight.org/TDEC2001.pdf.

TDEC. 2003a. Status report to the public. TDEC, DOE Oversight Division. September 2003. Available from URL: http://www.local-oversight.org/TDEC2003.pdf.

TDEC. 2003b. On-line search of the state's drinking water program. Available from URL: http://www.state.tn.us/environment/doeo/pdf/EMR2003.pdf.

TDOH (Tennessee Department of Health). 2000. Contaminant releases and public health risks: Results of the Oak Ridge health agreement studies. July 2000.

U.S. Census Bureau. 1940. Sixteenth census of the United States: 1940 population. Volume 1: Number of inhabitants. Available from the Tennessee State Library and Archives, Nashville, Tennessee.

U.S. Census Bureau. 1950. Census of population: 1950. Volume 1: Number of inhabitants. Available from the Tennessee State Library and Archives, Nashville, Tennessee.

U.S. Census Bureau. 1960. Census of population: 1960. Volume 1: Characteristics of the population, part A, number of inhabitants. Available from the Tennessee State Library and Archives, Nashville, Tennessee.

U.S. Census Bureau. 1970. 1970 census of population—number of inhabitants, Tennessee. Volume 1: Part 44. Available from the Tennessee State Library and Archives, Nashville, Tennessee.

U.S. Census Bureau. 1980. 1980 census of population—number of inhabitants, Tennessee. Volume 1: Part 44. Available from the Tennessee State Library and Archives, Nashville, Tennessee.

U.S. Census Bureau. 1993. 1990 census of population and housing, population, and housing unit counts, United States. U.S. Department of Commerce, Economics and Statistics Administration. August 1993. Available from URL: http://www.census.gov/prod/cen1990/cph2/cph-2-1-1.pdf.

U.S. Census Bureau. 2000. Population, housing unit, area, and density: 2000. American FactFinder. 2000. Available from URL: http://factfinder.census.gov/servlet/GCTTable?ds_name=DEC_2000_SF1_U&geo_id=04000US47&_box_head_nbr=GCT-PH1&format=ST-2.

U.S. DOE (U.S. Department of Energy). 2004. Oak Ridge Reservation Annual Site Environmental Report for 2003. DOE/ORO/2185, September 2004. Available from URL: http://www.ornl.gov/aser.

U.S.DOE. 1994. Electronic data package of the remedial investigation/feasibility study report for Lower Watts Bar Reservoir Operable Unit, DOE/OR/01-1282&D2. Oak Ridge, Tennessee: Oak Ridge National Laboratory and Jacobs Engineering Group, Inc. November 1994.

U.S.DOE. 1995a. Record of decision for Lower East Fork Poplar Creek, Oak Ridge, Tennessee. U.S. Department of Energy, Office of Environmental Management. July 1995.

U.S.DOE. 1995b. Record of decision for Lower Watts Bar Reservoir, Oak Ridge, Tennessee. U.S. Department of Energy, Office of Environmental Management. September 1995. Available from URL: http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf.

U.S. DOE. 1995c. Oak Ridge Reservation annual site report for 1994. Environmental, safety, and health compliance and environmental management staffs of the Oak Ridge Y-12 Plant, Oak Ridge National Laboratory, and Oak ridge K-25 site. October 1995.

U.S. DOE. 1996a. 1996 Baseline Environmental Management Report. Office of Environmental Management. Last updated on November 10, 1999. Available from URL: http://web.em.doe.gov/bemr96/.

U.S. DOE. 1996b. Federal facility agreement. Environmental management program fact sheet. Fall 1996.

U.S. DOE. 1996c. Environmental restoration activities at Oak Ridge operations office. Office of Environmental Management. March 1996.

U.S. DOE. 1996d. Clinch River/Poplar Creek Operable Unit. Environmental management program fact sheet. Fall 1996.

U.S. DOE. 2001a. Overview of CERCLA actions at off-site locations. Environmental management program fact sheet. September 2001.

U.S. DOE. 2001b. Bethel Valley Watershed overview. Environmental management program fact sheet. September 2001.

U.S. DOE. 2001c. Gunite and associated tanks remediation project. Environmental management program fact sheet. September 2001.

U.S. DOE. 2001d. Melton Valley overview. Environmental management program fact sheet. September 2001.

U.S. DOE. 2001e. Waste area grouping (WAG) 4 seeps. Environmental management program fact sheet. September 2001.

U.S. DOE. 2001f. Waste area grouping (WAG) 5 seeps C and D. Environmental management program fact sheet. September 2001. Available from URL:

U.S. DOE. 2002a. Proposal: Oak Ridge comprehensive closure plan. Office of Environmental Management. March 11, 2002. Available from URL: http://www.bechteljacobs.com/doeclean/_pu-ccp1.html.

U.S. DOE. 2002b. 2002 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee. Prepared by SAIC. March 2002.

U.S. DOE. 2002c. Record of decision for phase I interim source control actions in the Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee. U.S. Department of Energy, Office of Environmental Management. May 2002.

U.S. DOE. 2002d. Cleanup work begins at ORNL's Melton Valley. DOE News. October 15, 2002. Available from URL: http://www.oro.doe.gov/media_releases/2002/r-02-041.htm.

U.S. DOE. 2002e. Old hydrofracture facility waste tanks. Environmental management program fact sheet. March 2002.

U.S. DOE. 2002f. Oak Ridge Reservation Annual Site Environmental Report for 2002. September 2003.

U.S. DOE. 2003a. Federal facility agreement. Environmental management program fact sheet. February 2003.

U.S. DOE. 2003b. Comprehensive Waste Disposition Plan for the DOE Oak Ridge Reservation. Approved for public release: March 6, 2003.

U.S. DOE. 2003c. Lower Watts Bar Reservoir remedial action. Environmental management program fact sheet. April 2003.

U.S. DOE. 2003d. Cleanup Progress FY2003: Annual Report to the Oak Ridge Community. Prepared for the U.S. Department of Energy. DOE/ORO-2174.

U.S. DOE. 2004. Oak Ridge Reservation Groundwater Strategy. Prepared for the U.S. Department of Energy. May, 2004. DOE/OR/01-2069&D2.

U.S. Environmental Protection Agency (EPA). 1996a. Soil Screening Guidance: User's Guide. EPA/540/R-96/018. Office of Solid Waste and Emergency Response. Washington, DC.

U.S. EPA. 1996b. Soil Screening Guidance: Technical Background Document. EPA/540/R-95/128. Office of Solid Waste and Emergency Response. Washington, DC.

U.S. EPA. 1999. Understanding the Safe Drinking Water Act. Available from URL: http://www.epa.gov/safewater/sdwa/basicinformation.html.

U.S. EPA. 2002a. Tennessee NPL/NPL caliber cleanup site summaries. U.S.DOE Oak Ridge Reservation, Oak Ridge, Anderson County, Tennessee. Available from URL: http://www.epa.gov/region4/waste/npl/npltn/oakridtn.htm.

U.S. EPA. 2002b. NPL site narrative for Oak Ridge Reservation (U.S. DOE). Oak Ridge Reservation (U.S. DOE), Oak Ridge, Tennessee. Available from URL: http://www.epa.gov/oerrpage/superfund/sites/npl/nar1239.htm.

U.S. EPA. 2002c. Office of Solid Waste and Emergency Response (OSWER) Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). November 2002. Available from URL: http://www.epa.gov/correctiveaction/eis/vapor/complete.pdf.

USEPA. 2004. Office of Emergency and Remedial Response. User's Guide For Evaluating Subsurface Vapor Intrusion Into Buildings. February 2004. Available from URL: http://www.epa.gov/oswer/riskassessment/airmodel/pdf/2004_0222_3phase_users_guide.pdf.

U.S. Geological Survey (USGS). 1986. Preliminary delineation and description of the regional aquifers of Tennessee – the East Tennessee aquifer system. Water Resources Investigation Report 82-4091. Prepared in cooperation with the U.S. Environmental Protection Agency. Nashville, TN. 1986.

USGS. 1986b. Preliminary evaluation of the Knox Group in Tennessee for receiving injected wastes. Water Resources Investigations Report 85-4304. Prepared in cooperation with the U.S. Environmental Protection Agency. Nashville, TN. 1986.

USGS. 1988. Hydrology of the Melton Valley radioactive waste burial grounds at Oak Ridge National Laboratory, Tennessee. U.S. Geological Survey Open File Report 87-686. Prepared in cooperation with the U.S. Department of Energy. Knoxville, TN. 1988.

USGS. 1989. An investigation of shallow ground-water quality near East Fork Poplar Creek, Oak Ridge, Tennessee. Water Resources Investigations Report 88-4219. Prepared in cooperation with the U.S. Department of Energy. Nashville, TN. 1989.

USGS. 1997. Preliminary conceptual models of the occurrence, fate, and transport of chlorinated solvents in karst regions of Tennessee. Water Resources Investigation Report 97-4097. Prepared in cooperation with the Tennessee Department of Environment and Conservation, Division of Superfund. Nashville, TN. 1997.

USGS. 1998. Ground Water and Surface Water: A Single Resource. U.S. Geological Survey Circular 1139. Denver, CO. Available from URL: http://water.usgs.gov/pubs/circ/circ1139/.

USGS. 2004. National Geologic Map Database: GEOLEX database. Available from URL: http://ngmdb.usgs.gov. Last accessed July 29, 2004.

UT-Battelle. 2003. Oak Ridge National Laboratory Fact Sheet. Available from URL: http://www.ornl.gov/ornlhome/fact.pdf.

Whiteside R., Pawlowicz R., Whitehead L., Arnseth R. 2002. Improved well plugging equipment and waste management techniques exceed ALARA goals at the Oak Ridge National Laboratory. 2002 Waste Management Symposium, Tucson, AZ. February 24-28, 2002. Available from URL: http://www.wmsym.org/Abstracts/2002/Proceedings/12/234.pdf.

Appendix A. ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Absorption
The process of taking in. For a person or animal, *absorption* is the process through which a substance gets into the body through the eyes, skin, stomach, intestines, or lungs.

Activity
The number of radioactive nuclear transformations occurring in a material per unit time. The term for *activity* per unit mass is specific activity.

Acute
Occurring over a short time [compare with **chronic**].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with **intermediate-duration exposure** and **chronic exposure**].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems.

Ambient
Surrounding (for example, *ambient* air).

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Background radiation
The amount of radiation to which a member of the general population is exposed from natural sources, such as terrestrial radiation from naturally occurring **radionuclides** in the soil, cosmic radiation originating from outer space, and naturally occurring radionuclides deposited in the human body.

Bedding planes
The division of *sediment* or *sedimentary rock* into parallel layers (beds) that can be distinguished from each other by such features as chemical composition and grain size.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

Cancer
Any one of a group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk of getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA
[See **Comprehensive Environmental Response, Compensation, and Liability Act of 1980.**]

Chronic
Occurring over a long time (more than 1 year) [compare with **acute**].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with **acute exposure** and **intermediate-duration exposure**].

Committed Effective Dose Equivalent (CEDE)
The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to the organs or tissues. The *committed effective dose equivalent* is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues. The unit of dose for the CEDE is the rem (or, in SI units, the sievert—1 sievert equals 100 rem.)

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway
[See **exposure pathway.**]

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as **Superfund,** is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by *CERCLA,* is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances.

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other medium.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Curie (Ci)
A unit of radioactivity. One *curie* equals that quantity of radioactive material in which there are 3.7×10^{10} nuclear transformations per second. The activity of 1 gram of radium is approximately 1 Ci; the activity of 1.46 million grams of natural uranium is approximately 1 Ci.

Decay product/daughter product/progeny
A new nuclide formed as a result of radioactive decay: from the radioactive transformation of a radionuclide, either directly or as the result of successive transformations in a radioactive series. A *decay product* can be either radioactive or stable.

Depleted uranium (DU)
Uranium having a percentage of U 235 smaller than the 0.7% found in natural uranium. It is obtained as a byproduct of U 235 enrichment.

Dermal
Referring to the skin. For example, *dermal* absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see **route of exposure**].

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOE
The United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. *Dose* is a measurement of exposure. *Dose* is often expressed as milligrams (a measure of quantity) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the *dose,* the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually gets into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation *dose* is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure [**dose**] to a substance and the resulting changes in body function or health (response).

EMEG
Environmental Media Evaluation Guide, a media-specific comparison value that is used to select contaminants of concern. Levels below the EMEG are not expected to cause adverse noncarcinogenic health effects.

Enriched uranium
Uranium in which the abundance of the U 235 isotope is increased above normal.

Environmental media
Soil, water, air, **biota** (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and **biota** (plants and animals). *Transport mechanisms* move contaminants from the source to points where human exposure can occur. The *environmental media and transport mechanism* is the second part of an **exposure pathway.**

EPA
The United States Environmental Protection Agency.

Epidemiologic surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Equilibrium, radioactive
In a radioactive series, the state that prevails when the ratios between the activities of two or more successive members of the series remain constant.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. *Exposure* can be short-term [see **acute exposure**], of intermediate duration [see **intermediate-duration exposure**], or long-term [see **chronic exposure**].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biological tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An *exposure pathway* has five parts: a **source of contamination** (such as an abandoned business); an **environmental media and transport mechanism** (such as movement through **groundwater**); a **point of exposure** (such as a private well); a **route of exposure** (eating, drinking, breathing, or touching), and a **receptor population** (people potentially or actually exposed). When all five parts are present, the *exposure pathway* is termed a **completed exposure pathway.**

Exposure registry
A system of ongoing follow up of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with **surface water**].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the *half-life* is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the *half-life* is the time it takes for half the original amount of the substance to disappear either by being changed to another substance or by leaving the body. In the case of radioactive material, the *half-life* is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into other atoms (normally not radioactive). After two *half-lives,* 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. *Health consultations* are focused on a specific exposure issue. They are therefore more limited than public health assessments, which review the exposure potential of each pathway and chemical [compare with **public health assessment**].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to estimate the possible association between the occurrence and exposure to hazardous substances.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A *health statistics review* is a descriptive epidemiologic study.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with **prevalence**].

Incised Meander
Incised meanders result from down-cutting along the deepest part of a river's channel. The down-cutting is so rapid, the river maintains a meandering pattern while deepening its valley. This erosion process creates exposed bedrock on its banks permitting the discharge of groundwater to surface streams.

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see **route of exposure**].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].

Intermediate-duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with **acute exposure** and **chronic exposure**].

Ionizing radiation
Any radiation capable of knocking electrons out of atoms and producing ions. Examples: alpha, beta, gamma and x rays, and neutrons.

Isotopes
Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Identical chemical properties exist in *isotopes* of a particular element. The term should not be used as a synonym for "nuclide," because "isotopes" refers specifically to different nuclei of the same element.

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

mg/kg

Milligrams per kilogram.
mg/m^3

Milligrams per cubic meter: a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. *MRLs* are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). *MRLs* should not be used as predictors of harmful (adverse) health effects [see **reference dose**].

Mortality
Death. Usually the cause (a specific disease, condition, or injury) is stated.

Mutagen
A substance that causes **mutations** (genetic damage).

Mutation
A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The *NPL* is updated on a regular basis.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL
[See **National Priorities List for Uncontrolled Hazardous Waste Sites.**]

Parent
A radionuclide which, upon disintegration, yields a new nuclide, either directly or as a later member of a radioactive series.

Plume
A volume of a substance that moves from its source to places farther away from the source. *Plumes* can be described by the volume of air or water they occupy and the direction in which they move. For example, a *plume* can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see **exposure pathway**].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with **incidence**].

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action plan
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed by coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with **health consultation**].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or **radionuclides** that could result in harmful health effects.

Public health hazard categories
Statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five *public health hazard categories* are **no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard,** and **urgent public health hazard.**

Public health statement
The first chapter of an ATSDR **toxicological profile.** The *public health statement* is a summary written in words that are easy to understand. It explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public meeting
A public forum with community members for communication about a site.

Quality factor (radiation weighting factor)
The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses - on a common scale for all ionizing radiation - the approximate biological effectiveness of the absorbed dose.

Rad
The unit of absorbed dose equal to 100 ergs per gram, or 0.01 joules per kilogram (0.01 gray) in any medium [see **dose**].

Radiation
The emission and propagation of energy through space or through a material medium in the form of waves (e.g., the emission and propagation of electromagnetic waves, or of sound and elastic waves). The term "radiation" (or "radiant energy"), when unqualified, usually refers to electromagnetic *radiation.* Such *radiation* commonly is classified according to frequency, as microwaves, infrared, visible (light), ultraviolet, and x and gamma rays and, by extension, corpuscular emission, such as alpha and beta *radiation,* neutrons, or rays of mixed or unknown type, such as cosmic *radiation.*

Radioactive material
Material containing radioactive atoms.

Radioactivity
Spontaneous nuclear transformations that result in the formation of new elements. These transformations are accomplished by emission of alpha or beta particles from the nucleus or by the capture of an orbital electron. Each of these reactions may or may not be accompanied by a gamma photon.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RBC
Risk-based Concentration, a contaminant concentration that is not expected to cause adverse health effects over long-term exposure.

RCRA
[See **Resource Conservation and Recovery Act (1976, 1984).**]

Receptor population
People who could come into contact with hazardous substances [see **exposure pathway**].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Rem
A unit of dose equivalent that is used in the regulatory, administrative, and engineering design aspects of radiation safety practice. The dose equivalent in *rem* is numerically equal to the absorbed dose in rad multiplied by the quality factor (1 *rem* is equal to 0.01 sievert).

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RfD
[See **reference dose.**]

Risk
The probability that something will cause injury or harm.

Route of exposure
The way people come into contact with a hazardous substance. Three *routes of exposure* are breathing [**inhalation**], eating or drinking [**ingestion**], and contact with the skin [**dermal contact**].

Safety factor
[See **uncertainty factor**.]

Sample
A portion or piece of a whole; a selected subset of a population or subset of whatever is being studied. For example, in a study of people the *sample* is a number of people chosen from a larger population [see **population**]. An environmental *sample* (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sievert (Sv)
The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose, in gray, multiplied by the quality factor (1 sievert equals 100 rem).

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A *source of contamination* is the first part of an **exposure pathway.**

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, gender, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered *special populations.*

Specific activity
Radioactivity per unit mass of material containing a radionuclide, expressed, for example, as Ci/gram or Bq/gram.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Strike
The horizontal line marking the intersection between the inclined plane of a solid geological structure and the Earth's surface.

Substance
A chemical.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].

Surveillance
[see **epidemiologic surveillance**]

Survey
A systematic collection of information or data. A *survey* can be conducted to collect information from a group of people or from the environment. *Surveys* of a group of people can be conducted by telephone, by mail, or in person. Some *surveys* are done by interviewing a group of people.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A *toxicological profile* also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Uncertainty factor
A mathematical adjustment for reasons of safety when knowledge is incomplete—for example, a factor used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). *Uncertainty factors* are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use *uncertainty factors* when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a **safety factor**].

Units, radiological

Units	***Equivalents***
Becquerel* (Bq)	1 disintegration per second = 2.7×10^{-11} Ci
Curie (Ci)	3.7×10^{10} disintegrations per second = 3.7×10^{10} Bq
Gray* (Gy)	1 J/kg = 100 rad
Rad (rad)	100 erg/g = 0.01 Gy
Rem (rem)	0.01 sievert
Sievert* (Sv)	100 rem

*International Units, designated (SI)

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Watershed
A watershed is a region of land that is crisscrossed by smaller waterways that drain into a larger body of water.

Water table
The surface that lies between the *unsaturated zone* and the underlying *saturated zone* of the soil.

Other Glossaries and Dictionaries
Environmental Protection Agency http://www.epa.gov/OCEPAterms/
National Center for Environmental Health (CDC) http://www.cdc.gov/nceh/dls/report/glossary.htm
National Library of Medicine http://www.nlm.nih.gov/medlineplus/mplusdictionary.html

Appendix B. Site Geology and Hydrology

ORR is located in the East Tennessee Valley, which is part of the Valley and Ridge Province of the Appalachian Mountains. The East Tennessee Valley is bound to the west by the Cumberland Mountains of the Appalachian Plateau Province and to the east by the Smokey Mountains of the Blue Ridge Province. The defining characteristics of the Valley and Ridge Province are the southwest trending series of ridges and valleys caused by crustal folding and vaulting due to compressive tectonic forces as well as the differential weathering of the various formations underlying the area. There are ten geologic formations underlying parts of the ORR, all are of sedimentary origin. These formations range in age from early Cambrian (530 mya) to early Mississippian (354 mya). From youngest to oldest they are:

1. Fort Payne Chert (Mfp)
2. Chattanooga Shale (MDc)
3. Rockwood Formation (Sr)
4. Sequatchie Formation (Os)
5. Reedsville Shale (Or)
6. Chickamauga Group (Och)
7. Knox Group (O€k)
8. Conasuaga Group (€c)
9. Maynardville Formation (€)
10. Rome Formation (€r)

Each of these formations is described briefly in Table B-1. All of the formations consist mainly of shales, limestones and siltstones. The three major geologic formations are the Chickamauga Group, the Knox Group, and the Conasuaga Group. These formations are considered ‘major’ based on the location of the various plants (ETTP, ORNL, and Y-12), location of the contaminant plumes (see Figure 4), and proportion of ORR underlain by these three formations.

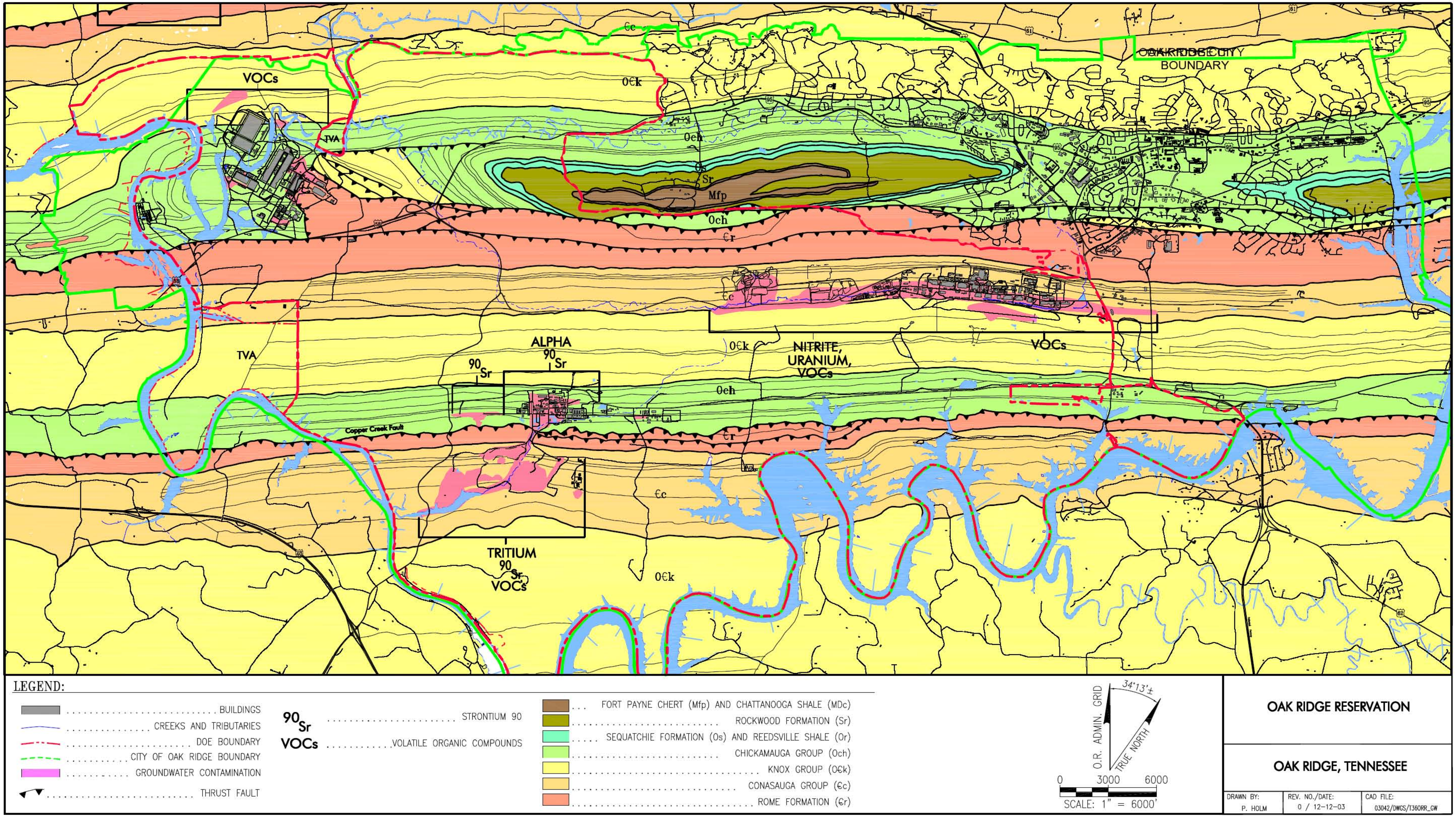

Figure B-1: Geologic Map of the ORR and Groundwater Contaminant Plumes

Table B-1: Hydrogeology of the Formations Underlying the Oak Ridge Reservation (USGS 2004)

Geologic Feature	Age	Geology	Description	Conductivity (at ORR)
Fort Payne Chert (Mfp)	Mississipian (early)	Bluish-gray Limestone	Thin outcrops at western edge of Valley and Ridge Province Average thickness 100' – 250'	Contains water in secondary openings. Yields from 0 to more than 300 gpm.
Chattanooga Shale (MDc)	Mississipian (early), Devonian (late)	Black, fissle shale	About 25 ft thick Very dark to black carbonaceous shale Overlies Rockwood Formation Underlies Fort Payne Chert	Low porosity and permeability. Yields little or no water to wells.
Rockwood Formation (Sr)	Silurian (early – middle)	Greenish to Brownish Shale, Limestone	Ranges in thickness from 150 – 1000 feet Limited outcrop results in limited recharge Some beds associated with iron ore (hematite) deposits Underlies Chattanooga Shale Overlies Sequatchie Formation	Not a good aquifer because of limited recharge. Groundwater occurs in fractures.
Sequatchie Formation (Os)	Ordovician	Shale, Limestone	Near ORR, thickness approx. 100ft. Overlies Chickamauga Group	Poor aquifer Groundwater occurs in fractures.
Reedsville Shale (Or)	Ordovician (late)	Shale	Uppermost layer of the Chickamauga Group Underlies the Sequatchie Formation Near ORR, thickness ranges from 250 – 400 feet	Poor aquifer Groundwater occurs in fractures.
Chickamauga Group (Och)	Ordovician (middle)	Limestone	ORNL (Bethel Valley) and ETTP are built on this group Approximately 2000' thick Overlies the Knox Group Underlies the Sequatchie Formation	AQUITARD - flow limiting strata Groundwater occurs in fractures Variable lithology results in varying conductivities
Knox Group (O€k)	Ordovician (early, middle), Cambrian (late)	Dolomite, Limestone	Overlies Conasauga Group (Shale) Massive calcareous unit that is the prominent formation in the Appalachian Valley ranging from 2000 – 4000 feet thick Contains fossil fuels (oil, gas) in other regions	AQUIFER Most important aquifer in the ORR area Groundwater occurs in joints and fractures Large springs are common Highly variable flow rates: from several gpm to several thousand gpm
Maynardville Formation	Cambrian (late)	Limestone, Dolomite	Off-site contamination at Y-12 occurs in this formation. Uppermost unit of the Conasauga Group Historically included in the Knox Group Relatively thin (thickness 60-250ft)	AQUIFER Generally yields several gpm up to 200 gpm
Conasauga Group (€c)	Cambrian	Shale, Limestone, Dolomite	Y-12 complex is built on this group Contains the largest waste management areas at ORR: Bear Creek Valley Melton Valley Very limited migration of contaminant plumes Most groundwater resurfaces to surface water Limestone layers retard downward migration of groundwater In some areas can be up to 2000' thick	AQUITARD – typically flow limiting strata Contains the AQUIFER subunit Maynardville Formation (limestone), which contains the only off-site contaminant plume from Y-12.
Rome Formation (€r)	Cambrian (early)	Shale, Siltstone	Underlies Conasauga Group Approximately 1500 feet thick	Groundwater occurs in fractures Upper zone is more permeable than lower zone Springs are common Wells can yield several gpm.

Since this health assessment is focused solely on groundwater in and around the ORR, it is necessary to first establish a basic understanding of general groundwater principles, particularly as they relate to the specific geology of the ORR. An important feature of the hydrology of the ORR is the interaction of groundwater with surface water. Depth to bedrock in the ORR is typically very shallow. In this physiographic region, groundwater flow tends to be localized (within a relatively small area such as a watershed), as opposed to regional (larger area such as the Oak Ridge Reservation or perhaps an even larger area), and flow-paths to surface water are short (USGS 1986b). So, a discussion on how groundwater and surface water interact is warranted.

In general, a stream can be described in three ways based upon it's interaction with groundwater. A stream can either be a *gaining stream*, a *losing stream*, (Figure 8) or a combination of both (Figure 14). In order to have a *gaining stream* system, the water table altitude must be higher than that of the stream (USGS 1998). The reverse is true for a *losing stream* system. Because the bedrock is very close to the ground surface in and around the ORR, and in many cases, occurs as outcrops, the streams are gaining. This is a very common situation in East Tennessee because of the topography of the area. The water table and the groundwater flow path typically mirror the undulations of the overlying land. Since surface water occurs at the low areas, groundwater often flows toward surface water. Therefore, the altitude of the water table is higher than that of the surface water. Recharge of groundwater around the ORR is spatially distributed (occurs over a large area as opposed to small outcrops or ridgelines), but discharge areas are at local springs, seeps as well as diffuse discharge into surface waters (MMES 1986, USGS 1986b, SAIC 2004). Indeed, groundwater constitutes much of the baseflow of many streams and tributaries in the area, including East Fork Poplar Creek (EFPC) (USGS 1989, SAIC2004).

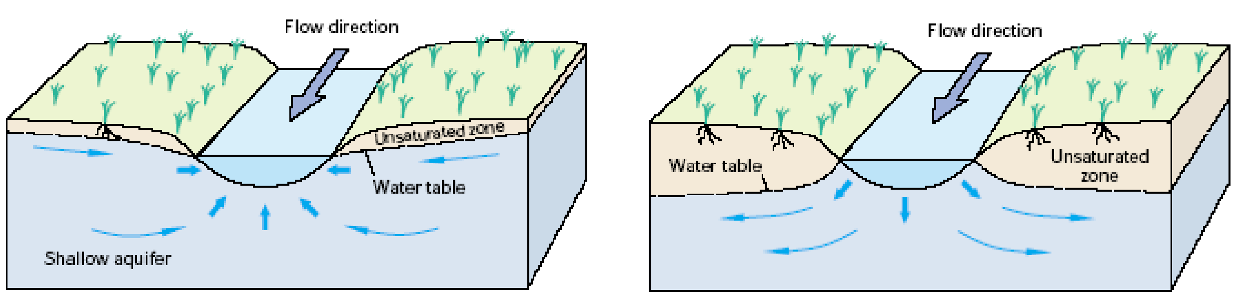

Figure B-2: Gaining (Left) and Losing (Right) Streams and Associated Groundwater Flow Direction

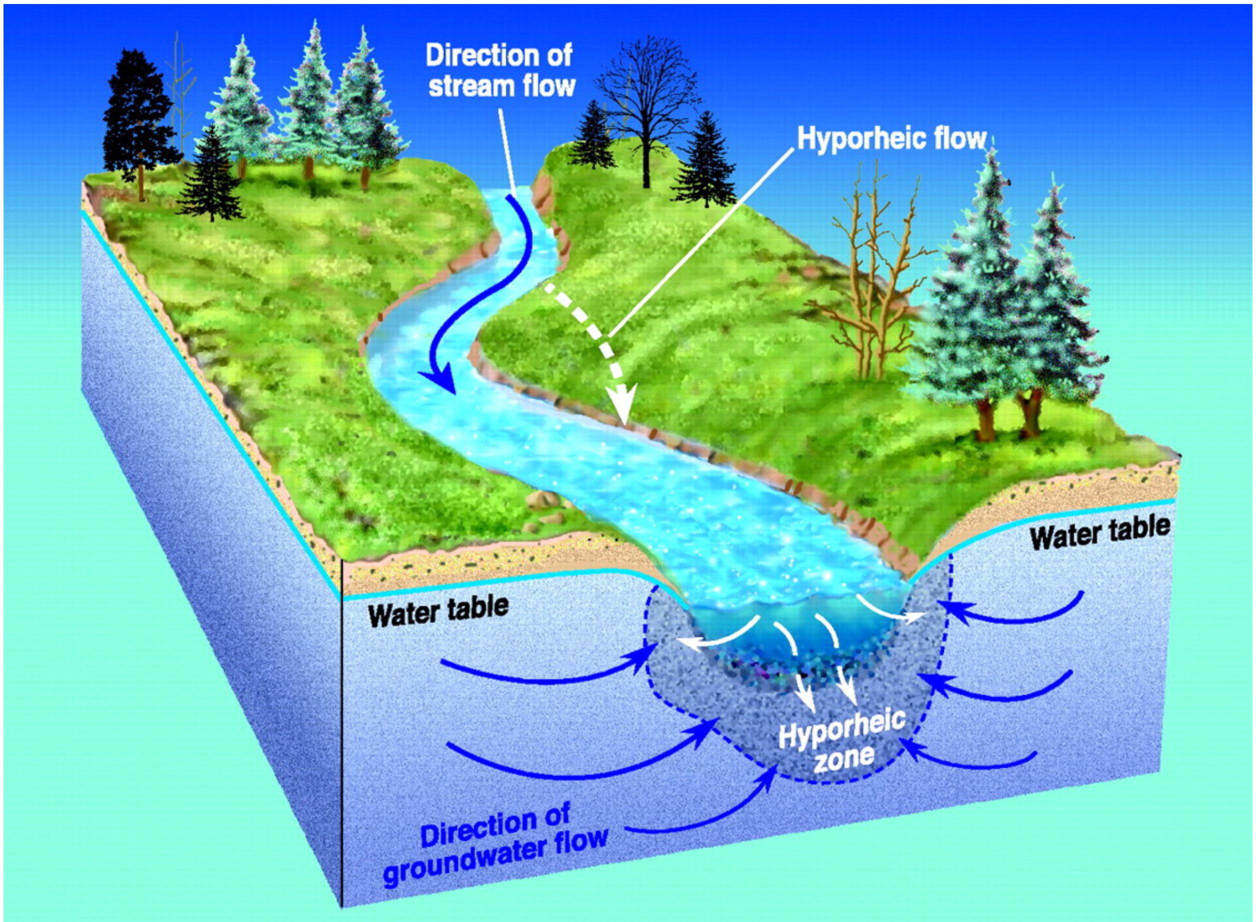

Figure B-3: Groundwater System Involving the Hyporheic Zones (Alley et. al 2002)

In the Bear Creek Valley watershed there are both gaining and losing reaches of Bear Creek. This illustrates the third groundwater-surface water system where there groundwater enters and exits the surface water at different sections of the stream. In this case the concept of hyporheic flow becomes relevant (Figure B-3). Hyporheic flow, or the hyporheic zone, refers to the areas beneath and adjacent to the stream where surface water and groundwater mix. In systems such as this, surface water contamination can percolate through the sediments and contaminate the groundwater (Alley et al. 2002).

Groundwater flow in this area (ORR) is influenced largely on the extent of fractures in the bedrock which create preferential flow paths. In the regional aquifers of East Tennessee, including those underlying the ORR, fractures in bedrock are typically limited to the upper extents of the bedrock formations and significantly decrease with depth (MMES 1986, USGS 1986b, USGS 1988, USGS 1989, SAIC 2004). The karst geology of the ORR makes accurate predictions of groundwater flow rate and direction problematic, particularly in the carbonate formations such as the Knox Group and the Maynardville Limestone. Most groundwater flow in these carbonate formations occurs in the shallow interval (<100 feet) through fracture flow and through solution-enlarged cavities. For example, there are several large solution cavities beneath Bear Creek which (along certain reaches) serve as a hydraulic drain to the Maynardville

Limestone (Lemiski 1994, SAIC 1996b). Groundwater will flow along bedding planes and along strike, especially in areas where carbonate units have well-developed conduit systems (ORNL 1982, USGS 1997). This is the case in the UEFPC Watershed where VOC contamination has migrated off-site from the Y-12 Complex and is migrating along strike in the Maynardville Limestone (ORNL 1982, SAIC 2004).

The numerous springs and seeps in the area support the notion of a very active shallow groundwater system in the ORR. Open cavities at bedrock outcrops in the ORR area range in size from small drains to easily enterable caves. These areas serve as rapid recharge areas and result in rapid flow rates through the interconnected fractures and solution cavities and can contribute to significant hydraulic head pressure changes during heavy rainfall events (SAIC 1996, Lemiszki 1994). The intermediate interval (100 feet – 300 feet) of the Maynardville Limestone is known to have high flow rates but does not receive the dilution effect that is seen in the shallow interval (SAIC 1996b), and therefore, is seen as an important interval with respect to contaminant transport. While fracture flow remains the dominant mode of groundwater movement at depth (below 300 feet), solution cavities and fractures are limited and decrease significantly beyond 300 feet.

While mapping springs and seeps in the ORR area, Lemiszki (1994) noted that most occurred along the banks of the Clinch River. For most of the year, these seeps and springs were underwater, but winter is when the Clinch River is in low stage and these karst features can be seen. There was a wide variety in flow rates observed. Some springs were mere trickles of water from bedrock outcrops while others were large volume springs (up to 25 gal/min) actively filling potholes along the river flats. This observation supports the notion that the incised meander (see Appendix A) of the Clinch River serves as an effective hydraulic barrier for groundwater flow.

An **incised meander** is formed when a stream's ancestral floodplain is uplifted causing intense downward erosion by the current stream. In East Tennessee, this uplifting caused the formation of many of the ridges in the area such as Black Oak Ridge, Pine Ridge, Chestnut Ridge, and Haw Ridge. The incised meander of the Clinch River cuts through these uplifted ridges creating "gaps". This deep, relatively rapid erosion of the bedrock creates exposed bedrock on the river banks. Groundwater is discharged to surface water where bedrock is exposed. Because of this deep erosion through bedrock, the Clinch River serves as an effective barrier to groundwater flow.

Groundwater flow in predominantly aquitard formations occurs mostly in the shallow interval (<100 feet) at the bedrock/residuum interface or in other preferential flow paths, such as fractures. In times of heavy precipitation, the elevation of the water table typically rises rapidly and discharge to streams increases. Groundwater flow through porous media in predominantly aquitard formations near the ORR is minimal.

Karst groundwater systems form through the chemical weathering of predominantly carbonate formations (Prothero and Schwab 1996). In the vicinity of the ORR, calcium carbonate ($CaCO_3$) limestones and calcium magnesium carbonate [$CaMg(CO_3)_2$] dolomites are eroded as rainwater (H_2O) combines with carbon dioxide (CO_2) to form carbonic acid (H_2CO_3). This weak acid solution dissolves limestone and dolomite according to the following reaction:

$$CaCO_3 \text{ (limestone)} + H_2CO_3 \text{ (carbonic acid)} \rightarrow Ca^{2+} \text{ (dissolved calcium)} + 2HCO_3^- \text{ (dissolved bicarbonate)}$$

SAIC (1996b) cites studies that show distinct groundwater geochemical facies in the Bear Creek Valley. In the shallow zone (<100 ft), the geochemical profile is similar to that of the equation above. This facies type indicates that there is a shallow water table and a short residence time, meaning that groundwater is quickly replaces by recharge as it is discharged to surface water. There is a gradual, but noticeable change in groundwater composition from Ca/Mg HCO_3 to a sodium bicarbonate (Na-HCO_3) at depth. This implies longer residence times at depth where groundwater mixes with older, less active brines. However, because of the interconnected karst networks in the area, Ca/Mg HCO_3 type groundwater occurs at many depths, but in the deepest wells Na-Cl groundwater dominates (SAIC 1996b).

Depending on the geology of the area, flow times from points of recharge to points of discharge can range from days to millennia (Figure 15). As is the case at the ORR, shallow surface water has short flow paths with relatively quick travel times. However, the limestones and dolomites of the Valley and Ridge Province often contain cracks, fissures, fractures, and solution cavities that can make groundwater flow direction and speed unpredictable (USGS 1997).

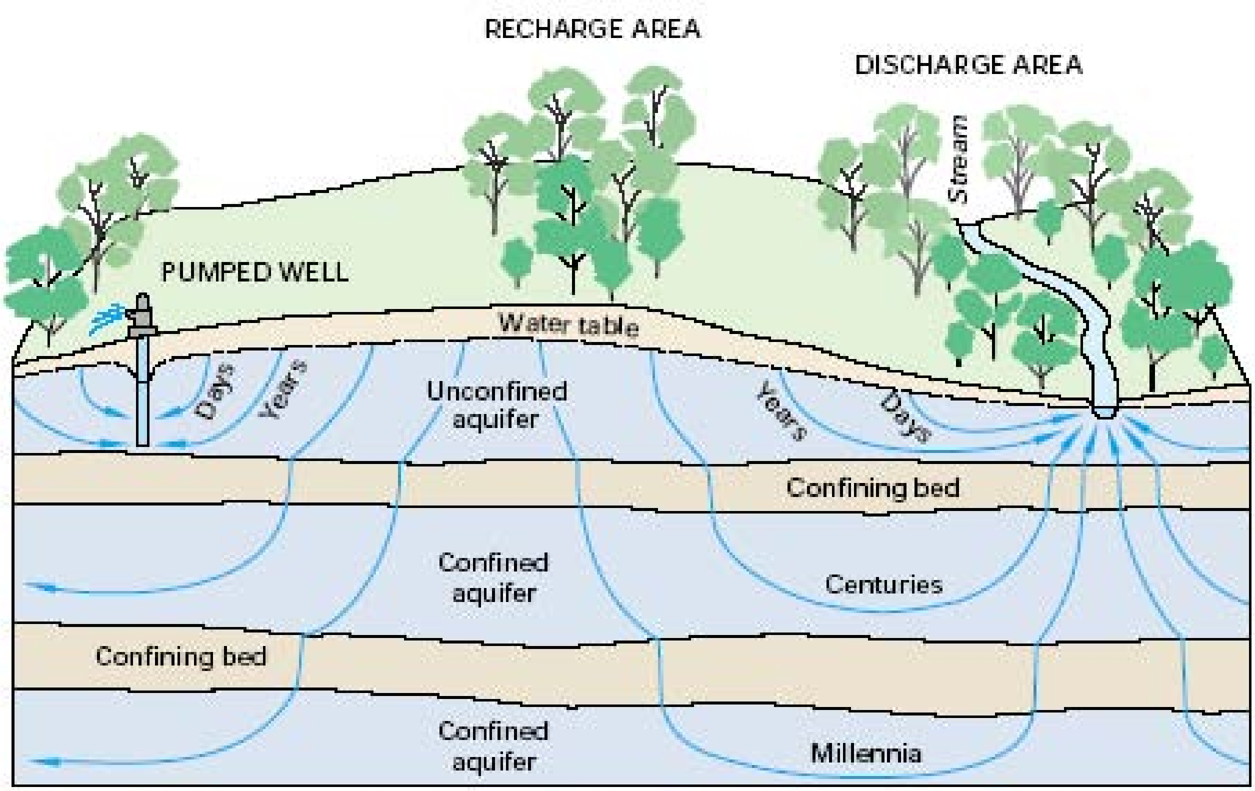

Figure B-4: Groundwater Flow Times

It is unlikely that contaminated groundwater at the ORR will flow beneath, and continue to flow away from, streams and rivers that surround the site. The vast majority of information available concerning the geology and hydrogeology of the site indicates that groundwater occurs as shallow flow with short flow paths to surface water (ORNL 1982, MMES 1986, USGS 1986b, USGS 1988, USGS 1989, SAIC 2004). The fractures and solution cavities present in the bedrock occur in shallow (0'-100' deep) bedrock and significantly decrease at depth. There is also evidence that beneath the alluvium at the bottom of the stream beds there is a silty-clay glei horizon that likely further impedes downward groundwater movement (USGS 1989). The incised meander (see Appendix A) of the Clinch River in bedrock represents a major topographic feature that prevents groundwater from passing beneath the river (ORNL 1982). The extensive interconnection between groundwater and surface water coupled with the fact that groundwater contamination sources at the ORR are in the shallow subsurface (with the exception of deep-well injection conducted at ORNL, which will be discussed in the Melton Valley Watershed section of this document), leads ATSDR scientist to conclude that on-site contaminated groundwater does not likely migrate beneath and away from streams and rivers either as slug-flow or in fractures, solution channels, or other conduits in the bedrock.

It is important for the reader to understand that ATSDR scientists acknowledge the fact that karst systems are notoriously difficult to fully characterize with respect to groundwater flow direction and rate. We have based our conclusions on currently available data concerning groundwater flow and specific contaminant fate and transport from well monitoring data. There are large solution cavities beneath ORR and the surrounding area which are often interconnected and have high flow rates. Some have been encountered in various well drilling activities or by casual observation, and some have yet to be discovered. It is our intention to assess the currently available data, and to arrive at a conclusion of whether the community has had (or is currently having) an exposure to contaminants in off-site groundwater.

Appendix C. Public Comments

ATSDR received comments on the Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the ORR Public Health Assessment, Public Comment Release (August 19, 2005), from peer reviewers, individuals, organizations, and agencies. We have also received additional comments at various public meetings. We thank all of those who took the time to comment. This appendix includes a listing of the public, peer review, and agency comments and our responses to them. Some grammatical and editing comments, such as typos and undefined acronyms, have been corrected in this document but not included in this appendix.

1. Reliability of data used in this PHA

Reviewer Comments:

“The nature and extent of contamination are described by something that I would compare to liar’s poker – the reader needs to have faith that the data are correctly and fully reported. These data may be included in many of the numerous documents cited, but this report itself concentrates on the maximum concentration reported in respect to the Comparison Values (CVs) sometimes as much as a decade ago. What are missing are any reports of data quality, variability of measurements (site, background and reference) over time and the date of the last measurement”

“When added, discussions of the historical monitoring data should also address the consistency and adequacy of the data sets for PHA purposes.”

ATSDR Response:

In preparing this PHA, ATSDR reviewed and evaluated environmental data provided to ATSDR scientists directly from the Department of Energy or in various reports prepared by the Environmental Protection Agency Region IV, the Tennessee Department of Environment and Conservation (TDEC) DOE Oversight Division, or their contractors. ATSDRs evaluation included the identification of inconsistencies and data gaps. The validity of analyses and conclusions drawn in this PHA are based on the reliability of the information referenced in reports related to the Oak Ridge Reservation (ORR). In our assessment, the quality of environmental data available in these documents is sufficient for public health decisions. A statement similar to this one has been added to the ‘Evaluation of Environmental Contamination and Potential Exposure Pathways’ section of this document.

2. Narrow focus of this PHA on groundwater

Reviewer Comments:

“[T]he document concentrates single-mindedly on groundwater itself and no pathways other than residential drinking water.”

"I am firmly convinced that isolated health assessments of the type attempted here (ignoring all other pathways and media) do a disservice to the public and do not assist ATSDR in its mission."

"You only talk about off-site groundwater."

ATSDR Response:

It may be unclear to the reviewer that there are 8 other PHAs being conducted for ORR. These PHAs address all other contaminants of concern and related pathways of exposure. This document was intended to be specific and narrowly focused on contaminated groundwater and associated off-site exposure pathways.

3. Adequacy and completeness of off-site groundwater sampling

Reviewer Comments:

"In some instances contaminated sources are not re-sampled!"

"The nature and frequency of the off-site sampling program is not well-described in the report and may be inadequate. Monitoring programs based on snapshots in time every few years or even on an annual basis often lead to false conclusions concerning public health safety and the effectiveness of remediation programs."

"Based on my reading of the report, the off-site monitoring program appears to be random and infrequent, particularly as it relates to residential wells."

ATSDR Response:

ATSDR used all available data in this assessment. We recognized the sporadic and inconsistent nature of the off-site residential sampling data and have noted this as a data gap in the document (p. 7). However, this sampling was conducted by TDEC and was never intended to be comprehensive or to fully characterize off-site contamination from ORR. TDEC does not have the resources or funding to complete a comprehensive sampling program. A recommendation has been added to this document that a regular monitoring of off-site residential wells should be included in DOE's groundwater monitoring program.

4. Health outcome data

Reviewer Comments:

"Based on their assumptions and views of the data, the authors reach conclusions for which their explanations are appropriate, and therefore they communicate the proposition that there are no adverse health effects expected, and if there are any in the area (not checked or evaluated) they are unrelated to site-based exposure via groundwater because of the absence of complete pathways."

"Sites such as the subject area often have the attention of activists and others creating a counter-balance to any tendency to whitewash a potentially dangerous situation. Frequently they seize upon some statistical aberration or local cancer cluster as their cause celebre, thereby inflaming public and agency reaction (and over-reaction). Although I know there have been issues in the area, especially regarding mercury, apparently they have not motivated anyone to get very excited about potential threats. Hence, I was surprised that the authors did not present some population-based statistics to validate their assertions that there was no threat. Even census tract data on longevity or disease incidence from the cancer registry would add confirming support for the conclusions which, to me, seemed stretched."

ATSDR Response:

ATSDR scientists generally consider health outcome data to evaluate the possible health effects in a population known to have been exposed to enough environmental contamination to experience health effects. In this pubic health assessment on off-site groundwater at ORR, ATSDR scientists determined that people were not and are not using private groundwater wells and were not exposed to ORR related contaminants from groundwater exposure. For these reasons, health outcome data were not evaluated in this public health assessment.

5. Include more maps

Reviewer Comments:

"The significant ETTP monitoring points should be clearly shown on a map. *This same comment applies to data locations for the other sites/watersheds.*"

"Potentiometric maps and geologic cross-sections are appropriate and needed to adequately evaluate potential hazards to public health."

"The report does not include maps of the contaminant plumes emanating from the Y-12 complex. Such maps are also appropriate and needed to adequately evaluate potential hazards to public health."

"In the discussion of contamination in Bethel Valley and Melton Valley, creeks are mentioned by name, such as White Oak Creek, Raccoon Creek, First Creek, and the Northwest Tributary, but there is no figure to show the reader the locations and the configurations of these creeks. This problem is actually generic to the whole report. There are figures in the draft PHA for releases to White Oak Creek, especially Figure 10, that show these creeks, although sometimes not too distinctly. A good figure showing the surface water drainage pattern for the ORR is considered a necessity for this report, because the message of this report is as much or more graphical and qualitative than it is quantitative."

"Figure B-1 does not include the Maynardville Formation, which is described in Table B-1 as a significant aquifer and is also mentioned several times in the text."

"Figure B-1 is an incomplete representation of the geologic and hydrogeologic relationships that exist on and around the ORR. Vertical profiles or cross-sections are needed to show the interrelationships of the various formations, aquifers, and flow paths. Depictions of flow gradient and conductivity calculations or models would also be helpful."

ATSDR Response:

Several maps and figures have been added to the document to address the issues raised by the reviewers. Figure 2 shows the monitoring locations near ETTP. Geologic cross-sections are provided in several maps including Figures 3, 6, 9, 11, and 12. The contaminant plume emanating from Y-12 and extending off-site into Union Valley is depicted in Figure 13 and Figure B-1. White Oak Creek, Raccoon Creek, First Creek, and the Northwest Tributary are represented in Figure 5.

The Maynardville Formation is a sub-group of the Conasauga Group. This is indicated in the text of the document as well as in Table B-1. Figure B-1 is intended to show the major geologic formations of the ORR

6. Vapor intrusion

Reviewer Comments:

"Absent are any consideration of vapor intrusion for VOCs and semi-VOCs, including some forms of mercury…"

"One potential pathway of human exposure that is not addressed in the report is the volatilization of contaminants from the groundwater system to the soil system and subsequent inhalation by residents in underground structures (i.e., basements or houses partially located below grade) or in buildings with cracked foundations."

ATSDR Response:

A thorough discussion of vapor intrusion as it relates to the EEVOC plume extending off-site from the Y-12 Complex has been added to the 'Evaluation of Environmental Contamination and Potential Exposure Pathways' section of the document.

7. Adequacy of institutional controls and pump-and-treat technology in Union Valley

Reviewer Comments:

"The document should detail which institutional controls are in place in Union Valley. It is our understanding that these include deed restrictions on groundwater use."

"The idea of institutional controls being adequate to exclude [hunting and fishing], of course, runs counter to the local culture."

"The administrative controls are not adequately described. Technical details of the plume, remediation system, and performance metrics are also lacking. The general tone of the section (*ATSDR's Conclusion for Bear Creek Valley and UEFPC Watersheds*) suggests that the pump-and-treat will be sufficient when it is well-known that this remediation technology is rarely effective in reaching site-specific remedial action objectives."

"The recommendation to solely rely on institutional controls set forth in the Interim Record of Decision is flawed given that the pump-and-treat remediation technology is ineffective in reducing contamination to safe levels."

"Most of the pathways seem to be well-defined. However, the Union Springs pathway seems ambiguous. It is unclear why an area zoned as industrial can be assumed to have unlikely human contacts. What about humans that exercise in this area during break periods at facilities? Also, workers involved in infrastructure maintenance may contact these seeps."

<u>ATSDR Response</u>:

The institutional controls are outlined under *'UEFPC Watershed'* in the 'Contamination at Bear Creek Valley and UEFPC Watersheds' section.

The issues of hunting and fishing are addressed in other PHAs for the ORR, including: White Oak Creek, Current Chemical Exposures and Mercury PHAs.

The efficacy of pump and treat technologies is certainly a debatable point; however, the purpose of this health assessment is not to recommend treatment technologies which would reduce contamination, nor is it our objective to evaluate whether the selected remediation tactics can reach site-specific remedial action objectives. It is our goal to evaluate whether exposure to contaminated groundwater is occurring, has occurred in the past, or will likely occur in the future. If a completed exposure route has been identified, we would then evaluate the health impacts, if any, from that level of exposure. The institutional controls that are in place were not intended to reduce the EEVOC plume's toxicity, mobility of volume of contamination. They were merely intended to 1) ensure that the public's health is protected by mitigating exposure, 2) to prohibit future activities that could lead to exposure, and 3) prohibit activities that can make the plume migrate faster or increase in extent.

The exposure scenario that is mentioned here is the possibility of someone coming in contact with contaminated groundwater in this area. Because of the zoning for this area as industrial, we do not anticipate any contact by people with groundwater. While it is entirely possible that maintenance workers could somehow come in contact with springs or seeps in the area, we feel that an exposure (especially one of any health consequence) of this nature is an unlikely scenario.

8. Description of contaminant sources and provision of additional data

Reviewer Comments:

"Deficiencies in the report with respect to the description of groundwater contamination include: (a) description of contaminant sources in the aquifer; (b) disconnect between the description and discussion of contaminants found in off-site monitoring points and the activities of the various facilities; (c) incomplete presentation of the positioning of off-site monitoring and residential wells (i.e., depths and hydrogeologic units) in relation to groundwater flow paths; (d) inadequate description of biogeochemistry of the groundwater system."

"The contamination discussion is too brief. Only selected contaminants are discussed without giving any sense of the data sets that were available to the PHA preparers. Were radionuclides and non-VOCs not a potential groundwater issue at ETTP? Summary tables of pertinent data sets should be provided so the reader can clearly see why, for example, only VOCs are discussed for ETTP groundwater. Otherwise it's left open to question whether or not data exists or was examined for other possible contaminants. *This same comment applies to the discussion of selected analytes/contaminants for the other sites, watersheds, or media.*"

"The PHA fails to give the reader the general perspective of what the potential groundwater contamination sources and constituents are, how much data is available, and why only certain contaminants are discussed. Consequently, the PHA discussions of only a few contaminants come across as selective and incomplete."

"The source data on area hydrogeology and groundwater monitoring are included only as reference citations. Sufficient portions of that data need to be presented in the PHA text and as tables and figures to support and justify ATSDR's conclusions. Without the supporting information, the lay reader does not get the sense that the historical data have been reviewed critically and that any potential data gaps have been looked for."

ATSDR Response:

We believe that the document contains adequate descriptions of relevant contaminant sources in each watershed. Each respective section has a subsection devoted to the contaminant sources as well as a section discussing relevant data from monitoring wells, residential wells, and seep/spring data. *(Monitoring well depth and biogeochemistry issues are discussed below)*

The primary contaminants of concern in groundwater at ETTP are VOCs. The primary contaminants in sediments at ETTP are inorganic elements, radionuclides, and polychlorinated biphenyls (PCBs). In soils, the contaminants of concern include inorganic elements, radionuclides, semi-volatile organic compounds (SVOCs), polyaromatic hydrocarbons (PAHs), and VOCs. As is the case with other watersheds discussed in the PHA, the contaminants that are discussed are the primary contaminants of concern in groundwater. A statement similar to this one has been added to the 'Contamination at ETTP' section for clarity.

The vastness of the data sets that exist concerning the hydrogeology of the ORR precludes their inclusion, even as summary tables, in this document. We feel that summarizing these studies in text is sufficient to convey the concepts of the hydrology of the area. These concepts are well-supported and are not of a generally contentious nature. Relevant data from off-site groundwater monitoring and from residential well sampling are included in summary form in the relevant sections. If the reader would like to review the raw data, we will be happy to provide them.

9. Well (monitoring and residential) depths and sampling depths

Reviewer Comments:

"…there is no information provided in the report that explains whether off-site wells are sampling groundwater from the shallow aquifer system or deeper formations."

"[Appendix B] indicates fractures and solution cavities occurring from 100' to 300' deep in bedrock, which seems to contradict the earlier statement … that they occur mostly from 0 – 100' deep. How deep is the Clinch River bottom on average? How deep is the hyporheic zone beneath the Clinch? How deep are typical groundwater drinking wells in the area?"

ATSDR Response:

Specific well depths were not available with the data received by ATSDR. However, from all reports reviewed by ATSDR, it appears that many of the samples were taken using multi-port sampling devices from wells that extend deep into bedrock (>500 feet). The Clinch River varies in depth but is typically around 100 feet deep.

Residential well depths were not reported along with the data. However, the depth of residential wells can vary greatly. Variables that affect well depth include: type of well, location of well with respect to surface water, composition of bedrock and location of the water table. Because of the cost of drilling and the likelihood of finding usable amounts of groundwater at depth, most private wells in this area are less than 200 feet deep.

The text mentioned in Appendix B contained a typo – an apparent remnant from earlier edits. This sentence has been corrected to read that fractures and solution cavities occur predominantly in the shallow zone (0' – 100' deep) and decrease significantly at depth.

10. Geochemistry of groundwater around ORR

Reviewer Comments:

"Deficiencies in the report include… inadequate description of biogeochemistry of the groundwater system."

ATSDR Response:

A general discussion about the geochemistry for the relevant formations underlying the ORR has been included in Appendix B.

11. More in-depth discussion of Karst

Reviewer Comments:

"Karst zones do not appear in Figs. B-2, -3, or –4, or in the text of Appendix B, although an exposition on this subject would be a useful addition to this Appendix."

"Also discussed in ORNL-5870 is the fact that the more calcareous formations underlying Bear Creek Valley often contain large solution-weathered cavities that are conduits for groundwater. This fact probably needs some additional explicit discussion in the PHA because the existence of this type of condition tends to fuel speculation by concerned citizens."

"Portions of the geology discussion are incorrect. Many of the streams on the Oak Ridge Reservation are now known to gain or lose water through their beds. This is especially true of Bear Creek. Acknowledgement of the presence of karst and the understanding of it's effects on groundwater flow and contaminant migration has changed substantially since the 1980s. Karst features are important conduits for groundwater in the Upper East Fork Poplar Creek watershed, Union Valley, Bear Creek Valley, at East Tennessee Technology Park and in Bethel Valley. It was the primary reason that X-10 waste disposal activities were moved from Bethel Valley to Melton Valley, which is underlain by shale bedrock. Additionally, groundwater flow in the industrial areas is strongly influenced by the presence of pipes, building formations, buried utilities, and backfill."

ATSDR Response:

A more thorough discussion of the karst geology beneath the ORR has been added to Appendix B. Also, a discussion of the presence of karst geology as well as buried pipelines and other structures below ground and their impact on groundwater flow, has been added to the '*UEFPC Watershed*' section of the document.

Appendix B addresses the fact that Bear Creek has both gaining and losing reaches. The presence of karst systems and their effect on groundwater movement in the Oak Ridge area is addressed repeatedly in the document; however, because of the variability and unpredictability that the presence of karst conduits introduce to a groundwater system, the topic has been expounded upon further in Appendix B.

12. Explanation of "incised meander"

Reviewer Comment:

"The important term "incised meander", occurring on page B-7, should be explained."

ATSDR Response:

The term "incised meander" has been defined in Appendix A and explained further in Appendix B.

13. Historical groundwater use and over-pumping of wells

Reviewer Comments:

"The PHA lacks any meaningful discussion on historical groundwater usage in the area. Other than the figures depicting offsite well locations near the ORR boundaries, there is no inventory or discussion of well usage in the area and how pumping may or may not have influenced localized flow of groundwater emanating from the ORR."

"There is a need in the conclusions section of the report to add a statement about the potential (or lack of potential) for induced infiltration of water through well pumping as an off-site groundwater exposure pathway (i.e., the potential that part of the discharge from a well near contaminated surface water could be water drawn from the contaminated surface water)."

ATSDR Response:

The figures depicting off-site well locations include residential wells from which we have sampling data. While it is true that most residences near the ORR receive their drinking water from municipal sources, we are aware that there are many more residential wells than are depicted on these maps. For the areas near ETTP and ORNL, there are a significant number of monitoring wells near the ORR border. We have evaluated these data and have concluded that contamination from the ORR has not migrated beyond the ORR boundaries in groundwater. This conclusion is based upon the limited data currently available. Should any new data become available that could change our assessment, the issue will be reevaluated.

It is true that heavy well pumping can create a negative hydraulic gradient and cause groundwater to flow toward the well in all directions. Also, the theoretical potential exists for contaminated water to be drawn from surface water sources. Based on available data, we do not believe this is occurring in residential wells surrounding the reservation. This discussion appears in the 'Conclusion' section of the PHA as a consideration.

14. Melton Valley contamination

Reviewer Comment:

"Page 21, lines 5 – 14 seem to discuss only strontium 90. What happened to the tritium and cesium 137 mentioned in the preceding paragraph? What about other contaminants (rad and chemical) that have been detected in wells throughout Melton Valley?"

ATSDR Response:

The contaminants mentioned are indeed contaminants of concern in Melton Valley; however, because of the close interaction between groundwater in the aquitard formations of Melton Valley and surface water, these contaminants migrate via surface water. Consequently, most of the monitoring that is performed in Melton Valley concerns surface water with emphasis on the WOD. Surface water contamination in this area is addressed in the White Oak Creek Public Health Assessment. Contaminant data from off-site wells near Melton Valley are discussed in the relevant section of this document.

15. Significance of "integration points"

Reviewer Comment:

Please explain the meaning and significance of an "integration point."

ATSDR Response:

Integration points are important in defining and integrating conditions at the watershed level and are key sites for assessing long-term water quality improvement as various remedial actions in the watershed are completed (SAIC 2005).

16. Significance of Comparison Values

Reviewer Comment:

"Although hazard identification as such is adequate, toxicological data themselves are not really brought into play, since the authors have determined that there are no completed pathways and therefore no subject population at risk to evaluate toxicologically. The significance (or lack thereof) of CVs as toxicologic benchmarks is not discussed."

ATSDR Response:

Comparison Values (CVs) are used to assess voluminous data sets in an efficient and consistent manner during the screening analysis. They enable you to identify substances that are not expected to result in adverse heath effects (i.e., substances detected below comparison values) and substances requiring further evaluation (i.e., substances detected above comparison values).

Comparison Values are not thresholds of toxicity. Comparison values should not be used to predict adverse health effects. These values serve only as guidelines to provide an initial screen of human exposure to substances. Although concentrations at or below the relevant comparison value may reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects.

A text box on page 12 reflects the above information and directs readers to Appendix A where there is a more thorough explanation of comparison values.

17. Presence of other springs in the area

Reviewer Comment:

"Bacon Springs where Oliver Springs get all there water from. Key Springs is one more. And right where the Oak Ridge outdoor swimming pool there is a spring that is where they get the water to fill the swimming pool up. All along the Black Oak Ridge there is springs and water coming out from that ridge line. All too much water to come from one mountain chain."

ATSDR Response:

Because of the karst nature of the geology in the Oak Ridge area there are many springs and seeps. ATSDR has reviewed all available data from seeps and springs that have been identified in the vicinity of the Oak Ridge Reservation. A summary and discussion of these data is provided in respective sections for each watershed.

18. Contamination in the Lower EFPC floodplain

Reviewer Comment:

"On page 23, under the heading Monitoring Wells, the sentence beginning 'As previously mentioned…' needs to be followed by a sentence that states how the contamination in the EFPC floodplain ground water arrived at the off-site monitoring locations, in not through '…a direct result of groundwater contamination emanating from the Y-12 complex.'"

ATSDR Response:

The groundwater contamination in the EFPC Floodplain results from contaminated surface water (EFPC) infiltrating into the groundwater. In 1993, ATSDR conducted a Health Consultation for this area and concluded that there is a possible health threat to people consuming groundwater in this area; however, based on available data, all residences in the area were using water from the municipal water system. This statement has been added in the document.

19. Contamination leaving the ORR via surface water

Reviewer Comment:

"The document needs to reiterate that while only one site has off-site migration of groundwater (i.e., EEVOC – not defined in the acronym list), the short groundwater pathway for subsurface contamination to surface creeks and streams does not imply that surface waters leaving the site are safe. There is a significant amount of groundwater contamination being diluted within the surface creeks and streams."

ATSDR Response:

Indeed, groundwater contamination is contributing to surface water contamination. This point is mentioned in the document and has been reiterated in the appropriate sections. However, this document is solely focused on human exposure to off-site groundwater. Exposure to contamination in surface water and other media is addressed in other ATSDR public health assessments including: Current & Future Chemical Exposure Evaluation (1990-2003), White Oak Creek Radionuclide Releases, and Y-12 Mercury Releases PHA's.

20. Figures are too general in Appendix B

Reviewer Comment:

"Pages B-5 and B-7. The discussion and two figures are very general and conceptual in nature. Need to provide specific local data to support what's depicted in the figures."

ATSDR Response:

Figures B-2, -3, and -4 are intended to be demonstrative of general surface water/groundwater interactions and not necessarily specific to the geology of the ORR area. Information presented in Appendix B is supported by cited sources throughout the text. These sources contain site-specific data to confirm concepts expressed in Appendix B. These concepts are well-supported and are not of a generally contentious nature. We feel that it is unnecessary and beyond the scope of this document to include these data.

21. Inadequacy of ATSDR response to Community Concern #4 (p. 51)

Reviewer Comment:

"Page 40, comment # 4. ATSDR's response is inadequate. The overall summary level discussion in the PHA does not reflect "a thorough investigation of the underlying geology." Previous geologic reports are cited in the PHA, but salient data from these reports are not presented to support or justify ATSDR's conclusions. Also, the response refers the reader to

Appendix B for "specific information regarding the geology and hydrogeology of the ORR." However, the information in Appendix B seems to be highly general, presenting textbook concepts without the support of localized, site-specific data."

ATSDR Response:

We believe that the comment itself is of such a general nature that it expresses the sentiment that drives the preparation of this PHA. This citizen is concerned that contaminated groundwater may be reaching private residents through karst conduits or other pathways. The entire PHA is designed to address this issue. In our response to this comment, we are expressing our recognition of these concerns and the fact that they are addressed throughout this PHA. We also hope that additions made to this PHA as a result of some of the excellent comments received through the public comment process has increased the thoroughness and specificity of the document.