Draft
for
Public Comment

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
EFPC	East Fork Poplar Creek
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
HRE	homogeneous reactor experiment
HRSA	Health Resources Services Administration

Acronyms (continued)

IAG	interagency agreement
IHP	intermediate holding pond
IROD	Interim Record of Decision
I 131	iodine 131
ISV	in situ vitrification
IWMF	interim waste management facility
LEFPC	Lower East Fork Poplar Creek
LLLW	liquid low-level waste
LWBR	Lower Watts Bar Reservoir
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mGy	milligray
mrem	millirem
µCi/mL	microcuries per milliliter
µg/L	micrograms per liter
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
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

Acronyms (continued)

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
RCRA	Resource Conservation and Recovery Act
RER	remediation effectiveness report
RfC	reference concentration
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
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
TWRA	Tennessee Wildlife Resources Agency
U 233	uranium 233
USACE	U.S. Army Corps of Engineers
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

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, and 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 generated a variety of radioactive and nonradioactive wastes, a portion of which remain in old waste sites. Also, 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 (PHA) focuses 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 result from discharge of 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 PHAs.

The overall goal of this PHA is to determine the potential public health hazard posed by historical releases of contaminants to groundwater. In that regard the PHA will evaluate all currently available groundwater monitoring data as well as demographics, 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 address fully specific community concerns solicited by ATSDR as part of the public health assessment process about site-related public health issues relating to off-site groundwater exposure.

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

Available data show that off-site contamination has only occurred in monitoring wells and seeps/springs in Union Valley. Residential wells have been unaffected by contamination resulting from ORR activities. Because 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 off-site east-northeast 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 notifies them of the potential for contamination and requires 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 to establish 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).

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). Please see Figure 2 for the original and current ORR boundaries.

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).

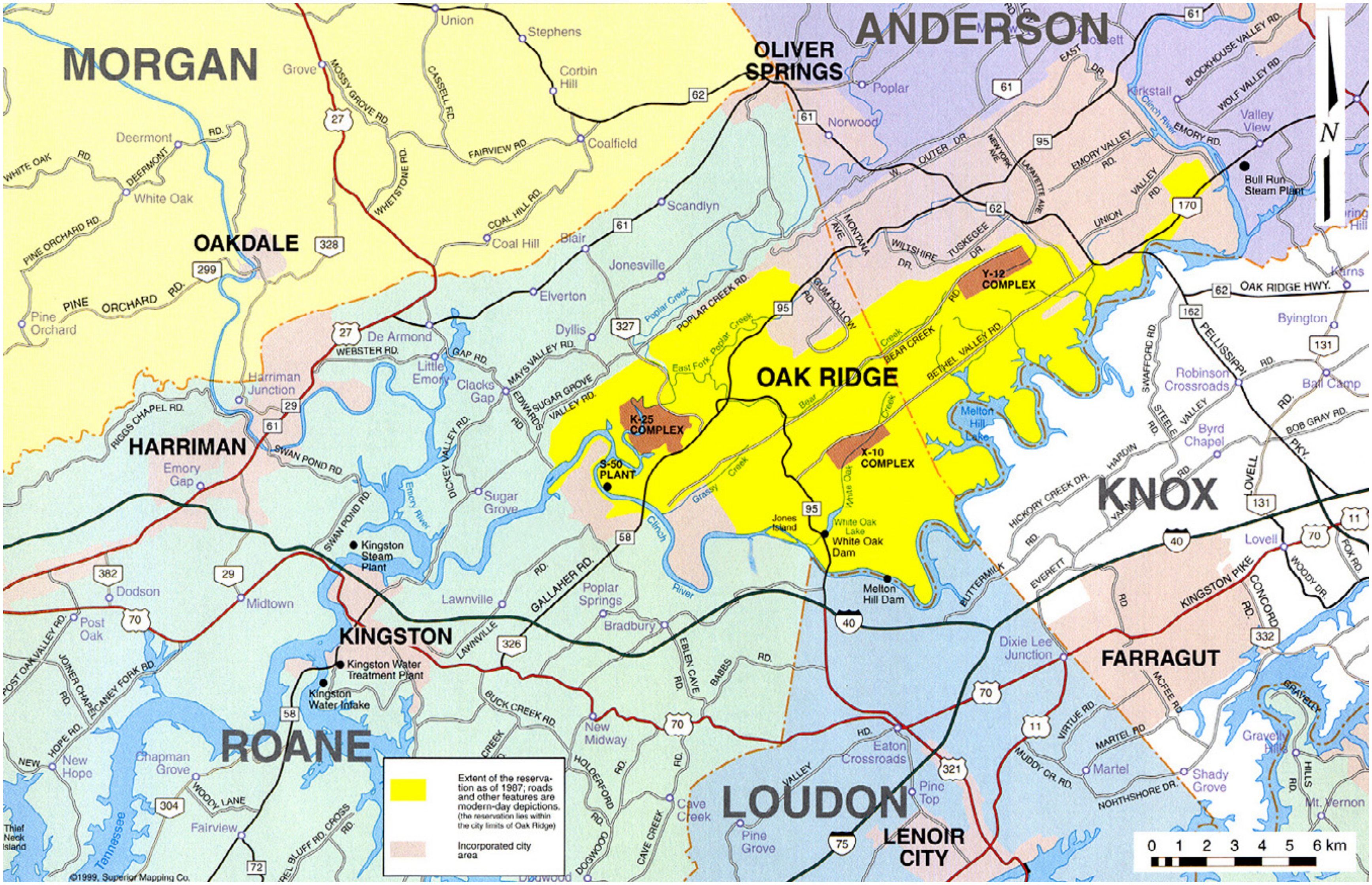
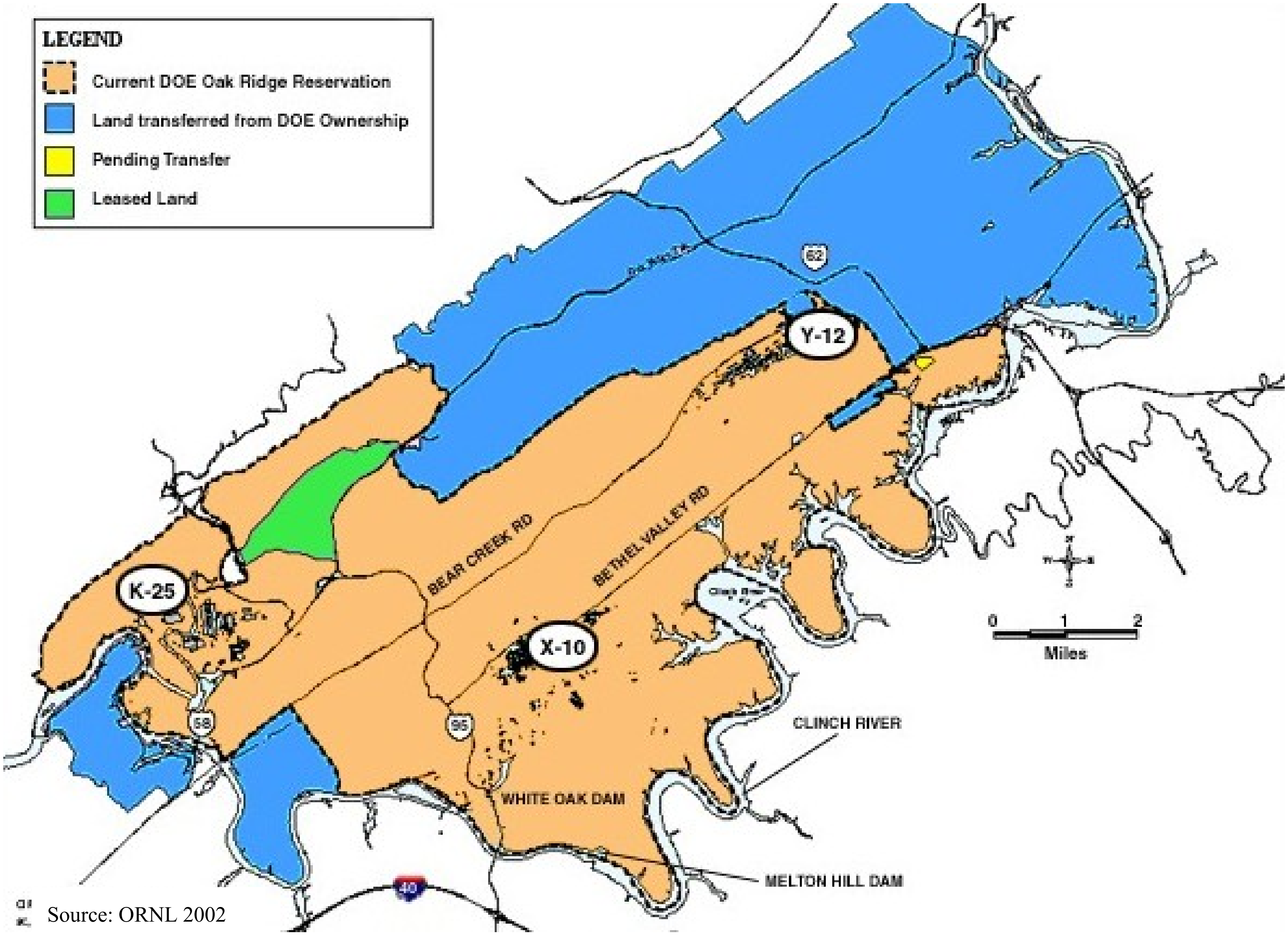


Figure 1: Location of the Oak Ridge Reservation



Source: ORNL 2002

Figure 2: Original and Current ORR Boundaries

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. The Bethel Valley and Melton Valley Watersheds will, however, be discussed together, as will the Bear Creek Valley and UEFPC Watersheds. These groups were created 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). As much as 95% of all groundwater from ORR discharges into local streams and eventually into the Clinch River (USDOE 2004).

> 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. Groundwater and surface water and groundwater contamination sources are extensively interconnected on the ORR, and 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 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 1980s 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. TDEC identified 71 residential wells for sampling. Most were situated southwest and within 2 miles of ORR boundaries because, given 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. Because 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 on whether they came from residential wells, monitoring wells, or from seeps and springs. A further distinction was made based on 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 3, Figure 4, and Figure 5) and sampling results will be discussed for each area in their 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-1990s, when the majority of available data in the OREIS database were 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.

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; 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 1996A).

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). Because, however, 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 1986; 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; but the complex fractures and fissures in this formation makes nearly impossible an accurate prediction of groundwater flow path.

Because the local water table occurs just below the surface in the unconsolidated zone, groundwater flow is generally consistent with the surface topography. But 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. During high precipitation events, however, the clay content in the soil can prevent rapid infiltration and could 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 1986, SAIC 2004).

Contamination at ETTP

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. 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, has 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 that the source of contamination has been eliminated. It could also be a result of increased biodegradation in those particular areas. A review of FY 2003 monitoring data collected from known and suspected exit point locations shows that 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) have decreased from 1997 — 1998 (SAIC 2004).

Off-Site Groundwater Monitoring Data

Seeps and Springs

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

> 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.

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 3). Also for both substances, samples taken from an adjacent location (CCC Well #1) on the same day(s) were below detection limits.

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

No contaminants were 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 collected on September 22, 1998 from four different wells. 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 its CV in one sample. Concurrent sampling at adjacent wells revealed concentrations well below the CV. As part of the Water Resources Restoration Program for ETTP, exit pathway monitoring wells are continually monitored. 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 have concluded that the public (community) is not being exposed to groundwater contamination from ETTP.

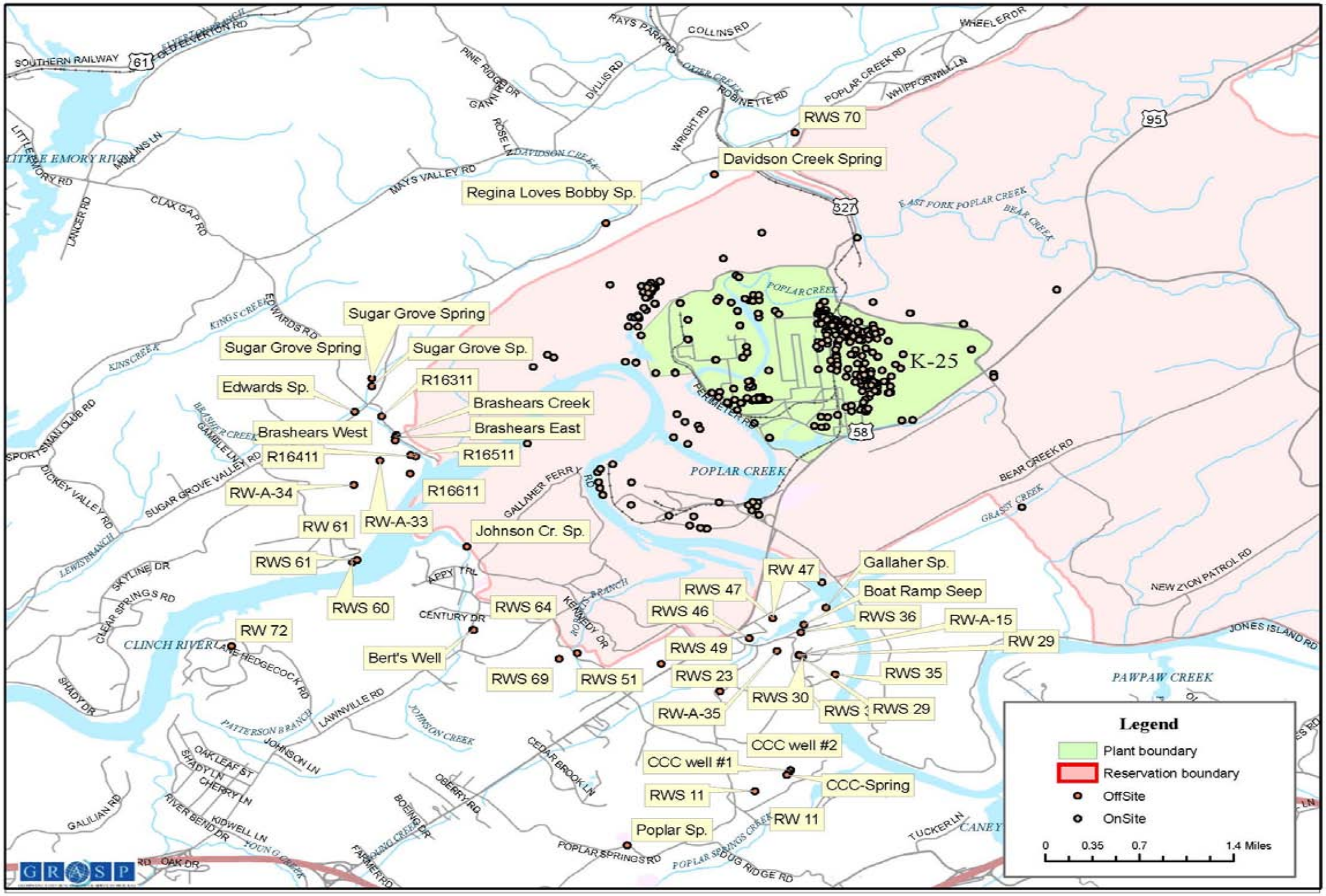


Figure 3: Off-Site Groundwater Sampling Locations Near ETTP

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 1 year. This initial time period was, however, 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 related to nuclear energy. From 1958 to 1987, the Oak Ridge Research Reactor operated to support various scientific experiments at X-10. For many years this reactor was the main radionuclide supplier to what was known as the Free World for medical, research, and industrial purposes (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 as groundwater storage as opposed to facilitating the spatial movement of groundwater (MMES 1986). 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.

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. In the Bethel Valley a hydrologic divide separates surface water flow in the western third of the watershed. West of the divide, surface water and groundwater flow west to Raccoon Creek 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. Because of the shallow active zone and the interaction with surface water, the common concept of contaminated groundwater plume migration is not appropriate in this area. 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 downgradient end (MMES 1986). This overflow occurs as springs or seeps, from which water flows downhill to creeks and streams.

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. 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 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).

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. That said, 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 2002b, US 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. Further 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 2002b). In November 1994, an action memorandum was approved, and by March 1995 a groundwater collection and transmission system was being used at the Corehole 8 Plume to prevent groundwater infiltration (SAIC 2002b; US 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. In addition, acting 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 2002b). 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 2002b; 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 removal of the tanks would result in a high dose rate to the workers (SAIC 2004).

Melton Valley Contamination

In the late 1950s, 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 24 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) — at least 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 subcontractor 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 (D&D) activities at OHF had been completed and 110 of 111 hydrofracture wells are now 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).

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 discharged from Melton Valley travel off the reservation through surface water and flow into the Clinch River (SAIC 2002b; 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 discharged over White Oak Dam (SAIC 2002b). SWSA 4 consists of 23 acres used between 1951 and 1974 for industrial and radioactive waste burial (SAIC 2002b). DOE's investigation revealed that two seeps produced about 70% of the overall ^{90}Sr 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 2002b).

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 2002b; 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 2002b; 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 2002b; U.S. DOE 2001f).

DOE's 1994 investigation showed that Seep C was a major source of ^{90}Sr releases to White Oak Creek (SAIC 2002b). 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 released to Melton Branch, and therefore to off-site locations (SAIC 2002b; 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 2002b; U.S. DOE 2001f). Currently, there are bimonthly sampling and weekly inspections of the treatment unit at Seep C (SAIC 2002b).

Seep D was also a major source of ^{90}Sr to the White Oak Creek watershed (SAIC 2002b). 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 2002b; 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 2002b). The amount of ^{90}Sr is, however, 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 2002b; 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 2002b).

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 and is closely coupled with surface water. More 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.

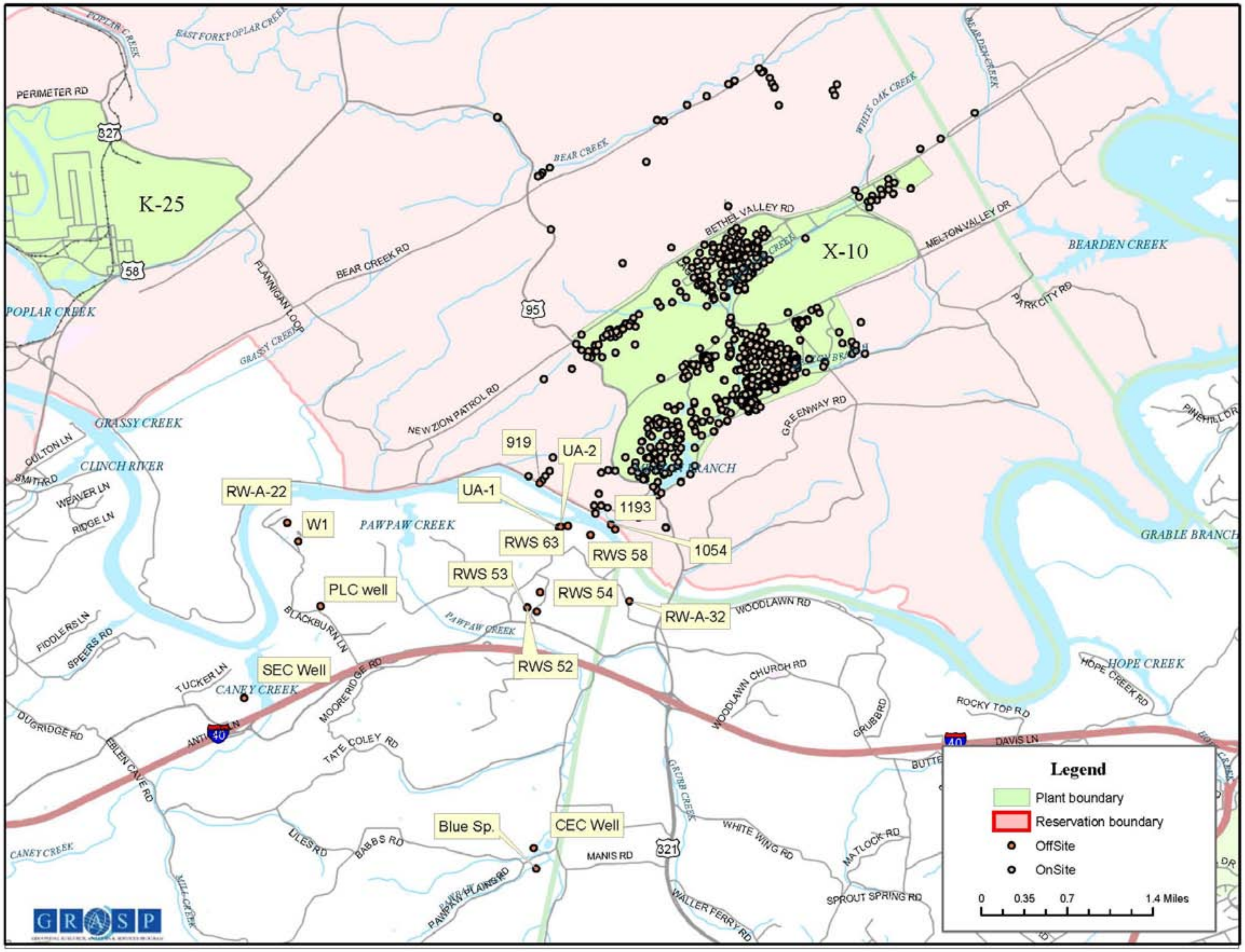


Figure 4: Off-Site Groundwater Sampling Locations Near ORNL

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 6 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 was taken 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, 6 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

No contaminants have been 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. No site-related groundwater contamination reated to operations in Bethel or Melton Valleys is beyond the ORR boundaries. 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 has 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 no public (community) exposure is expected 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 enrich uranium electromagnetically. In 1952, the facility was converted to enrich lithium-6 using a column-exchange process and to fabricate components for thermonuclear weapons using high-precision machining and other specialized processes. In 1992, after the Cold War ended, Y-12's mission was curtailed — the plant is currently used for weapons disassembly and weapon renovation operations. The National Nuclear Security Administration 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 1990s.

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 mile wide and 3.2 miles long; the area contains roughly 240 principal buildings, of which about 18 were directly involved with processing or storage of uranium compounds (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 ½-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).

Bear Creek Valley and Union Valley are underlain by the Conasauga Group. This formation is typically flow-limiting; however, the Maynardville Formation, which is a sub-group of the Conasauga, is a local aquifer and is the primary transport mechanism for groundwater and contaminants from the Y-12 Complex (SAIC 2004). Pine Ridge to the north of the Y-12 Complex and Union Valley is composed of the dense shales of the Rome Formation. This formation is higher in elevation than Bear Creek Valley and Union Valley and has a significantly lower hydraulic conductivity which prevents groundwater from flowing from the Maynardville Formation north to the residential areas of Scarboro and Oak Ridge (USGS 1989, SAIC 2004). Groundwater in the UEFPC watershed typically flows along strike in the Maynardville Formation between 100 ft and 400 ft below ground from west to east in Union Valley (Jacobs EM Team 1997a).

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.

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 no uranium was 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 might be going down overall after peaking following a 5-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). Because of high-flow conditions, FY 2003 saw anomalously high AWQCs exceedences. But these levels are expected to decrease markedly, thus reducing Zone 1groundwater contamination.

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; the long-term goal is to attain unrestricted use classification. The ROD identifies the comparative criteria for groundwater in Zone 2 as MCLs. The remedial action objective (RAO) for cleanup levels in Zone 2 is the risk to potential residents in the area to be below 1×10^{-5}. The RAO applies as the performance criterion at BCK 9.47, which 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 revealed that — as measured at the Maynardville Limestone picket A — of the total amount of water passing through the IP, only 3% was groundwater. In other words, 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. Following previously observed trends, uranium, nitrate, manganese, and for many years several VOCs have exceeded MCLs in Zone 3. 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, a very high interconnectivity exists between surface and groundwater. Gaining and losing reaches of Bear Creek occur 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. Completion of remedial actions in Bear Creek Valley has, however, 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. This contaminated plume is made up of several commingling plumes from a variety of sources. The contaminants 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 (Jacobs EM Team 1997a). 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 DNAPLs probably are present.

Groundwater in the UEFPC watershed typically flows along strike from west to east in the Maynardville Formation between 100 ft and 400 ft below ground. The Maynardville Limestone is the primary pathway for contaminant migration from Y-12. Because of the Maynardville Limestone's well-developed karst system, groundwater from adjacent formations tends to flow toward it (Jacobs EM Team 1997a). And 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

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

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).

In accordance with CERCLA requirements, in 1997 the Interim Record of Decision (ROD) for Union Valley was published. This ROD contains the selected interim remedial action for Union Valley, and considers two interim alternatives: Alternative 1 – no action, and Alternative 2 – institutional controls. The selected action was Alternative 2, which consists 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) appropriate DOE verification of compliance with the agreements and notification to state and local agencies. This remedy is not the final remedy for Union Valley; thus it does not have provisions to reduce the toxicity, mobility, or volume of the contaminants of concern. Subsequent actions for this characterization area are forthcoming. In the meantime, however, 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 to increase the extent of the contaminant plume (Jacobs EM Team 1997a).

The EEVOC plume is the only confirmed off-site contamination of ORR groundwater (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 PHA is to determine the extent of off-site groundwater contamination using existing information and the effect, if any, this contamination might 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, 6 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. Union Valley contains no residential wells.

Off-Site Groundwater Monitoring Data

Seeps and Springs

Not surprisingly, the samples that 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. These results are from a one-time sampling event on March 21, 1996. Samples were collected from each sampling location, split, and then 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. Two other samples (from SCR7.1SP and SCR7.18SP) had 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

No contaminants were 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

In off-site monitoring wells near the Y-12 Complex, 30 chemical contaminants and 12 radionuclides were detected above comparison values. Nine chemicals (indicated by superscript 3 in Table 4) were detected above CVs, but 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 5. As previously mentioned, groundwater does not migrate from Union Valley beneath Pine Ridge (see ATSDR's response to Public Comment #2); it is unlikely therefore that any contamination in the EFPC floodplain is a direct result of groundwater contamination emanating from the Y-12 Complex. Of the 30 total chemicals, 14 (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 12 radionuclides detected above CVs (Table 5), 7 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.

1 **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†*	*Comments*
2,4-Dinitro phenol ‡	15 / 103	15	20	RMEG	50	EFPC Floodplain*	3/12/1991	All samples detected above CVs were taken from wells in the EFPC Floodplain.
2-Nitroaniline‡	15 / 113	15	3.3	RBC for Tap Water	50	EFPC Floodplain*	3/12/1991	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Acetone‡	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 §	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‡	4 / 82	4	0.033	RBC for Tap Water	1	EFPC Floodplain*	3/12/1991	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Arsenic§	39 / 310	7	10	MCL	83	GW-169	9/28/1995	Arsenic has not been detected in subsequent samples.
Barium §	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‡	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.

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

Substance	*Detects / Samples*	*Samples Detected Above CVs*	*CV (ppb)*	*CV Source*	*Max Conc. (ppb)*	*Max Location*	*Max Conc. Date†*	*Comments*
Chloroform§	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§	88 / 354	13	100	LTHA	720	GW-169	4/27/1992	Subsequent samples were well below the CV for chromium.
Cobalt§	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§	139 / 354	10	100	EMEG	6320	WFANE1	11/19/1990	Most samples detected above CVs were taken from wells in the EFPC Floodplain.
Dibenzo(a,h) anthracene ‡	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 §	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‡	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 §	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 ‡	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 ‡	130 / 250	4	600	EMEG	4200	BRAND7	11/2/1990	All samples detected above CVs were taken from wells in the EFPC Floodplain.
Nickel§	100 / 358	16	100	LTHA	657	WFANE1	11/19/1990	Samples from both Union Valley and the EFPC floodplain exceeded the CV.

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

Substance	*Detects / Samples*	*Samples Detected Above CVs*	*CV (ppb)*	*CV Source*	*Max Conc. (ppb)*	*Max Location*	*Max Conc. Date†*	*Comments*
Selenium§	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§	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 §	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§	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.

*Several locations reported the same maximum concentration. All locations were in the EFPC Floodplain.

†Where more than one sampling location yielded the same maximum concentration, the most recent sample date is reported.

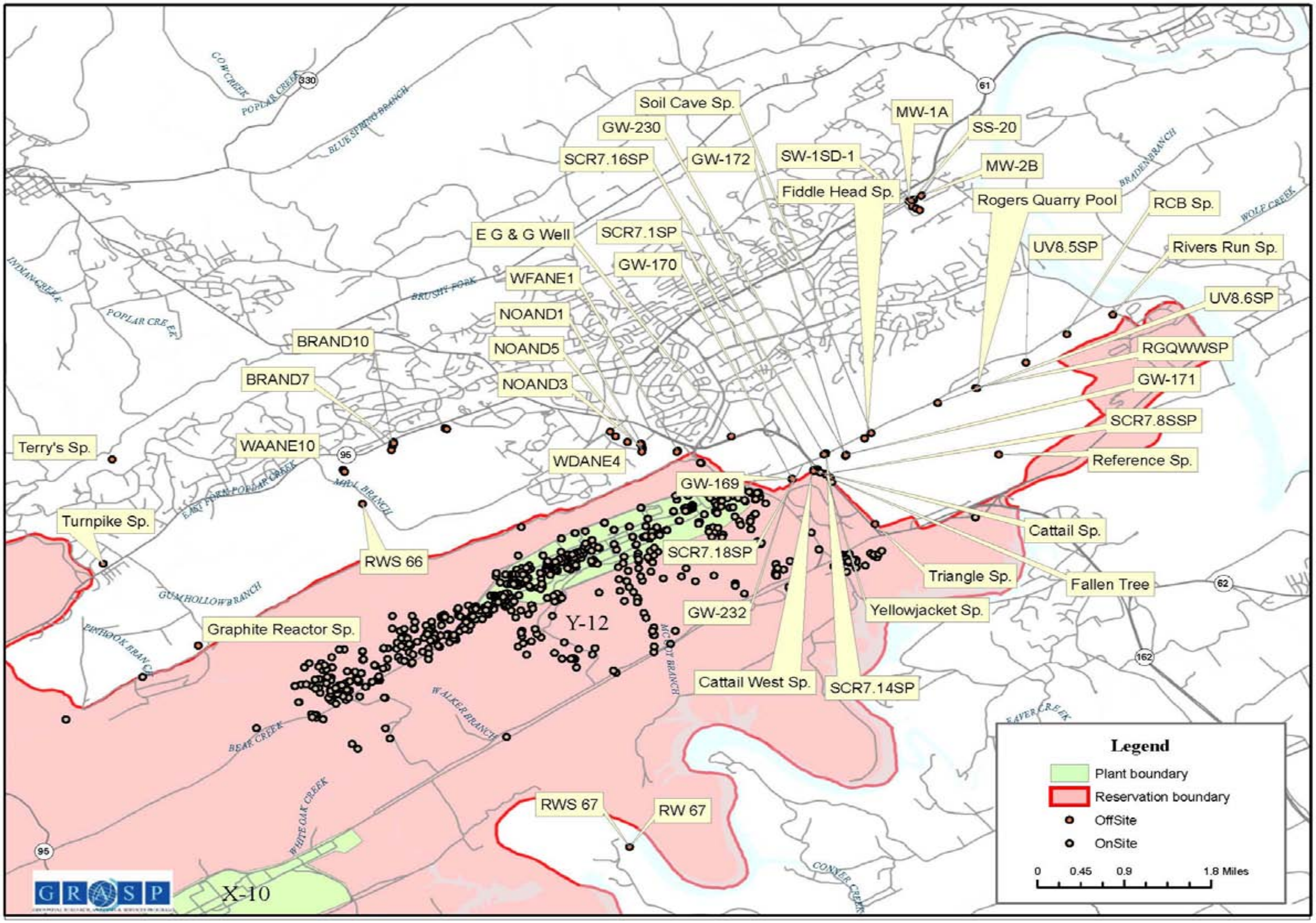
‡Contaminants detected above CVs only in the EFPC Floodplain.

§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, 2 liters water/day



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2 **Figure 5: 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. Throughout the watershed the uranium flux 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. Because 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 in 1942 the government acquired the ORR, it 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). Since the 1950s, however, 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 comprised 34,235 acres, which included 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; in 1980 the remaining 70% of the reservation was turned into the National Environmental Research Park. 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). Over the past several decades a large amount of land at the ORR that was formerly cleared for farmland has grown into full forests. 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 2002b).

Historically, forestry and agriculture (e.g., beef and dairy cattle) have constituted the primary uses of land in the area around the reservation. These uses of land are, however, 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 occur 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, these surrounding areas have minimal industrial development but 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 (Jacobs EM Team 1997a).

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 ¼ mile from the ORR; 778 children, 1,935 women of childbearing age, and 1,681 elderly persons live within a mile of the ORR (see Figure 2).

Demographics also provide details on population mobility and residential history in a particular area. This information helps ATSDR evaluate the time periods 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: Bureau of the Census 1900–1990, 2000

Figure 6 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 7 shows the population distribution within a 1 and 3 mile radius of the Y-12 complex — the only area where groundwater contamination has migrated off site. No residences are in the area surrounding the known off-site EEVOC plume, along Union Valley Road to the east-northeast of the Y-12 complex. 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.

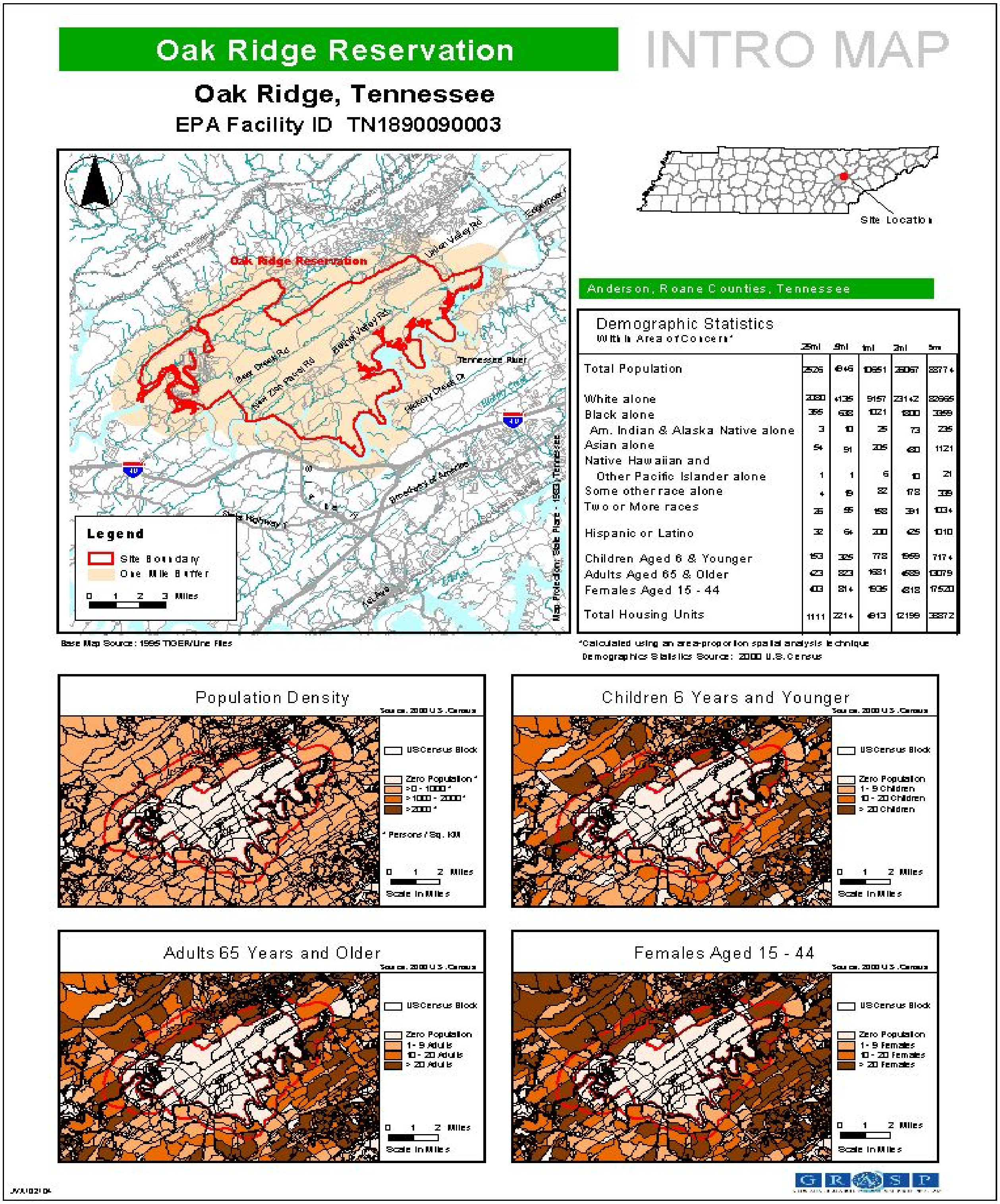

Figure 6: Demographics Within 5 Miles of ORR

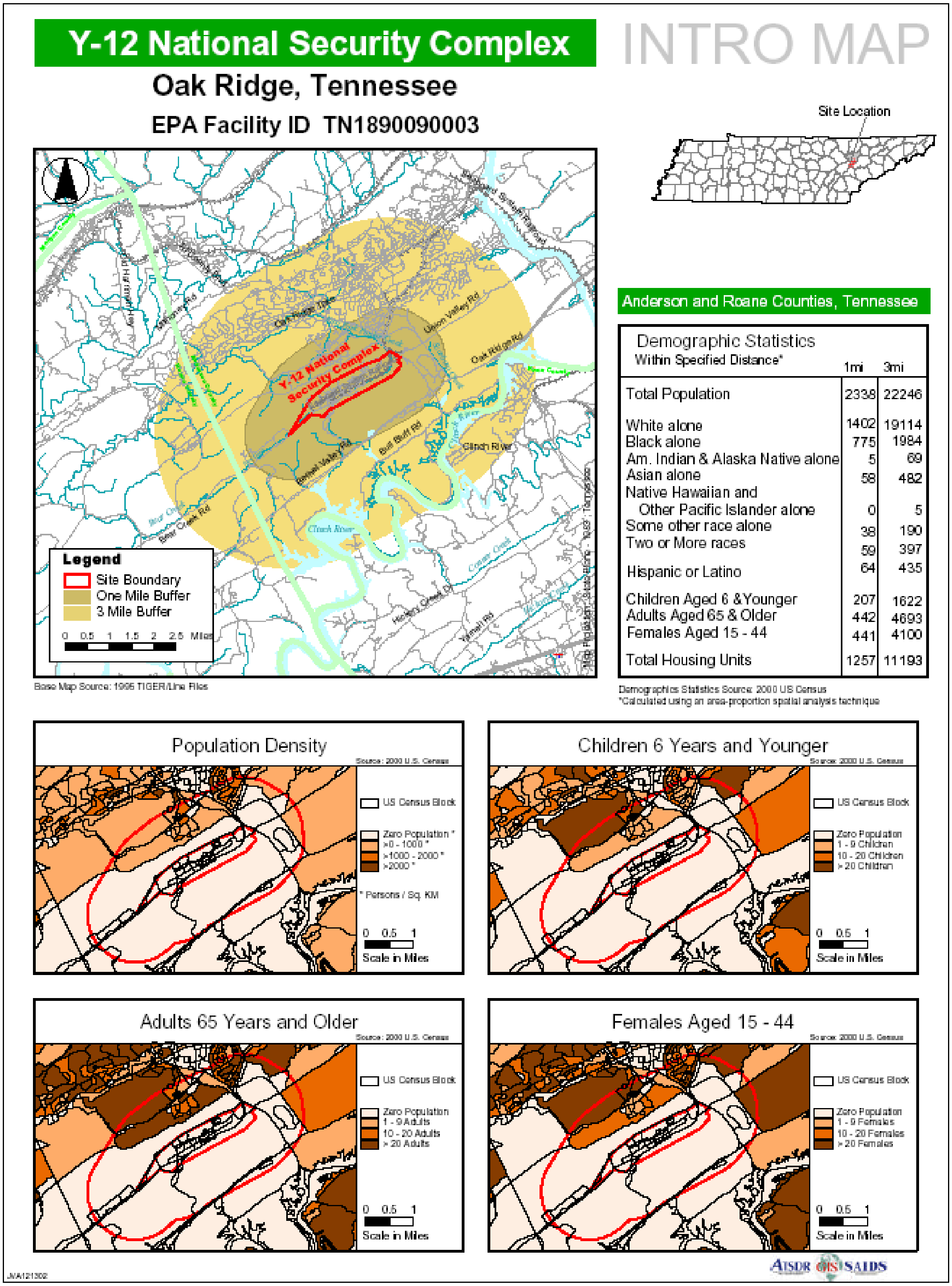

Figure 7: Demographics within 1 and 3 miles of the Y-12 Complex

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. Still, 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.

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. Because 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 two possible exposure scenarios to the EEVOC plume (Table 7): the first 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

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

the CV. As previously mentioned, the closest residential well to the EEVOC plume is approximately 2.25 miles away. No groundwater is being withdrawn for personal use in Union Valley. Institutional controls implemented in accordance with the Interim ROD for Union Valley (Jacobs EM Team 1997a) 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.

The second exposure scenario evaluated was the possibility of someone coming in direct contact with groundwater at seeps or springs in Union Valley. Because 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. Thus 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 they are addressed in various other PHAs including the White Oak Creek PHA, Y-12 Uranium PHA, and the Current and Future Chemical PHAs.

There are no *completed exposure pathways* for 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 (Jacobs EM Team 1997a). 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 off-site groundwater.

Table 7: Exposure Pathways

Pathway	*1. Source of Contamination*	*2. Fate and Transport*	*3. Point of Exposure*	*4. Route of Exposure*	*5. Receptor Population*	*Time Frame for Exposure*	*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.	**Potential** use of contaminated groundwater from private wells.	Ingestion, dermal contact, inhalation	**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 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**

IV. Public Health Implications

ATSDR scientists have determined that there are no *completed exposure pathways* for off-site groundwater at ORR. The only confirmed contamination to have migrated off site was from the EEVOC-contaminated groundwater plume originating in the Y-12 Complex. No site-related groundwater contamination has been 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. This PHA, however, addresses only human exposure to off-site groundwater.

Y-12

The exposure investigation of this document addressed two possible exposure scenarios for contacting contaminated groundwater emanating from the Y-12 complex, both were eliminated because of the absence of exposure points (i.e., contaminants have not been detected above CVs in private wells and there is no ready access to springs and seeps) and the absence of a receptor population. Exposure to the contaminated groundwater is unlikely to occur because no private wells and no residences are near the EEVOC plume in Union Valley. ATSDR scientists have determined that *no public health implications* are associated with contaminants from the Y-12 Complex.

ETTP and ORNL

A discussion of how the ORR groundwater typically flows has been presented in this document in the *Site Geology/Hydrogeology* section. That section illustrated that groundwater movement beneath streams and rivers in this area is at best limited. 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 (USGS 1989). 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 *no public health implications* are related to contaminated-groundwater exposure from either ETTP or from 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 (e.g., 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 because they might provide additional information about human health effects, and they are useful because they help identify the need for public health intervention activities (e.g., community health education). Nevertheless, health outcome data cannot—and they 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 when evaluating 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 evaluating 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 8 contains the actual comments and ATSDR's responses.

Table 8: 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.	Because 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

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 ***No Public Health Hazard*** ensues from exposure to contaminated groundwater emanating from ORR. The "No Public Health Hazard" conclusion category is used for sites which, because of their absence of exposure, do not pose a threat to public health. 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 7 illustrates the two exposure scenarios that were considered for this public health assessment: 1) contacting groundwater from private wells in Union Valley, and 2) contacting groundwater from seeps and springs in Union Valley. Because groundwater has short flow paths to surface water in this area, and and because no private wells are pumping groundwater in this area, ATSDR scientists concluded that *no completed exposure pathways exist* for off-site groundwater.

- Groundwater and surface water are highly interconnected throughout the ORR. Groundwater flow in this area (ORR) is influenced largely by the extent of those bedrock fractures that 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 extent 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 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 informing the community that ATSDR has evaluated off-site groundwater contamination from the Oak Ridge Reservation and has concluded that *no public health hazard* is associated with past and current releases. ATSDR will work with the Oak Ridge Reservation Health Effects Subcommittee to determine the best way to communicate the results of the evaluation to the people in the community.

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 already taken at the site, and those to be taken 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 1996a).

- 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 those agencies 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. In an effort to increase cost-effectiveness, the goal is to evaluate various groundwater remediation technologies for those areas within the same water transport system (watershed) having similar contamination problems and land uses.

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XI. References

Alley WM, Healy RW, LaBaugh JW, Reilly TE. 2002. Flow and storage in groundwater systems. Science 2002;296:5575.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1993. Health consultation for US DOE Oak Ridge Reservation: Y-12 weapons plant chemical releases into East Fork Poplar Creek, Oak Ridge, Tennessee. Atlanta: US Department of Human Services; April 5.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1996b. Health consultation for US DOE Oak Ridge Reservation: proposed mercury clean-up level for the East Fork Poplar Creek floodplain soil, Oak Ridge, Anderson County, Tennessee. Atlanta: US Department of Health and Human Services.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005. Public Health Assessment Guidance Manual (Update). Atlanta: US Department of Health and Human Services. Available at: http://www.atsdr.cdc.gov/HAC/PHAManual/index.html. Last accessed 27 May 2005.

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 US Department of Energy; September. Available at: http:www.ornl.gov/~dmsi/cip/cip4.htm. Last accessed 27 May 2005.

Bureau of the Census. 1940. Sixteenth census of the United States: 1940 population. Volume 1: Number of inhabitants. Washington, DC: US Department of Commerce. Available from the Tennessee State Library and Archives, Nashville, Tennessee.

Bureau of the Census. 1950. Census of population: 1950. Volume 1: Number of inhabitants. Washington, DC: US Department of Commerce. Available from the Tennessee State Library and Archives, Nashville, Tennessee.

Bureau of the Census. 1960. Census of population: 1960. Volume 1: Characteristics of the population, part A, number of inhabitants. Washington, DC: US Department of Commerce Available from the Tennessee State Library and Archives, Nashville, Tennessee.

Bureau of the Census. 1970. 1970 census of population—number of inhabitants, Tennessee. Volume 1: Part 44. Washington, DC: US Department of Commerce Available from the Tennessee State Library and Archives, Nashville, Tennessee.

Bureau of the Census. 1980. 1980 census of population—number of inhabitants, Tennessee. Volume 1: Part 44. Washington, DC: US Department of Commerce Available from the Tennessee State Library and Archives, Nashville, Tennessee.

Bureau of the Census. 1993. 1990 census of population and housing, population, and housing unit counts, United States. Washington, DC: US Department of Commerce, Economics and Statistics Administration; August. Available at: http://www.census.gov/prod/cen1990/cph2/cph-2-1-1.pdf. Last accessed 27 May 2005.

Bureau of the Census. 2000. Population, housing unit, area, and density: 2000. American FactFinder. Washington, DC: US Department of Commerce. Available at: http://factfinder.census.gov/servlet/GCTTable?ds_name=DEC_2000_SF1_U&geo_id=04000US47&_box_head_nbr=GCT-PH1&format=ST-2. Last accessed 27 May 2005.

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. Available at: 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. Available at: http://cedr.lbl.gov/DR/OAKPDF/historicalops.pdf. Last accessed 27 May 2005.

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 at: http://cedr.lbl.gov/DR/OAKPDF/historicalocations.pdf. Last accessed 27 May 2005.

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. Available at: http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf. Last accessed 27 May 2005.

DOE see U.S. Department of Energy.

EPA see US Environmental Protection Agency.

[EUWG] End Use Working Group. 1998. Final report of the Oak Ridge Reservation. Available at: http://www.oakridge.doe.gov/em/euwg/Cover.htm. Last accessed 27 May 2005.

[FAMU] Florida Agricultural and Mechanical University. 1998. Scarboro Community Environmental Study.

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 US Department of Energy, Office of Environmental Management; April.

Jacobs EM Team. 1997b. Record of Decision for the Clinch River/Poplar Creek operable unit, Oak Ridge, Tennessee. Prepared for the US Department of Energy, Office of Environmental Management; September. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf. Last accessed 27 May 2005.

Jacobs Engineering Group Inc. 1996. Remedial investigation/feasibility study of the Clinch River/Poplar Creek operable unit. Prepared for the US Department of Energy, Office of Environmental Management. March 1996. Available at: http://www.osti.gov/dublincore/gpo/servlets/purl/226399-5omhIT/webviewable/226399.pdf. Last accessed 27 May 2005.

[MMES] Martin Marietta Energy Systems, Inc. 1986. Environmental surveillance of the Oak Ridge Reservation and surrounding environs during 1985. Oak Ridge, Tennessee: ORNL-6271; April.

[ORNL] Oak Ridge National Laboratory. 1982. Environmental analysis of the operation of Oak Ridge National Laboratory (X-10 Site). Prepared for the US Department of Energy. ORNL-5870; November.

[ORNL] Oak Ridge National Laboratory. 2004. Oak Ridge Reservation annual site environmental report for 2003. Prepared for the US Department of Energy; September. Available at: http://www.ornl.gov/sci/env_rpt/aser2003/aser2003.htm. Last accessed 27 May 2005.

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

[ORNL] Oak Ridge National Laboratory. 2002. Oak Ridge National Laboratory land and facilities plan. Prepared for the US Department of Energy; August. Available at: http://www.ornl.gov/~dmsi/landUse/. Last accessed 27 May 2005.

[SAIC] Science Applications International Corporation. 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.

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

[SAIC] Science Applications International Corporation. 2002b. Land use technical report. Oak Ridge, TN; September 2002. Prepared for the U.S. Department of Energy, Office of Environmental Management.

[SAIC] Science Applications International Corporation. 2005. Remediation effectiveness report for the US Department of Energy Oak Ridge Reservation, Oak Ridge, TN. Prepared for the US 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.

[TDEC] Tennessee Department of Environment and Conservation. 2004. Environmental monitoring report: January through December 2003. Tennessee Department of Environment and Conservation, DOE Oversight Division; March.

[TDEC] Tennessee Department of Environment and Conservation. 2002. Status report to the public. Nashville, TN: DOE Oversight Division; March. Available at: http://www.local-oversight.org/TDEC2001.pdf. Last accessed 27 May 2005.

[TDEC] Tennessee Department of Environment and Conservation. 2003a. Status report to the public. Nashville, TN: DOE Oversight Division; September. Available at: http://www.state.tn.us/environment/doeo/TDEC%20status%20report%202004.pdf.

[TDEC] Tennessee Department of Environment and Conservation. 2003b. On-line search of the state's drinking water program. Available at: http://www.state.tn.us/environment/doeo/99empdw.pdf. Last accessed 3 June 2005.

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

[U.S. DOE] US Department of Energy. 2004. Oak Ridge Reservation Annual Site Environmental Report for 2003. DOE/ORO/2185, September 2004. Available at: http://www.ornl.gov/aser. Last accessed 31 May 2005.

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

[U.S. DOE] US Department of Energy. 1996d. Clinch River/Poplar Creek Operable Unit. Environmental management program fact sheet; fall 1996.

[U.S. DOE] US Department of Energy. 2001a. Overview of CERCLA actions at off-site locations. Environmental management program fact sheet; September.

[U.S. DOE] US Department of Energy. 2001b. Bethel Valley Watershed overview. Environmental management program fact sheet. September 2001.

[U.S. DOE.] US Department of Energy 2001d. Melton Valley overview. Environmental management program fact sheet; September.

[U.S. DOE] US Department of Energy. 2001e. Waste area grouping (WAG) 4 seeps. Environmental management program fact sheet; September.

[U.S. DOE] US Department of Energy. 2001f. Waste area grouping (WAG) 5 seeps C and D. Environmental management program fact sheet. September 2001.

[U.S. DOE] US Department of Energy. 2002a. Proposal: Oak Ridge comprehensive closure plan. Office of Environmental Management. March 11, 2002. Available at: http://www.bechteljacobs.com/doeclean/_pu-ccp1.html. Last accessed 31 May 2005.

[U.S. DOE] US Department of Energy. 2002b. 2002 remediation effectiveness report for the US Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee. Prepared by SAIC; March.

[U.S. DOE] US Department of Energy. 2003b. Comprehensive waste disposition plan for the DOE Oak Ridge Reservation. Approved for public release 6 March.

[U.S. DOE] US Department of Energy. 2004. Oak Ridge Reservation groundwater strategy. DOE/OR/01-2069&D2. Prepared for the US Department of Energy; May.

[EPA] Environmental Protection Agency. 2002a. Tennessee NPL/NPL caliber cleanup site summaries. U.S.DOE Oak Ridge Reservation, Oak Ridge, Anderson County, Tennessee.

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

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

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

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

[USGS] US Geological Survey. 1998. Ground water and surface water: a single resource. Denver, CO: US Geological Survey Circular 1139. Available at: http://water.usgs.gov/pubs/circ/circ1139/.

[USGS] US Geological Survey. 2004. National geologic map database: GEOLEX database. Available at: http://ngmdb.usgs.gov. Last accessed July 29, 2004.

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 at: http://www.wmsym.org/Abstracts/2002/Proceedings/12/234.pdf. Last accessed 31 May 2005.

XII. Bibliography

[ATSDR] Agency for Toxic Substances and Disease Registry. 1996a. Health consultation for U.S. DOE Oak Ridge Reservation: Lower Watts Bar Reservoir Operable Unit. Oak Ridge, Anderson County, Tennessee. Atlanta: US Department of Health and Human Services; February.

[ATSDR] Agency for Toxic Substances and Disease Registry, National Center for Environmental Health, National Institute for Occupational Safety and Health, Tennessee Department of Health, Tennessee Department of Environment and Conservation, US Department of Energy. 2000. Compendium of public health activities at the US Department of Energy; November. Available from: http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html. Last accessed 2 June 2005.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2004. Public Health Assessment, Y-12 Uranium Releases, Oak Ridge Reservation. Atlanta: US Department of Health and Human Services; January 30.

Benfield R. 2002. October 22 ORRHES meeting minutes. TDEC groundwater geologist presentation. Available at: http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m10_02.pdf. Last accessed 27 May 2005.

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.

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. Available at: http://cedr.lbl.gov/DR/OAKPDF/importexposure.pdf. Last accessed 27 May 2005.

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/dror.html. Last accessed 3 June 2005.

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. Available from URL: http://www2.state.tn.us/health/CEDS/OakRidge/Screen.pdf. Last accessed 27 May 2005.

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 at: http://cedr.lbl.gov/DR/OAKPDF/task6report.pdf. Last accessed 27 May 2005.

ChemRisk. 2000. Oak Ridge dose reconstruction project summary report. Reports of the Oak Ridge dose reconstruction, volume 7. Tennessee Department of Health; March. Available at: http://www2.state.tn.us/health/CEDS/OakRidge/ProjSumm.pdf. Last accessed 27 May 2005.

City of Oak Ridge. 2002. City of Oak Ridge water treatment Web site. Available at: http://www.cortn.org/PW-html/water_treatment.htm. Last accessed 27 May 2005.

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

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

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

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

Lockheed Martin Energy Systems, Inc. 1998. Draft accelerating cleanup: paths to closure Oak Ridge operations office. Prepared for the US Department of Energy, Office of Environmental Management Program; February. Available at: http://web.em.doe.gov/ftplink/closure/04exec1.pdf. Last accessed 27 May 2005.

MapQuest. 2003. Driving directions for North America. Available from URL: http://www.mapquest.com. Last accessed 27 May 2005.

[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.

[ORNL] Oak Ridge National Laboratory. 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. Oak Ridge, TN: Environmental Sciences Division, Oak Ridge National Laboratory, ORNL/GWPO-026; February.

Reidy C and Clinton S. 2004. Down under: hyporheic zones and their function. Seattle, WA: Center for Water and Watershed Studies, University of Washington. Available at: http://depts.washington.edu/cwws/Outreach/FactSheets/hypo.pdf. Last accessed 27 May 2005.

[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 US Department of Energy. DOE/OR/01-1546/V1&D1.

[U.S. DOE] US Department of Energy. 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.

[U.S. DOE] US Department of Energy. 1995b. Record of decision for Lower Watts Bar Reservoir, Oak Ridge, Tennessee. US Department of Energy, Office of Environmental Management. September 1995. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf. Last accessed 31 May 2005.

[U.S. DOE] US Department of Energy. 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.

[U.S. DOE] US Department of Energy. 1996a. 1996 Baseline Environmental Management Report. Office of Environmental Management. Last updated November 10, 1999. Available at: http://web.em.doe.gov/bemr96/. Last accessed 31 May 2005.

[U.S. DOE] US Department of Energy. 1996b. Federal facility agreement. Environmental management program fact sheet; fall 1996.

[U.S. DOE] US Department of Energy. 1996c. Environmental restoration activities at Oak Ridge operations office. Office of Environmental Management; March.

[U.S. DOE] US Department of Energy. 2001c. Gunite and associated tanks remediation project. Environmental management program fact sheet. September 2001.

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

[U.S. DOE] US Department of Energy. 2002d. Cleanup work begins at ORNL's Melton Valley. DOE News. October 15, 2002. Available at: http://www.oro.doe.gov/media_releases/2002/r-02-041.htm. Last accessed 31 May 2005.

[U.S. DOE] US Department of Energy. 2002e. Old hydrofracture facility waste tanks. Environmental management program fact sheet; March.

[U.S. DOE] US Department of Energy. 2002f. Oak Ridge Reservation annual site environmental report for 2002; September.

[U.S. DOE] US Department of Energy. 2003a. Federal facility agreement. Environmental management program fact sheet. February 2003.

[U.S. DOE] US Department of Energy. 2003c. Lower Watts Bar Reservoir remedial action. Environmental management program fact sheet; April.

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

[EPA] U.S. Environmental Protection Agency. 1999. Understanding the safe drinking water act. Available form URL: http://www.epa.gov/safewater/sdwa/30th/factsheets/pdfs/fs_30ann_sdwa_web.pdf. Last accessed 3 June 2005.

[EPA] Environmental Protection Agency. 2002b. NPL site narrative for Oak Ridge Reservation (U.S. DOE). Oak Ridge Reservation (U.S. DOE), Oak Ridge, Tennessee. Available at: http://www.epa.gov/oerrpage/superfund/sites/npl/nar1239.htm. Last accessed 31 May 2005.

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

UT-Battelle. 2003. Oak Ridge National Laboratory Fact Sheet. Available from URL: http://www.ornl.gov/ornlhome/fact.pdf. Last accessed 31 May 2005.

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