ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

K-25 AND S-50 URANIUM FLUORIDE RELEASES
OAK RIDGE RESERVATION (USDOE)
OAK RIDGE, ROANE COUNTY, TENNESSEE
EPA FACILITY ID: TN1890090003
DECEMBER 23, 2008

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

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THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Please address comments regarding this report to:

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PUBLIC HEALTH ASSESSMENT

K-25 AND S-50 URANIUM FLUORIDE RELEASES

OAK RIDGE RESERVATION (USDOE)

OAK RIDGE, ROANE COUNTY, TENNESSEE

EPA FACILITY ID: TN1890090003

Prepared by:

Site and Radiological Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

This information is distributed by the Agency for Toxic Substances and Disease Registry for public comment under applicable information quality guidelines. It does not represent and should not be construed to represent final agency conclusions or recommendations.

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 clean up 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. Nevertheless, the public health assessment 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. 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 this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports 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:

Agency for Toxic Substances and Disease Registry
ATTN: Records Center
1600 Clifton Road, NE (Mail Stop E-60)
Atlanta, GA 30333

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Acronyms and Abbreviations

ANL	Argonne National Laboratory
ATSDR	Agency for Toxic Substances and Disease Registry
CAP88-PC	Clean Air Act Assessment Package–1988
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	Curies
COC	contaminant of concern
CRM	Clinch River mile
CROET	Community Reuse Organization of East Tennessee
CV	comparison value
D&D	decontamination & decommissioning
DOE	US Department of Energy
EE/CA	engineering evaluation/cost analysis
EEWG	Exposure Evaluation Work Group
EFPC	East Fork Poplar Creek
U.S. EPA	US Environmental Protection Agency
ERAMS	environmental radiation ambient monitoring system
ETTP	East Tennessee Technology Park
FACA	Federal Advisory Committee Act
FFA	Federal Facility Agreement
ft	feet
HF	hydrogen fluoride
IAG	Interagency Agreement
ICRP	International Commission on Radiological Protection
kg	kilogram
Kr 85	krypton 85
LEFPC	Lower East Fork Poplar Creek
LWBR	Lower Watts Bar Reservoir
m	meter
mg/kg/day	milligram per kilogram per day
mrem/year	millirem per year
µg/L	micrograms per liter
MRL	minimal risk level
mSv	millisievert
NCEH	National Center for Environmental Health
NIOSH	National Institute for Occupational Safety and Health
Np 237	neptunium 237
NPL	National Priorities List
NRC	US Nuclear Regulatory Commission
OREIS	Oak Ridge Environmental Information System
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation

ORRHES	Oak Ridge Reservation Health Effects Subcommittee
OSHA	Occupational Safety and Health Administration
OU	operable unit
ppb	parts per billion
ppm	parts per million
PCB	polychlorinated biphenyl
pCi/L	picoCuries per liter
pCi/m^3	picoCuries per cubic meter
PCM	Poplar Creek mile
PHAWG	Public Health Assessment Work Group
Pu 239	plutonium 239
RAR	remedial action report
RASCAL	Radiological Assessment System for Consequence AnaLysis
RCRA	Resource Conservation and Recovery Act
RER	remediation effectiveness report
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RmAR	removal action report
ROD	record of decision
SDWIS	Safe Drinking Water Information System
SVOC	semi-volatile organic compound
Tc 99	technetium 99
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TDOT	Tennessee Department of Transportation
TRM	Tennessee River mile
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
U 234	uranium 234
U 235	uranium 235
U 238	uranium 238
UF4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
USACE	US Army Corps of Engineers
VOC	volatile organic compound
WBRIWG	Watts Bar Reservoir Interagency Working Group

I. Summary

ORR Background

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

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

ATSDR's Involvement and Other Health Activities at ORR

The Agency for Toxic Substances and Disease Registry (ATSDR), one of several agencies within the U.S. Department of Health and Human Services (HHS), is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. ATSDR, a sister agency to the Centers for Disease Control and Prevention (CDC), has for many years worked closely with the CDC's National Center for Environmental Health (NCEH). In December 2003, ATSDR and NCEH—charged with controlling and preventing diseases related to environmental causes—consolidated their administrative and management functions and are now known as NCEH/ATSDR. For more information on these and other affiliated agencies, please refer to http://www.atsdr.cdc.gov/ and http://www.cdc.gov/.

Since 1991, ATSDR has responded to requests and addressed health concerns of community members, civic organizations, and other government agencies in the affected areas of the ORR. One such response is ATSDR's work in determining whether levels of environmental contamination in areas off-site from ORR present a *public health hazard* to surrounding communities—that is, a source of potential harm to human health as a result of toxic substance exposures. For example, in the 1990s ATSDR's activities focused on *current* public health issues related to Superfund cleanup activities at various off-site areas affected by ORR operations, such as the East Fork Poplar Creek area and the Watts Bar Reservoir area. During that time, ATSDR identified and evaluated several public health issues and worked closely with many parties.

From 1991 to 2000, the Tennessee Department of Health (TDOH), in a research project known as the Oak Ridge Health Studies, evaluated whether off-site populations had been exposed to toxic substances in the *past*. During Phases I and II of the Oak Ridge Health Studies, the TDOH, after extensive reviews and screening analyses, identified four hazardous substances related to past ORR operations that could have been responsible for adverse health effects:

- radionuclides from White Oak Creek,
- radioactive iodine,
- mercury, and
- polychlorinated biphenyls (PCBs).

In addition to dose reconstruction studies on these four substances, the TDOH conducted additional screening analyses for releases of uranium, radionuclides, and several other toxic substances.

To expand on TDOH efforts and to identify contaminants of concern for further evaluation, in 2001 ATSDR scientists conducted a review and a screening analysis of the TDOH's Phase I and Phase II screening-level evaluation of past exposure (1944–1990). Using this review, ATSDR scientists are conducting public health assessments on

- X-10 iodine-131 releases,
- Y-12 mercury releases,
- Y-12 uranium releases,

- radionuclide releases from White Oak Creek,
- K-25 uranium and fluoride releases,
- PCB releases from X-10, Y-12, and K-25,
- chemical screening of potential exposures in off-site areas, and
- other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater.

In these public health assessments, ATSDR scientists evaluate and analyze the data and findings from previous studies and investigations to assess the public health implications of *past, current, and future* exposures. For more information on ATSDR's public health activities related to the ORR, please see the agency's Oak Ridge Reservation Web site at http://www.atsdr.cdc.gov/HAC/oakridge/.

ATSDR's Evaluation of Exposure to Uranium and Fluoride Releases from the K-25/S-50 Site

This public health assessment evaluates the historical atmospheric releases of radioactive and nonradioactive hazardous substances from the K-25 and S-50 plants. This document assesses—for people living in off-site communities—past exposures to these atmospheric radioactive and nonradioactive releases. The document also discusses potential current and future hazards at the K-25 site (i.e., if hazards are detected during ongoing remedial activities) and the community health concerns and issues associated with the releases from the K-25 and S-50 facilities.

This document does not, on the other hand, address potential releases and exposures to surface water or groundwater, emissions from the TSCA Incinerator (located within the K-25 site boundaries), or the release of other contaminants of concern such as mercury, iodine-131, and PCBs. ATSDR evaluated these potential exposures and contaminants in separate public health assessments. Please note also that this document does not address on-site exposures of past ORR workers to hazardous substances. ORR workers may have been exposed to hazardous substances at higher levels than the general public, but workers were trained in the safe handling and use of hazardous substances, and DOE or its predecessor agencies or contractors monitored their potential exposures.

The 1,700-acre K-25 site, which includes the former S-50 plant (37 acres), was previously referred to as the Oak Ridge Gaseous Diffusion Plant (ORGDP). It is now known as East Tennessee Technology Park (ETTP). The S-50 plant began separating uranium by liquid thermal diffusion in October 1944, but closed less than 1 year later, 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. In 1985, all gaseous diffusion operations ceased at the site, and in 1987 it was closed. Because uranium was released from the K-25 site through 1995, this PHA will focus on potential off-site exposures (both acute and chronic—see text box) from 1944 to 1995. Potential current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the site. After consideration of the various factors discussed below, ATSDR evaluated the potential health effects of fluoride and uranium releases from K-25 and S-50 for three communities which, based on their proximity, had the highest potential exposures: Happy Valley, Sugar Grove, and Union/Lawnville.

An ***acute exposure*** occurs over a short time period, whereas a ***chronic exposure o***ccurs over a long time (more than 1 year).

ATSDR developed the conclusions in this PHA based on an evaluation of available historic air and soil monitoring data, contaminant release estimates, the physical setting of the site and surrounding area, multiple years of site-specific meteorological data, and air dispersion models developed and approved by the U.S. EPA, DOE, and the U.S. Nuclear Regulatory Commission (NRC). Although each of the data sources has limitations, the cumulative data set provides an adequate basis for the public health determinations in this PHA.

ATSDR evaluated potential past chronic and acute exposures for nearby off-site residents to ionizing radiation, uranium, hydrogen fluoride, and fluoride released from the K-25/S-50 site. ATSDR determined that past chronic exposures to atmospheric releases of ionizing radiation and uranium, as well as acute exposures to ionizing radiation and uranium, were not a public health hazard. ATSDR concluded that historic short-term exposure to fluoride and hydrogen fluoride concentrations released as UF_6 during accidents or equipment maintenance is an indeterminate public health hazard. ATSDR classifies this acute exposure pathway as indeterminate because from this potential exposure, sufficient monitoring data are not available to make a professional judgment about the level of health hazard.

Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the site. Given ATSDR's evaluation, no potential, current, or future hazards to off-site residents have been identified, but remediation continues at the site.

Past Exposure (1944 to 1995)

Using ATSDR's evaluation of potential past exposures to K-25/S-50 releases for nearby off-site communities, past chronic exposures to uranium and to ionizing radiation—as well as acute exposures to uranium and to ionizing radiation—may have occurred, although not at levels expected to cause any adverse health effects. Historic short-term exposure to fluoride and to HF concentrations released as UF_6 during accidents or equipment maintenance is an indeterminate public health hazard. ATSDR classifies this pathway as indeterminate[1] because sufficient data will never be available to make a professional judgment about the level of health hazard from this exposure. Moreover, ATSDR's estimated historic off-site acute hydrogen fluoride concentrations are based on conservative worst-case assumptions and modeled air data. Use of these conservatively estimated concentrations as a basis for a health hazard category is not appropriate—the modeled results were highly uncertain, and actual occurrence of the estimated worst-case concentrations was highly unlikely.

ATSDR evaluated past chronic (annual) and acute (short-term) exposures to K-25/S-50 releases for nearby off-site communities. Both short-term and long-term exposures were assessed for ionizing radiation, uranium, hydrogen fluoride, and fluoride. To determine the public health implications of potential exposures, for each contaminant of concern, ATSDR matched the estimated concentrations and doses with health-protective comparison values.

Sources and Emission Estimates

Uranium hexafluoride (UF_6) was the primary airborne contaminant released from the K-25/S-50 sources. At atmospheric temperatures and pressures, UF_6 is a dense or heavy gas (heavier than air). When released in the air, UF_6 reacts rapidly with atmospheric water to form hydrogen fluoride, uranyl fluoride, and uranium oxide particulates. Initially, all of the UF_6 fed into the gaseous diffusion cascades was made from natural uranium. Beginning in 1952, however, uranium that had been reprocessed from previously fissioned material (reactor tails) was

[1] ATSDR was unable to locate sampling data for historic short-term exposure to fluoride and hydrogen fluoride released as UF_6 during accidents or equipment maintenance at the K-25 site. ATSDR used worst-case assumptions and modeled air data because of the absence of sufficient historical environmental sampling data. ATSDR categorizes this exposure scenario as an *indeterminate public health hazard* because sufficient data will never be available to make a professional judgment about the level of health hazard from this exposure.

introduced as UF_6 feed material. The UF_6 from spent reactor fuel contained fission products and transuranic radionuclides, including technetium 99 (Tc 99), neptunium 237 (Np 237), and very small quantities of plutonium 239 (Pu 239). Consequently, after 1952, airborne emissions from the K-25 facility also contained quantities of Tc 99 and Np 237, which are accounted for in airborne emission estimates. The very small quantities of Pu 239 included in the reactor tails account for less than 1 percent of the total radiation and therefore are not included in subsequent radiological dose assessments.

To evaluate past uranium releases and potential off-site exposures to the surrounding communities, ATSDR used background information and data from portions of the TDOH's *Task 6 of the Reports of the Dose Reconstruction, 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* (referred to as the "Task 6 report") (ChemRisk 1999a). The Task 6 report involved

- Collecting and reviewing information on processes related to uranium uses and releases for each ORR facility,
- Evaluating uranium effluent data relative to DOE historical uranium release reports,
- Updating airborne emission estimates based on the revised release estimates and comparing them with historical DOE emission estimates,
- Using air dispersion models to estimate historic uranium air concentrations at selected exposure areas, and
- Calculating uranium exposures for the selected exposure areas based on the modeled air concentrations and available soil and water monitoring data. Then, comparing the estimated exposures with screening indices to determine whether a more detailed dose reconstruction was warranted.

Relative to the K-25 facility, the Task 6 report found that for the Union/Lawnville exposure area, estimated uranium doses were below the screening indices, thus a more detailed dose reconstruction was not warranted (ChemRisk 1999a). The Task 6 report concluded that uranium emissions from the K-25/S-50 facility did not result in a significant public health risk to the surrounding community. This conclusion was based on the emissions data and dose estimation

model used in that study. The Task 6 report did, however, identify several issues regarding K-25/S-50 uranium releases that required further investigation. The Task 6 recommendations suggested using environmental monitoring and site-specific meteorological data to confirm the adequacy of the uranium emissions and dispersion estimates. In addition to these recommendations, concerned community members identified the need to evaluate fluoride releases and exposures and to assess the potential exposures for residents at the former Happy Valley labor camp.

In addition to its evaluation of the Task 6 report data, ATSDR also obtained and analyzed airborne uranium emissions data from DOE. To analyze the dispersion of the uranium isotopes and the resulting doses to the potentially exposed populations, ATSDR used the DOE estimate of total uranium activities (combined with the Task 6 estimate of uranium isotope proportions) and the Np 237 and Tc 99 release rates. The long-term or annual uranium release estimates represent the sum of individual release events for each year.

One of the specific tasks of this PHA is to determine whether any individual short-term release events represented an acute public health hazard to communities living near the ORR. The largest documented release of 1,184 kilogram of UF_6 occurred in September 1958. Although the available data are probably incomplete, ATSDR believes that because the records include the years of highest production and annual emissions, they are likely representative of the most significant individual release events. Individual release events also included "midnight negative" releases. The term refers to using the jets at night to accelerate the attainment of an adequate UF_6 negative to support a planned opening of isolated process gas equipment. In this PHA, ATSDR estimates potential exposures to short-term releases for each of the "maximally exposed" communities.

To estimate chronic (annual) doses to airborne radionuclides, ATSDR used the Clean Air Act Assessment Package–1988 (CAP88-PC). To evaluate the off-site concentrations and potential uranium and hydrogen fluoride doses from short-term or episodic releases from the K-25/S-50 facility, ATSDR used the Radiological Assessment System for Consequence AnaLysis (RASCAL3) model. Because the locations (and elevations) of the two DOE meteorological data towers (K-1208 and K-1209) at the K-25 site approximately correspond to the locations of K-25

and S-50 (respectively), meteorological data from each of these locations was used in the CAP88-PC model to evaluate contaminant dispersion and historic exposures from each source. Because no specific meteorological data are available for the September 1958 accidental release, the analysis was based on presumed worst-case weather conditions.

Since at least 1953 (and probably since the establishment of the ORR in 1942), DOE (or its precursor agencies and contractors) has been collecting various environmental measurements, including ambient activities of radiation in soil, water, and air. Since at least the mid-1960s, two stations adjacent to K-25/S-50 have been sampled for airborne radioactive gross alpha particulates (HP-35 and HP-33). With some simplifying assumptions, agreement is good between the historic measured gross alpha concentrations and those predicted using the CAP88-PC air dispersion model for K-25/S-50 air release estimates. This agreement between measured and modeled gross alpha concentrations during the period when measured gross alpha data are available provides confidence that the modeling procedure may be used to estimate off-site exposure doses for the earlier, maximum release years 1961 and 1963.

Except as included in UF_6 releases, DOE has not compiled any estimates of annual airborne fluoride releases. From 1971 to 1985, DOE did measure airborne fluoride concentrations at a number of locations around K-25. For other years ATSDR predicted fluoride air concentrations by using correlations with the airborne uranium releases. Yet because of increased distance from emission sources and because of the effects of topographic ridges between the emission sources and exposure areas, these estimates will overestimate concentrations at areas of potential exposure along the site perimeter.

Estimated Doses and Concentrations

Ionizing Radiation

ATSDR estimated radiological doses from K-25/S-50 airborne releases for the largest documented accidental release and for the largest estimated annual release for the communities closest to the facilities. The highest estimated short-term dose for off-site communities evaluated in this PHA is 34 mrem from a 1958 K-25 accidental release for the Sugar Grove community. The highest annual radiological dose is 30 mrem/year for the Union/Lawnville community from

the 1945 S-50 annual release. This is more than three times less than ATSDR's minimal risk level (MRL) of 100 mrem/year and over three times less than the radiation dose limit for the public of 100 mrem/year recommended by the International Commission on Radiological Protection (ICRP), the U.S. Nuclear Regulatory Commission (NRC), and the National Council on Radiation Protection and Measurements (NCRP). Also, the highest cumulative radiation dose from summing potential short-term and long-term doses for a specific exposure area (37 mrem/year for Sugar Grove) is below these health comparison values. The highest cumulative dose from historic short- and long-term exposures to airborne releases from K-25/S-50 radiological contaminants (including U 234, U 235, U 238, Np 237, and Tc 99) at the area of highest off-site exposure is also below ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Thus, historic exposure to airborne releases of ionizing radiation from the K-25/S-50 facility is not expected to cause any adverse health effects.

Uranium

The highest estimated short-term (1-hour; acute) off-site uranium air concentration (approximately 51 $\mu g/m^3$ at the nearest off-site exposure area) occurred during an accidental hydrogen fluoride and particulate uranyl fluoride release. On-site air concentrations would have been even higher, although Sugar Grove and Union/Lawnville residents would not have been exposed to such elevated air concentrations at on-site locations. ATSDR has not derived health-based guidelines for acute uranium inhalation exposure (an exposure occurring once or for only a short time [up to 14 days]). Workers exposed during accidental releases (31 workers exposed during the Gore, OK accident) have succumbed to hydrogen fluoride toxicity (respiratory and irritant effects) without signs of uranium-induced kidney toxicity—exposures of these workers were estimated to range from 0.6 to 24 milligrams of uranium. The chemical effects of uranium on the kidney occur from repeated exposures over a longer period of time and not from an acute exposure during an accidental release. Additionally, if people did not experience effects from hydrogen fluoride exposure during the accidental release, concurrent uranium exposure affecting the kidney is very unlikely. Thus, exposure to the estimated short-term exposure concentration is not expected to result in adverse effects, including kidney effects.

As a result of chronic operational emissions, long-term exposure to airborne uranium also occurred during the years 1944 to 1995. The highest annual uranium release (as UF_6) occurred in 1963. The maximum estimated annual uranium air concentration for this year in an area of potential off-site exposure (Union/Lawnville) is 0.04 $\mu g/m^3$—about 10 times lower than the chronic-duration inhalation MRL (0.3 $\mu g/m^3$) for soluble uranium compounds. Thus even if people were exposed to this maximum air concentration of estimated long-term uranium, in all likelihood the chemical toxicity of uranium would not have caused them adverse health effects.

Fluoride and Hydrogen Fluoride (HF from normal operations, accidents, or controlled releases)

Historically, fluoride and hydrogen fluoride were released as a result of normal operations, accidents, or controlled releases. As a result of releases during normal process operations, chronic (long-term) exposures to these releases could have occurred for people living around the K-25/S-50 facility. Accidents or controlled releases could have resulted in acute (short-term) hydrogen fluoride and fluoride exposures. In August 2003 the California EPA (Cal-EPA; Office of Environmental Health Hazard Assessment) prepared a chronic toxicity summary for fluorides, including hydrogen fluoride. The critical effect identified was skeletal fluorosis with a chronic inhalation reference exposure level of 14 $\mu g/m^3$ for hydrogen fluoride and 13 $\mu g/m^3$ for fluoride. The estimated maximum annual exposure concentration of 6 $\mu g/m^3$ for people living around the K-25/S-50 facility is well below Cal-EPA's reference levels. As such, the estimated long-term fluoride and hydrogen fluoride air concentrations—less than 6 $\mu g/m^3$—and resulting exposures were not a public health hazard.

ATSDR used short-term fluoride measurements and a dispersion estimate from the September 1, 1958, accidental release to calculate acute exposure concentrations to hydrogen fluoride. The highest measured short-term (24-hour) fluoride concentration of 26.3 ppb occurred at station F-2 in 1975. Similarly, modeled short-term (hourly) hydrogen fluoride concentrations of 156 and 27 ppb were estimated for the Sugar Grove and Union/Lawnville communities, respectively, for the September 1958 accidental UF_6 release. ATSDR's MRL for acute inhalation exposure to hydrogen fluoride and fluorine is 20 ppb and 10 ppb, respectively. Concentrations below these values are not expected to cause adverse health effects. The 20-ppb MRL for hydrogen fluoride in air is 25 times lower than exposures that caused mild upper respiratory tract inflammation in

human volunteers exposed for 1 hour (Lund et al. 1999). The highest average level (time weighted average) allowed by the Occupational Safety and Health Administration (OSHA) for HF in air for a 40-hour work week made up of 8-hour work days is 2.5 mg/m^3 (3 ppm or 3,000 ppb). The 20-ppb MRL for air concentrations of hydrogen fluoride is 150 times lower than OSHA's occupational level. Still, the largest documented accidental release from the K-25 facility could have produced temporary minor respiratory irritation in sensitive persons living in the Sugar Grove or Union/Lawnville communities. Thus while exposures to the maximum estimated hydrogen fluoride concentrations were unlikely, they were possible. But sufficient data were not available to make a professional judgment about the level of health hazard from this exposure, thus ATSDR classified this pathway as indeterminate. Moreover, ATSDR's estimated historic off-site acute hydrogen fluoride concentrations are based on conservative, worst-case assumptions and modeled air data. To use these estimated concentrations as a basis for a health hazard category is not appropriate; the estimated worst-case concentrations were highly unlikely to have actually occurred, and the modeled results can have a high degree of uncertainty.

Uranyl Fluoride and Hydrogen Fluoride (HF from UF_6 cylinders)

No past releases of uranyl fluoride and hydrogen fluoride ever occurred from the UF_6 storage cylinders located at ETTP. Removal of all of the UF_6 cylinders was completed in December 2006 (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007).

Current and Future Exposure

Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the K-25 site. Using ATSDR's evaluation, no potential current or future hazards to off-site residents have been identified at this time, although remediation continues at the site. ATSDR recommends that DOE continue to take precautionary measures to prevent any off-site releases of contaminants potentially remaining at the K-25 site.

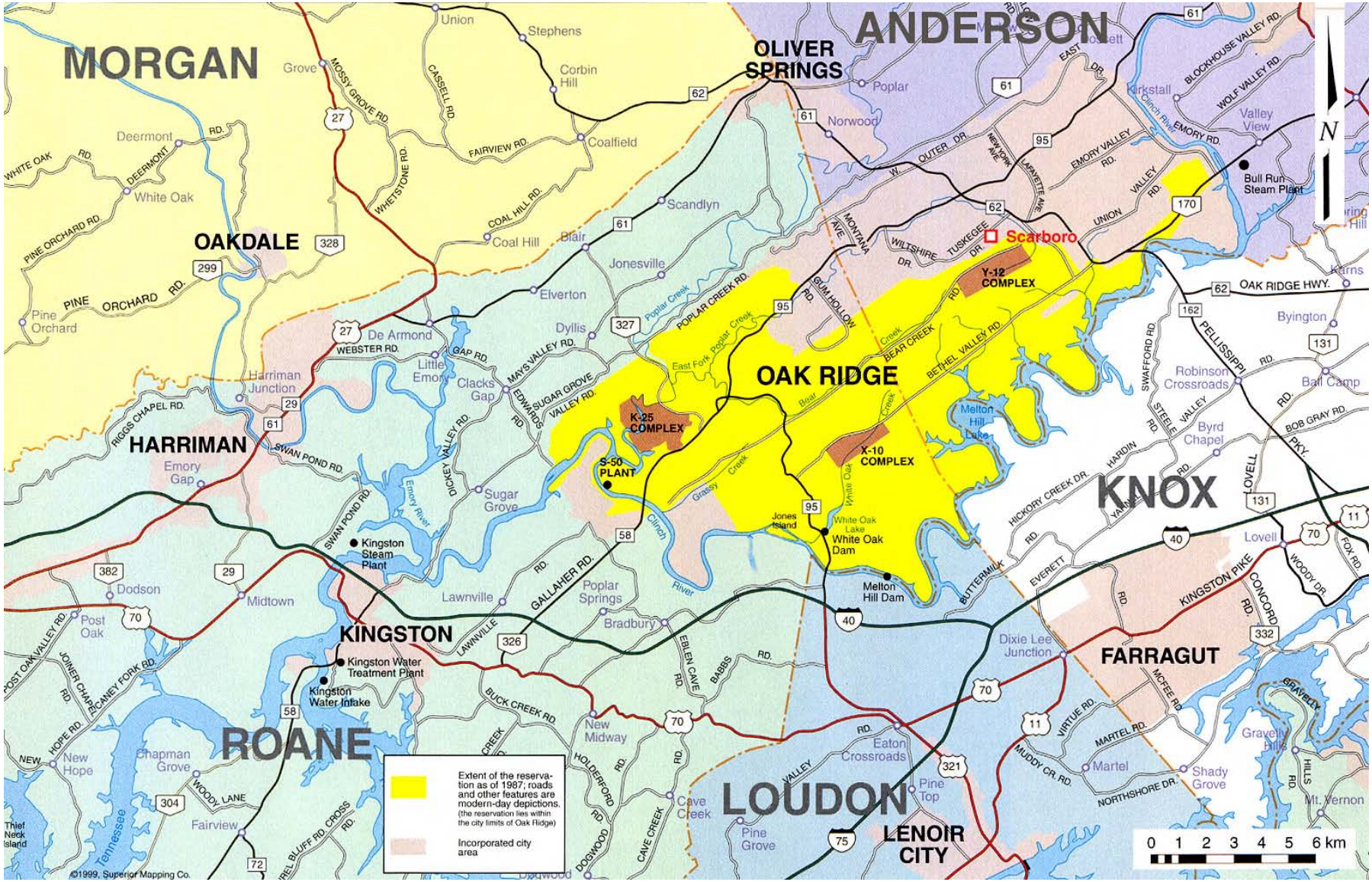
II. Background

II.A. Site Description

In 1942, as part of the World War II Manhattan Project, the U.S. government created the Oak Ridge Reservation (ORR) to develop and study nuclear products needed to make nuclear weapons (ChemRisk 1993a; ORHASP 1999; TDOH 2000). The majority of the ORR is within the city limits of Oak Ridge, in eastern Tennessee (ChemRisk 1999a; EUWG 1998; ORNL 2002). The reservation, comprising parts of Anderson and Roane Counties, is about 15 miles west of Knoxville, Tennessee (Bechtel Jacobs Company LLC et al. 1999; EUWG 1998; ORNL 2002; TDEC 2002). The Clinch River forms the reservation's southern and western borders (EUWG 1998). Figure 1 shows the location of the ORR.

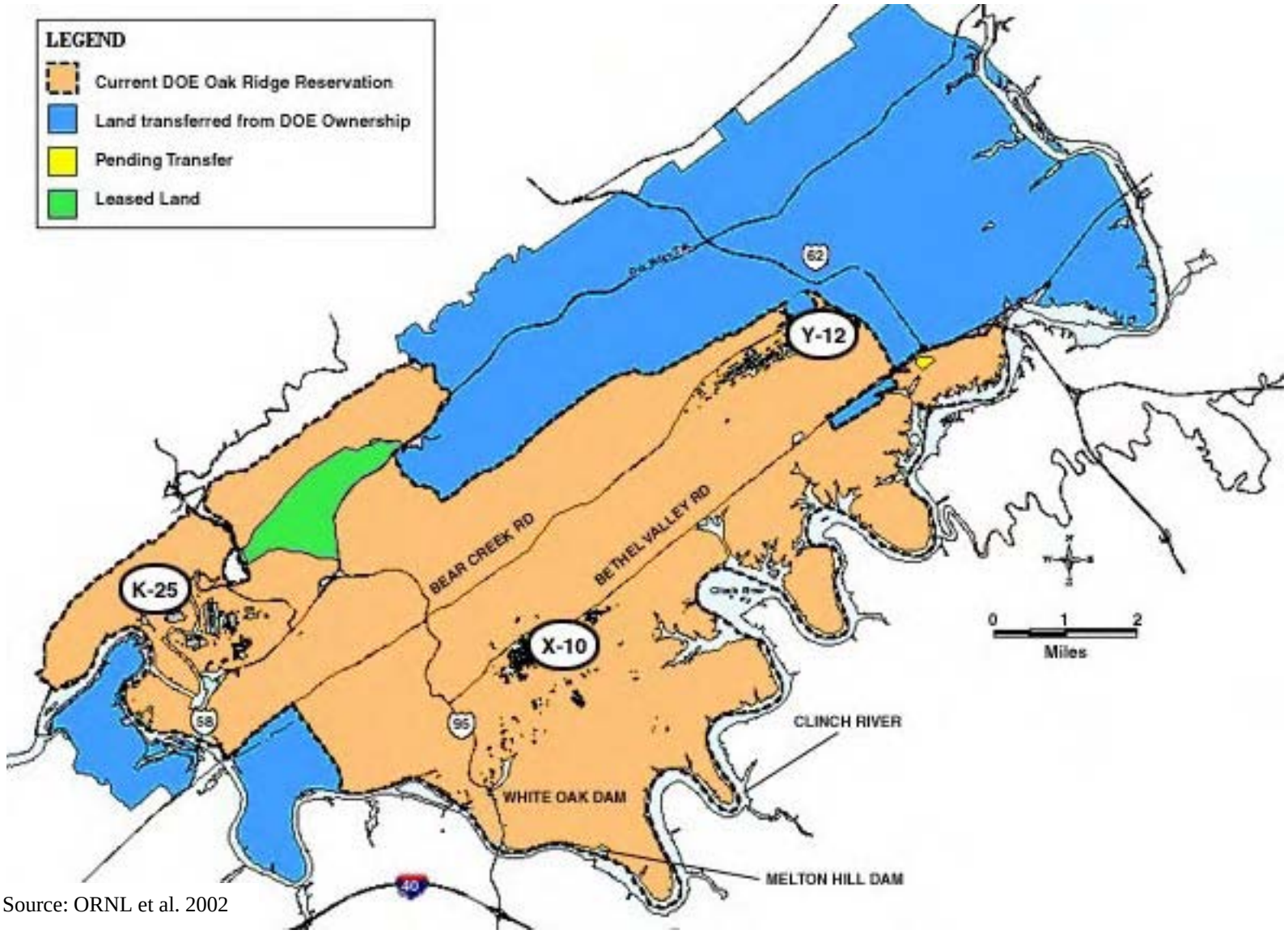
In the years following its 1942 acquisition of the 58,575-acre Oak Ridge Reservation (Bechtel Jacobs Company LLC et al. 1999; ORNL 2002), the federal government transferred 24,340 acres to other parties (e.g., the City of Oak Ridge, the Tennessee Valley Authority [TVA]); the U.S. Department of Energy (DOE) continues to control 34,235 acres of the original reservation (ORNL 2002). Figure 2 shows the original and current ORR boundaries. About 70% of the reservation, which is a designated National Environmental Research Park, has never been used for nuclear weapons-related operations (ORNL 2002).

Figure 1. Location of the Oak Ridge Reservation



Source: ChemRisk 1999a

Figure 2. Original and Current ORR Boundaries



Source: ORNL et al. 2002

Approximately 30% of the reservation is made up of three major facility areas that the government constructed as part of the Manhattan Project:

- *K-25 and S-50.* The K-25 site (formerly referred to as the Oak Ridge Gaseous Diffusion Plant [ORGDP]) and the former S-50 site, now collectively referred to as the East Tennessee Technology Park [ETTP]), were created to enrich uranium by gaseous diffusion (K-25) or liquid thermal diffusion (S-50).
- *Y-12.* The Y-12 plant (now known as the Y-12 National Security Complex) was used to enrich uranium by an electromagnetic process.
- *X-10.* The X-10 site (formerly referred to as Clinton Laboratories and now part of the Oak Ridge National Laboratory [ORNL]) was designed to develop methods for the separation of plutonium from uranium reactor fuels (ChemRisk 1993a; ChemRisk 1999a; ORNL 2002; TDOH 2000).

The K-25/S-50 site is close to the ORR's western, Poplar Creek border, near the creek's confluence with the Clinch River (ChemRisk 1999a; USDOE 1996). The site is within the Valley and Ridge Subregion of the Appalachian Highlands Province, close to the province's border with the Cumberland Plateau (USDOE 1995a). The 1,700-acre site is located in Roane County, approximately 10 miles west of downtown Oak Ridge (ORHASP 1999; TDOH 2000; USDOE 2003a; USDOE 2003b; USEPA 1991). Figure 1 shows the location of the K-25 site. Over 500 buildings are in the area where gaseous diffusion processes took place; they have a total floor area in excess of 15 million square feet. The site also has more than 270 auxiliary facilities used for support operations (e.g., testing, storage) that contain a combined floor area above 2.5 million square feet. Further, the site has approximately 290 additional buildings and trailers that have various uses, such as laboratories and offices (EUWG 1998).

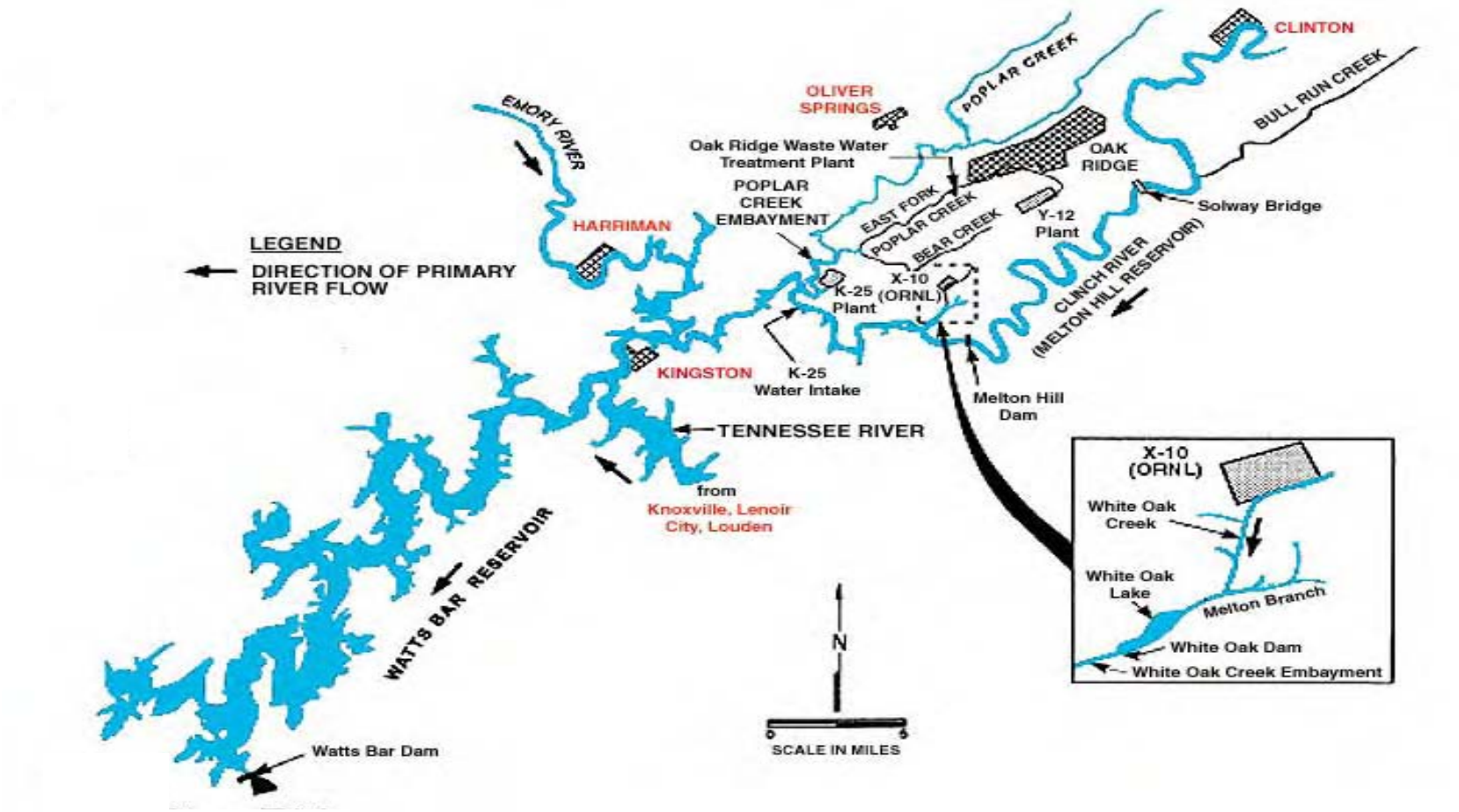
The S-50 site contained approximately 37 acres and was located southeast of the K-25 site, along the Clinch River. Figure 1 is a map showing the K-25 and S-50 areas, and Figure 3 shows the location of K-25 along the Clinch River. The S-50 site operated for less than 1 year and is now part of the K-25 site (ChemRisk 1999a). As all of S-50's buildings were destroyed and buried in 1946, no physical evidence of the site remains (ChemRisk 1999a; TDEC 2002).

In 1943, J.A. Jones began constructing labor camps, collectively referred to as "Happy Valley," to house construction workers and their families while the Oak Ridge Gaseous Diffusion Plant was under construction (Hewlett and Anderson 1962; Jacobs EM Team 1997a). Happy Valley was located in the lower reaches of East Fork Valley near the main K-25 gaseous diffusion plant. The westernmost portion of Happy Valley was between 1.0 and 1.5 miles farther southeast of the K-25 Power House area and the former S-50 plant (Prince 2003). By the end of 1944, an estimated 5,600 workers lived at Happy Valley. In the mid-summer of 1945, the total residential (worker and family) population peaked at over 8,700 (Keith and Baker 1946; Prince 2003). Small family units, barracks, hutments, and trailers were built to house the residents; shops, a school, a movie theatre, gas stations, and other facilities were also constructed (J.A. Jones Construction Company, date unknown; Keith and Baker 1946). Destruction of the site began in 1947 and by the mid-1950s all the Happy Valley buildings were razed (Jacobs EM Team 1997a).

The Sugar Grove community is on the K-25 site, about 1.6 miles north-northwest of the process buildings. Locally, Sugar Grove is referred to as the Blair Road community. Although residents of the community are nearest to the air emission sources on the K-25 facility, the community is separated from K-25 by the Black Oak Ridge, which trends northeast-southwest and has elevations as high as 380 feet (ft) (115 m) above the adjacent valleys. Many of the homes near the K-25 site were constructed as early as 1953 (USGS 1953).

Additionally, Union/Lawnville is located about 2.8 miles to the south-southwest of the K-25 site and former S-50 plant. The community's area is defined by the Union Church, which is on Lawnville Road about 0.6 miles north of Gallaher Road. The Clinch River is about 0.9 miles northeast of the Union Church and is the main surface water source for the community. In this public health assessment, the Union/Lawnville community is used as a reference location for releases from the K-25 site and the former S-50 plant (ChemRisk 1999a).

Figure 3. Map of Surface Water Bodies on and around the Oak Ridge Reservation



Source: Lockheed Martin Energy Systems, Inc. 1998

II.B. Operational History

Date: 1943 to 1987

Beginning in the early 1940s, significant amounts of uranium were processed on the ORR. Different methods, such as gaseous diffusion and liquid thermal diffusion, were used to enrich the uranium into uranium 235 (U 235), the uranium isotope also used for various research and development projects (ChemRisk 1993a).

Begun in 1943, the K-25 uranium enrichment facility was operating by January 1945. The main objective of the K-25 site was to use gaseous diffusion system of cascades to enrich uranium into the U 235 component (see the text box) (ChemRisk 1999a; USEPA 2005). Between 1945 and 1954, four additional gaseous diffusion process buildings (K-27, K-29, K-31, K-33) were erected, and the K-25 site was renamed the Oak Ridge Gaseous Diffusion Plant (ORGDP) (ChemRisk 1993a; ORHASP 1999).

The K-25 site operated as a weapons-grade uranium enrichment facility until 1964 (EUWG 1998). Buildings K-25 and K-27 were then closed because the military requirements had been fulfilled (ChemRisk 1993a). Between 1965 and 1985, the facility manufactured commercial-grade uranium, using uranium hexafluoride (UF_6) in the process. From the 1960s until 1985, centrifuge enrichment processes took place on the K-25 site (EUWG 1998). Activities at the remaining gaseous diffusion process buildings were discontinued in 1985, and the buildings were officially closed in 1987 (ChemRisk 1993a; ORHASP 1999; USDOE 2003b). The site name then reverted back from ORGDP to the K-25 site (ORHASP 1999).

A cascade is a system of gaseous diffusion process components arranged so as to enrich uranium in its U-235 component. During the gaseous diffusion process, uranium hexafluoride (UF_6) gas was put into a sequence of vessels that formed the "gaseous diffusion cascade." The "purge cascade" was part of the equipment used in the gaseous diffusion process. In the purge cascade, light gases (e.g., fluorine and air) were separated from the UF_6 that was being enriched. These light gases were removed so that they would not build up at the top of the cascade and prevent the flow of enriched UF_6. Historical releases from the purge cascade were less than 1% of the total airborne uranium releases from K-25 (ChemRisk 1999a).

The main processes and activities associated with uranium at the K-25 site include

- hydrogen fluoride and fluorine disposal (1944–1952),

- gaseous diffusion enrichment (1945–1985),
- UF 6 feed manufacturing (1952–1965),
- product and tails withdrawal (1945–1985),
- uranium recovery and decontamination (1944–1985)
- feed vaporization (1945–1985),
- research and development activities (1944–1985),
- K-25 laboratories (1944–1985),
- toll enrichment (1969–1985), and
- gas centrifuge program (1960s–1980s).

Building of the former S-50 liquid thermal diffusion plant began on June 6, 1944, and by October 1944 the facility was fully operational. The plant housed the processes to assess the financial and scientific feasibility of separating U 235 from uranium 238 (U 238) through liquid thermal diffusion. Because of constant equipment malfunctions and releases to the Clinch River and to the air, in September 1945 the plant was closed. The only documented process at the S-50 site was liquid thermal diffusion enrichment between 1944 and 1945 (ChemRisk 1999a).

Date: 1988 to present

Since the 1987 cessation of K-25 operations, many clean-up activities have been conducted to remove wastes and to restore the environment around the site. Reindustrialization at the site started in 1996, and as a result, in 1997 the K-25 site was renamed the East Tennessee Technology Park (ETTP) (ORHASP 1999; TDOH 2000; USDOE 2003b). Presently, the ETTP site consists of two business centers: the Heritage Center and the Horizon Center. The Heritage Center comprises 125 of the main buildings formerly used for gaseous diffusion processes; the Horizon Center consists of various buildings that are spread across 1,000 acres and are intended for high technology companies (USDOE 2003a). In addition, the Toxic Substances Control Act (TSCA) incinerator occupies part of the K-25 site. Indeed, K-25 is the only facility in the United States permitted to incinerate radioactive and hazardous contaminant wastes that contain polychlorinated biphenyls (PCBs) (TDEC 2002).

In December 2006, DOE completed its removal of the UF_6 cylinders from the cylinder storage yards at the K-25 site. From March 2004 to December 2006, DOE shipped approximately 6,000 UF_6 cylinders collectively containing about 119 million pounds of UF_6 off site to DOE's Portsmouth Gaseous Diffusion Plant (PORTS) in Portsmouth, Ohio (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007).

For additional details on historical operations at the K-25 site and the former S-50 site, please see Section 1.5 and Appendix B of Task 6 of the Reports of the Dose Reconstruction, *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* (ChemRisk 1999a) and also Section 3.1 of *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 Emission of Hazardous Material* (ChemRisk 1993a). The final reports of the Oak Ridge Dose Reconstruction are available via the Internet at http://health.state.tn.us/CEDS/OakRidge/ORidge.html. A timeline in this PHA (Figure 4) also provides details on historical K-25 and S-50 site activities.

II.C. Remedial and Regulatory History

On November 21, 1989, because of many on-site operations that released radioactive and nonradioactive wastes, the ORR was listed on the final National Priorities List (NPL) (EUWG 1998; USEPA 2004c). Various contaminants (e.g., uranium) are present in old waste sites at the ORR. These waste sites constitute 5% to 10% of the reservation. Releases from these waste sites, as well as leaching caused by abundant rainfall and high water tables, have contributed to the radionuclide contamination of surface water, groundwater, soil, and sediments at the ORR (EUWG 1998).

On January 1, 1992, the Federal Facility Agreement was implemented at the ORR. This agreement, which is also referred to as the Interagency Agreement for the Oak Ridge Reservation, is legally binding. The agreement establishes documentation, procedures, and schedules for remedial actions at the ORR (EUWG 1998; US DOE 2003b). The Federal Facility Agreement is available online at http://www.bechteljacobs.com/pdf/ffa/ffa.pdf.

The DOE is conducting remedial actions at the reservation under a Federal Facility Agreement (FFA), an interagency agreement between the DOE, the U.S. Environmental Protection Agency (U.S. EPA), and the Tennessee Department of

Environment and Conservation (TDEC). The U.S. EPA, TDEC, and the public all assist DOE with details for remedial activities at the ORR. The parties work together to ensure that clean-up actions are appropriate and to make sure that hazardous wastes associated with former and current ORR activities are adequately studied (USDOE 2003b). The DOE is remediating the ORR under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a federal statute that requires an FFA for all government-owned NPL sites (EUWG 1998; USDOE 2003b; USEPA 2004c). In addition, DOE is combining response measures from CERCLA with mandatory actions from the Resource Conservation and Recovery Act (RCRA) (USEPA 2004c). Figure 4 contains a timeline of air, biota, drinking water, sediment, soil, and surface water sampling data related to processes at the K-25 site.

Under a RCRA permit, DOE began conducting remedial actions at the reservation in 1986. Since then DOE has initiated about 50 response activities under the FFA that address on- and off-site contamination, as well as waste disposal issues related to the ORR (USEPA 2005). To ease the study and clean up of the ORR, the contaminated areas on the reservation were separated into five large tracts of land generally related to the reservation's major hydrologic watersheds (EUWG 1998).

For CERCLA purposes, environmental restoration at the K-25 site was separated into three administrative zones as shown in Figure 5. Zone 1 encompasses the approximate 1,400-acre area outside the main plant fence (most disposal activities occurred in this area) and Zone 2 includes the estimated 800-acre main plant area. The remaining zone, located along the ridge lines surrounding Zones 1 and 2, comprises the "balance of site" measuring about 2,800 acres (SAIC 2005).

Zone 1 contains soils contaminated with PCBs and radionuclides. Remedial actions in Zone 1 protect against exposures to humans by focusing on identified soil-contamination areas and known release sources. Zone 2 has contaminated subsurface structures, soil, and buried waste. Remedial activities in Zone 2 focus on protecting groundwater resources and preventing exposures to humans (SAIC 2004). The remaining zone or "balance of site" contains about 500 aboveground facilities that are or could be contaminated with radiological and other hazardous substances (SAIC 2005). The major remedial actions associated with both on- and off-site areas

affected by K-25 site-related contaminants are further detailed in Appendix C and shown in Figure 6.

II.D. Land Use and Natural Resources

When the 58,575-acre ORR was acquired in 1942, the federal government reserved 14,000 acres to establish businesses, housing, and support services for reservation personnel (ChemRisk 1993c; ORNL 2002). In 1959 this section of land became the self-governing city of Oak Ridge. with parks, homes, schools, offices, stores, and industrial areas (ChemRisk 1993c).

K-25 Gaseous Diffusion Site Timeline

MAJOR PROCESSES

- Gaseous Diffusion Up to 93% U-235, 1945-64
- Atomic Vapor Laser Isotope Separation, 1988-92
- S-50 Liquid Thermal Diffusion 1944-45
- Gaseous Diffusion <10% U-235, 1964-85
- Toxic Substance Incinerator, K-1435, 1989-present
- Gaseous Centrifuge Development, 1960-88

ENVIRONMENTAL DATA

Surface Water

- 1944-48, Radioactivity in Clinch River
- 1947-48, Radioactivity in Clinch River, Poplar Creek
- 1955-57, Mercury in Clinch River, Polar Creek
- 1960-64, Organic compounds, Radionuclides in Clinch River, Poplar Creek
- 1971-present, Uranium, Metals in Poplar and Bear Creeks
- 1972, Nitrates, Uranium in Bear and Poplar Creeks
- 1984, 1989-90, Mercury, Organics, Radionuclides in Clinch River, Poplar Creek
- 1986, Metals, PCBs Radionuclides in Clinch River
- 1990, Metals, Organics, Radionuclides in Melton Hill Norris and Watts Bar Reservoirs
- 1949-present, Radionuclides, Metals in Clinch River, Poplar Creek

Biota

- 1948-49, Radionuclides in Clinch River Fish
- 1961-present, I-131 and Sr-90 in Cows' Milk w/in 50 Miles of ORR
- 1967-present, Mercury, PCBs, Radionuclides in Clinch River Fish
- 1974-77, Mercury in Poplar Creek Fish
- 1977, Metals, PCBs, and Uranium in Clinch River and Poplar Creek Fish
- 1989, Metals, PCBs, Pesticides, SVOCs, Radionuclides in Clinch and Tennessee River, Poplar Creek Fish
- 1979, Metals in Clinch River Fish
- 1984, Metals, Organics, PCBs, Radionuclides in, Clinch River and Melton Dam Fish, Frogs, Turtles and Crayfish
- 1982, Mercury in Poplar Creek Fish
- 1985-present, Metals, and Organics in Mitchell Branch of Poplar Creek Fish
- 1986-89, Metals, Pesticides, PCBs in Melton Hill and Watts Reservoir Fish
- 1977-present, Radionuclides in Deer from ORR, Flouride and Radionuclides in Grass at K-25 Perimeter
- 1978-79, Tc-99 in Vegetation near K-25

Sediment

- 1951-56, Surface Gamma Radiation, Radioactivity, Radionuclides in Clinch and Tennessee River sediment
- 1960-64, Metals, Radionuclides in Clinch and Tennessee Rivers sediment
- 1970, Mercury in Melton Hill Reservoir sediment
- 1972-74, Mercury in Poplar Creek
- 1973-74, PCBs, Metals in Watts Bar and Melton Hill Reservoirs, Poplar Creek
- 1977, Radionuclides Clinch and Tennessee River sediments
- 1979, PCBs in Clinch River, Poplar Creek sediment
- 1984, Mercury, Radionuclides in Melton Hill Reservoir, Tennesse River sediment
- 1985, Metals, Organics, Radionuclides in Clinch River, Poplar Creek sediments
- 1989-90, Metals, Organics, Radionuclides in Clinch River, Poplar Creek, Melton Hill, Watts Bar, Norris Reservoirs sediment
- 1975-present, Metals in Clinch River and Poplar Creek sediment
- 1986, Cesium-137 in Watts Bar Reservoir

Air

- 1955-present, Particle Number, Fallout Particle Number, Beta Radioactivity, Beta Radioactivity in Rainwater, Uranium, Nickel, Lead, Chromium, Particulates
- 1963-present, I-131
- 1975-present, Particulate Gamma Emitters, Sr-90
- 1988-present, PCBs, Furans, Dioxins, Hexachlorobenzene, and Uranium from K-1435 Incinerator

Drinking Water

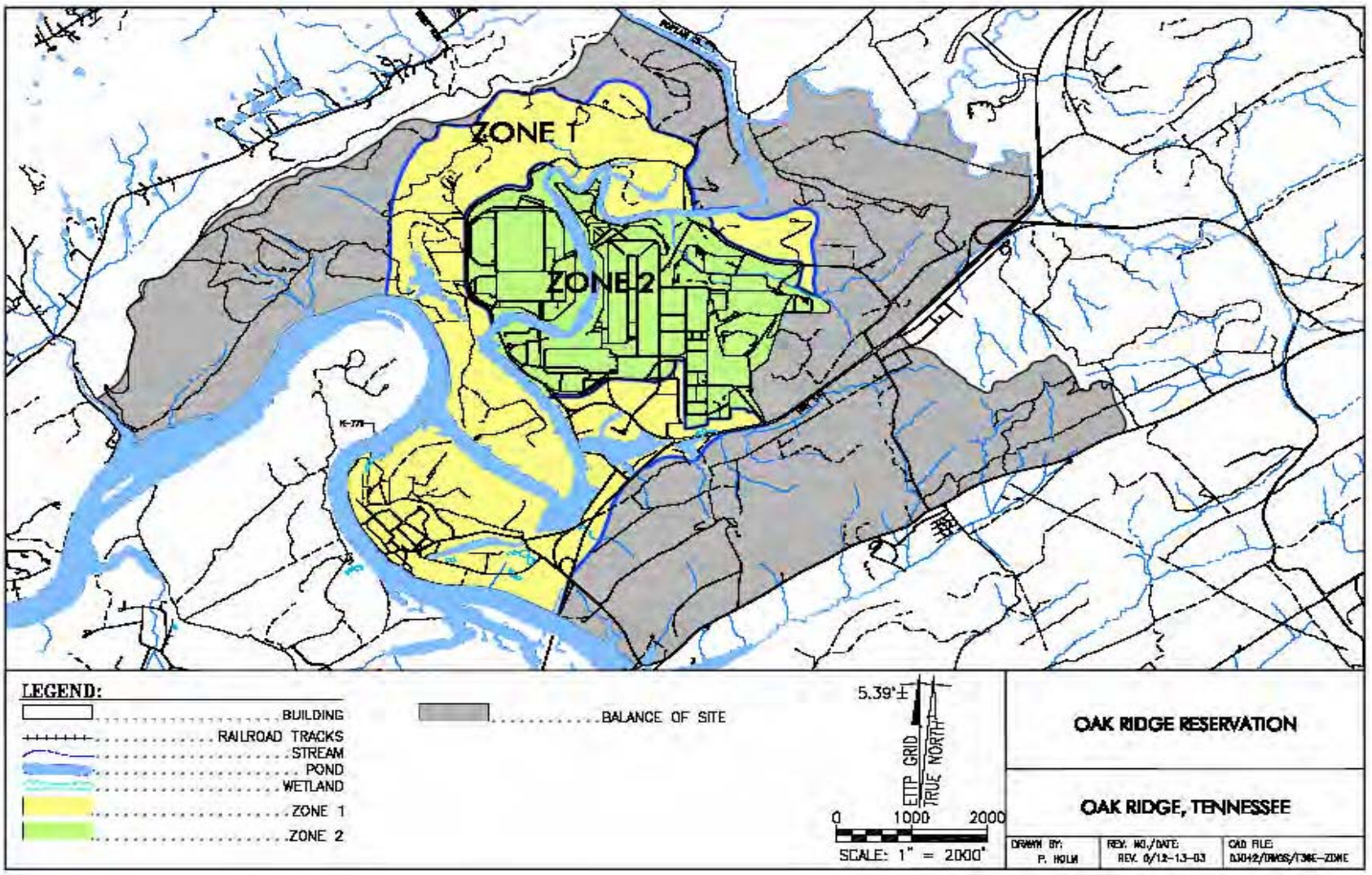
- 1959-present, Radionuclides in Water from Clinch River Water Intakes
- 1981, 83, Radionuclides, Metals in Residential Well Water
- 1986, Radioactivity in Residential Well Water
- 1986, Radioactivity, Radionuclides, Inorganics in Residential Well Water
- 1986, 89-present, Metals, Organics, Radionuclides in Residential Drinking Water

PUBLIC HEALTH ACTIVITIES

- 1942-93, Phase I Oak Ridge Health Study (10/93)
- 1942-93, Phase II Oak Ridge Health Studies (7/99)
  - Uranium dose reconstruction report 1944-90
  - PCB dose reconstruction report 1942-99
- 1942-96, Oak Ridge Health Agreement Steering Panel: Feasibility of Epidemiologic Studies (7/96)
- 1980-92, Health Statistics Review of Mortality Rates (1994)
- 1985-95, Health Consultation on Lower Watts Bar Reservoir (2/96)
- 1988-90, Health Statistics Review to Address Oak Ridge Physician's Concerns (10/19/92)
- 1990-92, Review of Clinical Information on Persons Living in or near Oak Ridge, Tennessee (9/92)
- 1990-95, Health Assessment of the East Tennessee Region, Second Edition (1996)
- 1990-96, Community Diagnosis Status Reports—Anderson County (1996)
- 1990-96, Community Diagnosis Status Reports—Roane County (1996)
- 1994-97, Governor of Tennessee's Independent Panel on the DOE TSCA Incinerator at the East Tennessee Technology Park (1/98)
- 1995, K1070A-Dye Trace Sampling Project (1996)
- 1996-present, Off-Site Residential Well Sampling Program (1997-present)
- 1997, Watts Bar Reservoir Exposure Investigation (3/98)

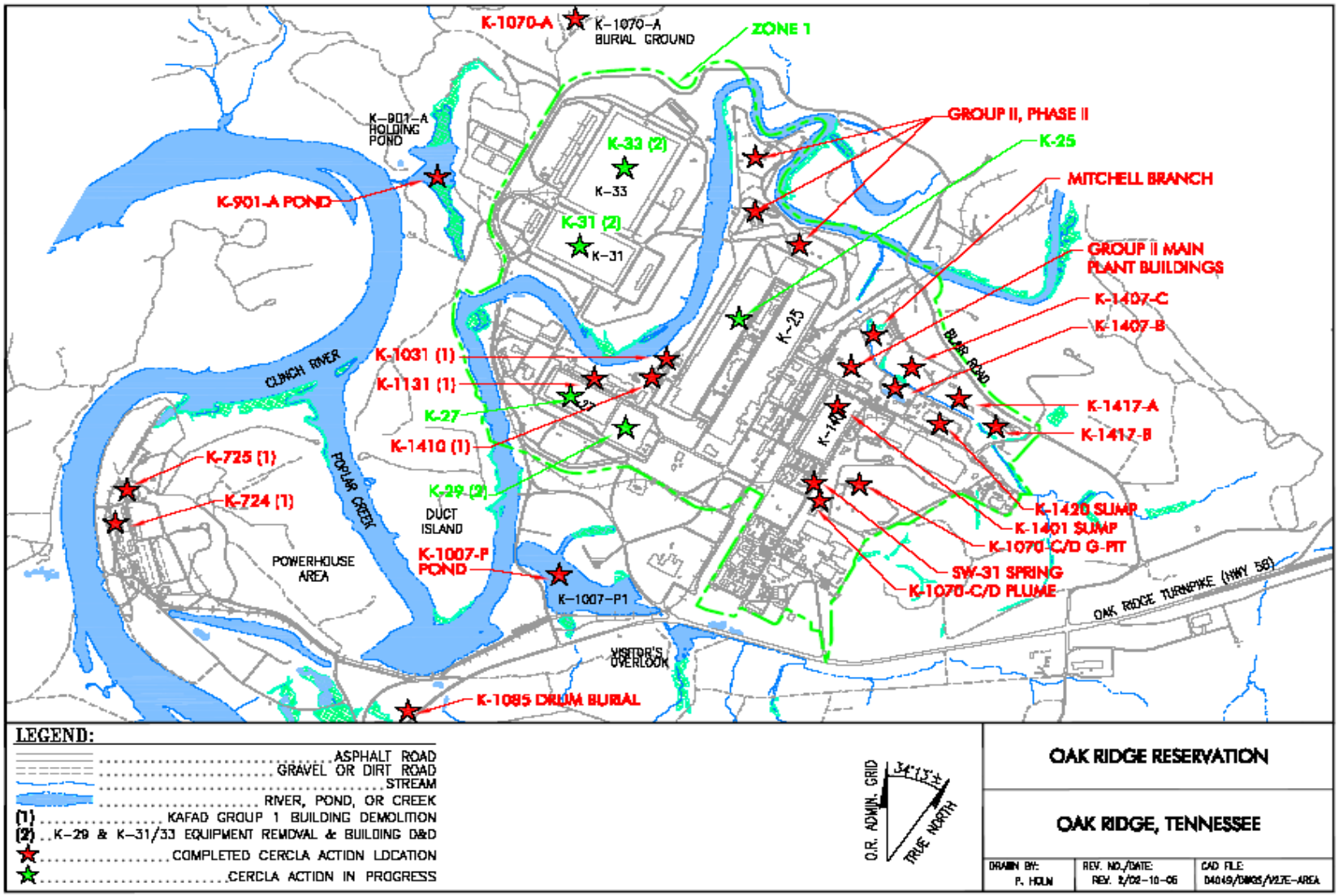
1944 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000

Figure 5. Administrative Zones for Environmental Restoration at the K-25 Site



Source: SAIC 2005

Figure 6. Map of the Major Remedial Activities at the K-25 Site



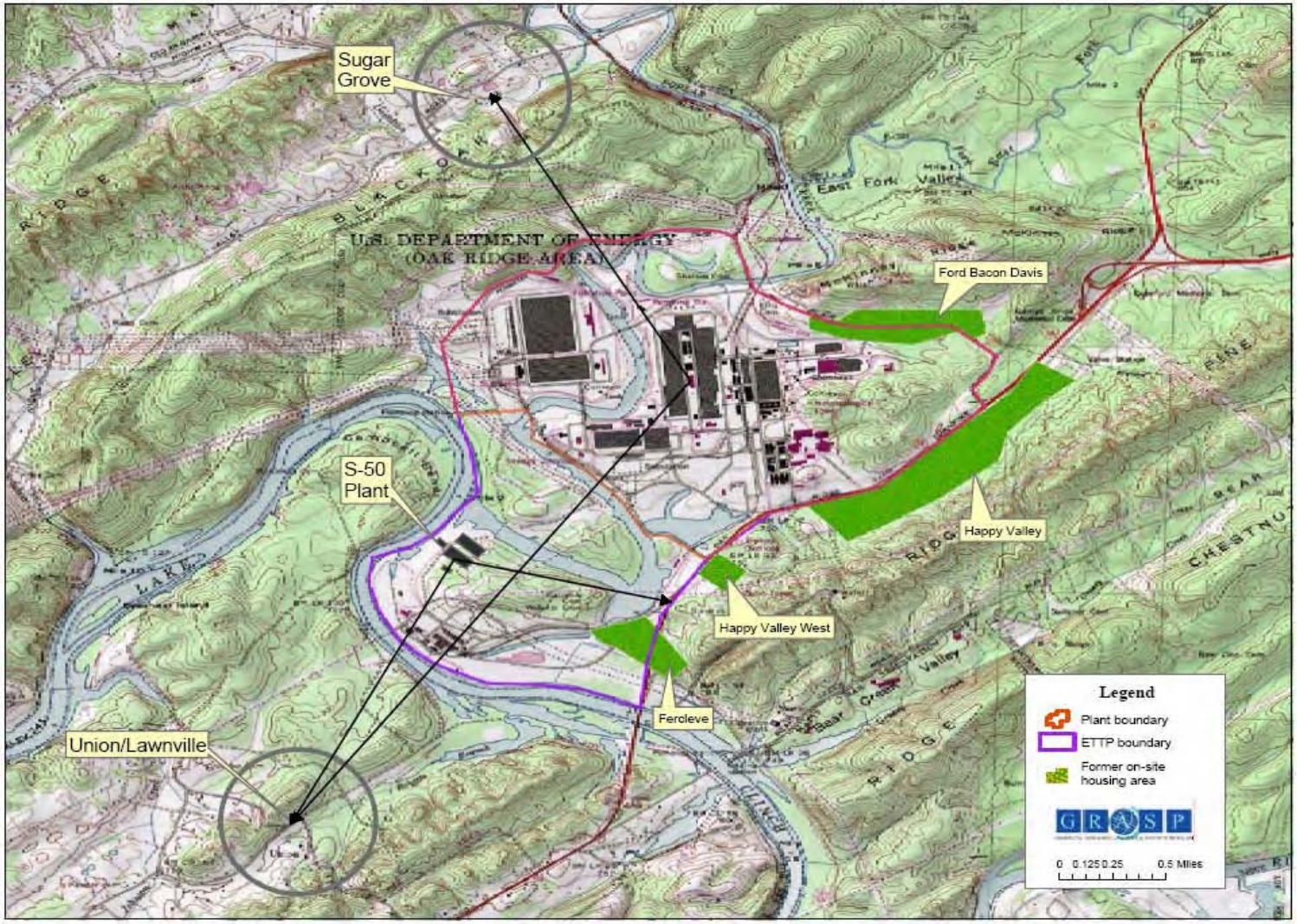
Source: SAIC 2005

As stated, the entire reservation is within Anderson and Roane Counties, and the majority of the ORR is within the Oak Ridge city limits (EUWG 1998). As of 2002, the ORR comprised 34,235 acres that included the three main DOE installations: K-25, Y-12, and X-10 (ORNL 2002). These three DOE facilities make up about 30% of the reservation. In 1980, the remaining 70% of the reservation became the National Environmental Research Park. The park designation for this portion of the ORR protects land intended for environmental research and education, and also shows that the development of energy technology is compatible with a quality environment (EUWG 1998).

The majority of Oak Ridge residents live along the northern and eastern borders of the reservation (Bechtel Jacobs Company LLC et al. 1999; ORNL 2002). Since the 1950s, however, the urban population of Oak Ridge has expanded to the west. Because of this growth, several homes in the city's western section border the reservation (Faust 1993). Except for these urban areas, the land surrounding the ORR is primarily rural. In fact, approximately 40% of the land close to the ORR is currently undeveloped (Bechtel Jacobs Company LLC et al. 1999; ChemRisk 1993c).

The closest homes to the K-25 site are about three-quarters of a mile north of the site boundary and about 1.6 miles (about 2,600 meters [m]) north-northwest of the process buildings and the contaminant release points (see Figure 7). In subsequent analyses, this community is referred to as the Sugar Grove community, but known locally as the Blair Road community. Although residents of the Sugar Grove community are nearest to the air emission sources on the K-25 facility, the community is separated from K-25 by the Black Oak Ridge, which trends northeast-southwest and has elevations as high as 380 feet (ft) (115 m) above the adjacent valleys. Many of these homes located near the K-25 site were constructed as early as 1953 (USGS 1953). The Union/Lawnville community is approximately 2.8 miles (about 4,500 m) south-southwest of the K-25 site and 1.5 miles (about 2,300 m) south-southwest of the S-50 facility (ChemRisk 1999a). The Happy Valley community, which housed workers and their dependents between approximately 1943 and 1947, was south of the K-25 gaseous diffusion plant and about 1 mile (approx. 1,600 m) east-southeast of the former S-50 plant (see Figure 7) (Prince 2003).

Figure 7. Closest Residential Areas to the K-25/S-50 Site



Note: The residential areas closest to K-25/S-50 emission sources (Sugar Grove, Union/Lawnville, and Happy Valley) represent areas of maximum potential exposure.

Current land use of the K-25 (ETTP) site emphasizes reindustrialization. This includes the reuse of materials, equipment, buildings, and utilities formerly used for gaseous diffusion processes (USDOE 2003a). Of the 1,700-acre K-25 site, about 700 acres are within a secured fence (USEPA 1991). In addition, only authorized personnel have access to the entire K-25 site (Radian Corporation 1993). The site includes former gaseous diffusion process buildings, testing facilities, maintenance operations, disposal areas, waste treatment plants, production areas, plating facilities, offices, laboratories, storage areas, change houses, and other buildings that aggregate over 17.5 million square feet (EUWG 1998). As stated, today two business centers operate at the K-25 site: the Horizon Center and the Heritage Center. The Horizon Center comprises about 1,000 acres of building sites. The Heritage Center encompasses 125 of the main facilities that were used for gaseous diffusion operations; the center leases these facilities to over 40 companies (USDOE 2003a).

Historically, commercial forestry and agriculture (e.g., beef and dairy cattle) represented the main land uses around the reservation, although both of these land uses are in decline. For a number of years, milk produced in the area was bottled for local distribution. The primary crops grown in the area include corn, tobacco, wheat, and soybeans (ChemRisk 1993c). Waterfowl, small game, and deer hunting occur seasonally within the ORR area (ChemRisk 1993c). During the annual deer hunts, all deer carcasses are subjected to radiological monitoring before they are released to the hunters. Monitoring ensures that none of the animals contain quantities of radionuclides that could cause “significant internal exposure” to the consumer (Teasley 1995).

As shown in the various maps, the K-25 site is near the confluence of Poplar Creek and the Clinch River (USDOE 1979). Figure 3 shows the surface water features in the site vicinity. Poplar Creek begins in the Cumberland Mountains and enters the reservation from north of the K-25 site (Loar et al. 1981). Poplar Creek converges upstream with East Fork Poplar Creek (EFPC) at Poplar Creek Mile (PCM) 5.5 (Jacobs EM Team 1997b). Poplar Creek travels through the K-25 plant area before it enters the Clinch River at Clinch River Mile (CRM) 12.0—the Poplar Creek embayment (Jacobs EM Team 1997b; Loar et al. 1981).

The K-25 site comprises a chain of limited drainage basins. Small streams such as Poplar Creek cross through these basins and eventually flow into the Clinch River (USDOE 1979). The Clinch

River represents the most direct destination for waters discharged from the K-25 site (Geraghty & Miller, Inc. 1989). Groundwater from the site also flows into Mitchell Branch, Poplar Creek, and the Clinch River (EUWG 1998). As a result of past gaseous diffusion operations, surface waters at the K-25 site have received small quantities of uranium and fluoride compounds. Radiological monitoring of K-25 surface waters indicates that levels are within the state of Tennessee's water quality standards, and in most cases nonradiological constituents have also been below the standard levels (USDOE 2003a).

Because Poplar Creek (along with EFPC) drains the ORR's northern and western boundaries, and the Clinch River constitutes the southern and eastern borders, all surface waters that leave the ORR travel through these water bodies and eventually reach the Lower Watts Bar Reservoir (LWBR) (Jacobs EM Team 1997b; SAIC 2002). Figure 3 shows the location of Poplar Creek, the Clinch River, and the Watts Bar Reservoir in relation to the ORR. Consequently, Poplar Creek, the Clinch River, and the Lower Watts Bar Reservoir have received several contaminants associated with ORR activities, including contaminants from White Oak Creek (Jacobs EM Team 1997b). For additional details on the relationship between White Oak Creek, the Clinch River, and the Watts Bar Reservoir, please refer to ATSDR's *White Oak Creek Radionuclide Releases Public Health Assessment,* which evaluated all radioactive contaminants released from the ORR to the Clinch River. Available at: http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html.

The K-25 site has a water intake located at CRM 14.4 that withdraws water from the Clinch River (ChemRisk 1999b). Figure 3 shows the location of the K-25 water intake. Through community concerns, Exposure Evaluation Work Group (EEWG, formerly referred to as the Public Health Assessment Work Group [PHAWG]) meetings, and discussions with DOE, ATSDR learned that this water intake provided domestic water to the Happy Valley community (1943–1947). In the past the K-25 site also relied on this water intake, and it continues today as a potable water source for the K-25 site, Beer Creek Industrial Park, and Building 9714 (ChemRisk 1999b). Pursuant to state and U.S. EPA requirements, chemical, radiological, bacteriological, and chlorine sampling of "finished water" from the treatment plant occurs regularly. As a result of public concerns voiced at a July 31, 2000 meeting, DOE–Oak Ridge Operations (DOE–ORO) conducted a special sampling effort that included testing for metals,

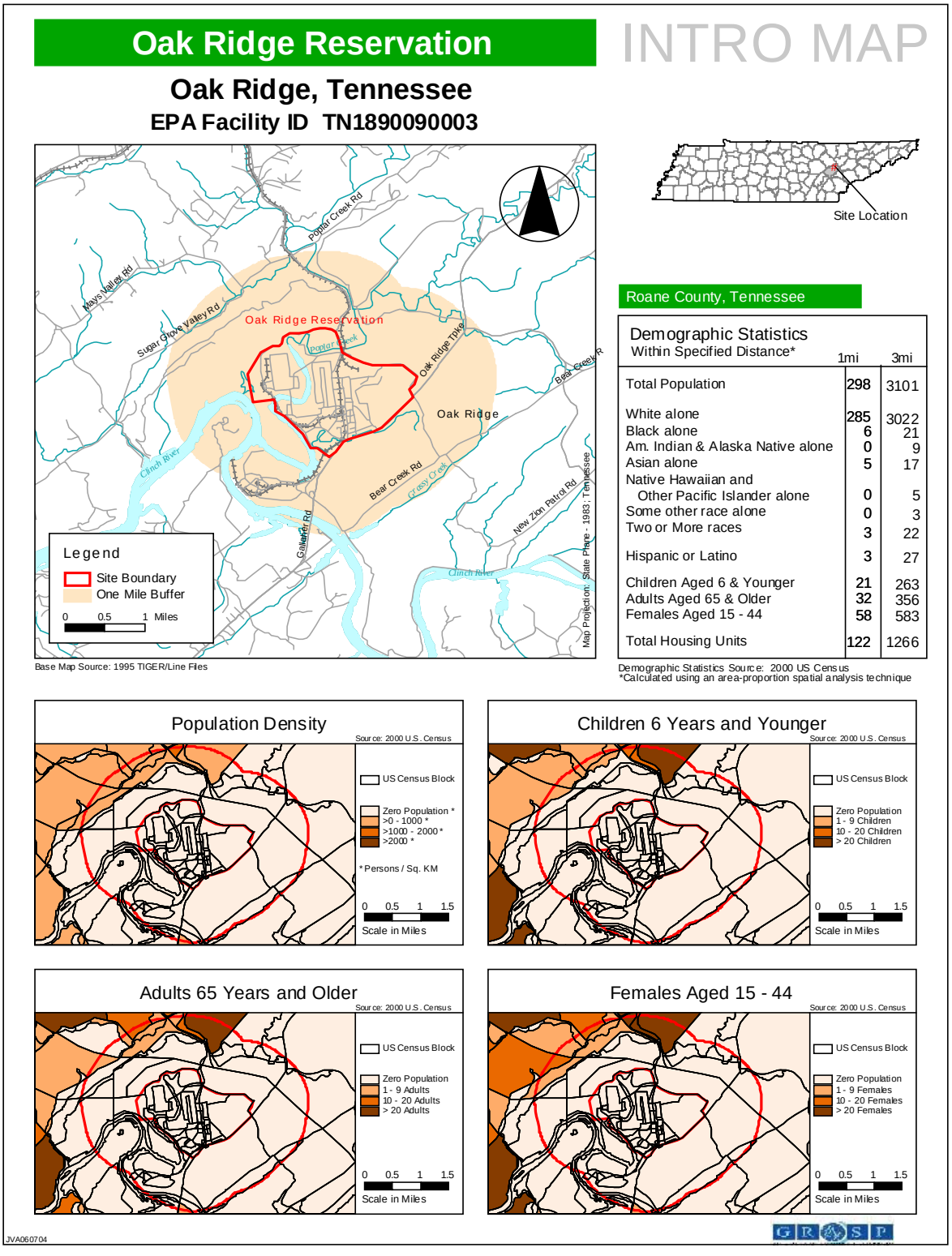
radionuclides, and chemicals in water directly from the tap. More than 475 drinking water samples were taken and analyzed, and DOE-ORO concluded that drinking water at the K-25 site was "safe to drink." More information on this sampling effort is available at the DOE-ORO Reading Room at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (DOE–ORO and CROET 2000). The drinking water quality report for this sampling effort is available at: http://www.state.tn.us/environment/doeo/pdf/PSBroch.pdf. In addition, ATSDR evaluated past, current, and future potential exposures to drinking water via the K-25 water intake in the *White Oak Creek Radionuclide Release Public Health Assessment.* You can obtain copies of this assessment online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR toll-free at 1-800-232-4636.

The K-25 site also includes the Poplar Creek/Clinch River Operable Unit (OU), which is used for drinking water, swimming, waterfowl hunting, shoreline recreation, and agriculture. The only unacceptable risk to human health is associated with fish consumed from Poplar Creek and the Clinch River. All fish in Poplar Creek are considered to be a health risk via consumption because of elevated mercury concentrations (Jacobs EM Team 1997b). TDEC has issued a fishing advisory that warns the public against consuming any fish from Poplar Creek or having contact with the water (Jacobs EM Team 1997b; TDEC 2004). TDEC also advises the public to avoid consumption of striped bass from the Clinch River arm of the Watts Bar Reservoir, and, for children, pregnant women, and nursing mothers, not to consume catfish and sauger from this part of the Watts Bar Reservoir (TDEC 2004).

II.E. Demographics

Again, in this health assessment ATSDR evaluates the potential health effects from K-25 and S-50 fluoride and uranium releases for the three communities with the highest potential exposures: Happy Valley, Sugar Grove, and Union/Lawnville. Given their community concerns, the public health assessment work group (PHAWG) meetings, the discussions with DOE, the previous assessments by TDOH, and especially the proximity to the K-25/S-50 facility, these communities would have been most affected by releases from these facilities. Figure 8 shows the current population distributions for 1-mile and 3-mile radii around the K-25/S-50 site.

Figure 8. 2000 Population Characteristics for the 1- and 3-Mile Areas around the K-25/S-50 Site



II.E.1. Happy Valley

In the fall of 1943, J.A. Jones established a labor camp known as the "Power House Camp" to house workers constructing the Oak Ridge Gaseous Diffusion Plant at K-25 (Hewlett and Anderson 1962; Jacobs EM Team 1997a). The camp contained prefabricated hutments to house approximately 3,700 workers (Keith and Baker 1946). In the beginning of 1944, J.A. Jones began to build a group of houses close to the main K-25 plant, which was known as the J.A. Jones Construction Camp (Hewlett and Anderson 1962; Keith and Baker 1946). As a result, the area grew to house most of the work force living in the K-25 area (Keith and Baker 1946). The combined camps were collectively referred to as "Happy Valley" (Hewlett and Anderson 1962). By the end of 1944, 5,600 workers lived at Happy Valley. Including families, by the mid-summer of 1945 the total number of residents peaked at over 8,700 (Keith and Baker 1946; Prince 2003). Happy Valley was a conglomeration of trailers, barracks, small family units, and hutments, as well as various facilities that included a movie theatre, a school, shops, and gasoline stations (J.A. Jones Construction Company, date unknown; Keith and Baker 1946). According to a recent review of the labor camp history, workers and families resided at Happy Valley between approximately 1943 and 1947, with destruction of the camp beginning in 1947. Anecdotal observations by an Oak Ridge community member suggest, however, that the labor camp may have been occupied as late as 1948. In any event, by the mid-1950s all of the structures within Happy Valley had been destroyed (Jacobs EM Team 1997a).

At its peak in 1945, Happy Valley had a population that exceeded 8,700 residents—composed of about 5,600 workers and over 3,100 dependents (Keith and Baker 1946; Prince 2003).

II.E.2. Sugar Grove

The Sugar Grove community is located about 1.6 miles north-northwest of the process buildings on the K-25 site. Locally, Sugar Grove is referred to as the Blair Road community. Many of the homes located near the K-25 site were constructed as early as 1953 (USGS 1953). Although residents of the community are nearest to the air emission sources on the K-25 facility, the community is separated from K-25 by the Black Oak Ridge, which trends northeast-southwest and has elevations as much as 380 feet (ft) (115 m) above the adjacent valleys.

As specific demographic information is not available for areas smaller than a census tract, the population estimate is based on counting the buildings from photo-interpreted topographic maps

and multiplying by the average number of people per household. These counts include all buildings such as garages, stores, and other nonresidential structures. Consequently, this method will provide a conservative overestimate of the total population. Using the 1980 aerial photo-based maps and 3.2 people per household, approximately 67 people lived in the Sugar Grove community *circa* 1953 and 1980 (see Figure 7). No specific census data were available for the Sugar Grove community. Data were, however, available for the total population of the Harriman District (see Figure 1 for the location of the city of Harriman) in which Sugar Grove is located. Table 1 shows the demographic data for this district from 1940–2000, which includes Sugar Grove and other rural areas in this part of Roane County, minus the population for the city of Harriman area.

Table 1. Population of Rural Areas Around the City of Harriman From 1940 to 2000

County	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Rural Areas in the Harriman District (including Sugar Grove, but minus the city population of Harriman)	4,729	4,532	9,533	5,388	7,760	7,253	3,659

Source: US Census Bureau 1940a, 1950a, 1960a, 1970a, 1980a, 1990a, 2000a

As shown in Table 1, the populations of Sugar Grove and other rural communities surrounding Harriman have fluctuated over time. The smallest population was recorded most recently in 2000, with 3,659 residents. The largest population was in 1960, when these rural areas reached a population of 9,533 residents (US Census Bureau 1940a, 1950a, 1960a, 1970a, 1980a, 1990a, 2000a).

II.E.3. Union/Lawnville

Union/Lawnville is located about 2.8 miles to the south-southwest of the K-25 site and 1.5 miles south-southwest of the former S-50 plant (see Figure 7). The community area is defined by the Union Church on Lawnville Road, which is just over one-half mile north of Gallaher Road. The Clinch River, almost a mile northeast of the Union Church, is the main surface water source for the community. During Phase II of the Oak Ridge Health Studies, TDOH determined that the Union/Lawnville community was “the most representative of maximum and typical exposures” from the K-25 site and former S-50 plant releases. Consequently, in this public health assessment ATSDR uses the Union/Lawnville community as a reference location (ChemRisk 1999a).

Specific demographic information is not available for areas smaller than a census tract; thus the population estimate was calculated using the method described above in the discussion on Sugar Grove. A review of the 1980 aerial photo-based maps and an assumption of 3.2 people per household means that between 1953 and 1980, approximately 58 persons lived in the immediate Union/Lawnville community (see Figure 7).

Union and Lawnville are located in Roane County, Tennessee. As specific demographic information was not available for these areas, demographic data from 1940–2000 are presented for a 10-mile area around the city of Kingston (see Figure 1) that includes the communities of Union and Lawnville, as well as other rural communities within the 10-mile area. Table 2 provides the total population of the communities in the10-mile area surrounding Kingston, which includes Union and Lawnville.

Table 2. Population within 10 Miles of Kingston from 1940 to 2000

County	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Kingston and Surrounding Communities (including Union and Lawnville)	3,635	4,864	8,005	7,802	10,115	10,366	12,340

Source: US Census Bureau 1940b, 1950b, 1960b, 1970b, 1980b, 1990b, 2000b

Table 2 shows that since 1940, Kingston and its surrounding communities have continued to grow from 3,635 to 12,340 residents. The smallest population was recorded in 1940—3,635 residents. The largest population was in 2000 when the areas within 10 miles of Kingston reached a population of 12,340 residents. Between this 60-year timeframe, the population of communities around Kingston more than tripled in size (US Census Bureau 1940b, 1950b, 1960b, 1970b, 1980b, 1990b, and 2000b).

II.F. Summary of Public Health Activities Pertaining to Uranium and Fluoride Releases from the K-25 Site and Former S-50 Plant

This section describes the public health activities that pertain to uranium and fluoride releases from the K-25 site and former S-50 plant (now part of the K-25 site). ATSDR, the TDOH, and other agencies have conducted additional public health activities at the ORR, described in Appendix B. See Figure 4 for a time line of public health activities related to the K-25 site.

II.F.1. ATSDR

Since 1992, ATSDR has made a determined effort to establish whether levels of environmental contamination at and near the ORR present a public health hazard. ATSDR has identified and evaluated several public health issues and has worked closely with many parties, including community members, physicians, and several federal, state, and local health and environmental agencies. While the TDOH conducted the Oak Ridge Health Studies to evaluate whether off-site populations have experienced exposures in the *past*, to avoid duplication of the state's efforts ATSDR's activities have focused on *current* public health issues. The following highlights major public health activities conducted by ATSDR that pertain to the Watts Bar Reservoir and K-25 uranium releases.

Health Consultation on the Lower Watts Bar Reservoir, February 1996.

In March 1995, DOE released a proposed plan to address the chemical and radiological contaminants in the Watts Bar Reservoir. Local residents were concerned about the contamination in the reservoir and also expressed concerns about the adequacy of DOE's proposed remedial actions and controls. The residents requested that ATSDR assess the health hazards associated with contaminants in the Lower Watts Bar Reservoir. ATSDR thereupon conducted the requested health consultation.

ATSDR uses a comparison value (CV) as a screening level during the public health assessment process. Substances found in amounts greater than their CVs are further evaluated. If a contaminant exceeds its comparison value, it does not necessarily mean that the contaminant will cause adverse health effects. Comparison values are used to help ATSDR determine which contaminants need to be evaluated more closely.

To evaluate the Lower Watts Bar Reservoir present and recent past exposures, ATSDR reviewed environmental sampling data from the 1980s and 1990s conducted by DOE, TVA, and various consultants. In addition, ATSDR examined TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. Initially, ATSDR screened the data to determine whether any contaminants were present at levels that exceeded health-based comparison values. Then, to determine whether current chemical and radiological contaminant levels could potentially affect area residents, ATSDR used both worst-case exposure scenarios and realistic exposure scenarios to estimate the doses for any contaminants above comparison values.

ATSDR found that polychlorinated biphenyls (PCBs) in the Lower Watts Bar Reservoir presented a public health concern. The agency concluded that frequent and long-term consumption of reservoir fish could moderately increase a person's risk of cancer, and that reservoir turtles may also contain PCBs at levels of public health concern. ATSDR further concluded that mothers who regularly consumed these fish while nursing or during pregnancy might increase the risk of having a child with developmental effects (ATSDR et al. 2000).

On the other hand, ATSDR determined that present contaminant levels in the reservoir sediment and surface water were not of public health concern. The reservoir was declared safe for recreational activities, such as skiing, swimming, and boating, and the municipal water was found safe to drink. Furthermore, ATSDR concluded that DOE's chosen remedial actions were protective of public health. These actions included ongoing environmental monitoring, continuing fish-consumption advisories, offering community and physician education concerning PCB contamination, and applying institutional controls to prevent resuspension, removal, disruption, or disposal of contaminated sediment (ATSDR et al. 2000).

After reviewing these findings, ATSDR made the following recommendations:

- To minimize exposure to PCBs, continue the Lower Watts Bar Reservoir fish advisory.
- ATSDR and the State of Tennessee should implement a community health education program regarding the Lower Watts Bar fish advisory and regarding the health effects of PCB exposure.
- Evaluate the likelihood of health effects from consumption of turtles in the Lower Watts Bar Reservoir. The evaluation should investigate turtle consumption patterns and PCB levels in edible portions of turtles.
- Do not disturb, remove, or dispose of surface and subsurface sediments without prior careful review by the interagency working group (see Section II.C.3. for a discussion of this group).
- Continue sampling of municipal drinking water at regular intervals. In addition, if a significant release of contaminants from the ORR is discharged into the Clinch River at

any time, DOE should notify the municipal water systems and monitor surface water intakes.

Coordination with Other Parties.

Since 1992 and continuing to the present, ATSDR has consulted regularly with representatives of other parties involved with the ORR. Specifically, ATSDR has coordinated its efforts with TDOH, TDEC, the National Center for Environmental Health (NCEH), the National Institute for Occupational Safety and Health (NIOSH), and DOE. In 1999 these coordinated efforts led to the establishment of the Public Health Working Group, which in turn led to the formation of the Oak Ridge Reservation Health Effects Subcommittee (ORRHES). In addition, ATSDR provided some assistance to TDOH in its study of past public health issues (ATSDR et al. 2000). ATSDR has also obtained and interpreted studies relevant to ORR prepared by academic institutions, consulting firms, community groups, and other parties.

Oak Ridge Reservation Health Effects Subcommittee.

The ORRHES was established in 1999 by ATSDR and Centers for Disease Control and Prevention (CDC) under the authority of the Federal Advisory Committee Act (FACA), and as a subcommittee of the U.S. Department of Health and Human Services' Citizens Advisory Committee on Public Health Service Activities and Research at DOE sites. The subcommittee consisted of persons representing diverse interests, expertise, backgrounds, and communities, as well as liaison members from federal and state agencies. It was a forum for communication and collaboration between the citizens and the agencies to evaluate public health issues and conduct public health activities at the ORR. To help ensure citizen participation, the meetings of the subcommittee's work groups were open to the public, and everyone was invited to attend and present his or her ideas and opinions. The subcommittee

- Served as a citizen advisory group to CDC and ATSDR and made recommendations on matters related to public health activities and research at the ORR.
- Allowed citizens to collaborate with agency staff members and to learn more about the public health assessment process and other public health activities.

- Helped to articulate and order the public health issues and community concerns evaluated by ATSDR.

How to obtain more information on ATSDR's activities at Oak Ridge

ATSDR has conducted several additional analyses that are not documented here or in Appendix C, as have other agencies that have been involved with this site. Community members can find more information on ATSDR's past activities by

1. *Visiting one of the records repositories.* Copies of ATSDR's publications on the ORR, along with publications from other agencies, can be viewed in records repositories at public libraries and the DOE Information Center in Oak Ridge. For directions to these repositories, please contact ATSDR at 1-800-CDC-INFO (or 1-800-232-4636).

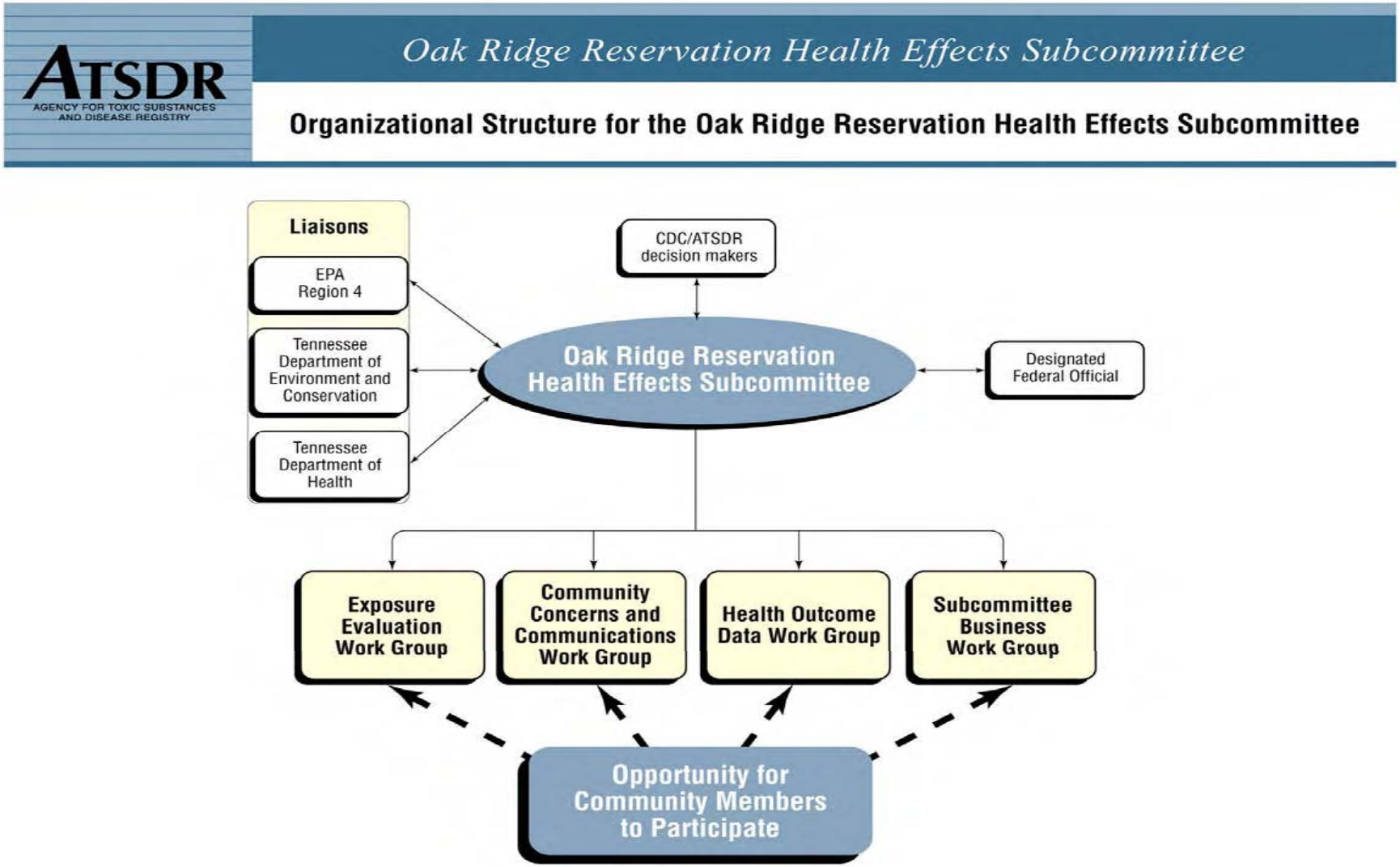
2. *Visiting the ATSDR or ORRHES Web sites.* These Web sites include our past publications, schedules of future events, and other information materials. ATSDR's Web site is at www.atsdr.cdc.gov and the ORRHES Web site is at www.atsdr.cdc.gov/HAC/oakridge. The most comprehensive summary of past activities can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html.

3. *Contacting ATSDR directly.* Residents can contact representatives from ATSDR directly by dialing the agency's toll-free number, 1-800-CDC-INFO (or 1-800-232-4636), and requesting to speak with a particular ATSDR representative.

The ORRHES created various work groups to conduct in-depth exploration of specific issues and present findings to the subcommittee for deliberation. Work group meetings were open to all who wished to attend, and those who did attend were invited to participate. Figure 9 shows the organizational structure of the ORRHES. For more information on the ORRHES, visit the ORRHES Web site at www.atsdr.cdc.gov/HAC/oakridge/index.html (ATSDR et al. 2000).

ATSDR Field Office. From 2001 to 2005, ATSDR maintained a field office in the city of Oak Ridge. The office was opened to promote collaboration between ATSDR and the communities surrounding the ORR by providing community members with opportunities to become involved in ATSDR's public health activities at the ORR (ATSDR et al. 2000).

Figure 9. Organizational Structure for the Oak Ridge Reservation Health Effects Subcommittee



II.F.2. TDOH

Oak Ridge Health Studies.

In 1991, DOE and the state of Tennessee entered into the Tennessee Oversight Agreement, which allowed the TDOH to undertake a two-phase, independent state research project to determine whether past environmental releases from ORR operations harmed nearby residents (ORHASP 1999).

Phase I. Phase I of the Oak Ridge Health Study was a Dose Reconstruction Feasibility Study. This was an evaluation of all past releases of hazardous substances and operations at the ORR. The study's objective was to determine the quantity, quality, and potential usefulness of the available information and data on these past releases and subsequent exposure pathways. Phase I of the health studies began in May 1992 and was completed in September 1993 (ATSDR et al. 2000). A brief summary of the Phase I Feasibility Study is provided in Appendix H.

The findings of the Phase I Dose Reconstruction Feasibility Study indicated that a significant amount of information was available to reconstruct the past releases and potential off-site exposure doses for four hazardous substances that had the largest potential risk for adverse health effects. These four substances include 1) radioactive iodine releases associated with radioactive lanthanum processing at X-10 from 1944 through 1956; 2) mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963; 3) PCBs in fish from EFPC, the Clinch River, and the Watts Bar Reservoir; and 4) radionuclides from White Oak Creek associated with various chemical separation activities at X-10 from 1943 through the 1960s (ATSDR et al. 2000).

Phase II (also referred to as the Oak Ridge Dose Reconstruction). Phase II of the health studies conducted at Oak Ridge began in mid-1994 and was completed in early 1999. Phase II was primarily a dose reconstruction study focusing on past releases of radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. In addition to the full dose reconstruction analyses, the Phase II effort included additional detailed screening analyses for releases of uranium and several other toxic substances that had not been fully characterized in Phase I. The significant findings of the Dose Reconstruction are presented in the paragraphs

below. The final reports of Phase II of the Oak Ridge Dose Reconstruction are available at http://health.state.tn.us/CEDS/OakRidge/ORidge.html.

Radioactive iodine releases were associated with radioactive lanthanum processing at X-10 from 1944 through 1956. Results of the Dose Reconstruction indicate that children who were born in the area in the early 1950s and who drank milk produced by their family's cows or goats living in their yards had a theoretical increased risk over background of developing thyroid cancer. The calculated risk of developing thyroid cancer for children living within a 25-mile radius of Oak Ridge was greater than 1 in 10,000.

The Dose Reconstruction evaluated mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963. Results of the Dose Reconstruction indicate that depending on their activities, persons living in the area during the years that mercury releases were highest (mid-1950s to early 1960s) may have received annual average doses of mercury exceeding the U.S. U.S. EPA reference dose.

U.S. EPA's reference dose is an estimate of the largest amount of a substance that a person can take in on a daily basis over their lifetime without experiencing adverse health effects.

Dose Reconstructions were conducted on PCBs in fish from EFPC, the Clinch River, and the Watts Bar Reservoir. Preliminary results of the Dose Reconstructions indicated that persons who consumed a large amount of fish from these waters might have received doses that exceeded the U.S. EPA reference dose for PCBs.

From 1943 through the 1960s, radionuclides associated with various chemical separation activities at the X-10 site were released into White Oak Creek. Eight radionuclides deemed more likely to carry significant risks were studied: cesium 137, ruthenium 106, strontium 90, cobalt 60, cerium 144, zirconium 95, niobium 95, and iodine 131. The results of the Dose Reconstruction indicate that for persons who consumed fish from the Clinch River near the mouth of White Oak Creek, the releases resulted in small, over-background increases in the radiation dose. The dose reconstruction scientists estimated that a man who ate up to 130 meals of fish from the mouth of White Oak Creek every year for 50 years (worst-case scenario) would face an excess cancer risk ranging from 4 to 350 in 100,000. For people who eat fewer fish and

for people who eat fish caught farther downstream, the risk from eating fish goes down proportionately.

Uranium was released from various large-scale uranium operations—primarily uranium processing and machining operations at the Y-12 plant and uranium enrichment operations at the K-25 and S-50 plants. Because uranium was not initially given high priority as a contaminant of concern, a Level II screening assessment for all uranium releases was performed. Preliminary screening indices were slightly below the decision guide of one chance in 10,000, which indicated that more work may be needed to better characterize uranium releases and any possible health risk. A brief summary of the Task 6 report is provided in Appendix H.

The *Screening-Level Evaluation of Additional Potential Materials of Concern* was conducted to determine whether contaminants other than those identified in the *Oak Ridge Dose Reconstruction Feasibility Study* warranted further evaluation to assess their potential to cause health effects to off-site populations. Three methods—a qualitative screening, a quantitative screening, and a threshold quantity approach—were used to evaluate the potential for 25 materials or groups of materials to cause off-site health effects. Using the screening results, five materials employed at the K-25 plant and 14 materials at the Y-12 plant warranted no further study. Three materials used at the K-25 plant (copper powder, nickel, and technetium 99), three materials used at the Y-12 plant (beryllium compounds, lithium compounds, and technetium 99), and one material used at the ORR (chromium VI) were determined to be potential candidates for further study. High priority candidates for further study included one material used at the K-25 plant (arsenic) and two materials used at the Y-12 plant (arsenic and lead). A brief summary of the Task 7 report is provided in Appendix H.

II.F.3. Tennessee Department of Environment and Conservation (TDEC)

Sampling of Public Drinking Water Systems in Tennessee.

In the 30-plus years since the passage of the Safe Drinking Water Act of 1974, the U.S. EPA has set health-based standards and has specified treatments for public drinking water systems. In 1977, U.S. EPA gave the state of Tennessee authority to operate its own Public Water System Supervision Program under the Tennessee Safe Drinking Water Act. Through this program,

TDEC's Division of Water Supply regulates drinking water at all public water systems. As a requirement of this program, all public water systems in Tennessee individually monitor their water supply for U.S. EPA-regulated contaminants and report their monitoring results to TDEC (TDEC 2003a). The public water supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides. U.S. EPA's monitoring schedules for each contaminant are available at http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf (USEPA 2004a). TDEC submits quarterly the individual water supply data to U.S. EPA's Safe Drinking Water Information System (SDWIS) (TDEC 2003a).

Moreover, in 1996 TDEC's DOE Oversight Division began participation in U.S. EPA's Environmental Radiation Ambient Monitoring System (ERAMS) drinking water program. As part of the Oak Ridge ERAMS program, TDEC collects samples from five facilities on the ORR and in its vicinity. These public water suppliers include the Kingston Water Treatment Plant (Tennessee River Mile [TRM] 568.4), DOE Water Treatment Plant at K-25 (Clinch River Mile [CRM] 14.5), West Knox Utility (CRM 36.6), DOE Water Treatment Plant at Y-12 (CRM 41.6), and Anderson County Utility District (CRM 52.5) (TDEC 2003b). Under the Oak Ridge ERAMS program, TDEC collects quarterly the finished drinking water samples from these five public water supplies and submits the samples to U.S. EPA for radiological analyses. The schedule and contaminants sampled at the supplies are available at http://www.state.tn.us/environment/doeo/pdf/EMP2006.pdf. More information related to your drinking water supply or additional water supplies in the area is available by calling U.S. EPA's Safe Drinking Water Hotline at 1-800-426-4791 or visiting U.S. EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater.

U.S. EPA's ERAMS program was established to provide radiological monitoring for public water supplies located near U.S. nuclear facilities.

Off-Site Residential Well Sampling.

Since 1993, TDEC (DOE Oversight Division) has conducted monitoring of off-site residential wells located outside the ORR. In 1996 and 1997, TDEC conducted a house-to-house survey to identify off-site residential wells located near the K-25, X-10, and Y-12 facilities. TDEC monitors the residential wells to

TDEC uses dye trace studies at the reservation to link contaminants in off-site springs with contaminants at the ORR (Benfield 2002).

determine whether off-site groundwater sources have been contaminated from ORR operations. As of 2003, no connections were established between ORR operations and off-site residential wells (ATSDR et al. 2000).

K1070-A Dye Trace Sampling.

In 1995, TDEC initiated a dye trace sampling study at the K1070-A waste burial ground on the K-25 site (ATSDR et al. 2000). This was part of a cooperative effort with DOE and its contractors, who were themselves conducting a DOE-initiated dye trace study. The TDEC study was conducted between 1995 and January 1996 to identify groundwater exit pathways along the Clinch River and across the western ORR boundaries at the K1070-A burial ground. TDEC collected data and samples that were analyzed by state laboratories. The sampling detected the same volatile organic compounds (VOCs) at spring 21-002 that were found in the K1070-A burial ground. Fluorescent dye was placed into wells at the burial ground, and the dye later appeared in spring 21-002. The dye was also found off site in a spring on the Clinch River (ATSDR et al. 2000).

II.F.4. DOE

Watts Bar Interagency Agreement, February 1991.

DOE, U.S. EPA, TVA, TDEC, and USACE comprise the Watts Bar Reservoir Interagency Working Group (WBRIWG). This group works collaboratively through the Watts Bar Interagency Agreement—an agreement that established guidelines related to any dredging in Watts Bar Reservoir. Through this agreement, these agencies review permitting and all other activities that could possibly disturb the sediment of Watts Bar Reservoir, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003c). The agreement also establishes guidelines for reviewing potential sediment-disturbing activities in the Clinch River below Melton Hill Dam, including Poplar Creek (Jacobs EM Team 1997b). According to the interagency agreement, DOE is required to take action if an institutional control is ineffective or if a sediment-disturbing activity could cause harm (USDOE 2003c).

Permit coordination under the Watts Bar Interagency Agreement was established to allow TVA, USACE, and TDEC (the agencies with permit authority over actions taken in Watts Bar

Reservoir) to discuss proposed sediment-disturbing activities with DOE and U.S. EPA before conducting the normal permit review process. This affords an opportunity to determine the presence of any DOE contaminants in the sediments. The coordination follows a series of defined processes as outlined in the agreement.

The basic process of obtaining a permit is the same for any organization or individual (Jacobs EM Team 1997b). If dredging is necessary in an area with contaminated sediments, DOE will assume that financial and waste management responsibility over and above the costs normally incurred (Jacobs EM Team 1997b). For more details, please see the Clinch River/Poplar Creek OU ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf and page 3-5 of the Lower Watts Bar Reservoir ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf (Jacobs EM Team 1997b; USDOE 1995b).

Independent Medical Evaluation of K-25 Workers.

In the fall of 1995, K-25 workers and persons living near the facility reported illnesses they believed were connected with potential exposures to K-25-related contaminants. Lockheed Martin Energy Systems, Inc., a DOE contractor at K-25, then requested that physicians investigate whether workplace factors had contributed to workers' these illnesses. Three physicians—Richard Bird from the JSI Center for Environmental Health Studies and the Beth Israel Deaconess Medical Center at the Bowdoin Street Health Center in Boston, Massachusetts, and James Lockey and Andrew Freeman from the University of Cincinnati College of Medicine in Cincinnati, Ohio—conducted medical evaluations of 53 past and current workers at the ORR's K-25 facility. The evaluations, which included self-selected participants, started in the fall of 1996 and took place over a 4-year period. A comprehensive review of historical and current medical records and visits to workplaces were conducted for each subject. In addition, the workers were required to undergo physical examinations, diagnostic testing, interviews to evaluate work history, and evaluations by medical specialists (ATSDR et al. 2000; Parson 2000).

The findings indicated that "several workers in the study group have one or more conditions that … have been exacerbated, aggravated, or directly caused by historical exposures in the K-25 work environment." The investigators stated, however, that some conditions were common to

other industrial settings, such as acute and chronic bronchitis and occupational asthma. Still, certain symptoms were more specific to work at the K-25 site, including possible beryllium sensitization (two workers), definite peripheral beryllium sensitization (five workers), chronic beryllium disease (one worker), peripheral neuropathies, toxic encephalopathy, and autonomic neuropathy with postural hypotension and cardiac arrhythmia. Also, some workers had different types of neuropsychological changes. These types of changes were consistent with significant depression and anxiety, toxic encephalopathy due to solvent and heavy metal exposures, and cerebrovascular problems. Yet in some instances the physicians could not assess whether the changes were caused by exposures in the workplace or from nonwork-related physical conditions (ATSDR et al. 2000; Parson 2000).

The physicians reported that they identified "several unique aspects and complicating factors" associated with workers' exposures to hazardous materials at the K-25 site. For instance, work was exchanged between the K-25 facility and the Y-12 plant, where beryllium was widely used. K-25 workers with longer periods of occupational exposures had higher serum PCB levels than did workers without prolonged exposures. The study nonetheless determined that the detected levels would not definitely cause adverse health effects (ATSDR et al. 2000; Parson 2000).

The study findings were released on July 31, 2000, in the "Summary Report of Findings of K-25 Worker Evaluations" and were presented at a public meeting on the same day. Each of the 53 workers was provided with an individual final medical report. The reports included physician-prepared summaries that detailed medical conditions most likely related to the workplace. The report also identified the conditions that could not be related to workplace factors "within a reasonable degree of medical probability and certainty." For workers who were believed to have a medical condition directly related to exposures at the workplace or a condition that was considerably aggravated by exposures in the workplace, the physicians prepared a separate "Work Related Abnormalities as Determined to Date." Following the study's August 1, 2000 release, DOE stated that it would work with DOE–Oak Ridge Operations (and its contractors) to assist those identified with work-related illnesses to enter claims for Tennessee workers' compensation benefits. In addition, DOE stated that it would examine the study's results and by August 31, 2000 recommend follow-up actions to Dr. David Michaels, Assistant Secretary of Energy for Environment, Safety and Health (ATSDR et al. 2000).

Aerial Radiological Surveys and ORR Off-Site Background.

To help characterize and define contamination resulting from past operations at the reservation, DOE and its predecessors from 1959 through 1997 performed aerial radiological surveys on the ORR site and its surrounding areas (Carden and Joseph 1998; USDOE 1997). The surveys were conducted by helicopters containing highly sensitive monitoring equipment capable of detecting the presence of fabricated and natural radioactivity (USDOE 1997). The methodology consisted of calibrating the aircraft-mounted instruments during flight against a known radiation source then surveying the intended target area. The surveys were carried out while the helicopter was at a constant airspeed and altitude. Any detected radiation sources were subsequently investigated on the ground by standard survey techniques. Aerial surveys are sufficiently sensitive to detect sources that do and do not constitute a hazard.

The most recent aerial radiological surveys, conducted from June 10 through June 27, 1997, included flyovers of the Oak Ridge Reservation and areas approximately 1 mile beyond the reservation's boundary. These off-site areas included residential and industrial areas located in Anderson, Knox, and Roane Counties. The data collected during the surveys were entered into a DOE-maintained database of ORR radiological data (USDOE 1997). The aerial surveys included 11 areas of interest associated with the K-25 site, shown in Figure 10 (Lockheed Martin Energy Research Corporation 1998). Section III of this PHA: Evaluation of Environmental Contamination and Potential Exposure Pathways, contains more information on aerial radiological surveys.

ORR Annual Monitoring.

Since the establishment of the ORR, DOE (or its precursor agencies or contractors) has been collecting various environmental measurements, including ambient activities of radiation in soil, water, and air (See Figure 4). Since at least 1959, records of these monitoring programs have been published as quarterly, semi-annual, or annual reports. From 1959 to 1970, these reports were titled *Environmental Levels of Radioactivity for the Oak Ridge Area* and were compiled and published by the Health Physics Division of the Oak Ridge National Laboratory (Abee 1960a–c, 1961; ORNL, date unknown 1-20). Beginning in 1971, the scope of the reports was expanded to include nonradiological monitoring data, and the reports were titled *Environmental Monitoring*

Report, United States Department of Energy, Oak Ridge Facilities (Union Carbide Corporation Nuclear Division 1972-1983; Martin Marietta Energy Systems 1984–1995). After 1995, DOE began including data from the environmental monitoring reports in the Oak Ridge Environmental Information System (OREIS, described below).

Oak Ridge Environmental Information System (OREIS).

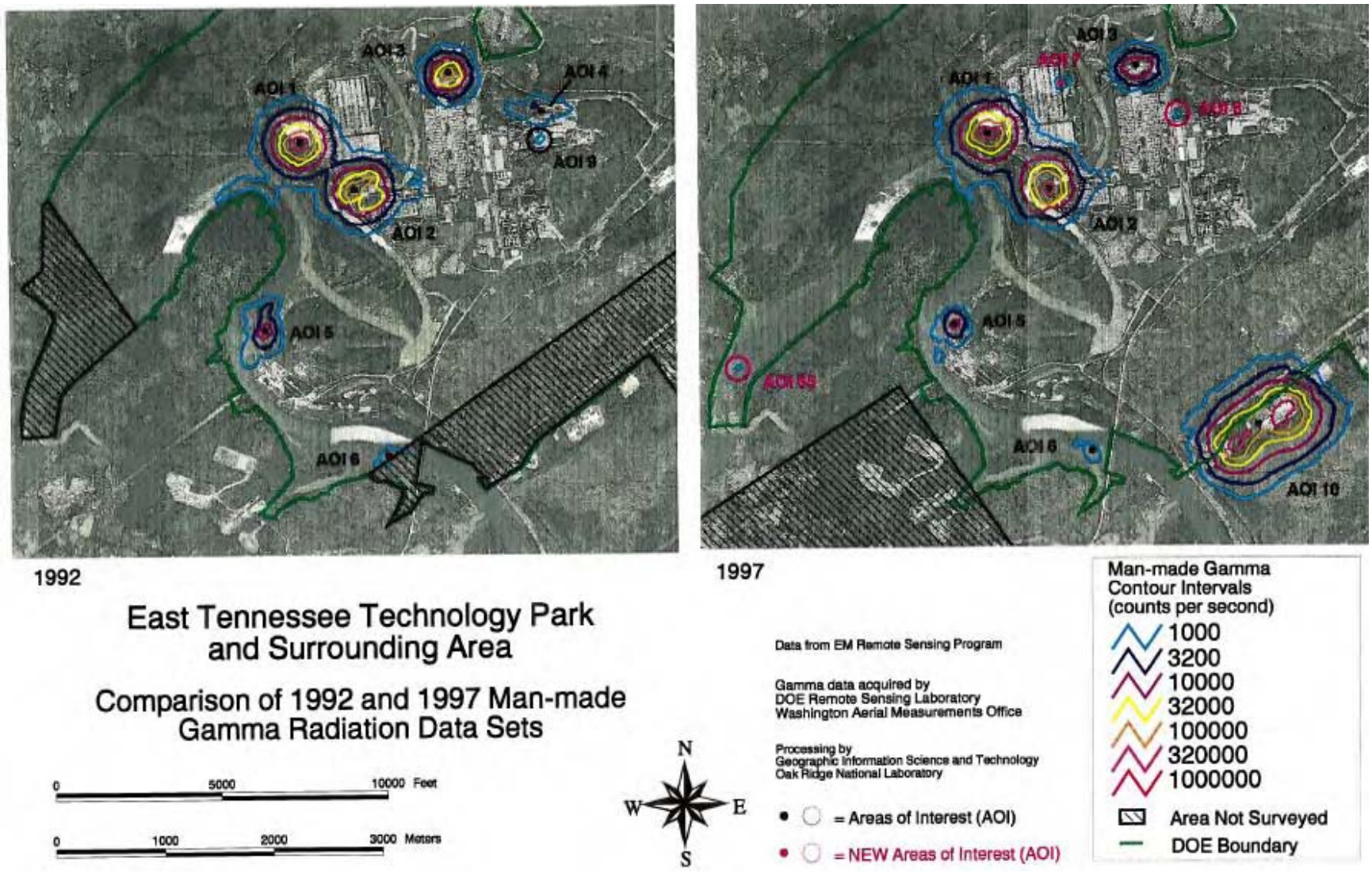
An abundance of environmental data is available for the ORR. Consequently, DOE created an electronic data management system to integrate all of the data into a single database. This facilitates public and governmental access to environmental data related to ORR operations while maintaining data quality. DOE's objective was to ensure that the database had long-term retention of environmental data and useful methods to access those data. OREIS contains data related to compliance, environmental restoration, and surveillance activities. Information from all key surveillance activities and environmental monitoring efforts is entered into OREIS. This information includes but is not limited to studies of the Clinch River embayment and the Lower Watts Bar, as well as annual site summary reports. As new studies are completed, the environmental data are entered as well (ATSDR et al. 2000).

Comprehensive Epidemiologic Data Resource (CEDR).

CEDR is a public-use database that contains information pertinent to health-related studies performed at the Oak Ridge Reservation and at other DOE sites. DOE provides this easily accessible, public-use repository of data (without personal identifiers) collected during occupational and environmental health studies of workers at DOE facilities and nearby community residents. This large resource organizes the electronic files of data and documentation collected during these studies and makes them accessible on the Internet at http://cedr.lbl.gov. Most of CEDR's large data collection pertains to about 50 epidemiologic studies of workers at various DOE sites. Of particular interest to Tennessee residents is an additional feature of CEDR (at http://cedr.lbl.gov/DR/ordr.html) that provides searchable text for about 1,800 original government documents (now declassified) used by the TDOH scientists for the Oak Ridge Dose Reconstruction. Also available through CEDR at http://cedr.lbl.gov are all of the technical and summary reports produced by this study. For the first time, this complex information is easily accessible and is concise, uncluttered, and comprehensible. In addition,

CEDR now provides images in slideshow format that give estimated concentrations, doses, and risk values for three contaminants (iodine, mercury, and uranium) in air at locations studied in TDOH's Dose Reconstruction, compliance, environmental restoration, and surveillance activities. Information from all key surveillance activities and environmental monitoring efforts is entered into OREIS. These include but are not limited to studies of the Clinch River embayment and the Lower Watts Bar, as well as annual site summary reports. As new studies are completed, the environmental data are entered as well (ATSDR et al. 2000).

Figure 10. Areas of Interest at the K-25 Site Included in Aerial Surveys



Source: Lockheed Martin Energy Research Corporation 1998

III. Evaluation of Uranium and Fluoride Releases, Exposure Pathways, and Environmental Contamination

III.A. Introduction

To identify contaminants that require further public health evaluation, ATSDR scientists in 2001 conducted a review and analysis of the Phase I and Phase II screening evaluation of TDOH's Oak Ridge Health Studies. In that screening evaluation TDOH conducted extensive reviews of available information and conducted qualitative and quantitative analyses of past (1944–1990) releases from the entire ORR as well as off-site exposures to hazardous substances. After ATSDR's review and analysis of Phase I and Phase II screening evaluations, ATSDR scientists determined that past releases of uranium, mercury, iodine 131, fluorides, radionuclides from White Oak Creek, and PCBs required further public health evaluations.

And as stated, the public health assessment is the primary public health process ATSDR uses to evaluate these contaminants further. ATSDR scientists have released, or are conducting public health assessments on, the following: Y-12 mercury releases, X-10 iodine 131 releases, White Oak Creek radionuclide releases, and PCB releases from X-10, Y-12, and K-25. ATSDR scientists previously prepared public health assessments on uranium releases from Y-12 and contaminant releases from the Toxic Substances Control Act (TSCA) Incinerator, and addressed current public health issues related to the East Fork Poplar Creek and the Lower Watts Bar Reservoir (LWBR). Public health assessments have been or will also be conducted on other issues of concern, such as contaminated off-site groundwater and a screening of current (1990 to 2003) environmental data to identify any other chemicals that require further evaluation.

In this public health assessment on K-25/S-50 uranium and fluoride releases, ATSDR scientists evaluated the data and findings of previous studies and investigations to

a. identify sources of uranium and fluoride releases,

b. assess the amounts of uranium and fluoride released,

c. evaluate past and current off-site exposure pathways,

d. estimate radiological doses and uranium and fluoride concentrations, and

e. determine the health implications of past, current, and future uranium and fluoride exposures for residents living near the ORR, specifically the communities of Sugar Grove, Union/Lawnville, and Happy Valley.

This section of the public health assessment discusses the sources, emissions, and concentrations of uranium, fluoride, and radioactive materials released from the K-25/S-50 site; describes how people living near the site may come into contact with these contaminants; evaluates potential doses and concentrations associated with potential exposures to these contaminants; and identifies and evaluates exposures for the potentially affected populations.

This assessment primarily evaluates the *long-term (chronic)* and *short-term (acute)* airborne releases of uranium hexafluoride and other associated radiological materials from many of the K-25 and S-50 buildings. These are the facilities involved in past gaseous diffusion operations. The assessment's goal is to estimate off-site concentrations and doses for people living in the communities of Sugar Grove, Union/Lawnville, and Happy Valley. Airborne uranium hexafluoride and other radiological materials are the primary contaminants of concern that require further evaluation; previous studies indicate that past releases of these contaminants may have resulted in off-site exposures at levels of health concern. The assessment includes an evaluation of on-site soil samples collected on or adjacent to the K-25/S-50 site. Many of the soil samples were collected within the boundary of the Oak Ridge Reservation between the K-25/S-50 site and any off-site populations. The releases of contaminants to the groundwater at the Oak Ridge Reservation, including the K-25 site, as well as off-site radionuclide releases to surface waters, are evaluated in separate public health assessments. For copies of these other assessments, please contact ATSDR toll-free at 1-800-232-4636.

An ***acute exposure*** occurs over a short time period, whereas a ***chronic exposure*** occurs over a long time (more than 1 year).

For the purposes of this document, the terms "on-site releases" and "on-site contamination" describe releases of hazardous substances and the resulting contamination of material within the fenced security area of the Oak Ridge Reservation (i.e., areas to which public access is restricted) controlled by DOE. This public health assessment considers on-site releases and contamination only in terms of off-site contamination sources and as means by which to evaluate the potential

effect of these releases on nearby off-site communities. "Off-site contamination" describes environmental media (e.g., soil, sediment, surface water, groundwater, air, or food-chain entities) contaminated as a result of nonradioactive or radioactive contaminants that have traveled off site from the ORR. This public health assessment also focuses on human exposure to contaminants in off-site environmental media located in publicly accessible areas surrounding the Oak Ridge Reservation. It is important to note that this document does not evaluate the impact of potential exposures for DOE workers to on-site contaminants—this is outside ATSDR's legislative mandate and is the responsibility of other organizations such as the National Institute for Occupational Safety and Health (NIOSH) (see the agency's Occupational Energy Research Program Web site for more information at http://www.cdc.gov/niosh/oerp/).

Exposure Evaluation Process

That releases of hazardous substances, (e.g., chemicals or radioactive materials) into the environment have the potential to cause harmful health effects is axiomatic. Such a release does not, however, always result in human exposure. People are only exposed to a chemical contaminant if they come into contact with it. If no one comes into contact with a contaminant, no exposure occurs, and thus no health effects occur. Often the general public does not have access to the source area of contamination or to areas where contaminants are moving through the environment. This lack of access to these areas becomes important in determining whether people could come into contact with the contaminants or with emissions of radiation from radiological contaminants.

The route of a contaminant from the release source to the people exposed in off-site areas is the exposure pathway. For an exposure to occur, a exposure pathway must be completed. A *completed exposure pathway* must include the following five elements:

The source of contamination is where the chemical or radioactive material was released. The environmental media (e.g., groundwater, soil, surface water, air, plants) transport the contaminants. The point of exposure is where people come in contact with the contaminated media. The route of exposure (e.g., eating, breathing, drinking, skin contact) is how the contaminant enters the body. The people actually exposed are the receptor population.

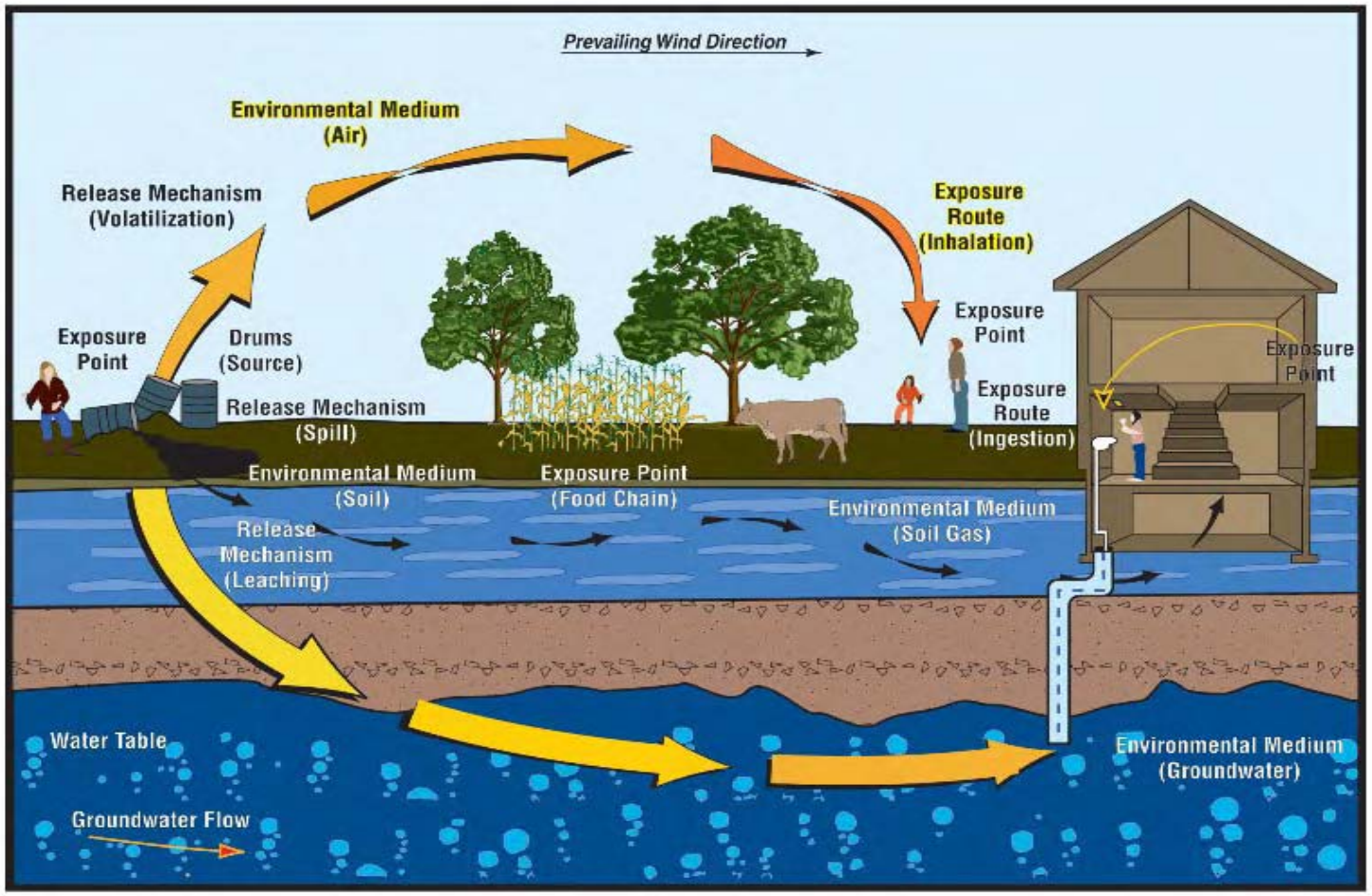
1. a source of contamination,
2. an environmental medium through which the contaminant is transported,
3. a point of human exposure,

4. a route of human exposure, and

5. an exposed population.

A *potential exposure pathway* is present when one or more of the elements are missing, but available information indicates that human exposure is likely to occur. Also, a pathway is considered potential when modeled data are used to predict human exposure. When one or more of the elements are missing, and available information indicates that human exposure is unlikely to occur, a site is categorized as *No exposure pathway* (ATSDR 2005). Figure 11 illustrates the pathways of exposure to contaminants.

Figure 11. Pathways of Exposure for Site-Specific Contamination



Source: ATSDR 2005

Notes:

The environmental medium (air) and exposure route (inhalation) are highlighted because the inhalation pathway is the main focus of this PHA.

The concentrations and distributions of hazardous substances in each of the pathways are evaluated in this section.

This assessment does not include ingestion of drinking water from surface water or groundwater sources because these are evaluated by ATSDR in other PHAs.

In this public health assessment ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a chemical or radiological contaminant—in this case, airborne releases of uranium and fluoride. An exposure pathway could involve air, surface water, groundwater, soil, dust, or plants and animals. Exposure can occur by breathing, eating, drinking, or by skin contact with a substance containing the chemical or radioactive contaminant. Exposure to radiation can occur by being near the radioactive material.

If exposure is possible, ATSDR scientists then consider whether environmental contamination is present at levels that might affect public health. ATSDR evaluates environmental contamination using available environmental sampling data and, in some cases, modeling studies. ATSDR selects contaminants for further evaluation by matching environmental contaminant concentrations with health-based comparison values. ATSDR develops comparison values from available scientific literature on subjects such as exposure and health effects. Comparison values are derived for each of the media and reflect an estimated concentration that is not expected to cause harmful health effects for a given contaminant, assuming a standard daily contact rate (e.g., the amount of water or soil consumed or the amount of air breathed) and representative body weight.

Note, however, that comparison values are not thresholds for harmful health effects. ATSDR comparison values represent contaminant concentrations that are many times lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. If specific contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (such as site-specific exposure, duration, and frequency) for health effects, including the toxicology of the contaminant, other epidemiology studies, and the weight of evidence.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/PHAManual/index.html or by contacting ATSDR at 1-800-CDC-INFO. An interactive program that provides an overview of the public health assessment process ATSDR uses to evaluate whether people will be harmed by hazardous materials is available at: http://www.atsdr.cdc.gov/training/public-health-assessment-overview/html/index.html.

Chemical Evaluation

ATSDR screened available chemical data for uranium and fluoride/HF to determine whether concentrations were above ATSDR's comparison values (see description below). To understand more completely the public health implications of exposure, ATSDR also reviewed relevant toxicologic and epidemiologic data to obtain information about the toxicity of the chemicals.

ATSDR selects chemicals for further evaluation by comparing the maximum environmental concentrations against media-specific, health-based comparison values. The maximum concentrations are used at this step of the screening process as a conservative measure even though we know that people are exposed to a range of concentrations and not just the maximum reported levels. As stated, comparison values are developed by ATSDR from available scientific literature on subjects such as exposure and health effects. Comparison values are derived for soil/sediment, water, and air: they reflect a concentration that is not expected to cause harmful health effects for a given contaminant, assuming a standard daily contact rate (for example, the amount of water or soil consumed or the amount of air breathed) and representative body weight (child or adult). Because they reflect concentrations much lower than those actually observed to cause adverse health effects, comparison values are protective of public health in essentially all exposure situations. As a result, exposure to chemical concentrations detected at or below ATSDR's comparison values are not expected to cause health effects in people. Therefore, levels below media-specific comparison values do not pose a public health hazard and are not evaluated further for a given media.

ATSDR uses comparison values to screen chemicals that require additional evaluation.

While concentrations at or below the respective comparison value can be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would be expected to produce adverse health effects; comparison values are not health-effect thresholds. ATSDR comparison values represent concentrations that are many times lower than levels at which, in studies on experimental animals or in human epidemiologic studies, no effects were observed. The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual differences, and factors that affect the route, magnitude, and duration of actual exposure. If contaminant concentrations are above comparison values or if no

comparison values exist for particular contaminants, ATSDR further analyzes exposure variables (such as site-specific exposure duration and frequency) for health effects, including the toxicity of the chemical, epidemiology studies, and the weight-of-evidence.

Weight-of-evidence is the extent to which the available scientific information supports the hypothesis that a substance causes an adverse effect in humans. For example, factors that determine the weight-of-evidence that a chemical poses a hazard to humans include the number of tissue sites affected by the agent; the number of animal species, strains, sexes, and number of experiments and doses showing a response; the dose-response relationship; statistical significance in the occurrence of the adverse effect in treated subjects compared with untreated controls; and the timing of the occurrence of the adverse effect.

For some public health assessments, however, critical data are unavailable, thus making impossible a professional judgment about the level of health hazard. In these instances, ATSDR must determine whether the needed data can be obtained. In preparing this document, for instance, evidence showed that fluoride and hydrogen fluoride were released as UF_6 at the K-25 site during accidents or during equipment maintenance. But with regard to these releases ATSDR was unable to locate environmental sampling data related to historic short-term exposure. Although ATSDR used worst-case assumptions and modeled air data to estimate exposures, the necessary and sufficient sampling data are nowhere to be found. Thus ATSDR cannot draw a conclusion about the true health hazard that existed in the past, and for this exposure scenario must use the *indeterminate public health hazard* conclusion category. Indeed, it appears that sufficient data will never be available on which to form a professional judgment about the level of health hazard from exposure to historic short-term fluoride and hydrogen fluoride released from the K-25 site.

Radiological Evaluation

The two broad classes of radiation exposure include external radiation and internal radiation. Internal exposures result from radioactive sources taken into the body through the inhalation of radioactive particles or through the ingestion of contaminated food. External exposure results from radiation sources originating outside the body, such as radiation emitted from contaminated sediment. These external sources can sometimes penetrate the human skin. Whether an exposure contributes to a person's external or internal exposure depends primarily on the type of

The radiation dose is the amount of energy from radiation that is actually absorbed by the body.

radiation—alpha and beta particles or gamma rays—to which a person was exposed (see the text box).

ATSDR scientists calculate the radiation dose by using the concentration of the radionuclide in the environment and, if available, site-specific exposure factors such as time spent outdoors and amount of water ingested. If these site-specific factors are unavailable, ATSDR either uses default values or derives region-specific values. Once these inputs are derived, the dose coefficient that converts the radiation concentration to the radiation dose is applied. ATSDR scientists might use worst-case exposure factors as the basis for determining whether adverse health effects are *possible*. Because of this approach, the estimated radiation doses are usually much higher, (i.e., more conservative) than the levels to which people are really exposed. Note that the concept of radiation dose is not as simple as related here. A number of other factors (e.g., how radionuclides decay, the critical organ concept, particle size distribution, and the chemical form might affect "dose" and therefore need to be factored into the dose derivation.

Beta particles can penetrate human skin and tissues and deliver a dose both internally and externally. Gamma rays can travel long distances and easily penetrate body tissues, and are therefore the primary type of radiation that results in external radiation exposures. Alpha particles cannot penetrate skin, so they pose a minimal external exposure concern. Alpha particles can inflict biological damage if the body takes them in, for example by breathing or swallowing radioactive material in air or food (ATSDR 1999b).

Internal radiation exposure from a radionuclide continues after the initial radioactive material has been taken into the body, even if no additional radionuclides are ingested or inhaled. That is, internal exposure of radiation from radioactive material commits the exposed person to receiving a radiation dose for a period of time that typically depends on the radionuclide's half-life and its rate of elimination from the body. (See the glossary in Appendix A for a description of half-life.) For an organ-specific dose this is known as the *committed equivalent dose*, and for a whole-body dose, the *committed effective dose*. Exposure to external radiation sources, however, stops when the source is removed or when a person moves away from the source. A dose associated with external radiation is called an *effective dose*. The doses are further defined as follows:

ATSDR uses the term "conservative" to refer to values that are protective of public health in essentially all situations. Values that are overestimated are considered to be conservative.

Committed Equivalent Dose

The International Commission of Radiological Protection's (ICRP's) term (starting with ICRP Publication 60) for the dose to organs and tissues of reference that a person will receive from an intake of radioactive material:

- for workers or adults, over a 50-year period following the intake, and
- for children, over a 70-year period following the intake.

Committed Effective Dose

ICRP's term for the sum of the products of 1) the weighting factors applicable to each body organ or tissue that is irradiated, and 2) the committed equivalent dose to the appropriate organ or tissue integrated over time (in years) following the intake, with the assumption that the entire dose is delivered in the first year following the intake. The integrated time for an adult is 50 years; for children, it is from the time of intake to 70 years. The committed effective dose is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues.

Effective Dose

ICRP's term (starting with ICRP Publication 60) for the sum of the products of 1) the weighting factors applicable to each body organ or tissue that is irradiated, and 2) the mean equivalent dose in the tissue or organ following exposure to external radiation.

Past, Current, and Future Exposure Pathways Evaluated

ATSDR evaluated the potential exposure pathways for radionuclides (uranium 234, 235, and 238, technetium 99, and neptunium 237), fluorides (in both fluoride and fluorine forms), and hydrogen fluoride from K-25 and S-50 site air emissions. Table 3 presents the sources, time frames, contaminants, and exposure areas evaluated in this PHA for past (1944 to 2006) exposures. Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the site. Using ATSDR's evaluation, no potential current or future hazards to off-site residents have been identified at this time, but remediation continues at the site. Figure 12 shows the locations of the significant emission sources at the K-25 site

relative to the points of historic exposure and the locations of the former cylinder storage yards. In this public health assessment Section II.E, Demographics, shows information on the population estimates and residential histories for the respective exposure areas.

Table 3. Exposure Sources, Time Frames, Contaminants, and Exposure Areas for the Evaluation of Past Exposures to K-25/S-50 Air Emissions

Source	*Timeframe*	*Contaminant (Exposure Duration)*	*Exposure Area*
Past Exposures			
K-25	1945 to 1995 1963 (maximum release year)	Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Union/Lawnville
	1960 to 1995 1963 (maximum release year)	Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Sugar Grove
S-50	1944 to 1945	Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Happy Valley
		Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Union/Lawnville

Notes:
Radionuclides include uranium (234, 235, and 238), technetium 99, and neptunium 237.

With respect to the K-25/S-50 site evaluated in this PHA, ATSDR assumed that uncontrolled releases of uranium and fluoride compounds would be transported in the atmosphere to off-site areas. Consequently, ATSDR also assumed that completed exposure pathways do exist for historic air releases for uranium and fluoride compounds. The remainder of this section will evaluate the doses and concentrations of uranium and fluoride compounds at the areas of highest exposure (Happy Valley, Sugar Grove, and Union/Lawnville areas). Section IV, Public Health Implications, explores whether these estimated doses and concentrations are (or were) a public health hazard.

Additionally, Appendix A provides a glossary of environmental and health terms presented in the discussion. Additional background information is provided in appendices as follows:

- Appendix B summarizes other public health activities at the ORR;
- Appendix C summarizes remedial activities related to the study area;

- Appendix D provides a description of the CAP88-PC Model and presents the output data from the model;
- Appendix E presents the model output for K-25 releases from the RASCAL3 model;
- Appendix F contains K-25 meteorological data;
- Appendix G details the measured versus predicted gross alpha concentrations at monitoring locations;
- Appendix H contains summaries of ATSDR and TDOH studies; and
- Appendix I provides toxicological data on specific contaminants evaluated in this public health assessment.

III.B. Past Releases from the K-25/S-50 Site (1944 to 2006)

III.B.1. Sources and Emissions Estimates of Airborne Uranium, Fluoride, Hydrogen Fluoride, and Other Radiological Contaminants

Sources

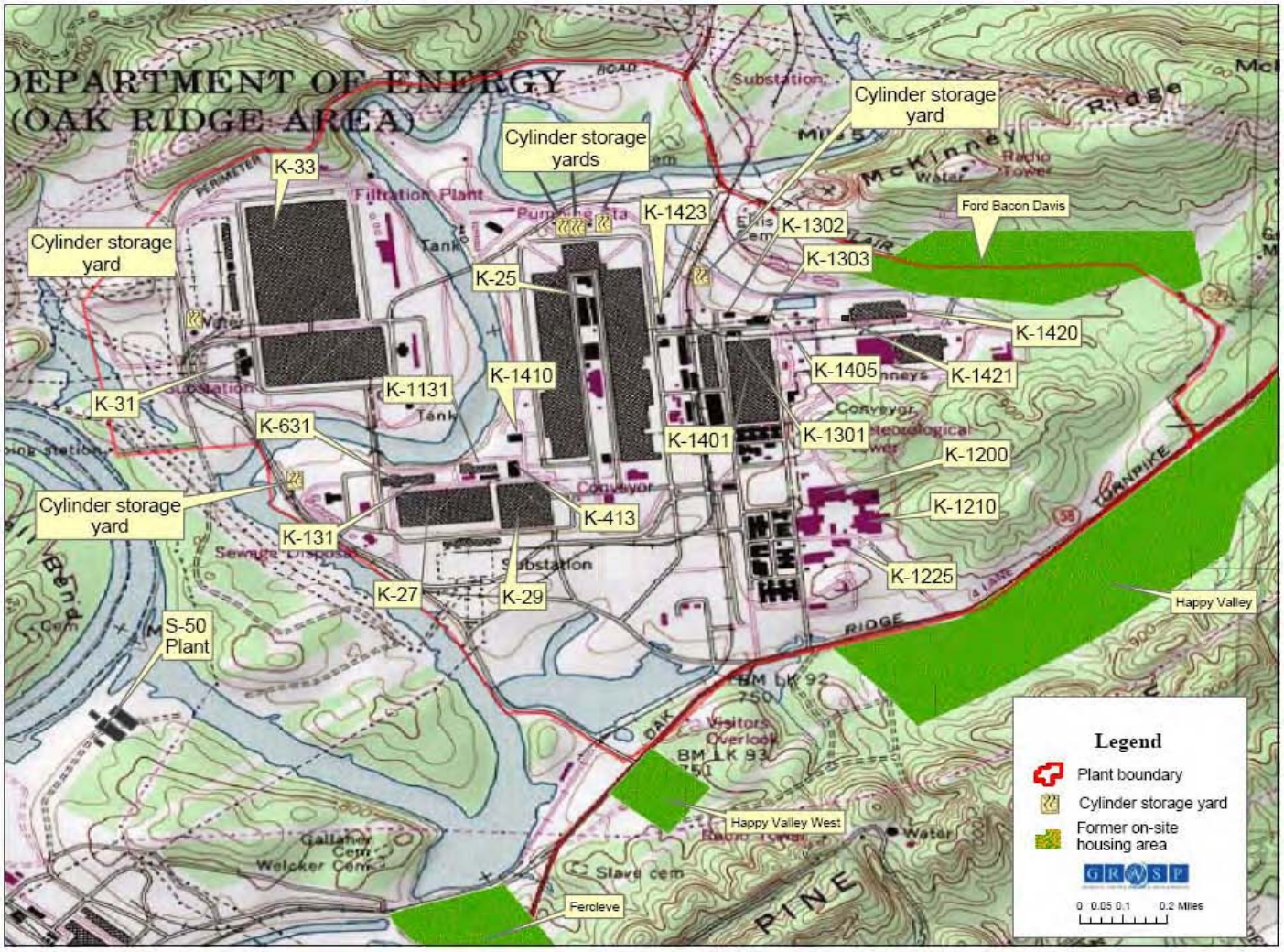
The primary airborne contaminant released from the K-25 and S-50 facilities was uranium hexafluoride (UF_6). The primary mission of the K-25 and S-50 facilities was the enrichment of U 235 via gaseous diffusion of uranium hexafluoride. From 1945 to 1963 the K-25 facility produced UF_6 that was highly enriched with the U 235 isotope (up to 93% U 235). From 1964 to 1985, the K-25 facility produced low enrichment UF_6 (up to 5% U 235). The S-50 facility, which operated for only about 12 months from 1944 to 1945, produced and released UF_6 with an enrichment of less than 1% U 235 (ChemRisk 1999a). These changes in the relative enrichment of the UF_6 are reflected in the proportions of U 234, U 235, and U 238 released to the atmosphere. At atmospheric temperature and pressure, UF_6 is a dense or heavy gas (heavier than air). When released in the air, UF_6 reacts rapidly with atmospheric water to form hydrogen fluoride and uranyl fluoride and uranium oxide particulates (ATSDR 2003).

The K-25 site has more than 500 buildings in the area where gaseous diffusion processes took place, over 270 auxiliary facilities for support services, and about 290 more buildings and trailers used for various purposes. Figure 12 shows the locations of the process buildings on the K-25/S-

50 site that were the primary sources of historic air emissions. Note that the process buildings—the specific release sources—are widely distributed across the K-25 site. Releases from these buildings occurred from a number of vents and stacks, many of which included some type of effluent treatment or trap to capture the uranium before it was released to the environment (ChemRisk 1999a). The specific contaminants and time frame for releases from each building are described in Table 4 (ChemRisk 1999a; Lay and Rogers 1986).

Initially, all of the UF_6 fed into the gaseous diffusion cascades was made from natural uranium. Beginning in 1952, however, uranium that had been reprocessed from previously fissioned material (reactor tails) was introduced as UF_6 feed material. The UF_6 from spent reactor fuel contained fission products and transuranic radionuclides including technetium 99 (Tc 99), neptunium 237 (Np 237) and very small quantities of plutonium 239 (Pu 239). Consequently, after 1952, airborne emissions from the K-25 facility also contained quantities of Tc 99, Np 237, and Pu 239. The proportion of spent reactor tails to natural uranium in the feed material varied significantly from 1952 to 1985, but must be accounted for in airborne emission estimates.

Figure 12. Locations of Primary Historic Air Emission Sources from the K-25/S-50 Site



Notes:

Descriptions of the past primary sources (specific buildings) including type of air releases, contaminants, and time frames are listed in Table 4.

Cylinder yard locations are approximate.

Table 4. Descriptions of the Past Primary Sources Contributing to Airborne Releases From the K-25 and S-50 Facilities

Process	*Buildings*	*Type of Air Releases*	*Contaminants*	*Time Frame*
S-50 Site				
Liquid thermal diffusion	S-50	-Routine releases from equipment conditioning exhausts -Accidental equipment failures and process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride)	October 1944 to September 1945
K-25 Site				
Hydrogen fluoride and fluorine disposal (fluorine/hydrogen fluoride converted to sodium fluoride then released to air)	K-1405	-Routine releases from disposal tower -Accidental equipment failures -Process errors	-UF_6 -Sodium urinate -Uranyl fluoride	1944 to 1952
Gaseous diffusion enrichment	K-25, K-27, K-29, K-31, and K-33	-Routine monitored purging of cascades -Unmonitored evacuations for maintenance -Accidental equipment failures and process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride)	1945 to1964 (highly enriched UF_6) 1945 to 1985 (low enrichment UF_6)
Feed vaporization and toll enrichment (cylinders heated to vaporize UF_6 for transfer to cascades)	K-131, K-1131, and K-1423	-Accidental equipment failures and process errors (e.g., faulty cylinder connections, valve failures, and overfilling)	UF_6 (enriched, natural, or depleted)	1945 to 1985
Product and tails transfers (gaseous UF_6 compressed/condensed into liquid and transferred to cylinders)	K-413, K-631, and K-1131	-Accidental equipment failures (including cylinder explosions and ruptures) -Process errors (faulty cylinder connections and valve failures)	UF_6 (enriched, natural, or depleted)	1945 to 1985
Uranium decontamination and recovery (process equipment cleaned with water, steam, acid, etc.; other waste material incinerated and ash recycled)	K-131, K-1301, K-1302, K-1303, K-1401, K-1410, and K-1421	-Routine releases from incinerator and cylinder purging/evacuation -Accidental equipment failures -Process errors	-UF_6 -Other uranium compounds	1945 to 1985
UF_6 feed manufacturing (production of UF_6 from uranium dioxide [UO_2] and hydrogen fluoride [HF]	K-1131	-Accidental equipment failures -Material transfer losses -Process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride); UO_2; UF_4; HF	1952 to 1961 1962 to 1965

Table 4 (continued). Descriptions of the Past Primary Sources Contributing to Airborne Releases from the K-25 and S-50 Facilities

Process	*Buildings*	*Type of Air Releases*	*Contaminants*	*Time Frame*
K-25 Site				
Gas centrifuge program (a developmental program to prototype and test high speed centrifuges used to enrich UF_6)	K-1423, K-1200, K-1210, and K-1225	-Accidental equipment failures -Process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride)	Early 1960s to late 1980s

Source: ChemRisk 1999a; Fricke 1996; Lay and Rogers 1986; USDOE 2003a

UO_2 is uranium dioxide.

UF_4 is uranium tetrafluoride.

From 1976 to 1980, airborne releases from the K-25 facility also included significant quantities of krypton 85 (Kr 85) (Lay and Rogers 1986). The krypton was apparently added to the UF_6 feed material as part of an Oak Ridge National Laboratory (ORNL) experiment. Available information is limited, and does not indicate the part of the feed material production and processing where krypton 85 was introduced or released. A summary of K-25 radionuclide emissions by Lay and Rogers (1986) indicates, however, that the experiment lasted 5 years and a total of 106.5 curies (Ci) of Kr 85 was released to the atmosphere. Annual Kr 85 releases varied from 6.5 Ci in 1976 to 41.5 Ci in 1978, and have been included in subsequent dispersion and dose calculations.[2]

Beginning in the 1950s, DOE (and its predecessors) accumulated approximately 6,000 UF_6 cylinders (collectively containing about 119 million pounds of UF_6) in six storage yards at the K-25 site. As of December 2006, however, DOE completed removal of all UF_6 cylinders from the cylinder storage yards at the K-25 site. Uranium hexafluoride, or UF_6, is a solid stored under vacuum in steel cylinders (Fricke 1996). When it is stored at temperatures below 134^{o}F (57^{o}C) at atmospheric pressure, depleted UF_6 is a white, crystalline solid (USDOE 1999).The cylinders were of several dimensions (the most common were 12 feet [about 3 ½ meters] long and 4 feet [about 1 meter] in diameter), had a nominal wall thickness of 3/16 inch (about 5 millimeters), and when full contained about 14 tons of UF_6. Figure 12 shows the location of the six former cylinder storage yards. If one of the cylinders had leaked, the UF_6 would have reacted with moisture in the atmosphere to form hydrogen fluoride (HF) gas and uranium reaction products such as solid uranyl fluoride. The solid would have sealed small leaks or cracks, preventing the escape of radioactive and chemical materials from the cylinders (Fricke 1996). No cylinders remain on site—removal was complete by December 2006.

[2] Kr-85 is not cited in the CAP88-PC model in Appendix D because there were no releases of Kr 85 in 1963, the release year included in the CAP88-PC model.

Annual Airborne Emission Estimates (1944 to 1995)

ATSDR evaluated total airborne uranium releases for the K-25/S-50 site based on estimates by DOE and ChemRisk. The DOE uranium release estimates are taken from quarterly, semi-annual, or annual environmental reports for the years 1959–1995 and from a Lay and Rogers (1986) historical summary. The ChemRisk estimates from the Task 6 report are based on more than 40 sources documenting over 1,200 uranium release events for the years 1944 to 1995 (ChemRisk 1999a); ChemRisk data were provided to ATSDR. Table 5 and Figure 13 show the total uranium releases (in Curies) to the atmosphere as estimated by DOE and by ChemRisk in its Task 6 report.

Although independently derived, the uranium release estimates are based on the same underlying monitoring and incident release reports. Additionally, S-50 facility emissions were not included in original DOE K-25 facility release estimates, and in the Task 6 report ChemRisk adds the S-50 facility releases for 1944 and 1945 to the DOE estimate. Similarly, ChemRisk did not independently estimate 1989 to 1995 releases in the Task 6 report, which were taken directly from DOE release estimates. As shown in Table 5 and Figure 13, these two semi-independent estimates of total airborne uranium releases are very similar.

That said, in two important attributes the DOE estimates of total airborne uranium releases are more conservative than the Task 6 report estimates. First, when the S-50 facility emissions are added to the DOE release estimates, the cumulative airborne uranium release, as estimated by DOE, is about 8% larger than the Task 6 report estimate. Second, and more importantly, the highest annual releases (1961 and 1963) as estimated by DOE are, for those years, more than 30% larger than the Task 6 report estimates.

The DOE estimate of total airborne uranium releases is more conservative than the Task 6 report estimate. But the Task 6 report emissions data are more complete in that they include the relative composition of the uranium isotopes U 234, U 235, and U 238 for each of the release years. ATSDR's analyses of the dispersion of the uranium isotopes and of the resulting doses to the potentially exposed populations uses the DOE estimate of total uranium activities and the

ATSDR uses the term "conservative" to refer to values that are protective of public health in essentially all situations. Thus for public health purposes, overestimated values are considered conservative values.

Task 6 report estimate of uranium isotope proportions. Table 5 shows the estimated annual airborne radionuclide releases (total uranium, technetium 99, and neptunium 237) from the K-25/S-50 facilities and the relative abundance of uranium isotopes. As mentioned previously, the very small quantities of Pu 239 included in the reactor tails account for less than one percent of the total radiation and therefore are not included in radiological dose assessments.

Table 5. Estimated Annual Airborne Radionuclide Releases from K-25/S-50

	Total Uranium (Curies)		*Relative Abundance (percent) Uranium Isotope Task 6 Report*			*Task 6 Report (Curies)*	
Year	DOE	Task 6 Report	Uranium 234	Uranium 238	Uranium 235	Technetium 99	Neptunium 237
1944	0.04	0.04	48.05	49.67	2.29	—	—
1945	2.05	2.05	48.06	49.65	2.29	—	—
1946	0.01	0.05	95.83	0.46	3.71	—	—
1947	0.01	0.05	96.52	0.18	3.30	—	—
1948	0.01	0.00	56.58	41.00	2.42	—	—
1949	0.01	0.05	40.73	57.50	1.76	—	—
1950	0.10	0.09	48.13	49.59	2.28	—	—
1951	0.02	0.13	46.29	51.55	2.16	—	—
1952	0.23	0.78	46.26	51.59	2.15	—	—
1953	1.60	1.41	66.40	30.65	2.96	2.9	0.110
1954	0.26	0.79	93.92	2.99	3.09	2.9	0.050
1955	0.26	0.26	62.95	34.49	2.57	2.9	0.050
1956	0.81	0.16	43.42	54.62	1.96	2.9	0.023
1957	0.15	0.21	48.53	49.28	2.20	2.9	0.024
1958	1.80	1.82	48.01	49.71	2.28	2.9	0.130
1959	1.10	0.59	66.66	30.52	2.82	2.9	0.039
1960	1.50	0.99	48.23	49.48	2.29	2.9	0.072
1961	3.10	0.60	54.39	43.32	2.28	2.9	0.054
1962	0.24	0.17	87.28	8.85	3.87	2.9	0.013
1963	3.10	2.02	79.58	16.03	4.39	2.5	0.049
1964	0.01	0.01	71.79	24.82	3.39	2.5	0.002
1965	0.14	0.67	83.20	12.96	3.84	2.5	0.013
1966	0.01	0.00	73.01	23.00	3.99	2.5	0.002
1967	0.01	0.00	68.25	28.07	3.68	2.5	0.002
1968	0.01	0.00	39.41	58.95	1.65	2.5	0.002
1969	0.01	0.01	50.96	46.54	2.49	2.5	0.003
1970	0.01	0.01	66.92	29.49	3.59	2.5	0.003
1971	0.02	0.09	77.87	17.87	4.26	2.5	0.003

	Total Uranium (Curies)		*Relative Abundance (percent) Uranium Isotope Task 6 Report*			*Task 6 Report (Curies)*	
Year	DOE	Task 6 Report	Uranium 234	Uranium 238	Uranium 235	Technetium 99	Neptunium 237
1972	0.03	0.05	63.13	33.55	3.32	2.5	0.004
1973	0.44	0.44	74.80	21.09	4.11	2.5	0.006
1974	0.13	1.18	78.64	17.01	4.34	0.27	0.014
1975	0.27	0.65	77.27	18.47	4.26	0.30	0.001
1976	0.05	0.25	80.60	15.00	4.40	6.79	0.002
1977	0.03	0.06	80.15	15.43	4.42	0.00	0.002
1978	0.02	0.04	81.76	14.73	3.51	0.29	0.002
1979	0.04	0.11	82.08	13.39	4.53	1.34	0.002
1980	0.03	0.20	76.13	19.82	4.04	0.88	0.002
1981	0.01	0.13	78.62	17.08	4.30	0.04	0.002
1982	0.01	0.11	74.03	21.91	4.06	0.03	0.002
1983	0.01	0.00	76.68	19.10	4.22	0.02	0.002
1984	0.01	0.00	77.55	18.17	4.28	0.02	0.002
1985	0.01	0.00	78.35	17.34	4.32	—	0.002
1986	0.01	0.00	89.39	5.85	4.76	—	0.002
1987	0.01	0.00	52.96	44.41	2.63	—	0.002
1988	0.31	0.31	48.05	49.67	2.29	—	0.002
1989	0.00	0.00	47.67	50.02	2.30	—	0.002
1990	0.00	0.00	37.29	61.18	1.53	—	0.002
1991	0.02	0.02	42.10	56.04	1.87	—	0.002
1992	0.06	0.06	39.55	58.76	1.69	—	0.002
1993	0.01	0.01	47.66	50.20	2.14	—	0.002
1994	0.01	0.01	55.61	41.58	2.82	—	0.002
1995	0.01	0.01	18.43	81.39	0.18	—	0.002
Totals	18.15	16.70	63.76	33.15	3.08	3.293	0.700

Notes:

— Technetium 99 (Tc 99) and neptunium 237 (Np 237) were not released during these years.

DOE uranium estimates are from Lay and Rogers (1986) and environmental monitoring reports.

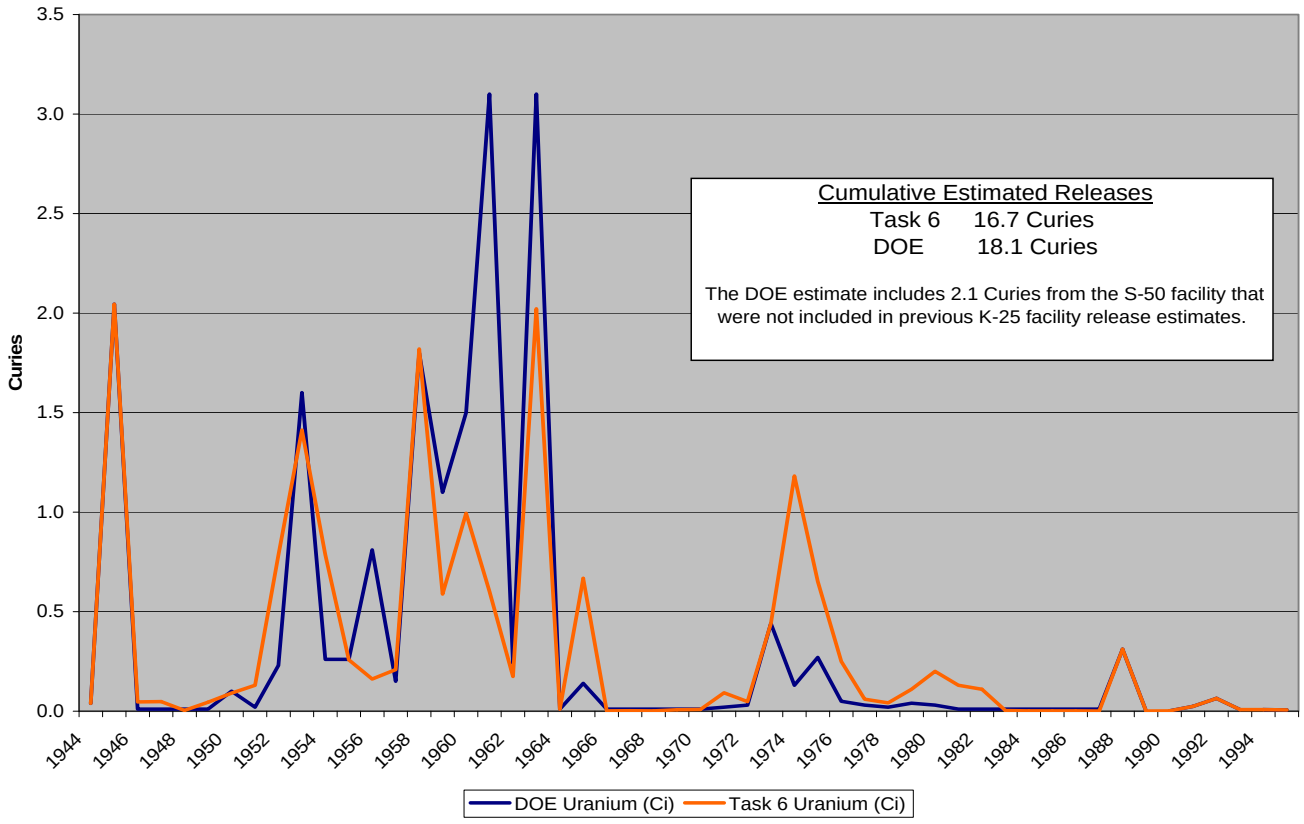
S-50 facility emissions were not included in the original DOE K-25 facility release estimates; ChemRisk added the 1944 and 1945 S-50 facility release estimates (shown in blue) to DOE's estimates. Thus, DOE uranium estimates include 1944–1945 S-50 releases from the Task 6 report.

Task 6 report uranium estimates are from ChemRisk in the Task 6 report (ChemRisk 1999a).

ChemRisk did not independently evaluate estimates for 1989 to 1995; the Task 6 report uranium estimates (shown in blue) were taken directly from DOE release estimates for 1988 to 1995.

Note that when the S-50 facility emissions are added to the DOE release estimates: 1) the cumulative DOE release estimate is greater than the Task 6 report estimate, and 2) during the maximum release years (1961 and 1963), DOE's estimates are much greater than the Task 6 report estimates.

Figure 13. Total Estimated Airborne Uranium Releases (in Curies) from the K-25/S-50 Facility



Notes:

DOE uranium estimates are from Lay and Rogers (1986) and environmental monitoring reports

S-50 facility emissions were not included in the original DOE K-25 facility release estimates; ChemRisk added the 1944 and 1945 S-50 facility release estimates to DOE's estimates. Thus, DOE uranium estimates include 1944-1945 S-50 releases from the Task 6 report.

Task 6 report uranium estimates are from ChemRisk in the Task 6 report (ChemRisk 1999a).

ChemRisk did not independently evaluate estimates for 1989 to 1995; the Task 6 report uranium estimates were taken directly from DOE release estimates for 1989 to 1995.

Note that when the S-50 facility emissions are added to the DOE release estimates: 1) the cumulative DOE release estimate is greater than the Task 6 report estimate, and 2) during the maximum release years (1961 and 1963), DOE's estimates are much greater than the Task 6 report estimates.

Historic Accidental or Short-Term Release Estimates (1944 to 1995)

The long-term or annual uranium release estimates, as shown in Table 5, represent the sum of individual release events for each year from 1944 to 1995. One of the specific tasks of this PHA is to determine whether any of these historic short-term release events represented an acute

public health hazard to the adjacent communities. Table 6 shows the four largest accidental releases that ChemRisk specifically identifies in its Task 6 report (ChemRisk 1999a) or that ATSDR obtained via accident report records (Union Carbide Nuclear Company 1952–1955, 1957–1958, 1958, 1958–1961). Although the available data are probably incomplete, these records include the years of highest production and annual emissions, and are likely representative of the most significant individual release events.

Table 6 also includes an estimate of the maximum magnitude of the "*midnight negative*" releases (see text box). An evaluation of releases from the Paducah Gaseous Diffusion Plant by Bechtel Jacobs Company LLC indicates that "…up to several thousand pounds of UF_6 could still have been available for release to the environment from a single cascade cell…" (Bechtel Jacobs Company LLC 2000). As use of the "midnight negative" process has also been reported for the K-25 facility, this PHA will assume that the K-25 midnight negatives were of a similar magnitude as the Paducah Gaseous Diffusion Plant midnight negatives. ATSDR has no information on the relative enrichment of material released during midnight negatives. That significant amounts of enriched material were released to the environment via this process is, however, unlikely—enriched product was too valuable to discharge.

> The term "midnight negatives" refers to using the jets at night to accelerate the attainment of an adequate UF_6 negative to support a planned opening of isolated process gas equipment" (Bechtel Jacobs Company LLC 2000).

Although Table 6 does not include any records of specific accidental releases from the S-50 facility, ATSDR did review a letter that discussed the frequency and causes of material losses from typical individual release events during a 2-month period in 1945 (Blackwood 1945). Although this summary does not list specific release events, it does indicate that four "open tit breaks" resulted in the release of 597 pounds of material and that 35 "column breaks" resulted in the loss of 1031.4 pounds of material. These records suggest that the individual ongoing operational releases from the S-50 facility were smaller than the specific releases listed in Table 6.

Also worth noting is that for many of the specific, documented release events, the reports state or infer that much of the material was not dispersed outside the buildings. Most likely, the majority of the released material was retained within the buildings and then recovered. Nevertheless,

because ATSDR cannot verify recovery for all accidental releases, this public health assessment will assume that all of the released material was dispersed to the ambient air. Thus our estimated releases will be higher—that is, more conservative—than the levels to which people were actually exposed.

Table 6. Significant Historic Short-Term UF_6 Release Estimates from the K-25 Facility

Date	*Building/Source*	*Amount*	*% U 235*	*Comments*
9/1/58	K-1131	1,184 kg 0.55 Ci	0.71%	Ruptured filter in hydrogen reduction system
12/30/52	K-402-1	1,138 kg <0.53 Ci	0.6%	Valve failure; most UF_6 retained in building
9/19/52	K-1131	454 kg 0.21 Ci	0.7%	Release occurred over 10-hour period
2/27/60	K-1131	681 kg 0.32 Ci	0.7%	Ruptured tube in cold trap
Various	Midnight negatives	907 kg maximum ~0.42 Ci	Unknown	Maximum amount of UF_6 in cascade cell assuming 10% reduction in pressure by purging and evacuation

Notes:
Kg – kilogram
Ci – curie
Building K-402-1 is located within Building K-27, presented in Figure 12.
See Figure 12 for the location of Building K-1131.

III.B.2. Historical Environmental Monitoring Data

Ambient Environmental Monitoring

Since the establishment of the ORR, DOE or its predecessors or contractors have been collecting various environmental measurements, including ambient activities of radiation in soil, water, and air (See Figure 4). And since at least 1959, records of these monitoring programs have been published as quarterly, semi-annual, or annual reports. Although some monitoring data have been collected over most of the operational history of the K-25/S-50 facility, extensive changes have been made in the specific parameters, analytical methods, and sample locations. The changes primarily involve measuring more parameters, improving analytical techniques, and using a larger number of sampling locations. Yet even in the face of such changes, some of the station locations have, over the years, remained fairly consistent. This is important because to

understand long-term trends, maintenance of consistent sampling parameters, methods, and locations is necessary.

Table 7 lists the ambient monitoring data available for evaluation of historic uranium and fluoride air emissions released from the K-25/S-50 facility. Since as early as the mid-1950s, two specific locations (HP-35 and HP-33) adjacent to the K-25/S-50 facility have been sampled for airborne radioactive particulates. A review of environmental monitoring reports shows that only gross beta measurements were collected until 1966, when gross alpha measurements were initiated. The sample station locations are shown in Figure 14. In the next section of this public health assessment, the gross alpha measurement data (presented in Table 8) are used to evaluate the ability of the CAP88-PC modeling procedures to estimate off-site radiological doses.

Table 7. Ambient Environmental Monitoring Data Adjacent to the K-25/S-50 Facility Used to Evaluate Historical Uranium and Fluoride Releases

Media Sampled	*Parameters*	*Stations**	*Time Period*
Air†	Gross Beta	HP-33/HP-35 (13/15)	1959 to 1983
	Gross Alpha	HP-33/HP-35 (13/15)	1966 to 1983
	Uranium isotopes	Perimeter/remote station	1975 to 1995
	Fluorides	F1-F6	1971 to 1985
Soil‡	Gross Alpha	HP-33/HP-35	1971 to 1975
	Uranium isotopes	HP-33/HP-35	1976 to 1984
Biota‡ (Pine needles/grass)	Uranium (total)	VS1-VS9	1974 to 1985
	Fluorides	VS1-VS9	1974 to 1985

Notes:

* Sampling also occurred at many other locations; these are the stations of interest for this PHA.

† Most of the air samples were collected and analyzed weekly and then averaged; this PHA uses annual averages.

‡These data are included in doses modeled using CAP88-PC (see Appendix D). The CAP88-PC program computes radionuclide concentrations in air, rates of deposition on ground surfaces, radionuclide concentrations in food, and intake rates for people ingesting food produced in the assessment area.

Although some of the station names have changed over time, the locations were apparently constant.

Locations of sample stations are shown in Figure 14

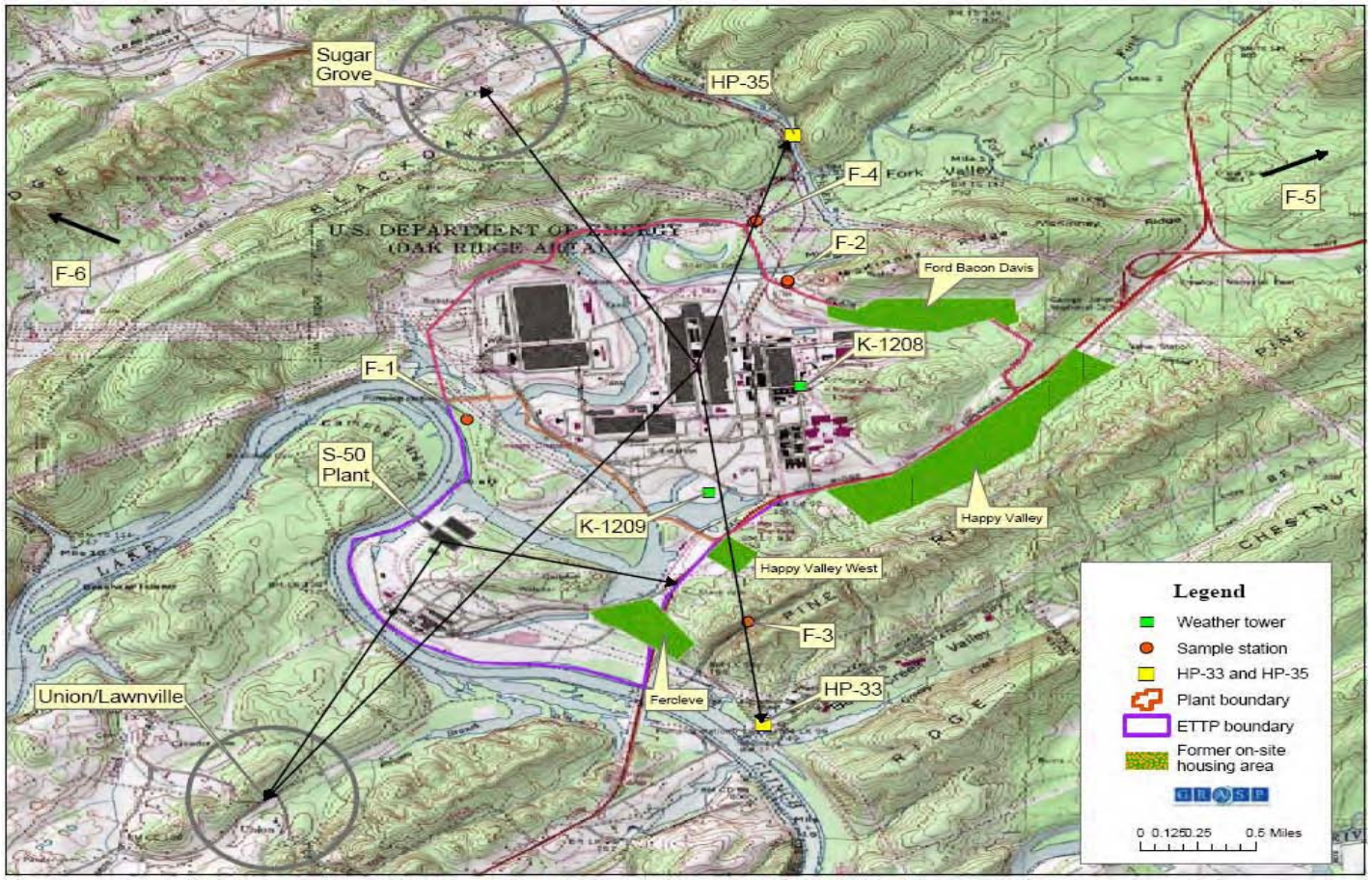
Please note that this list of monitoring data is not intended as a comprehensive list of all ambient monitoring data available from the K-25/S-50 facility.

Table 8. Average Annual Airborne Gross Alpha Concentrations in Curies at Monitoring Stations HP-33 and HP-35 (1966–1983)

Year	*Station HP-33*	*Station HP-35*
1966	5	7
1967	3	5
1968	1.5	2
1969	1.5	2
1970	1	1
1971	1	1
1972	2	3
1973	1.6	2.3
1974	1.5	1.6
1975	1.4	1.6
1976	1.7	3.1
1977	1.6	1.3
1978	1.1	2.2
1979	1.2	1.5
1980	1.1	1.5
1981	0.85	0.89
1982	1.1	1
1983	1.3	1

A review of the available documents and emission reports reveals no record of long-term fluoride emissions. From 1971 to 1985, measurements of airborne fluoride were, however, collected at six locations around the K-25 perimeter. Figure 14 shows monitoring station locations (F-1 to F-6). These records measured actual airborne fluoride concentrations over the sampling duration of either 24-hour or 6- to 7-day collection periods, and for each station, the reported results include annual averages and maximum 7-day concentrations. All of the monitoring results are reported in the annual environmental monitoring reports for the respective years. These reports provide limited information on analytical methods—but whether the methods are uniform for all years is not known. Table 9 shows the measured annual average fluoride concentrations from 1971–1985 for monitoring stations F-1 to F-6.

Figure 14. Locations of Emission Sources, Exposure Areas, Meteorological Towers, and Monitoring Stations



Sugar Grove is 2,570 m NNW of K-25; Union/Lawnville is 4,323 m SSW of K-25 and 2,335 meters SSW of S-50; and Happy Valley is 1,447 m ESE of S-50.

HP-33 and HP-35 are DOE monitoring stations; K-1209 and K-1208 are weather stations.

Distances and directions of exposure areas and HP-35/HP-33 monitoring stations (relative to K-25/S-50 emission sources) were used as reference locations for estimating doses and concentrations.

Fluoride monitoring stations (F-1, F-2, F-3, F-4, F-5, and F-6)

Station F-5 is approximately 6.4 kilometers (4 miles) northeast of K-25; Station F-6 is approximately 8 kilometers (5 miles) northwest of K-25.

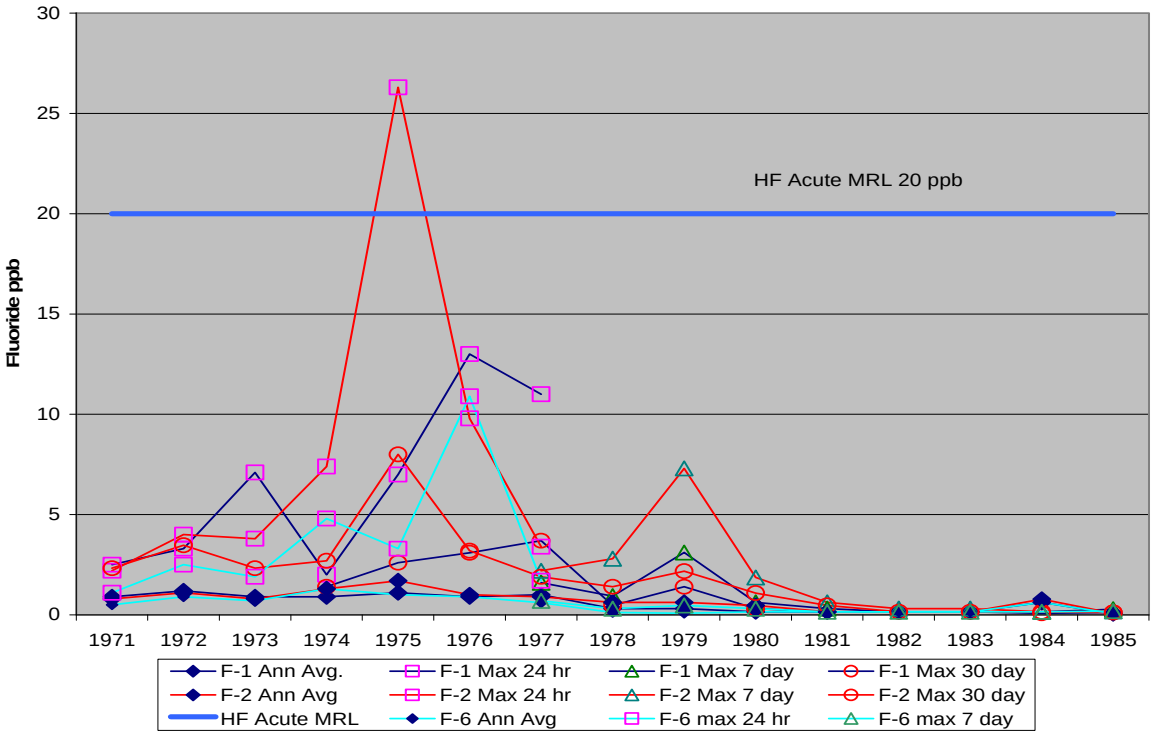
Figure 15 shows the 16-year (1971 to 1985) measured airborne fluoride concentrations (in parts per billion, or ppb) for three stations (F-1, F-2, and F-6). For the different years all of the annually averaged fluoride concentrations are less than 2 ppb and are relatively uniform. For each year the shorter duration values represent the maximum 24-hour, 7-day, or 30-day concentrations. The highest recorded value of 26.3 ppb for a 24-hour sample at station F-2 is the highest measured air fluoride concentration for any station and for any time period—it is about two times higher than any other measured value. Station F-2 is on the site perimeter, approximately 800 m (0.5 miles) downwind (NE) of the K-25 facility. It represents the perimeter location of maximum airborne fluoride concentration. In the next section of the public health assessment, ATSDR will use these measured fluoride air concentrations to estimate the annual average fluoride air concentrations for the years before and after fluoride was measured.

Table 9. Measured Annual Average Fluoride Concentrations (in ppb) at Monitoring Stations F-1 to F-6 (1971–1985)

Year	*F-1*	*F-2*	*F-3*	*F-4*	*F-5*	*F-6*
1971	0.9	0.8	0.8	1	0.7	0.5
1972	1.2	1.1	1.3	1.2	1	0.9
1973	0.9	0.8	0.8	0.7	0.7	0.7
1974	0.9	1.3	1.3	1.3	1.1	1.3
1975	1.1	1.7	1.2	1	1.1	1
1976	0.9	1	0.9	1.2	0.7	0.9
1977	1	0.9	0.6	0.8	0.6	0.6
1978	0.3108	0.6216	0.3108	0.12432	0.10878	0.12432
1979	0.3108	0.6216	0.3108	0.3108	0.09324	0.0777
1980	0.1554	0.4662	0.3108	0.1554	0.1554	0.1554
1981	0.1554	0.1554	0.1554	0.1554	0.1554	0.1554
1982	0.1554	0.1554	0.1554	0.1554	0.1554	0.1554
1983	0.1554	0.1554	0.1554	0.1554	0.1554	0.1554
1984	0.6216	0.777	—	0.777	0.6216	0.6216
1985	0.06216	0.0777	0.06216	0.06216	0.427869	0.06216

Because of mechanical problems with air samplers, in 1984 no samples were collected at monitoring station F-3.

Figure 15. Measured Airborne Fluoride Concentrations at Stations F-1, F-2, and F-6



Notes:

Measured airborne fluoride concentrations (in parts per billion, or ppb) at stations F-1, F-2, and F-6 are from the annual environmental monitoring reports.

Twenty-four hour, 7-day, and 30-day values are maximum short-term concentrations for each year and are not reported for all years that fluorides were measured.

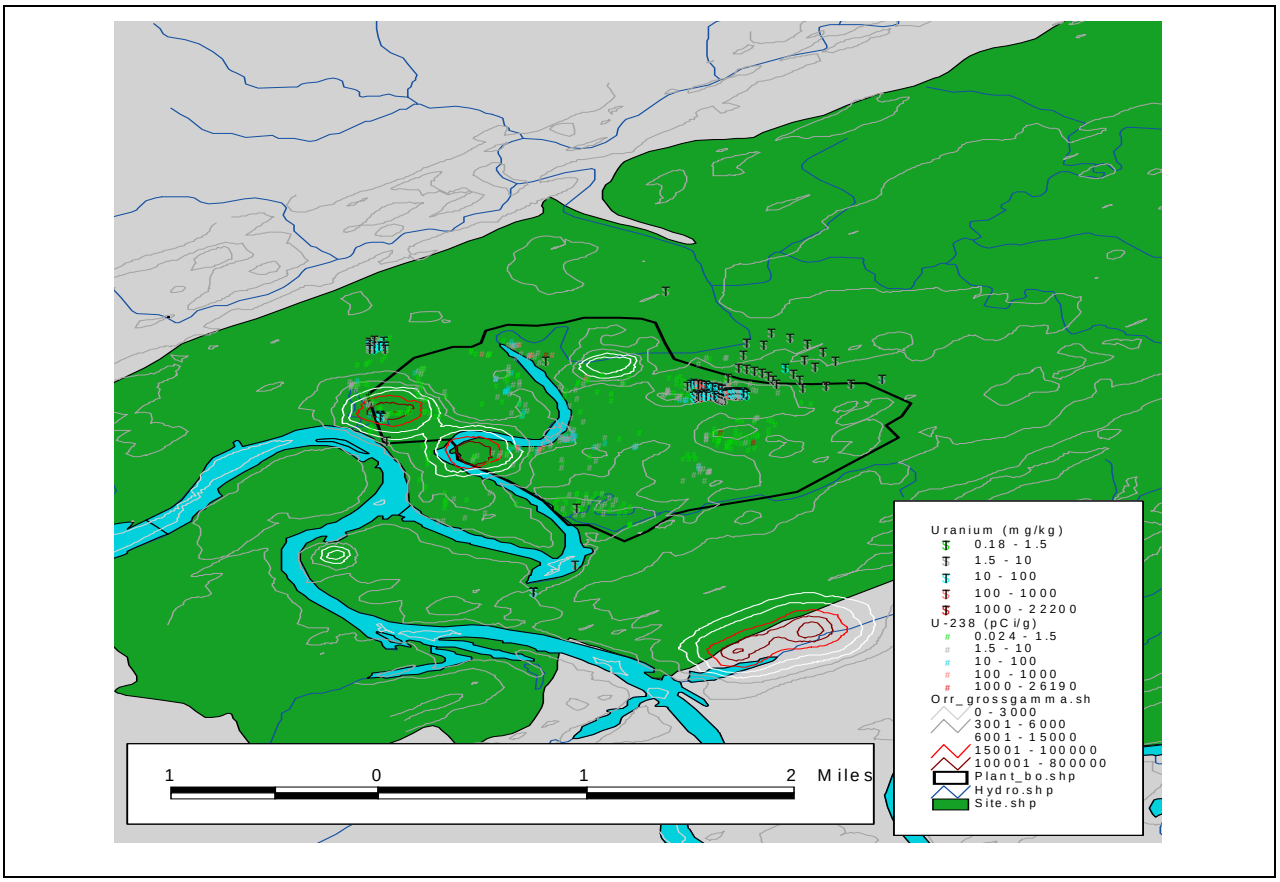
The minimal risk level (MRL) of 20 parts per billion (ppb) is for fluoride as hydrogen fluoride (HF). Although environmental measurements were fluoride, releases were most likely as HF. Fluorine is very reactive, and thus it will persist in the atmosphere in elemental form. Therefore, the MRL for HF is the most appropriate comparison value.

Aerial Radiological Surveys of ORR and Surrounding Areas

Since 1959 and through to 1997, DOE and its predecessors have used aircraft-mounted instruments to perform aerial gamma radiation surveys on the ORR site and its surrounding areas. As the methodology and detection capabilities have improved, so has the sophistication of the surveys. Today, the aerial surveys will readily detect sources that constitute a hazard. Any detected radiation sources are then investigated on the ground by standard survey techniques.

Around the ORR, including the Union/Lawnville and Happy Valley areas, the single-contour anomalies show no elevated ground-level gamma readings (Figure 16). A single contour is defined as radiation limited in its area; that is, only a spot of radiation with no additional radiation detected at decreasing levels radiating from the central spot. If elevated readings within this single contour are found, the source of the radiation is determined. By this method, an inventory of known "off-site" radiation sources has been established and maintained. The published radiation contour maps of the Oak Ridge area identify these source locations as "regions of interest." They include such sites as the Atomic City Auto Parts, the CSX Railroad bed, and other places related to past or current nuclear operations, as well as the Bull Run Steam plant where flyash from operations is stored (Maurer 1992).

Figure 16. Contours of Aerial Gamma Survey and Uranium Soil Concentrations



Notes:

Areas of elevated gamma contour uranium soil concentrations are known disposal/remediation sites.

Total uranium is in mg/kg; U 238 is in pCi/g.

An aerial survey has detected both 1) the Chattanooga shale outcroppings on East Fork Ridge, which contain elevated concentrations of uranium and its decay products, and 2) a few small cesium 137 deposits along the Clinch River, detectible during low water levels. The Clinch River deposits have been studied by TDEC/Oak Ridge Operations (ORO) and have been deemed a nonhazard (Storms and Rector 1997). Because the aerial surveys are sufficiently sensitive to detect sources that do not constitute a hazard, by implication they will readily detect gamma sources that do constitute a hazard. Except for a few known locations due to past or present operations, the off-site areas surrounding the ORR do not indicate areas of above-background gamma radiation.

Yet the uranium isotopes released from K-25/S-50 operations are mixed-emitting radionuclides. The emissions comprise mostly alpha particles with some gamma contribution. Although some gamma-emitting radionuclides were present in the recycled feed material (1952–1963 time frame), the recycled uranium feed material was a relatively small proportion of the total uranium processed (Bechtel Jacobs Company LLC 2000). Consequently, K-25/S-50 air releases are an unlikely source of significant gamma radiation.

Uranium Soil Samples

Data from the Oak Ridge Environmental Information System (OREIS) has been electronically transferred to ATSDR. Relevant records from this dataset, including soil, air, and biota analyses, were for this assessment reviewed and evaluated relative to other data. More details of the OREIS are contained in Section II.F.4. Public Health Activities in this PHA.

On-site ORR soil samples collected on or adjacent to the K-25/S-50 facility include both chemical and radioactive uranium analyses. Figure 16 shows total uranium concentrations and U-238 activities in soil samples collected from 1983 to 2001 at specific locations. Nonradioactive total uranium concentrations (in mg/kg) are shown as triangular data points, and U 238 activities (in pCi/g) are shown as circular data points. Although both elevated uranium concentrations and activities are found around the K-25/S-50 facility, most of the values represent background levels of uranium. Elevated uranium levels are primarily found at known waste disposal locations and are also found in some of the samples located downwind (northeast)

of the site boundary. Figure 16 shows the contours of aerial gamma survey and uranium soil sample concentrations.

III.B.3 Estimated Annual (Chronic) and Short-term (Acute) Doses and Concentrations (1944 to 2006)

Estimated Annual Radiological Doses and Concentrations

Past chronic (or annual) radiological doses and past air concentrations of uranium and fluoride were estimated using the Clean Air Act Assessment Package—1988 (CAP88-PC), an air dispersion/dose assessment model developed by the U.S. EPA and the DOE (Parks 1997) (see Table 10). Specific off-site air concentrations and annual radiological doses are calculated for the 1945 airborne releases from S-50 and for the 1963 airborne releases from K-25—these are the years with the highest annual airborne radionuclide emissions (see Table 5). This assessment is based on the assumption that if the year with the highest annual emissions (i.e., 1945 and 1963) did not represent a public health hazard, then neither did any other year with lower emissions. The estimated annual radiological doses to people residing in the vicinity of the K-25/S-50 site, presented as "Individual Effective Equivalent Dose Rate" in mrem/year in Table 10, include all the air exposure pathways and all radionuclides (uranium 234, uranium 235, uranium 238, technetium 99, and neptunium 237) as shown in Table 3.[3] Doses in CAP88-PC are calculated as 50-year effective equivalent doses integrated over a 70-year lifetime such that ongoing exposures to long-lived radionuclides are included in the dose assessments.

The past chronic (annual) radiological doses and air concentrations of uranium and fluoride at discrete areas such as Union/Lawnville, Sugar Grove, and Happy Valley were modeled as specific distances and directions from the plume origin. Figure 14 shows these locations with their respective distances and directions from K-25 and S-50. The Happy Valley exposure area, however, was not affected by K-25 site releases, and the Sugar Grove exposure area was not affected by S-50 site releases. By the time of significant releases from the K-25 facility (around 1952 to 1953), the Happy Valley labor camp was abandoned (see Table 5). Similarly, during the

[3] As previously mentioned, the very small quantities of Pu 239 included in the reactor tails account for less than one percent of the total radiation and therefore are not included in the radiological dose assessments.

S-50 facility's 1944 to 1945 operating period, the Sugar Grove community had not been established.

Although based on higher annual emissions, the doses from the K-25 release are much lower than the doses from the S-50 release. The exposure areas for the K-25 release are approximately cross-wind of the source area. By contrast, the Happy Valley exposure area is much closer to the S-50 source than to other areas, and the Union Valley/ Lawnville area is downwind of a relatively strong south-southwest component (Figure F-2; K-1209 tower).

Furthermore, exposures to the Sugar Grove area are overestimated. This is because steep-sided Black Oak Ridge rises some100 meters (330 feet) to separate the K-25 emission source from the Sugar Grove exposure area. Because dispersion from the CAP88-PC model does not accommodate this type of complex topography, the doses in the table below are a health-protective overestimate of likely doses to the Sugar Grove community. Section IV, Public Health Implications, discusses the public health implications of exposure to these estimated radiological doses, total uranium air concentrations, and fluoride air concentrations.

Table 10. Estimated Annual Radiological Doses for the Maximum Release Years (K-25–1963; S-50–1945)

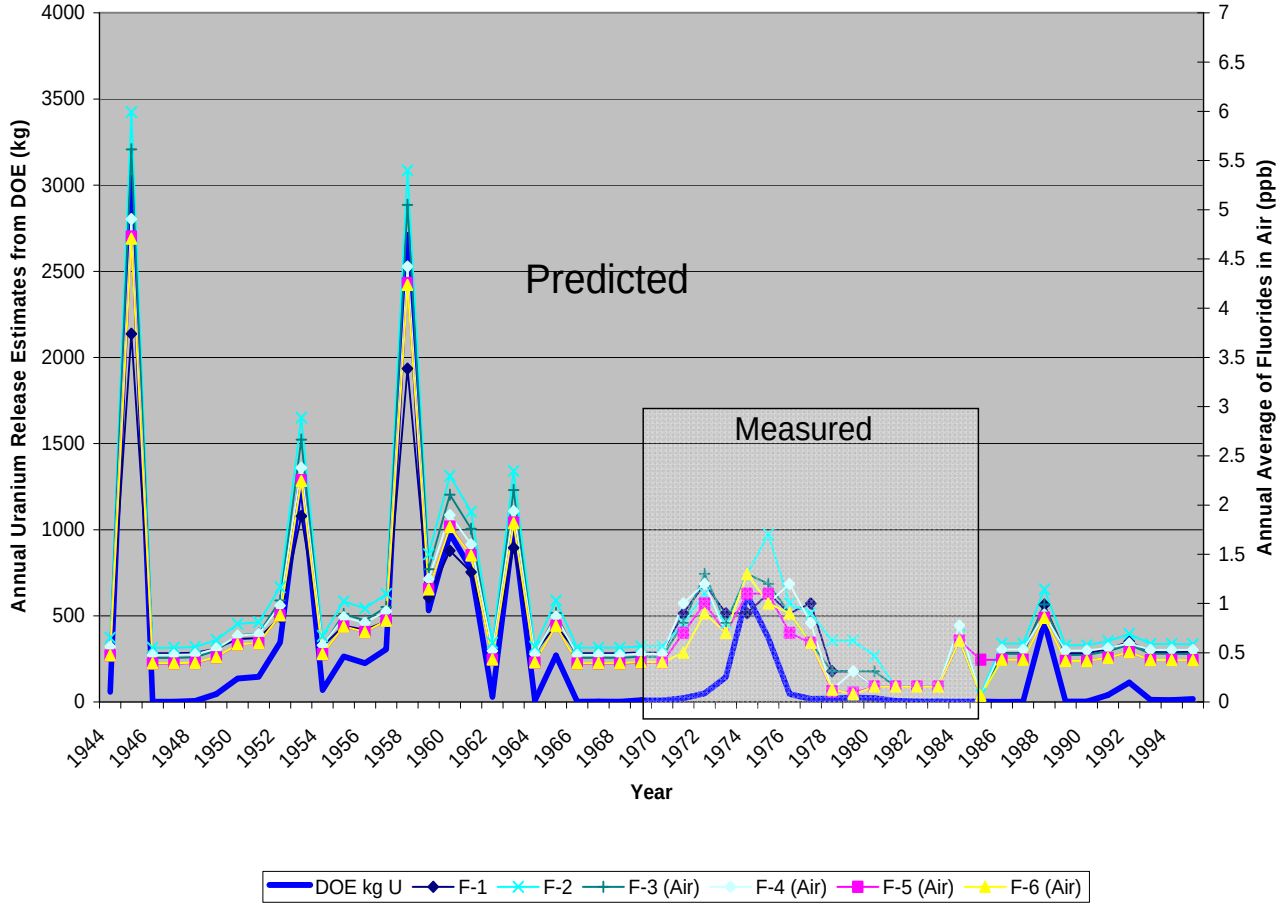
Source	*Exposure Area*	*Release Year*	*Individual Effective Equivalent Dose Rate (mrem/year)*	*Total U Annual Air Concentration* µg/m^3*	*Fluoride Annual Air Concentration ppb***
K-25	Sugar Grove	1963	3	0.0011	<5
	Union/Lawnville	1963	1	0.0003	<5
S-50	Happy Valley	1945	14	0.02	<5
	Union/Lawnville	1945	30	0.04	<5

Notes:

CAP88-PC model output is pCi/m3 for each uranium isotope at each location; those results are divided by specific activity for each isotope and summed (U-234, U-235, and U-238) for a total U air concentration.

*Fluoride annual air concentration is from Figure 17.

Figure 17. Measured and Predicted Fluorides in Air at Selected Stations: Annual Averages



Notes:

Measured and predicted annual average fluoride air concentrations (ppb) at various locations around K-25.
Predicted concentrations are calculated using linear regression of measured fluoride concentrations with annual uranium emissions (in kg).
Correlation coefficients of these relationships vary from 0.5 to 0.7.
Fluoride air concentrations were measured from 1971 to 1985.

CAP88-PC uses site-specific annual weather data. These data include a frequency distribution of wind directions, velocities, and atmospheric stabilities. For the K-25 and S-50 facilities evaluation, ATSDR used hourly meteorological data from two on-site K-25 weather tower stations. Site-specific meteorological data for 1945 or 1963 are not available; thus 2002 data from the L-1209 meteorological tower and 1999 data from the K-1208 meteorological tower

were used as a proxy for historic release conditions at S-50 and K-25, respectively (Figure 14). The dose assessment portion of the CAP88-PC model assumes a "rural default" for food consumption, and population estimates used in this evaluation are the 1980 census data provided with the CAP88-PC model. See Appendix D for additional details of the CAP88-PC system, limitations, conservative assumptions, and the system's output for K-25/S-50 facility releases.

Agreement between Measured and Predicted Concentrations

In an effort to provide confidence that the CAP88-PC modeling procedures can be used to estimate off-site exposure doses for the maximum release years of 1945 for S-50 and 1963 for K-25, ATSDR compared measured-and-modeled gross alpha concentrations during the1966–1993 period, when measured gross alpha data are available. The measured annual average gross alpha concentrations from monitoring locations HP-33 and HP-35 (see Table 7 and Figure 14) were compared with the estimated annual average gross alpha concentrations predicted using CAP88-PC and with the DOE and Task 6 K-25/S-50 emission estimates (see Table 5). Although the agreement between measured and predicted gross alpha concentrations was not perfect, the overall trends showed that the CAP88-PC modeling procedures and the estimated emissions rates adequately predicted the environmental concentrations of radionuclides released from the facility. This agreement between measured and modeled gross alpha concentrations during the period when measured data are available provides confidence that the CAP88-PC modeling procedure may be used to estimate off-site exposure doses for the earlier maximum release years. Appendix G shows further details on the measured versus predicted gross alpha concentrations for 1966 to 1983 at the HP-35 and HP-33 monitoring locations.

Estimated Fluoride Concentrations

Figure 17 shows the measured and predicted annual average fluoride air concentration (in ppb) at the six K-25 perimeter-monitoring stations. The annual average 1971–1985 air concentrations of fluoride are shown relative to the estimated annual uranium air emissions (in kg) measured at each of the six monitoring stations. The relationship between the estimated uranium emissions and measured fluoride air concentrations for the 1971–1985 period is used to predict the annual

average fluoride air concentrations for those years before and after fluoride was measured.[4] The correlation coefficients for those relationships vary from about 0.5 to 0.7, which indicates moderate agreement between estimated annual uranium emissions and annual airborne fluoride concentrations measured at the monitoring stations.

As shown in Figure 17, in 1945 the highest predicted yearly fluoride air concentration was about 6 ppb (7.2 $\mu g/m^3$). Note that the maximum uranium emission in kg is for 1945 at the S-50 plant and that the correlations are based on emissions and measurements from the K-25 facility. Nonetheless, predicted historic long-term airborne fluoride concentrations at the K-25 perimeter locations are, for the maximum K-25 release year, less than 6 ppb (1958; 2,711 kilograms of uranium). Also, as with the measured short-term fluoride concentrations in Figure 15, because of its downwind location station F-2 had the highest predicted annual average fluoride concentrations. Moreover, the fluoride monitoring location with the best correlation coefficient (0.74) was station F-6—considered by DOE to be a background location (Union Carbide Corporation Nuclear Division 1974). In 1976 the maximum measured short-term fluoride concentration (24-hour) was 10.9 ppb at the F-6 station, located about 8 km (~5 miles) upwind (northwest) of the K-25 facility.

For both the short-term (24-hour, 7-day, and 30-day) and annual average fluoride air concentrations, measured and predicted values at the six monitoring stations will be higher than the values in areas of potential off-site exposure. The accidental releases of UF_6 evaluated in the next section of the public health assessment use the RASCAL3 air dispersion model to evaluate further predicted HF concentrations at off-site areas.

Estimated Short-Term (Acute) Exposures (1944 to 1945)—Accidental or Episodic Releases

Past short-term (or acute) off-site concentrations and potential doses to uranium and HF from past accidental or episodic releases from the K-25/S-50 facility were estimated using the Radiological Assessment System for Consequence AnaLysis (RASCAL) 3.0. This is a computer model developed by the NRC and designed for the assessment of radiological accidents. In this

[4] The predicted fluoride concentrations were estimated using the FORECAST function in an EXCEL spreadsheet. The relationship is a linear regression between known fluoride air concentrations and known uranium emissions in kg (DOE estimate).

assessment of short-term releases and potential acute exposures, worst-case meteorological and exposure assumptions for the September 1, 1958 accidental UF_6 release were used to calculate radiological doses, uranium doses, and hydrogen fluoride concentrations in Sugar Grove and Union/Lawnville (see Table 11). This 1958 accidental UF_6 release represents the largest single release event (1,184 kilograms of UF_6) included in the available documents (Table 6). The radiological doses calculated using the RASCAL3 model are lung-specific equivalent doses in mrem.

This worst-case UF_6 release scenario assumes emission from the 23m-high roof vents and that 100% of the UF_6 released was emitted to the atmosphere. As we do not have specific meteorological data for the time of this accidental release, the scenario assumes conditions that result in minimum plume dispersion and maximum off-site exposure (e.g., light winds, a stable atmosphere, and no precipitation). And as we do not know the wind direction, we have to assume that the wind could be toward either Sugar Grove (NNW) or Union/Lawnville (SSW). Also, these results ignore the effect of topography on plume dispersion such that doses/concentrations at Sugar Grove are likely to be much lower due to the effect of the 100m-Black Oak Ridge (Figure 7). The Public Health Implications section discusses the possible consequences of exposure to these estimated short-term concentrations and doses of uranium and UF.

The RASCAL3 model was specifically designed to assess short-term or episodic emissions from gaseous diffusion plants and other nuclear facilities. It includes subprograms that specifically evaluate the dispersion and atmospheric transformation of UF_6 to uranium oxides and HF in accidental release scenarios. For this analysis, the relevant components of the RASCAL model use Gaussian models to describe the atmospheric dispersion of radioactive effluents from nuclear facilities. Theoretical description of the model components are presented in the RASCAL users guide (NRC 2001). Appendix E includes additional details about the RASCAL3 model, the case summary, and model output of this analysis.

Table 11. Maximum Potential Concentrations from the September 1, 1958, Accidental UF6 Release (Plume Centerline)*

Distance (km)	*Uranium Dose† (mrem)*	*Uranium Inhaled‡ (mg)*	*Uranium Concentration§ ($\mu g/m^3$)*	*Hydrogen Fluoride Concentration[q] (ppb)*
0.5	942	9.7	1,340	1,310
1.0	569	5.9	833	2,680
1.5	67	0.7	97	461
2.0	48	0.5	69	267
2.57 (Sugar Grove)	34	0.4	51	156
3.0	27	0.3	38	108
4.32 (Union/Lawnville)	12	0.1	17	27
5.0	8	0.1	11	14

Notes:

* Doses/concentrations are estimated using the RASCAL3 model and assume worst-case release conditions and meteorological and exposure assumptions. Note that effects could be toward either Sugar Grove or Union/ Lawnville, but for the same release event, not toward both.

† Inhaled lung dose equivalent (acute exposure equals 1 hour)

‡ Assumes inhalation rate of 1.2 m^3/hr

§ Inhaled uranium dose in milligrams/inhalation volume m^3

[q] Maximum 1-hour hydrogen fluoride concentration in parts per billion

III.C. Current and Future Releases from the East Tennessee Technology Park

Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the K-25 site. ATSDR's public health evaluation notes that no potential current or future hazards to off-site residents have been identified at this time, but remediation continues at the site. ATSDR recommends that DOE continue to take precautionary measures to prevent any off-site releases of contaminants potentially remaining at the K-25 site.

IV. Public Health Implications

IV.A. Introduction

This public health assessment addresses potential off-site (community) exposures to radioactive and nonradioactive hazardous substances released to the atmosphere either from the Oak Ridge Gaseous Diffusion Plant (K-25) or from the former S-50 liquid thermal diffusion plant. Specifically, this PHA evaluates the potential for off-site community exposures to and potential health effects from atmospheric releases of hazardous substances from the K-25/S-50 facility. Table 12 is a summary of the public health implications from ATSDR's evaluation of past, current, and future exposures.

ATSDR defines an ***acute exposure*** as contact with a substance that occurs once or for only a short time (14 days or less). An ***intermediate exposure*** is defined as contact with a substance occurring for more than 14 days and less than 1 year (15–364 days). ***Chronic exposure*** occurs over a long time (365 days or more). See Appendix A for additional information.

The preceding sections of this PHA have defined and evaluated the specific time frames, populations, and likely exposure scenarios for evaluating historic air emissions from the K-25/S-50 facility. The preceding evaluation has also provided conservatively estimated doses and concentrations for both *short-term (acute)* and *long-term (chronic)* exposures to the communities most likely to be affected by these releases. This assessment has used site-specific environmental monitoring and meteorological data to estimate and to validate the calculation of potential doses and concentrations. The specific questions and the process for addressing the questions underlying this PHA are based on outstanding community concerns and the recommendations of a prior evaluation of K-25/S-50 releases and exposures.

This **Public Health Implications** section addresses the potential health effects associated with exposure to the estimated radiological doses and uranium and fluoride/HF concentrations and compares the estimated exposure doses and concentrations to levels where potential adverse health effects have been observed. Section IV.D., Adequacy of Available Data for Public Health Determination, discusses how ATSDR uses health-protective exposure and modeling assumptions to accommodate uncertainties related to the available data and dose estimation processes. For detailed toxicological information on the substances discussed in the section below, please refer to ATSDR's toxicological profiles available at http://www.atsdr.cdc.gov/toxpro2.html#-A-.

Table 12. Summary of Public Health Implications from ATSDR's Evaluation of Past, Current, and Future Exposures to K-25/S-50 Releases

Time Frame	*Source*	*Date of Highest Release*	*Contaminant*	*Maximum Exposure Area*	*Exposure Duration*	*Estimated Dose/ Concentration*	*Comparison Value*	*Is the Dose/ Concentration Above or Below the Comparison Value?*	*Conclusion*
Past (1944 to 2006)	S-50	1945	Ionizing radiation	Union/ Lawnville	Chronic	30 mrem/year	100 mrem/year	Below	Past chronic exposure to K-25/S-50 site radioactive releases are not expected to result in adverse health effects.
	K-25	1958	Ionizing radiation	Sugar Grove	Acute	34 mrem/year	100 mrem/year	Below	Past acute exposure to K-25/S-50 site radioactive releases are not expected to result in adverse health effects.
	K-25	1963	Uranium	Union/ Lawnville	Chronic	0.04 µg/m^3	0.3 µg/m^3	Below	Past chronic exposure to airborne uranium releases from the K-25/ S-50 site are not expected to result in adverse health effects.
	K-25	1958	Uranium	Sugar Grove	Acute	51 µg/m^3	ATSDR has not derived health-based guidelines for acute uranium inhalation exposure	NA	Exposure to the estimated short-term exposure concentration is not expected to result in adverse effects, including kidney effects.
	K-25	1945	Fluoride*	Sugar Grove and Union/ Lawnville	Chronic	Less than 6 ppb (7.2 µg/m^3)	10.8 ppb (13 µg/m^3)	Below	Past chronic releases of fluoride were below levels associated with adverse health effects.

Time Frame	Source	Date of Highest Release	Contaminant	Maximum Exposure Area	Exposure Duration	Estimated Dose/ Concentration	Comparison Value	Is the Dose/ Concentration Above or Below the Comparison Value?	Conclusion
	K-25	1945	Hydrogen fluoride	Sugar Grove and Union/ Lawnville	Chronic	Less than 6 ppb (7.2 µg/m^3)	11.7 ppb (14 µg/m^3)	Below	Past chronic releases of hydrogen fluoride were below levels associated with adverse health effects.
	K-25	1975	Fluoride	Sugar Grove and Union/ Lawnville	Acute	26.3 ppb	20 ppb	Above	ATSDR concludes that acute off-site exposure to fluoride is an indeterminate† public health hazard because sufficient data are not available to make a professional judgment about the level of health hazard from this exposure. The highest recorded short-term (24-hour) fluoride concentration was measured at monitoring station F-2, which is located along the northeast perimeter of K-25 about 0.5 miles from the release point. The closest residents are located more than 1 mile north-northwest from monitoring station F-2.

Time Frame	Source	Date of Highest Release	Contaminant	Maximum Exposure Area	Exposure Duration	Estimated Dose/ Concentration	Comparison Value	Is the Dose/ Concentration Above or Below the Comparison Value?	Conclusion
	K-25	1958	Hydrogen fluoride	Sugar Grove	Acute	156 ppb	20 ppb	Above	ATSDR concludes that acute off-site exposure to hydrogen fluoride is an indeterminate† public health hazard because sufficient data are not available to make a professional judgment about the level of health hazard from this exposure. The estimated worst-case hydrogen fluoride air concentrations are based on mathematical dispersion modeling that used conservative worst-case assumptions and modeled air data. It is not appropriate to use these estimated worst-case concentrations as a basis for a health hazard category, because the estimated concentrations are highly unlikely to have actually occurred and because of the high uncertainty in the modeled results.

*Short- and long-term fluoride exposure was evaluated as hydrogen fluoride, which is the most likely form present and is a highly reactive respiratory irritant.

†ATSDR was unable to locate sampling data for historic short-term exposure to fluoride and hydrogen fluoride released as UF_6 during accidents or equipment maintenance at the K-25 site. ATSDR used worst-case assumptions and modeled air data as sufficient historical environmental sampling data do not exist. Therefore, ATSDR uses the *indeterminate public health hazard* conclusion category—sufficient data will never be available to make a professional judgment about the level of health hazard from this exposure.

NA–not applicable

IV.B. Past Exposure (1944 to 2006)

ATSDR evaluated past chronic (annual) and acute (short-term) exposures to K-25/S-50 releases for nearby off-site communities (see text box). Both short-term and long-term exposures were assessed for ionizing radiation, uranium, hydrogen fluoride, and fluoride. The estimated concentrations and doses are presented below and, for each contaminant of concern, compared with health-protective comparison values.

Note particularly the many uncertainties involved in determining estimated doses for all potential historic exposures, including quantities released, the duration of the release, and the exact location of various persons at the time of the accident. To account for these uncertainties, ATSDR has relied on health-protective assumptions regarding contaminant dispersion and dose estimation. Section IV.D., Adequacy of Available Data for Public Health Determination, discusses the limitations of the available data and dose estimation processes and explains why the resulting doses are overestimates of historical doses to the off-site communities.

IV.B.1. Chronic (Annual) and Acute (Short-Term) Health Implications

Ionizing Radiation

For the communities closest to the facilities, ATSDR estimated historical radiological doses from K-25/S-50 site airborne releases for 1) the largest documented accidental release, and 2) the largest estimated annual release. In addition, ATSDR estimated a cumulative dose by combining the highest short- and long-term doses for the community potentially receiving the highest off-site releases. Because all the estimated radiological doses were below relevant health comparison values, adverse health effects would not be expected.

Chronic

For the year of maximum emissions, ATSR estimated the highest annual radiological dose (less than 30 mrem/year or 0.3 millisieverts [mSv]) for the Union/Lawnville community. The 1945 S-50 off-site radiation exposure resulted in airborne releases of UF_6 and associated radionuclides (Np 237 and Tc 99). Doses for years with smaller annual emissions will be commensurately less. For annual committed effective doses to the general population, the International Commission on

Radiological Protection (ICRP) recommends a limit of 100 mrem/year (1 mSv) above background (ICRP 1991). This highest annual radiological dose of less than 30 mrem/year is more than three times less than the ICRP recommended dose, ATSDR's minimal risk level (MRL) of 100 mrem/year, and the radiation dose limit for the public of 100 mrem/year recommended by the U.S. Nuclear Regulatory Commission (NRC) and the National Council on Radiation Protection and Measurements (NCRP). No adverse health effects have been seen at the estimated chronic exposure dose levels from ionizing radiation from the K-25/S-50 site, and no apparent increased cancer risk would be expected (ICRP 1991; USEPA 1999).

Acute

ATSDR evaluated potential radiological doses from the largest documented accidental or short-term releases. The largest estimated short-term dose (calculated as an inhaled lung dose equivalent) was less than 34 mrem/year to the Sugar Grove community following a 1958 accidental release from the K-25 facility. This estimated dose is more than two times less than the 100 mrem/year dose limit recommended for the public by the ICRP, NRC, and NCRP, as well as ATSDR's MRL. Therefore, historic acute exposure to airborne releases of ionizing radiation from the K-25/S-50 facility is not expected to cause any adverse health effects.

Chronic and Acute Cumulative Dose

The highest cumulative radiation dose from summing potential short-term and long-term doses for a specific exposure area (37 mrem/year for Sugar Grove) is below all relevant health comparison values.[5] ATSDR added the largest annual dose (whole-body effective dose) for the Sugar Grove community (3 mrem) to the largest short-term dose (34 mrem) to yield an annual cumulative dose to airborne releases from K-25/S-50 radiological contaminants (including U 234, U 235, U 238, Np 237, and Tc 99) at the area of highest off-site exposure. The highest cumulative dose from historic short- and long-term exposure is approximately 7.1 mrem/year—

[5] The estimated annual radiological dose for the maximum release year (3 mrem/year) from K-25 (see Table 11) is added to the maximum dose from the September 1, 1958 accidental UF_6 release (34 mrem; see Table 11) from the K-25 site for the Sugar Grove community. Because the S-50 plant was no longer operational during the K-25 accidental release, the doses presented in Table 11 for the S-50 plant were not included in this summation.

about one-tenth of the 71-mrem/year screening value (or 5,000 mrem over 70 years).[6] Estimated cumulative doses to other potentially exposed communities are also below the 71 mrem/year screening value and the 100 mrem/year dose limit recommended for the public by the ICRP, NRC, and NCRP, as well as ATSDR's MRL. Therefore, historic exposure to airborne releases of ionizing radiation from the K-25/S-50 facility is not expected to cause any adverse health effects.

ATSDR concludes that past acute and chronic exposure to radioactive materials in off-site media from K-25/S-50 airborne releases is not expected to result in adverse health effects.

Uranium

ATSDR estimated historical uranium airborne releases from the K-25/S-50 site for the largest documented accidental release and for the largest estimated annual release for the communities located closest to the facilities. ATSDR determined that historic airborne releases of UF_6 from the K-25 and S-50 facilities are not a hazard with respect to the chemical toxicity of uranium. Also, the highest estimated airborne uranium releases for both long- and short-term exposures are below levels at which, due to the chemical toxicity of uranium, adverse health effects could occur.

Chronic

Long-term exposure to airborne uranium occurred from 1944 to 1995 as a result of elevated operational emissions. The highest annual uranium release (as UF_6) from K-25 occurred in 1963. The maximum estimated annual uranium air concentrations for 1963 in an area of potential off-site exposure (Union/Lawnville) is 0.04 $\mu g/m^3$—about 10 times lower than the chronic-duration inhalation MRL (0.3 $\mu g/m^3$) for soluble uranium compounds. This MRL is averaged over a time period of 1 year or longer. An exposure to an estimated uranium air concentration of 0.04 $\mu g/m^3$ over 1 year or longer is unlikely to result in any adverse health effects attributable to the chemical toxicity of uranium.

[6] To sum the equivalent lung dose (short-term exposure) with the whole-body effective dose (long-term exposure), the lung dose is multiplied by the tissue weighting factor of 0.12 and then added to the annual dose (ICRP 1977; 34 mrem x 0.12 = 4.1 mrem + 3 mrem= ~7 mrem/year).

Acute

The highest estimated short-term (1-hour; acute) off-site uranium air concentration (approximately 51 μg/m^3 at the nearest off-site exposure area; see Table 11) occurred during an accidental release in the form of hydrogen fluoride and particulate uranyl fluoride. On-site air concentrations would have been even higher, although Sugar Grove and Union/Lawnville residents would not have been exposed to elevated air concentrations at on-site locations. ATSDR has not derived health-based guidelines for acute uranium inhalation exposure—that is, an exposure occurring once or for only a short time (up to 14 days). Workers exposed during accidental releases (31 workers exposed during the Gore, OK accident) have succumbed to hydrogen fluoride toxicity (respiratory and irritant effects) without signs of uranium-induced kidney toxicity (exposures of these workers were estimated to range from 0.6 to 24 milligrams of uranium). The chemical effects of uranium on the kidney occur from repeated exposures over a longer period of time and not from an acute exposure during an accidental release. Additionally, if people did not experience effects from hydrogen fluoride exposure during the accidental release it is unlikely that the concurrent uranium exposure would affect the kidney. Thus, exposure to the estimated short-term exposure concentration is not expected to result in adverse effects, including kidney effects.

Moreover, in the past, to reduce the UF_6 concentration in the process gas system and to perform maintenance and inspection on process gas equipment, UF_6 was reportedly released at night through jets on top of the process buildings. These “midnight negative” releases potentially contained significant quantities of uranium and hydrogen fluoride. Still, the quantities released are likely to have been less than the 1958 accident and therefore are not considered a public health hazard.

ATSDR concludes that historic airborne releases of UF_6 from the K-25 and S-50 facilities are not a public health hazard with respect to the chemical toxicity of uranium. Further, because the conservative assumptions used in the modeling process likely overestimate the real historic concentrations, ATSDR has determined that both short- and long-term exposures to airborne uranium from K-25 and S-50 site releases would not be expected to result in adverse health effects.

Fluoride and Hydrogen Fluoride (HF From Normal K-25 Operations)

Historically, as a result of releases during normal process operations, people living around the K-25/S-50 site could have received chronic (long-term) exposures to fluoride and hydrogen fluoride (HF). From 1971 to 1985, airborne fluoride concentrations were measured at six stations around the K-25 site perimeter. Using this evaluation, ATSDR concludes that although people living in the communities closest to the K-25/S-50 site might have been exposed to long-term fluoride and HF released into the air during normal operations from the K-25/S-50 facility, these exposures would not be expected to result in adverse health effects.

Acute (short-term) fluoride and HF exposure could have only resulted from accidents or controlled releases. (Appendix E contains details on an estimation of the HF accidental releases). With regard to fluoride and HF released as UF_6 during historical accidents or equipment maintenance at the K-25 site, ATSDR was unable to locate sufficient environmental sampling data to estimate adequately any short-term, off-site (community) exposure. Consequently, for people living near the K-25/S-50 site, ATSDR scientists are not able to make a professional judgment about the level of health hazard from acute fluoride and HF exposure.

Chronic

Long-term air releases of HF also occurred at the K-25/S-50 site. At this site, uranium releases and ambient air concentrations of fluoride are reasonably correlated. Thus for the years before monitoring data were available, ATSDR used the correlation between annual uranium releases and measured fluoride concentrations at the site perimeter to estimate concentrations from long-term exposure to fluoride. Because of the increased distance from emission sources and the effects of topographic ridges between the emission sources and exposure areas, estimated concentrations at the site perimeter will overestimate concentrations at areas of potential exposure. ATSDR assumed that the largest annual HF release coincided with the highest annual uranium release. The highest estimated annual average fluoride concentration in air (less than 6 ppb in 1945) was at the F-2 station.

In August 2003, the California EPA (Cal-EPA; Office of Environmental Health Hazard Assessment) prepared a chronic toxicity summary for fluorides, including hydrogen fluoride.

The critical effect identified was skeletal fluorosis, with a chronic inhalation reference exposure level of 14 ug/m^3 for hydrogen fluoride and 13 ug/m^3 for fluoride (Cal-EPA 2003). The estimated maximum annual exposure concentration of less than 6 ppb (7.2 ug/m^3) for people living around the K-25/S-50 facility is well below Cal-EPA's reference levels. As such, the estimated long-term fluoride and hydrogen fluoride air concentrations—less than 6 µg/m^3—and resulting exposures are not expected to result in adverse health effects.

Acute

The highest recorded short-term (24 hour) fluoride concentration of 26.3 ppb was measured at monitoring station F-2, which is located along the northeast perimeter of the K-25 site about 0.5 miles from the release point. The closest residents are located more than 1 mile north-northwest from monitoring station F-2 and are separated from K-25 and monitoring station F-2 by Black Oak Ridge. ATSDR's MRL for acute inhalation exposure to hydrogen fluoride and fluorine is 20 ppb and 10 ppb, respectively. Concentrations below these values are not expected to cause adverse health effects. The 20-ppb MRL for HF in air is 25 times lower than exposures that caused mild upper respiratory tract inflammation in human volunteers exposed for 1 hour (Lund et al. 1999). The highest average level (time weighted average) allowed by the Occupational Safety and Health Administration (OSHA) for HF in air for a 40-hour work week made up of 8-hour work days is 2.5 mg/m^3 (3 ppm or 3,000 ppb). The 20-ppb MRL for air concentrations of HF is 150 times lower than OSHA's occupational level.

ATSDR was unable to locate sufficient historical environmental monitoring data on fluoride and HF released as UF_6 during accidents or equipment maintenance at the K-25 site. Therefore, ATSDR estimated historic off-site acute hydrogen fluoride concentrations using accident records and mathematical dispersion modeling. To calculate acute exposure concentrations to HF, ATSDR used the short-term fluoride measurements, worst-case assumptions, and modeled dispersion estimates from the September 1, 1958, accidental release. The highest measured short-term (24-hour) fluoride concentration of 26.3 ppb occurred in 1975 at station F-2. The modeled short-term (hourly) HF concentrations of 156 and 27 ppb were estimated for the Sugar Grove and Union/Lawnville communities, respectively, for the September 1958 accidental UF_6 release (Table 11). Note too that because these estimated worst-case HF concentrations are based on health-protective assumptions, they are overestimated concentrations that for several reasons are

unlikely to have actually occurred: first, the fate and transport mathematical model does not account for the complex topography of the K-25 site. Second, ATSDR does not have any record of the specific meteorological conditions at the time of this release so the most conservative meteorological conditions were used to estimate concentrations. Third, ATSDR assumed that off-site exposure occurred outside at the point of maximum HF concentration. Finally, ATSDR assumed that all of the UF_6 released was discharged to the atmosphere with no retention in the K-1131 building. Because of the high uncertainty in these estimated HF concentrations, use of these estimated concentrations as a basis for a health hazard category is not appropriate. Therefore, ATSDR scientists are not able to make a professional judgment about the level of health hazard from the potential acute fluoride and HF exposures for people living near the K-25/S-50 site.

Other accidental releases involved smaller quantities and probably did not affect the off-site communities. For instance, smaller, short-term accidental or process releases such as "midnight negatives" and equipment purging are unlikely to have resulted in any adverse health effects to community residents.

Given this evaluation, ATSDR concludes that long-term fluoride and HF released during the normal operations of the K-25/S-50 facility did not pose a public health hazard for communities living near the K-25/S-50 site, ATSDR also concludes that the short-term, off-site (community) exposure to fluoride and HF released during accidents or equipment maintenance at the K-25 site are an indeterminate public health hazard—sufficient environmental sampling data are not available to make a professional judgment about the level of health hazard from this exposure. In addition, ATSDR modeled air data and estimated off-site acute hydrogen fluoride concentrations using conservative, worst-case assumptions. Nevertheless, because of the high uncertainty in these modeled estimates, using them to estimate worst-case concentrations as a basis for a professional judgment about the health hazard level is not appropriate .

Uranyl Fluoride and Hydrogen Fluoride—Potential UF_6 Cylinder Releases

In December 2006, the UF_6 cylinders stored at ETTP were completely removed (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007). Before removal, no uranyl fluoride or hydrogen fluoride was released from the tanks.

IV.C. Current and Future Exposure

Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the K-25 site. Using ATSDR's public health evaluation, no potential current or future hazards to off-site residents have been identified at this time, but site remediation continues. ATSDR recommends that DOE continue to take precautionary measures to prevent any off-site releases of contaminants potentially remaining at the K-25 site.

IV.D. Adequacy of Available Data for Public Health Determination

The public health evaluation in this PHA specifically addresses the recommendations from a previous assessment of uranium releases from the Oak Ridge Reservation (*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*, referred to as the Task 6 report) and community health concerns related to the K-25 and S-50 facilities. Table 13 identifies these public health issues (the recommendations and concerns), the actions taken by ATSDR, and the findings associated with these issues.

The Task 6 report determined that K-25/S-50 uranium releases did not present a significant public health hazard to the Union/Lawnville community—the reference community in the Task 6 report. This determination was, however, based on estimated uranium release data and nonsite-specific meteorological data. Consequently, the recommendations made in the Task 6 report were directed toward 1) additional quantification of the uranium release estimates, 2) improvement of the atmospheric dispersion modeling through use of site-specific meteorological data, and 3) an evaluation of the uranium dispersion model's validity by comparing it with direct environmental monitoring data. The Task 6 report also included several recommendations to address the uncertainty inherent in this type of dose estimation process.

Table 13. Task 6 Public Health Issues, Actions, and Findings Addressed in this PHA

Recommendation or Concern	*Action*	*Finding*
Additional records research and data evaluation regarding S-50 plant operations and potential releases.	A reevaluation of S-50 releases was conducted using multiple years of site-specific meteorological data.	Health-protective dose estimates for S-50 releases are below levels constituting a public health hazard.
Review of additional data regarding unmonitored K-25 uranium releases.	Long-term analysis of estimated K-25 releases was compared with measured ambient gross alpha concentrations to assess adequacy of estimated emissions.	Measured gross alpha air concentrations are adequately predicted using estimated emissions and the CAP88-PC air dispersion model. Consequently, unmonitored releases are unlikely to represent a significant additional source component.
Refinement of the approach used to evaluate surface water and soil-based exposure concentrations. This refined approach could possibly involve shifting to a source term-based approach and use of additional measurement data.	Measured radionuclide concentrations compared with estimated concentrations predicted from air dispersion models. Radionuclides released to off-site surface waters are addressed in the *White Oak Creek Radionuclide Releases Public Health Assessment*. For copies of this assessment, please contact ATSDR toll-free at 1-800-232-4636.	Measured soil radionuclide concentrations are about 10 times less than the value used for Task 6 report calculations. Soil/ingestion concentrations in this PHA are based on the CAP88-PC deposition velocity (0.18 cm/sec).
Improved atmospheric modeling for K-25/S-50 by using wind data from multiple stations and years. Evaluation of the uncertainty associated with the air concentrations would provide upper and lower bounds of confidence in the estimates.	Improved atmospheric modeling conducted using site-specific stations and multiple years.	Doses/concentrations varied by about 20% over a 5-year period. Estimated doses predicted using worst-case meteorological conditions.
Improvement of the exposure assessment to include region-specific consumption habits and lifestyles, identification of likely exposure scenarios instead of hypothetical upper bound and typical assessments, and inclusion of uncertainty analysis to provide statistical bounds for the evaluations of risk.	Worst-case exposure factors used in estimating exposure doses at specific locations. Rural default consumption/exposure factors are health-protective.	Predicted, health-protective doses are below levels constituting a public health hazard. Consequently, there is no public health basis for further, probability-based analyses.
Refinement of the chemical toxicity evaluation, possibly to include other approaches/models and an uncertainty analysis.	Potential exposures/doses to uranium and fluoride/HF evaluated with respect to chemical toxicity.	Conservative, estimated doses/concentrations are below levels constituting a public health hazard. There is no public health basis for further, probability-based analyses.
The potential public health hazard posed by K-25/S-50 fluoride and hydrogen fluoride emissions.	Health-protective fluoride/HF concentrations estimated for areas of potential off-site exposure.	Fluoride and HF was released as UF_6 during accidents or equipment maintenance. ATSDR concluded that historic short-term exposures to the maximum estimated fluoride and HF concentrations released were unlikely, but possible. As ATSDR does not have specific information to rule out these maximum calculated exposures, this pathway is indeterminate.
Assessment of potential exposures from K-25 and S-50 emissions for the residents of the Happy Valley labor camp (circa 1944-47).	Potential doses to residents of Happy Valley estimated for S-50 releases.	Health-protective estimates of radiological and fluoride/HF doses or concentrations are below levels constituting a public health hazard.

In addition to the Task 6 report recommendations, the Oak Ridge community identified several public health issues that should be addressed in this public health assessment. Those issues are identification of a potentially exposed population that lived adjacent to the K-25/S-50 site at the Happy Valley labor camp and potential exposures to fluorides/hydrogen fluoride released—together with uranium—from the K-25/S-50 site. In addition to these issues, ATSDR believes that potential exposures to the Sugar Grove community and short-term incidental releases to all potentially exposed communities must be evaluated to provide a complete public health assessment of historic, current, and future K-25/S-50 emissions.

ATSDR has chosen to address the uncertainty in the emission estimates by determining whether the existing release estimates can be used to predict adequately the measured air concentrations of uranium (as gross alpha). Using site-specific meteorological data, the CAP88-PC air dispersion model (see Appendix D) quite accurately predicted gross alpha concentrations at several monitoring locations, especially when those modeled predictions were compared with previous uranium release estimates. This agreement between the measured and predicted gross alpha air concentrations indicates that the air dispersion model (using site-specific meteorological data) is a valid tool for assessing atmospheric dispersion, and that the emission estimates are reliable indicators of past emissions.

That said, the primary limitation of this approach is that historical monitoring data are only available for a portion of the operating history of the K-25/S-50 facility. Yet the 18-year period for which gross alpha ambient air monitoring data are available appears adequate for determining both annual and long-term trends between measured and predicted air concentrations. Similarly, meteorological data are not available for all years. But again, a multi-year data comparison indicates reasonable agreement between years and use of the most conservative weather year ensures that the evaluation procedure is health-protective.

Information on the specific sampling and analytical methods used for historical monitoring (before about 1971) is likewise limited. Fluorides in air may be present in the gas phase (generally hydrogen fluoride) or in a particulate phase (ATSDR 2003). According to the 1975 environmental monitoring report (Union Carbide Corporation Nuclear Division 1976), airborne fluoride concentrations in the ppb range were collected for 24-hour periods with an 8-day

frequency. Samples were collected in a caustic solution and analyzed with an ion-specific electrode. This method should capture both the HF and particulate fluoride compounds; but it cannot discriminate the relative proportions. Whether this sampling and analytical methodology was consistent over the entire sampling period (1971–1985) is not known. Because 24-hour samples were reported for 1971–1977 and 7-day samples were reported for 1978–1985, it is likely that the duration of sample collection changed. Annual averages, however, were reported for all periods.

Weekly airborne radionuclide samples for both gross alpha and gross beta were collected on filter paper, and radioactive decays were counted using "gross beta and gross alpha counting techniques" (Union Carbide Corporation Nuclear Division 1976). Although uranium releases from the K-25/S-50 facility would have predominately been gaseous UF_6, this compound is not stable in the atmosphere and would rapidly transform to uranium oxide particulates. Consequently, the particulate filter sampling method should provide adequate collection of airborne uranium. If the gross alpha counting technique included decays in an appropriate energy range, this method will provide a reasonable estimate of airborne uranium particulates.

Additionally, both of the air dispersion models used have another limitation: they do not consider the effect of topography on plume transport. But this limitation is partially overcome by using site-specific meteorological data, which reflects the influence of the topography on measured wind directions and velocities. Also, because the net effect of the ridges surrounding the K-25/S-50 facility reduces contaminant transport to exposure areas on the both slopes of the ridges, the resulting doses are health-protective overestimates. A related limitation of the measured monitoring data is that no sample stations are located in the areas of potential exposure (Figure 14). The HP-35 station is, however, located in the predominant downwind direction and should record maximum long-term concentrations. Again, because exposure areas are mostly isolated from K-25/S-50 air releases by ridges, the measured concentrations are potential exposure overestimates.

Still, while the estimated short-term and annual doses listed in Tables 8 and 9 are likely overestimates,[7] the estimated short-term doses from the largest accidental release are higher than the estimated doses from the largest annual release. This apparent discrepancy is because the short-term doses are lung-specific dose equivalents, and the annual doses are whole-body effective doses. To directly compare these doses, the short-term dose equivalents must be multiplied by a tissue-weighting factor. For lung doses this factor is 0.12 (ICRP 1977). Also, differences appeared in the particle deposition velocities used in the two dispersion models. The RASCAL3 model assumes a deposition velocity of 0.3 meter/second (m/s) while CAP88-PC uses a deposition velocity of 0.18 m/s. The higher deposition velocity will result in higher doses at close-in distances and lower doses at more distant locations.[8]

In this PHA, ATSDR has not attempted any type of probability-based assessment of historical contaminant concentrations or doses. ATSDR believes that conservative, health-protective estimates of exposures to the highest annual releases and to the largest documented accidental releases do not constitute public health hazards. Although the short-term estimated exposure to HF was identified as an indeterminate public health hazard, ATSDR believes that the health-protective assumptions used for estimating historical exposures make potential adverse health effects unlikely, and if effects were to occur, they would be relatively minor and temporary. In a recent analysis titled *Comparative Bias Associated with Various Estimates of Dose to Maximally Exposed Individuals,* the use of deterministic, health-protective screening assessments are supported as long as the estimated doses do not exceed the target criterion (Wilson and Hinton 2003). Similarly, the National Council on Radiation Protection and Measurements (NCRP) has indicated that uncertainty analysis is unnecessary and may even be misleading for environmental radiological doses of less than 2 rem (2,000 mrem) (NCRP 1996).

The 18-year relationship between estimated uranium emissions and measured gross alpha concentrations at the HP-35 location shows several years in which estimated emissions overpredicted measured gross alpha concentrations (Figure G-1; 1973–1976 timeframe).

[7] Specific accident reports indicate that large proportions (up to 90%) of released UF_6 were retained in the respective buildings and subsequently recovered. This evaluation of historic accidental releases assumes that 100% of material was emitted to atmosphere.

[8] Deposition velocities for both RASCAL3 and CAP88-PC are fixed values and cannot be adjusted in the respective models.

Consequently, any probability-based assessment would have to include the possibility that emissions were lower than estimated (as well as higher). Every other assumed parameter would also have to include factors leading to higher atmospheric dispersion and lower overall exposures. As any probability-based analysis will only produce a wide range of lower doses than those estimated in this PHA—a further evaluation showing that historic exposures to K-25/S-50 air releases is without public health basis.

V. Health Outcome Data Evaluation

Health outcome data measure 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 diseases occur and to whom they occur. By comparing disease occurrences in different populations over periods of years, public health officials use health outcome data to look for unusual patterns or trends in disease occurrence. These health outcome data evaluations are descriptive epidemiologic analyses. They are exploratory, given that they could provide additional information about human health effects, and they are useful, in that they help identify the need for public health intervention activities (e.g., community health education). That said, however, health outcome data cannot—and are not meant to—establish cause and effect between environmental exposures to hazardous materials and adverse health effects in a community.

ATSDR scientists generally consider health outcome data evaluation when a plausible, reasonable expectation of adverse health effects is associated with observed levels of contaminant exposure. In this public health assessment on K-25/S-50 fluoride and uranium releases, ATSDR scientists determined that potential off-site exposures were possible to past radioactive and nonradioactive substances released from the K-25/S-50 site.

Criteria for Conducting a Health Outcome Data Evaluation

To determine how to use or analyze health outcome data in the public health assessment process, or even whether to use it at all, ATSDR scientists receive input from epidemiologists, toxicologists, environmental scientists, and community involvement specialists. These scientists consider the following criteria, based only on site-specific exposure considerations, to determine whether to include a health outcome data evaluation in the public health assessment.

1. Does the site contain at least one current (or past) potential or completed exposure pathway?
2. Can the time period of exposure be determined?

3. Can the population be quantified that was or is being exposed?

4. Are the estimated exposure doses(s) and the duration(s) of exposure sufficient for a plausible, reasonable expectation of health effects?

5. Are health outcome data available at a geographic level or with enough specificity to be correlated to the exposed population?

6. Do the validated data sources or databases have information on the specific health outcome(s) or disease(s) of interest—for example, are the outcome(s) or disease(s) likely to occur from exposure to the site contaminants—and are those data accessible?

Using the findings of the exposure evaluation in this public health assessment, ATSDR sufficiently documented completed past exposure pathways to airborne radioactive and nonradioactive hazardous substances. That documentation covered the years 1944 to 1995 and included people living in off-site communities (Union/Lawnville, Happy Valley, and Sugar Grove) near the K-25/S-50 site. In this public health assessment, the documented evidence of off-site acute and chronic exposure to uranium and ionizing radiation indicates that estimates of past doses are below doses associated with health effects (see Section IV, Public Health Implications). Acute exposure to hydrogen fluoride for the Sugar Grove and Union/Lawnville communities following the largest short-term or accidental UF_6 releases could have caused temporary respiratory irritation to sensitive persons living in these off-site areas. Historic concentrations were, however, probably much lower than those estimated in this public health assessment.

Because past chronic and acute exposures to uranium and ionizing radiation were not expected to cause health effects, and because past acute exposures to hydrogen fluoride for the Sugar Grove and Union/Lawnville communities were likely much lower than estimated, no further analysis of health outcome data is appropriate. Analysis of site-related health outcome data is not scientifically reasonable unless the level of estimated exposure is likely to result in an observable number of health effects. And because such an estimate of exposure is not feasible, the requirement to consider analysis of site-related health outcome data on the basis of exposure is complete.

Responding to Community Concerns

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. Community concerns are important and the public health assessment process must address them. The individual community health concerns addressed in the Community Health Concerns section (Section VI) of this public health assessment are concerns from the ATSDR Community Health Concerns Database that are related to issues associated with releases from the K-25/S-50 site.

Area residents have also voiced concerns about cancer. Citizens living in the communities surrounding the ORR have expressed many concerns to the ORRHES about a perceived increase in cancer in areas surrounding the ORR. A 1993 TDOH survey of eight counties adjacent to the ORR indicated that cancer was mentioned more than twice as often as any other health problem. The survey also showed that 83% of the surveyed population in the surrounding counties believed it was important to examine the actual occurrence of disease among residents in the Oak Ridge area.

To address these concerns, ORRHES requested that ATSDR conduct an assessment of health outcome data (cancer incidence) in the eight counties surrounding the ORR. Therefore, ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment of cancer incidence is a descriptive epidemiologic analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of conducting this evaluation was to provide citizens living in the Oak Ridge Reservation area with information regarding cancer rates in their county compared with the State of Tennessee. Note, however, that this evaluation only examines cancer rates at the population level—not at the individual level. The evaluation is not designed for specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect.

"Cancer incidence" refers to newly diagnosed cases of cancer that are reported to the Tennessee Cancer Registry.

The results of the cancer incidence assessment released in 2006 indicated that when compared with cancer incidence rates for the State of Tennessee, both higher and lower rates of certain cancers occurred in some of the counties examined. Most of the cancers in the eight-county area

occurred at expected levels, and no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. The document is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

In addition, over the last 20 years, local, state, and federal health agencies have conducted public health activities to address and evaluate public health issues and concerns related to chemical and radioactive substances released from the Oak Ridge Reservation. For more information, please see the Compendium of Public Health Activities at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

VI. Community Health Concerns

To address the health concerns community members have raised about the ORR, ATSDR actively gathered comments and other information from the people who live or work near the reservation. ATSDR is particularly interested in hearing from area residents and from civic leaders, health professionals, and community groups. ATSDR will address their specific health concerns in the ORR public health assessments that are related to those concerns.

Moreover, to improve the documentation and organization of community health concerns at the ORR, ATSDR developed a **Community Health Concerns Database** specifically designed to compile and track community health concerns related to the site. The database allows ATSDR to record, to track, and to respond appropriately to all community concerns and to document ATSDR's responses to these concerns.

From 2001 to 2005, ATSDR compiled more than 3,000 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.

In this public health assessment, the community health concerns addressed are those in the ATSDR Community Health Concerns Database regarding releases from the K-25 site and the former S-50 site. The following table contains summarized concerns and issues along with ATSDR's responses. The concerns and responses are sorted by category:

- geographic areas of concern,
- exposure pathway concerns,
- health concerns,
- concerns related to workers, and
- concerns about fluoride [fluorine], hydrogen fluoride, uranium hexafluoride, uranium, and uranyl fluoride).

1 **Community Health Concerns From the Oak Ridge Reservation Community Health Concerns Database**

	Summarized Concern/Issue	*ATSDR's Response*
Geographic Areas of Concern		
1	A community member's parents lived in Happy Valley from 1943 through 1948, and his sister and brother were born while his parents lived there. Both of his parents, who were now deceased, had suffered from cancer. He said that most of the people who lived in Happy Valley are dead now and some of the surviving former residents he had spoken with had some kind of cancer or their spouse had died with cancer. Have there been any studies such as dose reconstruction on this area and the people who lived at Happy Valley? He is concerned that his parents and others who lived in the Happy Valley area just east of DOE's K-25 Gaseous Diffusion Plant from 1943 through 1948 were at a high risk of developing illnesses due to exposures to chemicals released into the air and water from this plant. This community (comprised of DOE workers, DOE subcontract workers, and their families) was downwind from the K-25 plant and the community's water came from a treatment facility downstream from the plant. Will ATSDR be looking at water sources related to Happy Valley? What dangerous environmental exposures were his family members exposed to while living in Happy Valley? He is asking ATSDR to investigate this matter to determine the risks that his family members and other residents of Happy Valley were subjected to during 1943 through 1948.	To respond to concerns about possible past exposures for former residents of Happy Valley, ATSDR evaluated potential exposures to this community in this PHA. The State of Tennessee's Oak Ridge Dose Reconstruction did not include an evaluation of the Happy Valley community. Through, however, work group meetings and ATSDR's community health concerns database, ATSDR learned about the Happy Valley, Happy Valley West, Ford Bacon Davis, and Fercleve labor camps (see Figure 7)—established to house workers constructing the Oak Ridge Gaseous Diffusion Plant at K-25. Over 8,700 residents, including 5,600 workers and 3,100 dependents, lived at Happy Valley during its existence (about 1943–1947; but a community member's anecdotal observations suggest that Happy Valley may have been occupied as late as 1948.) Happy Valley was located in the lower reaches of East Fork Valley, near the main Gaseous Diffusion Plant at K-25. The westernmost portion of Happy Valley was between 1.0 and 1.5 miles further southeast of the K-25 Power House area and the former S-50 plant. Possible past exposures via the K-25 drinking water intake were evaluated in a separate public health assessment titled *White Oak Creek Radionuclide Releases*. ATSDR conservatively assumed that Happy Valley residents could have been exposed over a 7-year period (from 1944 to 1950). ATSDR did not identify any Clinch River monitoring data for radionuclides covering the period when Happy Valley was used as a housing area. In the absence of historical monitoring data, ATSDR used the 50th percentile of the modeled radioactivity concentrations in the Grassy Creek area of Clinch River as reported in the Oak Ridge Dose Reconstruction Task 4 report (available online at http://health.state.tn.us/CEDS/OakRidge/WOak1.pdf). ATSDR estimated an annual whole-body dose of 14 mrem for drinking water at Happy Valley in the past, which is at least seven times lower than ATSDR's minimal risk level (MRL) for ionizing radiation of 100 mrem/year and the maximum dose limit recommended for the public of 100 mrem/year by the International Commission on Radiological Protection (ICRP), the U.S. Nuclear Regulatory Commission (NRC), and the National Council on Radiation Protection and Measurements (NCRP). Therefore, adverse health effects would not be expected to result from past exposures to drinking water at K-25 for Happy Valley residents. You can obtain copies of this PHA at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR toll-free at 1-800-232-4636. In this PHA, ATSDR evaluates historical air releases and examines possible exposures to contaminants released to the air from the former S-50 plant for Happy Valley residents. It is important to note that ATSDR only evaluated potential exposures to airborne releases from the former S-50 plant—not releases associated with the K-25 facility—for Happy Valley residents because the Happy Valley labor camp was abandoned before significant releases occurred from the K-25 facility (about 1952–1953). ATSDR used a worst-case scenario to evaluate potential off-site exposures, which used the maximum releases that occurred and assumed that all released material was dispersed to the outside atmosphere, in addition to many other conservative (protective) assumptions. Please see Tables 4 and 5, as well as Figure 13, for more information on this evaluation.

	Summarized Concern/Issue	ATSDR's Response
	Continued Dose reconstructions are based on historical events, performed to address public concerns about the cause of cancer among individuals. To achieve this goal in Oak Ridge, historical exposures will need to be traced to the initial establishment of ORR. If ORRHES attempts to determine whether past events during the years of maximum exposure in the community resulted in cancer or other diseases with a long latency period, another community member agreed, efforts should be made to locate persons who lived in the area at that time. These individuals should serve as the study population. A community member was initially unable to locate data about Happy Valley, but PHAWG assisted him in this effort. However, he needs more assistance in locating additional data to address his concerns about cancer-causing agents. Identifying a potential correlation between his parents' cancers and the environment is important due to his concerns about historical health effects, future generations, and a potential predisposition to the disease. In conducting the health statistics review (HSR), the community member urged ATSDR to research historic records to the extent possible. Due to TDOH's data gaps, he acknowledged that a wealth of information will be missing. For instance, the Tennessee Cancer Registry will not contain information regarding the 1940s transients. In a personal effort, he has been attempting to locate residents who lived in Happy Valley at the same time as his parents. In addition to conducting the HSR and other formal studies, he encouraged ATSDR to also collect qualitative data by interviewing persons. This approach can assist in identifying health effects among current and future residents in the communities of concern. He also asked ATSDR to refrain from limiting the HSR to 1990 census data.	ATSDR concluded, based on estimated concentrations and doses, that historic chronic exposure to ionizing radiation, uranium, fluoride, and hydrogen fluoride, as well as acute exposure to ionizing radiation and uranium in airborne releases from the S-50 plant, would not be expected to result in adverse health effects. ATSDR concluded that acute exposures to the maximum estimated fluoride and hydrogen fluoride concentrations were unlikely but possible. ATSDR classified this pathway as indeterminate because sufficient data are not available to make a professional judgment about the level of health hazard. In addition, ATSDR's estimated historic off-site acute hydrogen fluoride concentrations are not appropriate to use as a basis for a health hazard category—they are estimated worst-case concentrations, and they are highly unlikely to have actually occurred, given that they are based on modeled results with a high degree of uncertainty. Nonetheless, even based on these worst-case assumptions, exposures would have only been expected to possibly cause minor, temporary respiratory irritation in sensitive individuals. Furthermore, this evaluation of acute exposures is based on estimated releases occurring after Happy Valley had already closed. For more information on ATSDR's findings and public health evaluation of the Happy Valley community, please see Section III and Section IV, respectively, in this PHA. ATSDR uses the public health assessment process to evaluate the public health implications of exposure to environmental contamination and to identify the appropriate public health actions or a study for particular communities. In public health assessments, ATSDR scientists conduct a health effects evaluation by carefully examining site-specific exposure conditions about actual or likely exposures; conducting a critical review of available toxicological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure); and comparing an estimate of the amount of exposure (i.e., dose) to which people might frequently encounter at a site to situations that have been associated with disease and injury. This health effects evaluation involves a balanced review and integration of site-related environmental data, site-specific exposure factors, and toxicological, radiological, epidemiologic, medical, and health outcome data to help determine whether exposure to contaminant levels might result in harmful outcomes. The goal of the health effects evaluation is to decide whether harmful outcomes might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses and concentrations in perspective. The output is a qualitative description of whether site exposure doses and concentrations are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or further study any potential harmful exposures. In addition, ATSDR will consider evaluating health outcome data if a plausible, reasonable expectation of adverse health effects is associated with the observed levels of exposure to contaminants. The PHA report presents conclusions about the actual existence and level of the health threat (if any) posed by a site. It also recommends ways to stop or reduce exposures. An overview of the PHA process is available at: http://www.atsdr.cdc.gov/training/public-health-assessment-overview/html/index.html.

	Summarized Concern/Issue	*ATSDR's Response*
	Continued	

	Summarized Concern/Issue	ATSDR's Response
2	There is a high incidence of cancer in the Union and Lawnville areas. How can a person get agencies to perform studies in a geographic area of concern?	Area residents living in the communities surrounding the Oak Ridge Reservation have expressed concerns to ATSDR and to the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) about a perceived increase in cancer in areas surrounding the ORR. In 1993, the Tennessee Department of Health (TDOH) conducted a study of the eight-county area surrounding the reservation. According to the study, people mentioned cancer as a health problem more than twice as much as any other health problem. In addition, 83% of the population surveyed in the surrounding counties believed it was very important to examine the actual occurrence of disease among residents in the Oak Ridge area. To address these concerns, ORRHES requested that ATSDR conduct an assessment of health outcome data (cancer incidence) in the eight-county area (Anderson, Blount, Knox, Loudon, Meigs, Morgan, Rhea, and Roane) surrounding the reservation, which includes the Union and Lawnville areas. Therefore, ATSDR conducted an assessment of *cancer incidence* (newly diagnosed cases of cancer) using cancer incidence data already collected by the Tennessee Cancer Registry for 1991–2000. This assessment of cancer incidence is a descriptive epidemiologic analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of conducting this evaluation was to provide citizens living in the Oak Ridge Reservation area with information regarding cancer rates in their county compared with the state of Tennessee. This evaluation only examines cancer rates at the population level—not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect. The results indicated both higher and lower rates of certain cancers in some of the counties examined when compared with cancer incidence rates for the state of Tennessee. Yet no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. The document is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html. In addition to the eight-county area, ORRHES requested that ATSDR evaluate the cancer incidence rates for 49 specific census tract areas around the Oak Ridge Reservation. ATSDR was unable to conduct this analysis, however, because a high percentage of the addresses for several of the areas were either for post office boxes or rural routes, which did not allow the data to be incorporated into certain geographic areas. For further inquiries about cancer rates in your area of Tennessee, please contact the Tennessee Cancer Registry by phone at 1-800-547-3558 or by email at tncancer.registry@state.tn.us. If you are concerned about your risk of developing cancer, you should discuss this with your physician. If you want more information about cancer, please visit the American Cancer Society's Web site at http://www.cancer.org or call the agency directly at 1-800-227-2345. You can also visit the National Cancer Institute's Web site at http://www.cancer.gov/ or call the agency directly at 1-800-422-6237.

	Summarized Concern/Issue	*ATSDR's Response*
3	Members of the public want ATSDR to perform additional off-site sampling from the Gallaher Valley area and incorporate the data from the Roane County Gallaher Valley area (where the TSCA Incinerator is located) with the other data.	Regarding sampling at the Toxic Substances Control Act (TSCA) Incinerator, please refer to ATSDR's public health assessment on the TSCA Incinerator at http://www.atsdr.cdc.gov/HAC/oakridge/phact/tsca/index.html or contact ATSDR toll-free at 1-800-232-4636 to obtain a copy of the document. ATSDR is using the public health assessment process to evaluate previous studies and environmental data to determine whether releases of hazardous substances from the Oak Ridge Reservation could have affected the health of people in communities near the reservation. The public health assessment is the primary public health process ATSDR uses to • Identify populations off the site who could have been exposed to hazardous substances • Determine the potential health effects of exposure • Address the site-specific health concerns of people in the community • Recommend any needed follow up public health actions to address exposure • Communicate ATSDR's findings to the public ATSDR is conducting nine public health assessments to evaluate potential exposures to chemical and radiological off-site releases from the K-25, Y-12, and X-10 facilities. ATSDR uses conservative (protective) exposure assumptions to consider the closest populations to the sources and the highest possible contaminant concentrations. ATSDR uses these worst-case exposure scenarios so that potential exposures are not underestimated and to evaluate the populations that would be most affected by potential exposures. If ATSDR identified data gaps in sampling during the preparation of its public assessments at the Oak Ridge Reservation, then the agency would notify the U.S. Environmental Protection Agency (USEPA), the US Department of Energy (DOE)—or both—and request the collection of additional data to fill those data needs. Thus, if ATSDR believed that additional sampling was necessary for any areas, then it would recommend that sampling be conducted. Given the agency's findings in this public health assessment, however, additional sampling is not necessary.

	Summarized Concern/Issue	ATSDR's Response
Exposure Pathway Concerns		
4	Some water monitoring data indicate that tritium is present in East Tennessee Technology Park water samples. However, previous water sampling efforts did not include analysis for tritium.	Tritium is very difficult to extract from water samples because it is present in water form. Nonetheless, the measured tritium levels detected at ETTP are well below the regulatory limit (H Crabtree, TDEC Radiological Monitoring Program, ORRHES meeting minutes, October 22, 2002). The K-25 site has a water intake that withdraws water from the Clinch River, which is located at CRM 14.4 (ChemRisk 1999b). Please see Figure 3 for the location of the K-25 water intake. Although this intake is located on site at the reservation, through community concerns, Exposure Evaluation Work Group (EEWG, formerly referred to as the Public Health Assessment Work Group [PHAWG]) meetings, and discussions with DOE, ATSDR learned that this water intake provided domestic water to the Happy Valley community during its existence (1943–1947). The K-25 water intake also continues to be used today for potable water (non-domestic) on site at the Oak Ridge Reservation by the K-25 site, Beer Creek Industrial Park, and Building 9714 (ChemRisk 1999b). ATSDR evaluated off-site groundwater in its public health assessment titled *Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation* (available at http://www.atsdr.cdc.gov/HAC/pha/oakridge_gw_7-06/gor_toc.html). In this document, ATSDR evaluated tritium and other contaminants of concern in on-site groundwater. ATSDR concluded that because of the close interaction between groundwater in the aquitard formations of Melton Valley and surface water, tritium detected in on-site groundwater migrates off the reservation via surface water—it does not leave the reservation via groundwater. For ATSDR's evaluation of exposures to off-site surface water releases of tritium and other radiological contaminants, please see the *White Oak Creek Radionuclide Releases Public Health Assessment.* You can obtain copies of this assessment by calling ATSDR toll-free at 1-800-232-4636 or from http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html. For past exposures, ATSDR concluded that exposures to radionuclides, including tritium, released off site via surface water were not expected to result in adverse health effects. For current exposures, of the seven radionuclides detected in surface water released off site from White Oak Creek to the Lower Watts Bar Reservoir, hydrogen 3 (H 3, also known as tritium) reached the highest concentration (853 pCi/L) in the collected surface water samples. ATSDR concluded that the likelihood of adverse health effects from H 3 is extremely low; the concentrations were well below the U.S. EPA's current maximum contaminant level (MCL) for drinking water of 20,000 pCi/L of tritium.

	Summarized Concern/Issue	ATSDR's Response
4	*Continued*	Also in the *White Oak Creek Radionuclide Releases Public Health Assessment,* ATSDR evaluated past potential exposures to drinking water via the K-25 water intake. For past exposures, ATSDR used conservative assumptions assuming that Happy Valley residents could have been exposed over a 7-year period (from 1944 to 1950). ATSDR estimated an annual whole-body dose of 14 mrem for drinking water at Happy Valley in the past, which is at least seven times lower than ATSDR's minimal risk level for ionizing radiation of 100 mrem/year and the maximum dose recommended for the public of 100 mrem/year by the International Commission on Radiological Protection (ICRP), the U.S. Nuclear Regulatory Commission (NRC), and the National Council on Radiation Protection and Measurements (NCRP). Therefore, adverse health effects would not be expected to result from past exposures to drinking water at K-25 for Happy Valley residents. The K-25 water intake continues to be used today for potable water by the K-25 site, Beer Creek Industrial Park, and Building 9714—all located on site at the Oak Ridge Reservation (ChemRisk 1999b). Chemical, radiological, bacteriological, and chlorine sampling of "finished water" from the treatment plant is regularly conducted pursuant to the state and U.S. EPA requirements. As a result of public concerns voiced at a July 31, 2000, meeting, DOE–Oak Ridge Operations (DOE–ORO) conducted a special sampling effort that included testing for metals, radionuclides, and chemicals in water directly from the tap. More than 475 drinking water samples were taken and analyzed, and DOE-ORO concluded that drinking water at the K-25 site was "safe to drink." More information on this sampling effort is available at the DOE-ORO Reading Room at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (DOE–ORO and CROET 2000). To view the drinking water quality report for this sampling effort, go to http://www.state.tn.us/environment/doeo/pdf/PSBroch.pdf. In addition, for 30 years under the Safe Drinking Water Act of 1974, the U.S. EPA has set health-based standards and specified treatments for substances in public drinking water systems. In 1977, U.S. EPA gave the state of Tennessee authority to operate its own Public Water System Supervision Program under the Tennessee Safe Drinking Water Act. Through this program, TDEC's Division of Water Supply regulates drinking water at all public water systems. As a requirement of this program, all public water systems in Tennessee individually monitor their water supply for U.S. EPA-regulated contaminants and report their monitoring results to TDEC (TDEC 2003a). The public water supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides. For U.S. EPA's monitoring schedules for each contaminant, go to http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf (USEPA 2004a). On a quarterly basis, TDEC submits the individual water supply data to EPA's Safe Drinking Water Information System (SDWIS) (TDEC 2003a). To look up information and sampling results for public water supplies in Tennessee, go to EPA's Local Drinking Water Information Web Site at http://www.epa.gov/safewater/dwinfo/tn.htm (USEPA 2004b).

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	Summarized Concern/Issue	ATSDR's Response
4	*Continued*	In addition, in 1996 TDEC's DOE Oversight Division started to participate in U.S. EPA's Environmental Radiation Ambient Monitoring System (ERAMS) drinking water program. As part of the Oak Ridge ERAMS program, TDEC collects samples from five facilities on the ORR and in its vicinity. These public water suppliers include the Kingston Water Treatment Plant (Tennessee River Mile [TRM] 568.4), DOE Water Treatment Plant at K-25 (Clinch River Mile [CRM] 14.5), West Knox Utility (CRM 36.6), DOE Water Treatment Plant at Y-12 (CRM 41.6), and Anderson County Utility District (CRM 52.5) (TDEC 2003b). Under the ERAMS program, TDEC collects finished drinking water samples from these five public water supplies on a quarterly basis and submits the samples to U.S. EPA for radiological analyses. In addition to tritium, samples are analyzed for other radionuclides including gross alpha, gross beta, gamma, radium, strontium, plutonium, uranium, and iodine. Monitoring has indicated that concentrations of radiological contaminants are below regulatory criteria. The schedule and contaminants sampled at the supplies are available at http://www.state.tn.us/environment/doeo/pdf/EMP2006.pdf. To find more information related to your drinking water supply or additional water supplies in the area, please call U.S. EPA's Safe Drinking Water Hotline at 1-800-426-4791 or visit U.S. EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater.
5	The community needs the data from the secret well-monitoring done since the 1980s, including the surface and groundwater studies at Y-12 and K-25 as this data directly impacts the surrounding residents. Has the porosity of the limestone bedrock below K-25, Y-12, and X-10 been quantified?	ATSDR evaluated surface water and groundwater associated with off-site releases from the ORR in the Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation. In this PHA, ATSDR evaluated contaminants released from the Oak Ridge facilities that have been detected in off-site groundwater. Available data indicate that off-site contamination has only occurred in monitoring wells and seeps/springs in Union Valley, and residential wells have been unaffected by ORR-related 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. ATSDR scientists concluded that on-site groundwater does not pose a public health hazard because there is no completed exposure pathway for ingestion or direct contact with contaminated groundwater emanating from the ORR. Sufficient evidence supports that no human exposure to off-site contaminated groundwater has occurred, no exposures are currently occurring, and exposures are not likely to occur in the future. For specific information regarding the geology and hydrology of the ORR, please refer to Appendix B in the groundwater PHA (available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html).
6	Will the uranium releases to water and sediments be looked at?	Yes, ATSDR evaluated potential exposures to uranium via off-site releases of surface water and sediments In the *White Oak Creek Radionuclide Releases Public Health Assessment*. ATSDR evaluated potential off-site exposures for radionuclide releases, including uranium, from the Oak Ridge Reservation to the Clinch River and the Lower Watts Bar Reservoir. ATSDR concluded that adverse health effects would not be expected from potential past, current, or future exposures to uranium detected in off-site surface water or sediments. You can obtain copies of this assessment online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR toll-free at 1-800-232-4636.

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	Summarized Concern/Issue	***ATSDR's Response***
7	I recall during the CIP-CUP upgrading program when converters (the huge pieces of equipment used in the gaseous diffusion process that contained the barrier materials that separated the uranium gasses) were removed from the system, taken to the K-1420 Decontamination Facility and cut open. All of the internal parts were removed to be replaced by new parts. Some of the parts were huge bowl-shaped aluminum pieces that riggers loaded onto flat-bed trailers and hauled to the peninsula at the K770 Salvage Yard. Bulldozers pushed the contaminated parts off the trailers onto the ground and later into huge piles. We saw large quantities of yellowish green product (enriched uranium) on and in these parts. Often the pieces were covered with uranium dust and sediments around the periphery and any rough parts or projections on them. We wondered and discussed among ourselves what happened to this enriched uranium when the rains washed it into Poplar Creek which flowed into the Clinch River.	In the *White Oak Creek Radionuclide Releases Public Health Assessment*, ATSDR evaluated whether radionuclides, including uranium, released from the Oak Ridge Reservation could be harmful to people living along and using the Clinch River and the Lower Watts Bar Reservoir. ATSDR concluded that people who used or lived along the Clinch River or Lower Watts Bar Reservoir in the past, or who currently do so or will in the future, might have or might yet come in contact with radionuclides, including uranium, that entered the Clinch River or Lower Watts Bar Reservoir via White Oak Creek. ATSDR's evaluation of data and exposure situations for users of these waterways indicates that the levels of radionuclides in the sediment, surface water, and biota are—and have been in the past—too low to cause observable health effects. You can obtain copies of this assessment online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR toll-free at 1-800-232-4636.

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	Summarized Concern/Issue	ATSDR's Response
Health Concerns		
8	Members of the community who are not presently sick still worry that they will become sick in the future as a result of the very shortsighted approach to reindustrialization at the K-25 site.	Reindustrialization is the method being used at the former K-25 site, now known as the East Tennessee Technology Park (ETTP), to decontaminate and decommission buildings and transfer reusable buildings to the private sector. Initially, buildings containing too much contamination were scheduled to be demolished (TDEC 2000, 2004). Under the accelerated reindustrialization cleanup, however, all buildings that are not transferred to new owners will be demolished (TDEC 2004). As a result of reindustrialization at ETTP, there are workers employed at the ORR who are not associated with DOE operations. Thus, accessible contaminated areas become an issue because members of the public (not only DOE employees) who work at the reservation now have access to and are present at the ORR (TDEC 2004). ATSDR understands that there are concerns about exposures to contaminants remaining at ETTP for people working on site, such as radiation from buildings (Ledwidge 1999; TDEC 2004). Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. If you are concerned about exposures that might be occurring on site at ETTP, please contact NIOSH at 1-800-35-NIOSH (1-800-356-4674). Also, please visit DOE's Safety and Health Web site at http://www.energy.gov/safetyhealth/index.htm for information about various programs and contacts regarding the safety and health of DOE workers.
9	Treatment and testing needs to be provided to sick workers and residents at independent hospitals and by physicians who are not affiliated with DOE. Treatment and testing must be provided for workers who should not be working at the ORR's X-10, Y-12 and K-25 facilities because this is a Superfund site that is being cleaned up. One recommendation was to set up a cutting-edge treatment center for affected Oak Ridge residents.	ATSDR is using the public health assessment process to evaluate previous studies and environmental data to determine whether releases of hazardous substances from the Oak Ridge Reservation could have affected the health of people in communities near the reservation. The public health assessment is the primary public health process ATSDR uses to • identify populations off the site who could have been exposed to hazardous substances, • determine the potential health effects of exposure, • address the site-specific health concerns of people in the community, • recommend any needed follow up public health actions to address exposure, and • communicate ATSDR's findings to the public.

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	Summarized Concern/Issue	ATSDR's Response
9	*Continued* A common place should be available where both workers and residents can go for help if they have the same types of exposures, such as nickel poisoning. A clinic is needed because DOE is not supporting the process of treating sick workers and physicians in Oak Ridge do not want to become involved in worker exposure controversies. I am a victim of K-25. If we help the people who live here now, then new residents and industry might come to Oak Ridge. However, the problems will continue to escalate if help is not provided to those who are here.	ATSDR worked with the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) to ensure that the public health questions of people living in the Oak Ridge Reservation area will be answered. In response to community concerns regarding a clinic, the ORRHES Needs Assessment Work Group conducted a comprehensive program review of the various federal agencies to determine whether it is possible to establish an occupational/environmental clinic or another form of clinical intervention near the Oak Ridge Reservation. On August 27, 2002, the ORRHES made the following recommendation to ATSDR. "The Oak Ridge Reservation Health Effects Subcommittee (ORRHES) has determined that discussion of public health activities related to the establishment of a clinic, clinical evaluations, medical monitoring, health surveillance, health studies, and/or biological monitoring is premature. Thus, the ORRHES recommends that formal consideration of these issues be postponed until the ATSDR public health assessment (PHA) process identifies and characterizes an exposure of an off-site population at levels of health concern. If this exposure warrants follow-up public health activities, the ORRHES will then consider these issues in making its recommendations to ATSDR." This ORRHES recommendation is based on the review, evaluation, and understanding of the comprehensive program review presented by the Needs Assessment Work Group at the August 27, 2002, ORRHES meeting. The August 27, 2002, ORRHES meeting minutes are available on ATSDR's Web site at http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m8_27.html. Also, please refer to the Environmental and Occupational Medical Resources Fact Sheet (at http://www.atsdr.cdc.gov/HAC/oakridge/factsheets/env_med_res.html) developed by the former ORRHES to provide guidance to persons seeking medical assistance for an environmentally- or occupationally-related illness or injury. This fact sheet provides information on the Association of Occupational and Environmental Clinics (AOEC) for persons who think something in the environment is causing an illness. To request assistance from AOEC, please call 1-888-347-2632 or access the AOEC Web site at http://www.aoec.org. Further, the U.S. Department of Labor is the lead agency in administering the Energy Employees Occupational Illness Compensation Program for former and current workers. You can obtain more information on this program at http://www.dol.gov/esa/regs/compliance/owcp/eeoicp/main.htm.

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	Summarized Concern/Issue	ATSDR's Response
10	In addition to iodine 131 exposures from the RaLa process, what is the extent that thyroids of residents and workers could have been adversely affected by exposures to other contaminants (e.g., cumulative impacts from other radionuclides via the RaLa process; X-10 radionuclides released via other processes, thyroid-impacting contaminants at the three major facilities, and non-local exposures)? Fluoride and certain mixed chemicals possibly affect the thyroid in the same way as iodine. Thus, fluoride from K-25 could be a contributing factor to some of the thyroid problems. HF effects were quickly connected to the high rates of thyroid illness seen in the work force due to accumulation of mercury in the thyroid gland leading to thyroid cancer like problems normally associated with radiation damage.	Exposure to fluoride does not affect the thyroid in the same way as iodine. Exposure to radioactive iodine (Iodine 131 or I 131) can result in cancer to the thyroid, but exposure to fluoride has never been shown to result in thyroid cancer. Inhalation would have been the primary route of exposure for off-site residents to any fluoride released in the past from the K-25 site. According to ATSDR's T*oxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine* (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf), most scientific investigators do not consider it likely that cancer can result from fluoride inhalation. Further, no studies were located regarding cancer in animals, or endocrine effects in animals or humans, after inhalation exposure fluoride, hydrogen fluoride, or fluorine. When inhaled, fluoride can enter your blood stream through your lungs, but it is not known how quickly this happens. Much of the fluoride leaves your body, but some is stored in your bones and teeth. Inhalation exposure to fluoride most commonly occurs in workplace settings. However, if people living in nearby communities were exposed to off-site releases of fluoride from the K-25 site, acute low-level off-site exposures might have resulted in nasal and eye irritation. The major health effect associated with chronic inhalation exposure to fluoride is skeletal fluorosis. This disease only occurs after long0term exposure and can cause denser bones, joint pain, and a limited range of joint movement. Any fluoride released from the K-25 site to off-site areas would have been in the form of a gas. Thus, oral exposure could have resulted concomitantly with inhalation exposure. After entering your body via ingestion, about half of the fluoride leaves the body quickly in urine, usually within 24 hours unless large amounts are ingested. Most of the fluoride ion that stays in your body is stored in your bones and teeth. The main studies of ingestion have found health effects including fluorosis of teeth and bones. No evidence to date has suggested that fluoride is an endocrine disruptor, but some data from drinking water suggest that exposure to fluoride could potentially affect some endocrine glands (ATSDR 2003). For more information, please see ATSDR's Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf). In this PHA, ATSDR evaluated measurements of airborne fluoride concentrations collected at six sampling locations around the perimeter of K-25 from 1971 to 1985. To estimate concentrations from long-term exposure to fluoride for years before monitoring data were available, ATSDR used a correlation between annual uranium releases and measured fluoride concentrations at the site perimeter. Estimated concentrations at the perimeter (Station F-2, at the perimeter of the K-25 site about 0.5 miles downwind or northeast of the K-25 facility) represent the point of maximum airborne fluoride concentrations, which will overestimate concentrations at areas of potential exposure due to increased distance from emission sources and the effects of topographic ridges between the emission sources and exposure areas.

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	Summarized Concern/Issue	***ATSDR's Response***
10	*Continued*	ATSDR evaluated the potential past exposure pathways for fluorides (in both fluoride and fluorine forms) to reach off-site communities from the K-25/S-50 site. Fluoride exposures were evaluated for Union/Lawnville from the K-25 site for 1945 to 1995 and the Sugar Grove community from the K-25 site for 1960 to 1995. Fluoride exposures from the S-50 plant from 1944 to 1945 were evaluated for both Happy Valley and Union/Lawnville. As shown in Figure 17 of the PHA, the highest predicted yearly fluoride air concentration was about 6 ppb in 1945 at the K-25 perimeter locations. The evaluation in this public health assessment shows that chronic (long-term) fluoride exposures are not a public health hazard and therefore no adverse health effects would have been expected from off-site fluoride releases in the past. The highest recorded value of 26.3 ppb for a 24-hour sample, occurring at sampling station F-2 in 1975, is the highest measured air fluoride concentration for any station during any time period, and it is about two times higher than any other measured value. If sensitive people were exposed at these acute (short-term) levels, minor temporary adverse health effects such as nose, throat, and eye irritation could have occurred. Because, however, so much uncertainty is associated with historical events, past exposure to the maximum air concentration poses an ***indeterminate public health hazard***—sufficient data are not available to make a professional judgment about the level of health hazard from this exposure.

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	Summarized Concern/Issue	ATSDR's Response
11	What health effect does depleted uranium have on the general public?	Natural uranium is actually a mixture of three types (or isotopes) of uranium: uranium 234 (U 234), uranium 235 (U 235), and uranium 238 (U 238). Chemically, these three types of uranium behave the same, but they are differing radioactive materials exhibiting different radioactive properties. Human activities, such as industrial processing of uranium, can change the ratios of the isotopes. Enriched uranium refers to when the fraction of U 235 is increased, whereas depleted uranium refers to when the portion of U 235 is decreased. Enrichment is an industrial process used to increase the amount of U 234 and U 235 and decrease the amount of U 238 in natural uranium. The product of this process is enriched uranium, and the leftover is depleted uranium. Enriched uranium is more radioactive than natural uranium, and natural uranium is about twice as radioactive as depleted uranium (ATSDR 1999a). Scientists have observed chemical effects from uranium in humans, such as signs of kidney disease and adverse effects on bodily tissues. Depleted uranium, however, is a weak radioactive substance and is not likely to cause cancer. In fact, no human cancer of any type has been observed as a result of exposure to depleted uranium. Nonetheless, there is a chance of developing cancer from any radioactive material like uranium, and uranium can also decay into other radioactive substances (e.g., radium) that can cause cancer in people who are exposed over long enough time periods. Still, according to ATSDR's *Toxicological Profile for Uranium*, "because the specific activities of … depleted uranium are low, no radiological health hazard is expected from exposure to … depleted uranium." Further, "there are no unequivocal studies that show that intake of … depleted uranium can induce radiation effects in humans or animals. The available information on humans and animals suggests that intake of uranium at the low concentrations usually ingested by humans or at levels found at or near hazardous waste sites is not likely to cause cancer" (ATSDR 1999a). Just like adults, children are also exposed to small amounts of uranium in their drinking water, food, and air. It is possible that children could have the same types of health effects as adults following exposure to large concentrations of uranium, such as kidney damage. We do not know, however, if children's susceptibility to uranium exposure is different from adults. Further, we do not know for sure if uranium exposure can adversely affect the human fetus, but animal studies have shown birth defects and an increase in fetal deaths following exposure to high uranium doses in drinking water (ATSDR 1999a). For more information on uranium, please see ATSDR's *Toxicological Profile for Uranium* available at http://www.atsdr.cdc.gov/toxprofiles/tp150.pdf. Based on ATSDR's evaluation in this PHA, exposures to airborne uranium releases from the K-25 site are not expected to cause adverse chemical or radiological health effects in off-site communities. Please see Section III and Section IV of this public health assessment for more information on ATSDR's health evaluation of potential uranium exposures.

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	Summarized Concern/Issue	*ATSDR's Response*
12	It is a waste of resources to study uranium if there is no evidence that it is carcinogenic. Has cancer been observed as a result of exposure to uranium?	ATSDR does not agree that substances should only be studied if they are carcinogenic. In exposed persons many substances can cause health effects other than cancer, and it is as important to use resources to study these substances as it is to study compounds found to cause cancer. Regarding uranium, it is a chemical compound that is also radioactive. Uranium mixtures include depleted, natural, and enriched uranium, all of which have the same chemical effect on the human body. Depleted uranium is less radioactive than natural uranium, and enriched uranium is more radioactive than natural uranium. Scientists have observed chemical effects from uranium in humans, such as signs of kidney disease and adverse effects on bodily tissues. Scientists have not, however, detected harmful radiation effects resulting from exposure to natural uranium, but some effects might be possible. Natural and depleted uranium are weak radioactive substances and are not likely to cause cancer from exposure to their radiation. In fact, no human cancer of any type has been observed as a result of exposure to natural or depleted uranium. However, there is a chance of developing cancer from any radioactive material like uranium, and uranium can also decay into other radioactive substances (e.g., radium) that can cause cancer in people who are exposed over long enough time periods. Just like adults, children are also exposed to small amounts of uranium in their drinking water, food, and air. It is possible that children could have the same types of health effects as adults following exposure to large concentrations of uranium, such as kidney damage. We do not know, however, if children's susceptibility to uranium exposure is different from adults. Further, we do not know for sure if uranium exposure can adversely affect the human fetus, but animal studies have shown birth defects and an increase in fetal deaths following exposure to high uranium doses in drinking water (ATSDR 1999a). For more information on uranium, please see ATSDR's *Toxicological Profile for Uranium* available at http://www.atsdr.cdc.gov/toxprofiles/tp150.pdf.

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	Summarized Concern/Issue	ATSDR's Response
13	What is the long-term effect on the community from 50-60 years of exposure to small concentrations of uranium, considering DOE operated multiple sites over the years with multiple emission sources?	Uranium was released from various large-scale operations, primarily uranium processing and machining operations at the Y-12 plant and uranium enrichment operations at the K-25 and S-50 plants. Phase I of the Tennessee Department of Health's (TDOH) Oak Ridge Health Study evaluated all past releases of hazardous substances and operations at the ORR. The study indicated that four substances had the largest potential risk for adverse health effects—uranium was not one of them. A brief summary of the Phase I Feasibility Study is provided in Appendix H of this PHA. Phase II of the health studies primarily consisted of a dose reconstruction study focusing on past releases of radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. In addition to the full dose reconstruction analyses, the Phase II effort included further detailed screening analyses for releases of uranium and other toxic materials that had not been fully characterized in Phase I (a brief in Appendix H summarizes the *Screening-Level Evaluation of Additional Potential Materials of Concern, Task 7*). Because uranium was not initially given high priority as a contaminant of concern, a Level II screening assessment for all uranium releases was performed. Preliminary screening indices for Y-12 and K-25 were below the Oak Ridge Health Agreement Steering Panel (ORHASP) decision guide of one chance in 10,000. The ORHASP final report is available at http://health.state.tn.us/CEDS/OakRidge/ORHASP.pdf. To expand upon the efforts of the TDOH—but not to duplicate them—ATSDR scientists conducted a review and a screening analysis of the department's Phase I and Phase II screening-level evaluation of past exposure (1944-1990) to identify contaminants of concern for further evaluation. Using this review and addressing community concerns about uranium, ATSDR scientists conducted a public health assessment on Y-12 uranium releases (released in January 2004) and prepared this public health assessment on K-25 uranium (and fluoride) releases., ATSDR concluded, based on the TDOH's estimated doses for past exposures and ATSDR's evaluations in both of these public health assessments, that no adverse health effects would be expected from past off-site exposures to uranium released from the Y-12 plant or the K-25 site. In the Y-12 PHA, ATSDR evaluated both radiation and chemical aspects of long-term (chronic) past and current uranium exposure, and concluded that past and current off-site exposure to uranium from the Y-12 plant would not cause harmful health effects.You may obtain copies of this public health assessment on the Internet at http://www.atsdr.cdc.gov/HAC/PHA/oakridgey12/oak_toc.html or by calling ATSDR toll-free at 1-800-232-4636. In this public health assessment, ATSDR evaluated historical exposures to chemical and radiation effects of airborne uranium releases from the K-25/S-50 site for the largest estimated annual releases for the communities located closest to the facilities. ATSDR determined that long-term exposure to the highest estimated airborne uranium releases would not be expected to result in adverse health effects. Please see Section III and Section IV in this public health assessment for more information on ATSDR's assessment of chronic exposures to uranium releases from the K-25/S-50 site.

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	Summarized Concern/Issue	ATSDR's Response
14	Because there is not much margin of safety between the RfD and a level at which severe effects can occur, it is likely that the reference dose for fluoride is not protective of all individuals.	ATSDR did not use the US Environmental Protection Agency's (USEPA) reference dose (RfD) for fluoride in this public health assessment. The oral RfD is based on a cosmetic effect on teeth called dental fluorosis that develops as a result of excess fluoride exposure. The RfD of 0.06 mg/kg/day is based on a study on children consuming fluoride in their drinking water that found no observable adverse effect from consuming fluoride levels of 0.1–1.0 ppm in drinking water. Although there is much controversy over whether dental fluorosis is a toxic and/or adverse health effect, the US EPA has determined that it is a cosmetic effect—not a toxic and/or adverse health effect. It is important to note that ATSDR would not use this RfD as a comparison value in this public health assessment because it is based on a cosmetic effect—not an adverse health effect—and it is based on oral exposure to drinking water. This PHA is evaluating adverse health effects resulting primarily from off-site inhalation exposures. Here ATSDR evaluated potential adverse health effects resulting from past chronic and acute off-site exposure to fluoride released from the K-25 site. ATSDR had not derived a chronic duration minimal risk level (MRL) for inhalation to fluoride or hydrogen fluoride because no chronic duration studies have been located. Thus for chronic exposures, ATSDR compared the maximum estimated annual exposure concentration of less than 6 ppb to the California EPA's (Cal-EPA) reference exposure level (REL) of 10.8 ppb (13 $\mu g/m^3$), a level at which the critical effect identified from chronic inhalation was skeletal fluorosis. Cal-EPA derived the chronic REL based on occupational exposure from a study (Derryberry et al. 1963) that found skeletal fluorosis (increased bone density) as the critical effect, with a lowest-observed-adverse-effect-level (LOAEL) of 1.89 mg/m^3 and a no-observed-adverse-effect-level (NOAEL) of 1.07 mg/m^3. After adjusting for exposure continuity and utilizing an intraspecies uncertainty factor of 10, the resulting REL was 13 $\mu g/m^3$. Please see http://www.oehha.ca.gov/air/chronic_rels/HyFluoCREL.html for more information on this Cal-EPA reference exposure level. To evaluate acute exposures, ATSDR compared the highest estimated acute fluoride concentration released from the K-25 site of 26.3 ppb to the MRL of 20 ppb for acute inhalation exposure to hydrogen fluoride. The MRL is based on a minimal LOAEL of 0.5 ppm (500 ppb) fluoride for upper respiratory irritation as reported in Lund et al. 1997. The 20 ppb MRL is 25 times lower than exposures that caused mild upper respiratory tract inflammation in human volunteers exposed for 1 hour (Lund et al. 1999). In addition, the MRL is 150 times lower than the highest average level allowed by the Occupational Safety and Health Administration (OSHA) for hydrogen fluoride in air for a 40-hour work week (8-hour work days) of 3,000 ppb. For more information on this MRL, please ATSDR's Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf). Please see Section IV in this public health assessment for more information on these values (based on health effects) used to evaluate the public health implications of exposure to fluorides and related compounds released from the K-25/S-50 site.

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	Summarized Concern/Issue	ATSDR's Response
15	The true magnitude of the HF releases and long-term health effects are linked to asthma and lung damage, arthritis and bone/joint damage, neurological and foggy thinking effects, thyroid and parathyroid damage, birth defects, white and phage cell suppression, extreme fatigue, AND perpetuating DOE's entire "mysterious illness" cover up. It is deceptive for DOE public relations persons to list only the prompt symptoms of HF inhalation and leave off the other effects directly linked to K-25's mysterious illnesses.	According to ATSDR's *Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine* (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf) and the California Environmental Protection Agency's (Cal-EPA) *Chronic Toxicity Summary: Fluorides Including Hydrogen Fluoride* (available at http://www.oehha.ca.gov/air/chronic_rels/HyFluoCREL.html#download), no studies on chronic human inhalation exposure to pure hydrogen fluoride are available (ATSDR 2003; Cal-EPA 2003). In addition, no specific data are available regarding possible effects on human developmental or reproductive systems following inhalation of hydrogen fluoride (ATSDR 2003; Chemical Substances Bureau 1999). ATSDR welcomes the commenter to provide ATSDR with peer-reviewed, scientific literature that supports the health effects being mentioned as associated with long-term exposure to hydrogen fluoride to enable the agency to investigate this issue further. If nearby off-site communities were exposed to hydrogen fluoride released from the K-25/S-50 site, exposures would have likely occurred via inhalation. Chronic human exposure to low doses of hydrogen fluoride via inhalation has resulted in irritation and congestion of the nose, throat, and bronchi of lungs. In addition, there have been reports of increased bone density among workers who had long-term inhalation exposures to hydrogen fluoride (USEPA 1989). Though there have been reports of asthma and related respiratory effects in some worker studies, multiple exposures to respiratory irritants and other compounds make it difficult to determine whether these symptoms are the result of inhaled HF (Cal-EPA 2003). Nonetheless, given the evaluation in this public health assessment, adverse health effects were not expected to result in off-site communities, based on the estimated hydrogen fluoride concentrations released. In this public health assessment, ATSDR evaluated potential chronic exposures to fluoride and hydrogen fluoride (HF) released as a result of normal process operations from the K-25/S-50 site. ATSDR used a correlation between annual uranium releases and measured fluoride concentrations at the site perimeter to estimate concentrations from long-term exposure to fluoride for years before monitoring data were available. Estimated concentrations at the site perimeter will overestimate concentrations at areas of potential exposure due to the increased distance from emission sources and the effects of topographic ridges between the emission sources and exposure areas. ATSDR assumed that the largest annual HF release coincided with the highest annual uranium release. The highest estimated annual average fluoride concentration in air (less than 6 ppb in 1945) was at the F-2 station. A chronic toxicity summary prepared by the California EPA in 2003 for fluorides (including hydrogen fluoride) identified skeletal fluorosis as a critical effect with a chronic inhalation reference exposure level of 14 ug/m^3 for hydrogen fluoride and 13 ug/m^3 for fluoride (Cal-EPA 2003). The estimated maximum annual exposure concentration, less than 6 ppb (7.2 ug/m^3) for people living around the K-25/S-50 facility, is well below Cal-EPA's reference levels. As such, ATSDR concluded that the estimated long-term fluoride and hydrogen fluoride air concentrations and resulting exposures are not expected to result in adverse health effects.

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	Summarized Concern/Issue	ATSDR's Response
16	HF is highly reactive and is cumulative in the body. Hydrogen fluoride retains in the body and less than one quarter is excreted. It accumulates over time of exposure and even low doses matter.	If nearby off-site communities were exposed to hydrogen fluoride released from the K-25/S-50 site, exposures would have likely occurred via inhalation. According to ATSDR's *Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine* (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf), when you breathe in air containing hydrogen fluoride, it enters your bloodstream quickly through your lungs. Contrary to the commenter's statement that "less than one quarter [of hydrogen fluoride] is excreted," almost all of the substance that enters your body via inhalation is quickly removed from the body in the urine; although some is stored in bones and teeth. Human studies (Collings et al. 1951; Rye 1961) indicate that fluoride absorbed from inhaled hydrogen fluoride and fluoride dusts over an 8-hour work shift is excreted even during exposure, with urinary excretion peaking approximately 2–4 hours after cessation of exposure (about 10 hours following beginning of exposure) (ATSDR 2003).
17	Selenium-based glutathione (GSH) and the copper-zinc-based superoxide dimutase (SOD) are affected by hydrogen fluoride and fluorine ion effects. Glutathione is the main enzyme that clears toxic metals from the body and without it being at full potential toxic metals concentrations rise in the body leading to increases in free radical damage to cells via reactive oxygen damage (ROS). SOD is responsible for repair of the ROS damage to the cells. So, the main problem is both the loss of the mechanism that clears the toxic material and the loss of the mechanism that repairs the damage due to rise in the toxic materials driving high rates of ROS damage. There is a direct connection with the toxic releases from the DOE plants and damage to these two enzymes. The largest driver for the damage to these two enzymes turned out to be the high amounts of hydrogen fluoride emitted from the K-25 plant and the TVA coal power plants that were used to supply the coal power to run this plant. In the mid 1980s the news was clear that Oak Ridge plant operations were causing all kinds of excess illnesses in the workers and local population, as this is when the glutathione toxic metals clearance mechanism was discovered. The fluoride toxic effect and the other pollution that damaged the GSH levels raised the levels of toxic metals in person's bodies leading to levels of free radical damage and DNA damage seen in much older people.	ATSDR is not aware of any peer-reviewed scientific studies regarding the "damage or loss of the mechanism that clears the toxic material and the loss of the mechanism that repairs the damage due to rise in the toxic materials driving high rates of ROS damage" from exposure to hydrogen fluoride, but welcomes the commenter to provide copies of or references to the studies. Glutathione (GSH) is known as a substrate in both conjugation reactions and reduction reactions, catalyzed by glutathione S-transferase enzymes in cytosol, microsomes, and mitochondria. Metals, including fluoride, react with GSH as part of the normal detoxification process. This can lead to a depletion of the available GSH pool. Oxidative stress is caused by an imbalance between the production of reactive oxygen and a biological system's ability to readily detoxify the reactive intermediates or easily repair the resulting damage. All forms of life maintain a reducing environment within their cells. The cellular redox environment is preserved by enzymes that maintain the reduced state through a constant input of metabolic energy. In chemical terms, oxidative stress is a large increase (becoming less negative) in the cellular reduction potential, or a large decrease in the reducing capacity of the cellular redox couples, such as GSH. The effects of oxidative stress depend upon the size of these changes, with a cell being able to overcome small changes and regain its original state. A particularly destructive aspect of oxidative stress is the production of reactive oxygen species, which include free radicals and peroxides. Most of these oxygen-derived species are produced at low levels by normal aerobic metabolism and the damage they cause to cells is constantly repaired. The best studied cellular antioxidants are the enzymes superoxide dismutase (SOD), catalase, and glutathione peroxidase. As previously mentioned, ATSDR is not familiar with any peer-reviewed scientific studies that evaluate the "damage or loss of the mechanism that clears the toxic material and the loss of the mechanism that repairs the damage due to rise in the toxic materials driving high rates of ROS damage" from exposure to hydrogen fluoride, but invites the commenter to provide ATSDR with any scientific documents and/or references of these studies.

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	Summarized Concern/Issue	ATSDR's Response
Concerns Related to Workers		
18	Can the K-25 study on cyanide be re-done?	In the fall of 1995, employees at the K-25 site (now known as East Tennessee Technology Park, or ETTP) on the US Department of Energy (DOE) Oak Ridge Reservation (employees of Lockheed Martin Energy Systems, Inc.) reported suffering from health problems, including sleeplessness, headaches, muscle aches, fatigue, muscle tremors, and depression, and requested that the National Institute for Occupational Safety and Health (NIOSH) investigate these problems in relation to possible cyanide exposure. Although worker health issues are a concern to ATSDR, worker-related issues are under the purview of NIOSH, a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. The study began in the fall of 1996 and took place over a 4-year period. Twenty-two employees were interviewed. Very sensitive techniques, using the minimum detectable concentrations for long-term samples on the order of 1/5,000 of the most restrictive occupational exposure criteria, were used to collect air samples for cyanide. Even using these techniques, no cyanides (gaseous or particulate-borne) were detected in the air samples. The air sampling results show that the employees currently are not experiencing occupational inhalation exposures of hydrogen cyanide, cyanide salts, or any of a wide variety of gaseous or particulate-borne compounds containing the cyanide ion. Further, no evidence of any occupational exposures to these compounds by routes other than inhalation was found. A review of routine water sampling records indicates that cyanide is not a contaminant in the K-25 water supply nor is it a contaminant of concern for direct skin contact or ingestion because most of the concerned employees work in offices or similar "finished" indoor spaces. NIOSH concluded, based on the results of this evaluation, that no relationship could be established between the health problems reported by employees and chronic, occupational cyanide intoxication from exposures to those compounds or any other related substances. The findings of this investigation were presented during a public meeting held July 11, 1996, and were also published in the following report (released in July 2000): *Blade LM and Worthington KA. Health Hazard Evaluation Report No. HETA-96-0071-2584, Lockheed Martin Energy Systems, Inc., US Department of Energy Oak Ridge K-25 Site, Oak Ridge, Tennessee.* If NIOSH had concluded that workers were in fact being exposed to harmful levels of cyanide at the ETTP site, then additional study would be warranted. Based on the findings of the investigation, however, occupational exposures to cyanide were not identified. Therefore, an additional study would not be justified. For information on NIOSH's occupational energy research program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. For more information on workers studies, see ATSDR's Compendium of Public Health Activities at the ORR at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

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	Summarized Concern/Issue	*ATSDR's Response*
19	Unlike Y-12, information on people who were contaminated at K-25 and ORNL is being kept a secret. It seems nearly impossible for DOE to oversee 130 different contractors and to make sure that the health, safety, and environment is secure at all facilities. There have been recent worker injuries at Y-12, which were avoidable, and a release of fluorine from K-25. Supervision and oversight is needed of all of the contractors working at the ORR. Why are only K-25 workers being included for uranium screening in DOE's Worker Surveillance Program? Program eligibility criteria is needed to determine cancers that could be caused by radiation and cancers that could be caused by other types of exposures.	Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. NIOSH has an occupational energy research program to handle these worker-related issues. For information on this program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. If you are concerned about worker-related exposures occurring on the ORR, please contact NIOSH directly at 1-800-35-NIOSH (1-800-356-4674). In addition, specific federal regulations establish requirements for a radiological protection program, including monitoring requirements for personnel. A DOE Order delineates requirements to ensure worker protection in all environment, safety, and health disciplines. DOE's Office of Health has many responsibilities, including developing programs to protect the safety and health of workers at DOE facilities, conducting studies to determine potential health effects from exposure to hazardous substances, and developing regulations to address specific workplace hazards at DOE facilities. If you are concerned about these and other types of worker-related issues associated with the Oak Ridge Reservation, please contact DOE's Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756.

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	Summarized Concern/Issue	ATSDR's Response
20	Fluorides cause health effects similar to pesticides. In fact, HF makes rat poison, calcium fluoride, in the body and is related to an insecticide used on fruits, cryolite. Workers are full of this poison. It would be fully expected to see long-term pesticide like illnesses for workers slowly poisoned with the same poison.	Calcium fluoride (CaF_2) or fluorite, commonly called fluorspar, is a mineral that is an important natural starting material for the production of fluorine chemicals, including fluorine, hydrogen fluoride, and sodium fluoride (ATSDR 2003). Cryolite, an insecticide, is used on many vegetables, fruits, and ornamental crops (USEPA 1996). Fluoride can enter the atmosphere in dusts and aerosols from the manufacture and use of pesticides, such as sodium fluoride, sodium fluorosilicate, barium fluorosilicate, and cryolite (NAS 1971a). Most occupational exposure to fluoride occurs as a result of inhalation of hydrofluoric acid fumes or dust from cryolite or fluorspar. Skeletal fluorosis is associated with long-term exposure to very high oral doses of fluoride or occupational exposure to cryolite ($A_1F_6Na_2$) dust, which would involve inhalation and oral exposure to fluoride (ATSDR 2003). Poorly soluble fluoride compounds, such as calcium fluoride, do not appear to be well absorbed. Studies have shown that very little (<10%) fluoride was absorbed in fasting subjects injected with calcium fluoride (Afseth et al. 1987; Trautner and Einwag 1987). Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. ATSDR is not familiar with any scientific documentation supporting that K-25 workers have been found to have high levels of cryolite in their bodies, but suggests the commenter to forward this information directly to the National Institute for Occupational Safety and Health (NIOSH) at 1-800-35-NIOSH (1-800-356-4674) or the Department of Energy's (DOE's) Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756. If fluorides entered the atmosphere from the use of calcium fluoride and/or cryolite at the K-25 site, these concentrations would have been included in ATSDR's public health evaluation of off-site releases presented in Section III of this public health assessment. Please see that portion of the document for more information and ATSDR's response to comment 10 in this section of the PHA.

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	Summarized Concern/Issue	*ATSDR's Response*
21	There are some people who worked at the ORR facilities (X-10, K-25, and Y-12) and also live in the community. How do we separate exposures that could have occurred at the workplace from exposures that could have occurred from living in the community?	ATSDR is using the public health assessment process to evaluate previous studies and environmental data to determine whether releases of hazardous substances from the Oak Ridge Reservation could have affected the health of people in communities near the reservation. The public health assessment is the primary public health process ATSDR uses to • identify populations off the site who could have been exposed to hazardous substances, • determine the potential health effects of exposure, • address the site-specific health concerns of people in the community, • recommend any needed follow up public health actions to address exposure, and • communicate ATSDR's findings to the public. As mentioned on several occasions, ATSDR does not evaluate workplace exposures and does not evaluate exposures on an individual, person-by-person basis. During the public health assessment process, ATSDR scientists review environmental data to determine whether people could have been or could be exposed to contaminants off the site. ATSDR assesses site-specific factors to determine if off-site exposure to contaminants in various media (air, biota, foodstuffs, sediment, and water) could have occurred or is occurring and evaluates if there is a completed exposure pathway for people to contact substances in these media. Because ATSDR's evaluations are based on contaminant concentrations in media and potential exposures to these media in the environment—not on actual detected levels of contaminants in individuals' bodies—the site-specific exposure evaluations provide estimated doses to off-site releases that could have occurred in the community only. These evaluations do not take into account exposures potentially occurring in the workplace, which are under the purview of other agencies such as NIOSH and DOE.

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	Summarized Concern/Issue	ATSDR's Response
Concerns about Fluoride (Fluorine), Hydrogen Fluoride, Uranium Hexafluoride, Uranium, and Uranyl Fluoride		
22	A 2000 DOE report on K-25 states that fluorine/fluoride was used/released in massive amounts, but the report did not quantify the fluoride/fluorine releases or reference sources of information.	Even after a review of available documents and emission reports, DOE has not compiled any estimates of annual airborne fluoride releases (except as included in UF_6 releases). Thus no record of long-term fluoride emissions is available. Measurements of airborne fluoride concentrations were, however, collected at six sampling locations around the perimeter of K-25 from 1971 to 1985. To estimate concentrations from long-term exposure to fluoride for years before monitoring data were available, ATSDR used a correlation between annual uranium releases and measured fluoride concentrations at the site perimeter. The relationship between the estimated uranium emissions and measured fluoride air concentration for the 1971–1985 period is used to predict the annual average fluoride air concentrations for years before and after fluoride was measured (see Table 9 and Figure 17). Estimated concentrations at the perimeter (Station F-2, at the perimeter of the K-25 site about 0.5 miles downwind or northeast of the K-25 facility) represent the point of maximum airborne fluoride concentrations, which will overestimate concentrations at areas of potential exposure due to increased distance from emission sources and the effects of topographic ridges between the emission sources and exposures areas. Locations of monitoring stations (F-1 to F-6) are presented in Figure 14 of the PHA. These records measured actual airborne fluoride concentrations over the sampling duration of either 24-hour or 6- to 7-day collection periods and the reported results include annual averages and maximum 7-day concentrations for each station. All of the monitoring results are reported in the annual environmental monitoring reports for the respective years. Figure 15 presents the measured airborne fluoride concentrations (in parts per billion, or ppb) for three stations (F-1, F-2, and F6) over a 16-year period (1971 to 1985). All of the annually averaged fluoride concentrations are less than 2 ppb and relatively uniform for the different years. The highest recorded value of 26.3 ppb for a 24-hour sample at station F-2 is the highest measured air fluoride concentration for any station during any time period, and it is about two times higher than any other measured value. As shown in Figure 17 of the PHA, the highest predicted yearly fluoride air concentration was about 6 ppb in 1945 at the K-25 perimeter locations. Also, as with the measured short-term fluoride concentrations, station F-2 had the highest predicted annual average fluoride concentrations due to its downwind location. The maximum measured short-term fluoride concentration (24-hour) at the F-6 station, located about 5 miles upwind (northwest) of the K-25 facility, was 10.9 ppb in 1976. ATSDR evaluated the potential past exposure pathways for fluorides (in both fluoride and fluorine forms) to reach off-site communities from the K-25/S-50 site. Fluoride exposures were evaluated for Union/Lawnville from the K-25 site for 1945 to 1995 and for the Sugar Grove community from the K-25 site for 1960 to 1995. Fluoride exposures from the S-50 plant from 1944 to 1945 were evaluated for both Happy Valley and Union/Lawnville. ATSDR also evaluated potential fluoride exposures for ETTP workers and the nearest off-site communities in the event that a natural disaster or an accident resulted in releases from the UF_6 cylinder storage yards. See Sections III and IV in the PHA for more information on this public health evaluation.

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	Summarized Concern/Issue	*ATSDR's Response*
23	Oak Ridge scientists have not reported some issues occurring in Oak Ridge, such as those involving depleted uranium. Depleted uranium shows up in soldiers; it is in their lymphatic systems and in their bones.	Natural uranium, enriched uranium, and depleted uranium are mixtures of primarily three uranium isotopes (U-238, U-235, and U-234; chemically similar but with a different number of neutrons). Natural uranium is, by weight, more than 99% U-238, 0.72% U-235, and 0.005% U-234. Enriched uranium is more than 0.72% U-235 by weight, and depleted uranium is less than 0.72% U-235 by weight. All three isotopes are radioactive but have different specific activities (that is, radioactivity per gram of material). U-238 has the lowest specific activity, and U-234 has the highest. The K-25 site no longer contains UF_6 cylinders holding depleted uranium hexafluoride. In December 2006, DOE completed its removal of the UF_6 cylinders from the six former cylinder storage yards (see Figure 12 in this PHA for the approximate location of the storage yards). From March 2004 to December 2006, DOE shipped approximately 6,000 UF_6 cylinders collectively containing about 119 million pounds of UF_6 off site to DOE's Portsmouth Gaseous Diffusion Plant (PORTS) in Portsmouth, Ohio (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007). Regarding on-site uses and exposures to depleted uranium, ATSDR's public health assessments will not be investigating these issues. Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. NIOSH has an occupational energy research program to handle these worker-related issues. For information on this program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. If you are concerned about worker-related exposures occurring on the ORR, please contact NIOSH directly at 1-800-35-NIOSH (1-800-356-4674). There are federal regulations that establish requirements for a radiological protection program, including monitoring requirements for personnel. A DOE Order delineates requirements to ensure worker protection in all environment, safety, and health disciplines. DOE's Office of Health has many responsibilities, including developing programs to protect the safety and health of workers at DOE facilities, conducting studies to determine potential health effects from exposure to hazardous substances, and developing regulations to address specific workplace hazards at DOE facilities. If you are concerned about these and other types of worker-related issues associated with the Oak Ridge Reservation, please contact DOE's Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756.

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	Summarized Concern/Issue	ATSDR's Response
24	An undocumented release that occurred was the purge of the cascades at K-25, which occurred on a weekly basis. The purge of the cascade resulted in large and presumably undocumented releases of UF6. One massive release happened in the purge cascade that went on for days and dumped nearly a foot of UO_2F_2 on the floors, and HF vapors rained down clear to Ohio.	"A cascade is a system of gaseous diffusion process components arranged so as to enrich uranium in its U-235 component." During the gaseous diffusion process, uranium hexafluoride (UF_6) gas was put into a sequence of vessels that formed the "gaseous diffusion cascade." The "purge cascade" was part of the equipment used in the gaseous diffusion process. In the purge cascade, light gases (e.g., fluorine and air) were separated from the UF_6 that was being enriched. These light gases were removed so that they would not build up at the top of the cascade and prevent the flow of enriched UF_6 (ChemRisk 1999a). In the Task 6 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 6 report), the Task 6 team conducted an independent evaluation of airborne uranium releases from the K-25/S-50 site by reconstructing releases for certain time periods. As part of its evaluation, the Task 6 team analyzed actual monitoring data obtained from the purge cascade system to calculate purge cascade releases. In fact, according to the Task 6 report, purge cascade releases "…were the only airborne releases…historically monitored on a routine basis" from the K-25 site. Although, the releases from the purge cascade constituted a small portion of the total uranium releases from the K-25 site. In fact, based on the Task 6 report's analysis, "…historical releases from the purge cascade were less than 1 percent of the total airborne uranium releases from K-25" (ChemRisk 1999a). More information on the Task 6 team's release estimates for the purge cascades is available in Section 2.2.3 of the Task 6 report available online at http://health.state.tn.us/CEDS/OakRidge/Uranium.pdf.
25	The K-29 incident resulted in large and presumably undocumented releases of UF_6.	On May 27, 1981, low-level radioactive uranium hexafluoride leaked from a compression cell at the K-29 facility. According to the Task 6 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 6 report) (at http://health.state.tn.us/CEDS/OakRidge/Uranium.pdf), the release from the cell following the high temperature reaction resulted in the atmospheric release of a total of 3.3E-03 curies of radioactivity and 2,000 grams of uranium (64 grams of uranium 235 and 1,936 grams of uranium 238). The same exact amounts were also released to the atmosphere during this incident as a result of a ruptured breached converter. Thus, a total of 4,000 grams of uranium were released to the atmosphere due to this compression cell leak at the K-25 facility. When preparing its 1999 report, the Task 6 team developed a database to track airborne uranium releases from the K-25 site for 1944 to 1995. Data were obtained from the K-25 Uranium Accountability Group, which was responsible for keeping track of uranium moving throughout the plant. The Task 6 team obtained material release reports that kept record of accidental and chronic environmental releases. These accidental atmospheric releases from the K-29 facility were recorded and the uranium release amounts were incorporated into the past release estimates in the Task 6 report (see Table E-1 on page E-32 of the report). In this public health assessment, ATSDR used the Task 6 report's estimates to assess potential past exposure for off-site communities to releases of UF_6 from the K-25 site. Thus, the estimated atmospheric releases from this 1981 accident are incorporated into the evaluations conducted by both the Task 6 team in its dose reconstruction and by ATSDR in this PHA. Please see the Task 6 report and Sections III and IV in this PHA for ATSDR's evaluation of these releases.

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	Summarized Concern/Issue	ATSDR's Response
26	There are places on the reservation that are unmarked burial grounds that contain uranium.	On November 21, 1989, the ORR was listed on the U.S. Environmental Protection Agency's (USEPA) final National Priorities List (NPL) because of many on-site operations that produced radioactive and nonradioactive wastes (EUWG 1998; USEPA 2004c). Various contaminants including uranium are present in old waste sites at the ORR. These waste sites constitute 5% to 10% of the reservation. Releases from these waste sites, as well as leaching caused by abundant rainfall and high water tables, have contributed to the radionuclide contamination of surface water, groundwater, soil, and sediments at the ORR (EUWG 1998). DOE is conducting remedial actions at the reservation under a Federal Facility Agreement (FFA) to ensure that appropriate clean up actions are selected, and to make sure that hazardous wastes associated with former and current ORR activities are adequately studied (USDOE 2003b). Remedial activities associated with wastes from K-25/S-50 activities are detailed in this public health assessment in Section II.C. and in Appendix C. To expand upon the efforts of the Tennessee Department of Health's (TDOH) Oak Ridge Health Studies, ATSDR scientists conducted a review and a screening analysis of the department's Phase I and Phase II screening-level evaluation of past exposure (1944-1990) to identify contaminants of concern for off-site exposure that required further evaluation. Pursuant to this review and its addressing of community concerns about uranium, ATSDR scientists conducted a public health assessment on off-site Y-12 uranium releases (released in January 2004; available at http://www.atsdr.cdc.gov/HAC/PHA/oakridgey12/oak_toc.html) and prepared this public health assessment to evaluate off-site K-25 uranium (and fluoride) releases. In addition, ATSDR evaluated off-site releases of radioactive uranium in its *White Oak Creek Radionuclide Releases Public Health Assessment* (available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html) and the potential for off-site uranium releases via groundwater (available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html) in a PHA titled *Contaminated Off-Site Groundwater from the Oak Ridge Reservation*. For copies of these other assessments, please contact ATSDR toll-free at 1-800-232-4636. It is important to note that although uranium is present on the reservation, the public does not have access to these areas. ATSDR is evaluating releases that could potentially leave the reservation and affect off-site communities—not contaminants that remain on site. DOE has and continues to conduct remedial activities to remove and/or contain the wastes in these areas to prevent off-site contaminant migration. In our public health assessments for the Oak Ridge Reservation, ATSDR assesses remedial activities that have occurred at the reservation and evaluates any on-site wastes (remaining in burial grounds and other areas) that could travel off the reservation to off-site communities.

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	Summarized Concern/Issue	ATSDR's Response
27	There are millions of tons of uranium kept in UF_6 storage tanks at the ORR.	The K-25 site no longer contains UF_6 cylinders holding depleted uranium hexafluoride. In December 2006, DOE completed its removal of the UF_6 cylinders from the six former cylinder storage yards (see Figure 12 in this PHA for the approximate location of the storage yards). From March 2004 to December 2006, DOE shipped approximately 6,000 UF_6 cylinders collectively containing about 119 million pounds of UF_6 off site to DOE's Portsmouth Gaseous Diffusion Plant (PORTS) in Portsmouth, Ohio (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007).
28	You need to recognize and accurately report that the fluoride component is one of the biggest industrial problems here today in Oak Ridge.	In conducting public health assessments, ATSDR scientists are evaluating and analyzing the information, data, and findings from previous studies and investigations to assess the public health implications of past, current, and future exposures. For our work at the Oak Ridge Reservation, ATSDR's role is to evaluate potential exposures to fluoride and other contaminants potentially released from the reservation, to assess the possible public health impacts of potential exposures on off-site residents, and respond to community concerns regarding the releases and health effects associated with these contaminants. Our mission is not, however, to investigate and report industrial issues concerning the Oak Ridge Reservation. Instead, our assessments are health-based and our goal is to investigate potential public health hazards that might exist from possible releases from the ORR to off-site areas. ATSDR uses the public health assessment process to • identify populations (groups of people) off the site who could have been exposed to hazardous substances at levels of health concern, • determine the public health implications of exposure, • address the site-specific health concerns of people in the community, • recommend any needed follow-up public health actions to address exposure, and • communicate ATSDR's findings to the public.
29	In addition to Oak Ridge residents, there are quite a few people living in surrounding areas who are concerned about fluoride and fluorine products.	Many community members, from Oak Ridge and other surrounding areas, notified ATSDR of concerns about potential fluoride and fluorine products released from the Oak Ridge Reservation. Fluoride and fluorine products were not evaluated previously by the state in its 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study* because these substances are primarily associated with acute (short-term) health effects, whereas the state was interested in evaluating chronic exposures. To address these community concerns, in this public health assessment ATSDR evaluates the public health implications for off-site exposures to fluorides and related compounds (including hydrogen fluoride and uranyl fluoride) released from the K-25/S-50 site in the past. Please see Sections III and IV in this public health assessment for ATSDR's evaluation of potential exposures to these substances released from the K-25/S-50 site.

	Summarized Concern/Issue	*ATSDR's Response*
30	Why did the State not specifically look at fluorine, fluoride and UF_6? He felt that the State of Tennessee's screening process for past exposures was wrong, noting that fluoride gas converts to HF, which penetrates through the skin to the bone. Reports used for the state's feasibility study and dose reconstruction did not qualify fluorine or fluoride releases or reference sources of information. Fluorides should have received more attention during the Dose Reconstruction. No systematic effort was made during the Oak Ridge Dose Reconstruction or since the effort was completed to go back with additional information and make sure that nothing was missed or not assessed quantitatively. Fluorine/fluorides definitely need further attention based on the amount now known to have been released. There was avoidance in putting hydrogen fluoride from the screening process into the deeper ORHASP investigations and this then keeping the biggest of Oak Ridge problems out of public sight.	In its 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study*, the state identified fluorine and fluoride compounds as substances released from the K-25 site and considered the potential of these releases to impact the health of people living near the reservation. According to the feasibility study, the state did not evaluate fluorine and fluoride compounds further because these substances are primarily associated with acute exposures—they are not generally related to chronic, long-term health effects which the state was investigating. Please see Appendix H for the brief on the 1993 Phase I feasibility study. Copies of the Tennessee Department of Health reports are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780). Nonetheless, ATSDR added these substances to its list of contaminants to investigate further, and as a result, ATSDR evaluates the public health implications for off-site exposures in the past to fluorides and related compounds (including hydrogen fluoride and uranyl fluoride) released from the K-25/S-50 site in this public health assessment. ATSDR added these substances to its list of public health assessments because of the agency's experience at the Paducah Gaseous Diffusion Plant in Kentucky that had many of the same applications of fluoride products as K-25 and because individuals in the community expressed concern to ATSDR about potential exposures to these substances. ATSDR discussed these issues with the state, and subsequently decided to evaluate fluoride and related substances. Please see Sections III and IV in this public health assessment for ATSDR's evaluation of potential exposures to these substances released from the K-25/S-50 site.

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	Summarized Concern/Issue	ATSDR's Response
31	Most people had been under the impression that only uranium was released from the K-25 facility, but then they later found out that this was not the case. There was recycling and other elements that were blended at the facility. Would this change the sampling data used in the K-25 public health assessment or was this taken into account?	Phase I of the Tennessee Department of Health's (TDOH) Oak Ridge Health Study evaluated all past releases of hazardous substances and operations at the ORR. The study indicated that four substances had the largest potential risk for adverse health effects—radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. A brief summary of the Phase I Feasibility Study is provided in Appendix H. In addition to conducting a full dose reconstruction analyses in Phase II, the state included further detailed screening analyses for releases of uranium, radionuclides, and other toxic materials from Y-12 and K-25 that had not been fully characterized in Phase I (a brief in Appendix H summarizes the *Screening-Level Evaluation of Additional Potential Materials of Concern, Task 7*). By 2000, many contaminants used at the K-25 facility were unclassified and these were considered in the state's supplementary evaluation. [Please note, however, that the sampling data for this PHA did not change because ATSDR already had the original data.] During this supplementary analysis, the state took into account additional contaminants as well as the recycling and blending of substances associated with the K-25 site. Preliminary screening indices for these additional contaminants from K-25 were below the Oak Ridge Health Agreement Steering Panel (ORHASP) decision guide of one chance in 10,000. The ORHASP final report is available at http://health.state.tn.us/CEDS/OakRidge/ORHASP.pdf. In addition, ORHASP noted the following: "With even the most conservative assumptions concerning potential material losses, none of the formerly classified substances at either Y-12 or K-25 qualified for additional evaluations." ATSDR scientists conducted a review and a screening analysis of the department's Phase I and Phase II screening-level evaluation of past exposure (1944-1990) to identify contaminants of concern for further evaluation. ATSDR also had reviewers analyze the screenings to evaluate whether the findings were scientifically appropriate and suitable for making public health decisions. Uranium emissions represented the primary releases from the K-25 facility, which were evaluated by the state, but fluoride was not previously evaluated. Using ATSDR's past evaluations of gaseous diffusion plants and because of community concerns received on this issue, ATSDR recognized that fluoride could be a potential problem and wanted to evaluate it. In addition, other radiological by-products released when uranium was released were evaluated in the state's screening assessments. ATSDR also considers these in its PHA when estimating radiological doses. As a result, this public health assessment evaluates potential exposures to uranium, fluoride, hydrogen fluoride, and radiological by-products released from the K-25 facility. Please see Sections III and IV in this PHA for more information on ATSDR's public health evaluation of potential exposures to these contaminants released from the K-25 site.

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	Summarized Concern/Issue	*ATSDR's Response*
32	Oak Ridge also burned uranyl fluoride compounds (UO_2F_2) in the incinerator (4 million pounds per year) and the elemental toxic effects of fluoride are not mutable.	Without additional information, ATSDR is unable to determine whether the commenter is referring to the Toxic Substances Control Act (TSCA) Incinerator or an incinerator that might have operated historically at the K-25 site. If the commenter is referring to the TSCA Incinerator, ATSDR evaluated the amount of waste burned each year at this facility in the *Toxic Substances Control Act Incinerator (TSCA) Public Health Assessment* (released in December 2005; available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/tsca/index.html). From 1991 to 2002, the total amount of waste burned per year at the TSCA Incinerator was almost always less than 2,000 tons per year (or less than 4,000,000 pounds per year), including a variety of wastes. For reference, please see Figure 5 in the TSCA PHA that details the annual treatment statistics for the incinerator. ATSDR's evaluation of wastes treated at the TSCA Incinerator indicates that it is unlikely that the amount of one substance noted by the commenter—uranyl fluoride—could have been released in the amount of 4,000,000 pounds per year as the total amount of all waste burned per year was almost always less than this amount. Thus, the available data do not indicate that such quantities of waste were ever treated at the TSCA Incinerator. ATSDR welcomes any additional information from the commenter on these statistics to enable further investigation.

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	Summarized Concern/Issue	ATSDR's Response
33	K-25 routinely released huge amounts of HF gas to the air both during its operation and now during dismantlement from many trapped deposits. Oak Ridge's management rather than truthfully report the problem designed a carefully crafted plan to attempt to cover it up and also to make the local doctors rich in supporting the cover up. Oak Ridge shut down the K-25 gas diffusion plant and this stopped part of the larger hydrogen fluoride releases in the area and it also cut some 3,000 megawatts of load from the TVA coal plants, which reduced hydrogen fluoride emissions more. This put the emissions from the plants into a sudden nose-dive to help conceal the rising health problem from the local townships. Oak Ridge also pulled out its old scientists to deny the huge losses of HF from the K-25 plant. Thousands of tons of HF were released from K-25, which lost around 10% of the UF6 it processed. The danger of K-25 was hydrogen fluoride systemic chemical poisoning. The releases of huge amounts of a systemic poison called hydrogen fluoride became a quadruple effect on the community closest to the nuclear bomb factory of Oak Ridge. DOE admits that thousands of inadvertent UF6 and HF K-25 releases occurred, but the real order of magnitude is more a thousand-thousand releases.	Historically, people living in communities around the K-25/S-50 site could have received chronic exposures to fluoride and hydrogen fluoride (HF) as a result of releases during normal process operations. In this public health assessment (please refer to sections III and IV of this document), ATSDR used a correlation between annual uranium releases and measured fluoride concentrations at the site perimeter to estimate concentrations from long-term exposure to fluoride for years before monitoring data were available. Estimated concentrations at the site perimeter will overestimate concentrations at areas of potential exposure due to the increased distance from emission sources and the effects of topographic ridges between the emission sources and exposure areas. ATSDR assumed that the largest annual HF release coincided with the highest annual uranium release. The highest estimated annual average fluoride concentration in air (less than 6 ppb in 1945) was at the F-2 station. A chronic toxicity summary prepared by the California EPA in 2003 for fluorides (including hydrogen fluoride) identified skeletal fluorosis as a critical effect with a chronic inhalation reference exposure level of 14 ug/m3 for hydrogen fluoride and 13 ug/m3 for fluoride (Cal-EPA 2003). The estimated maximum annual exposure concentration, less than 6 ppb (7.2 ug/m3) for people living around the K-25/S-50 facility, is well below Cal-EPA's reference levels. As such, ATSDR concluded that the estimated long-term fluoride and hydrogen fluoride air concentrations and resulting exposures are not expected to result in adverse health effects. Acute HF and fluoride exposures could have resulted from accidents or controlled releases. ATSDR estimated historic acute HF concentrations using accident records and air dispersion modeling. ATSDR used short-term fluoride measurements, worst-case assumptions, and a modeled dispersion estimate from the September 1, 1958, accidental release to calculate acute exposure concentrations to HF. The highest measured short-term (24-hour) fluoride concentration of 26.3 ppb occurred in 1975. Similarly, modeled short-term (hourly) HF concentrations of 156 and 27 ppb were estimated for the Sugar Grove and Union/Lawnville communities, respectively, for the September 1958 accidental UF6 release (Table 11). It is important to note that because these estimated worst-case modeled concentrations are based on health-protective assumptions, the concentrations are likely overestimated for several reasons: 1) the fate and transport mathematical model does not account for the complex topography of the K-25 site; 2) ATSDR does not have any record of the specific meteorological conditions at the time of this release so the most health-protective meteorological conditions were used to estimate concentrations; 3) ATSDR assumed that off-site exposure occurred outside at the point of maximum HF concentration; and 4) ATSDR assumed that all of the UF6 released was discharged to the atmosphere with no retention in the K-1131 building. ATSDR's minimal risk level (MRL) for acute inhalation exposure to HF and fluorine is 20 ppb and 10 ppb, respectively. The 20 ppb MRL for HF in air is 25 times lower than exposures that caused mild upper respiratory tract inflammation in human volunteers exposed for 1 hour (Lund et al. 1999). The highest average level (time weighted average) allowed by the Occupational Safety and Health Administration (OSHA) for HF in air for a 40-hour work week made up of 8-hour work days is 2.5 mg/m3 (3 ppm or 3,000 ppb). The 20 ppb MRL for air concentrations of HF is 150 times lower than OSHA's occupational level.

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	Summarized Concern/Issue	*ATSDR's Response*
33	*Continued*	If sensitive people in nearby communities were exposed at these acute (short-term) levels, minor temporary adverse health effects such as nose, throat, and eye irritation could have occurred. However, because there is so much uncertainty associated with historical events, past acute exposure to the maximum air concentrations of fluoride and hydrogen fluoride poses an indeterminate public health hazard because sufficient data are not available to make a professional judgment about the level of health hazard. Further, ATSDR used worst-case assumptions and modeled air data to evaluate historic short-term exposure to hydrogen fluoride released as UF6 during accidents or equipment maintenance at the K-25 site, which are not appropriate to use as a basis for a health hazard category because they are estimated worst-case concentrations that were highly unlikely to have actually occurred and because they are based on modeled results with a high degree of uncertainty. Therefore, sufficient historical environmental monitoring data do not exist to enable ATSDR to make a conclusion about the true health hazard that existed from acute exposure to HF and fluoride exposures.
34	It is hard to imagine that DOE could not pinpoint a fluorine leak in an old building that made several guards sick, closed down a portal, evacuated an "at risk" part of the plant, and went on for a week or longer. How much was emitted to air? This shows continued disregard for environment, health, and safety to allow such releases to continue as they are cumulative and linked to long-term health damage.	ATSDR believes the commenter is referring to a fluorine leak that occurred at the K-1302 building at the K-25 site in December 2000. Regarding the worker health issue part of this comment, though worker health issues are a concern to ATSDR the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. NIOSH has an occupational energy research program to handle these worker-related issues. For information on this program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. If you are concerned about worker-related exposures occurring on the ORR, please contact NIOSH directly at 1-800-35-NIOSH (1-800-356-4674). If you are concerned about worker-related issues associated with the Oak Ridge Reservation, you can also contact DOE's Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756.

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	Summarized Concern/Issue	ATSDR's Response
35	The salt reactor is not being decontaminated but being decommissioned.	The Molten Salt Reactor Experiment (MSRE) is located not at the K-25 site but south of the former X-10 site, now known as the Oak Ridge National Laboratory (ORNL). From June 1965 to December 1969, ORNL ran the MSRE to demonstrate the positive aspects of the concept of molten uranium fluoride salt reactors. After the reactor was shut down, fuel salt from the MSRE circuit was drained to two drain tanks. The molten salt was comprised of a mixture of zirconium fluoride, lithium fluoride, uranium fluoride, and beryllium fluoride, as well as a small portion of plutonium fluoride that was added to the molten salt. For the purposes of decontamination, circulating of a "clean" salt was used and released into a third drain tank. Surveillance and maintenance activities of the facility began when it was closed in 1969 and have continued since that time (Haghighi et al. 2002; SAIC 2005). Surveillance activities conducted after the MSRE closed suggested that the facility posed a risk to human health and the environment because of elevated levels of gaseous uranium hexafluoride (UF_6) and fluorine in the off-gas lines connected to the three drain tanks and because of uranium deposits in the auxiliary charcoal bed cell. Following the detection of these gases and uranium deposits, activities were initiated to manage the fuel and flush salts safely and to remove the uranium deposits (SAIC 2005). In July 1998, an interim action record of decision (ROD) signed to remove the flush salts and fuel from the MSRE called for chemically treating the salt, separating the uranium and converting it to a stable oxide, and transferring the uranium to the ORNL uranium 233 repository. In fiscal year 2003, many actions associated with salt processing were finished, such as startup testing on fuel salt removal equipment and discussions of off-site disposal to the Waste Isolation Pilot Plant in New Mexico. In fiscal year 2004, DOE issued a Notification to Proceed with Fuel Salt Disposition (FSD) actions. In December 2004, remedial activities began at the first of three tanks. The purpose of the remedial interim action, according to the ROD, is to mitigate current on- and off-site potential risks resulting from the salts within the drain tanks. As of fiscal year 2005, remedial actions for the fuel and flush salt removal at the MSRE were still in progress (SAIC 2005). In 1998, activities began to remove the uranium deposits from the MSRE. As of fiscal year 2005, the uranium-laden charcoal was being kept in interim storage at the MSRE, where it will possibly remain for 2 years until it is either shipped off site to the Nevada Test Site for disposal or processed for storage at the Melton Valley Storage Tanks (MVSTs). Further characterization of the auxiliary charcoal bed indicated that the remaining uranium 233 in the charcoal bed (about 350 grams to 550 grams) exceeds the goal for this action (250 grams). Alternative approaches to remove the uranium deposited in the upper section of the auxiliary charcoal bed are currently being evaluated (SAIC 2005). Therefore, as detailed above, actions to decontaminate the MSRE have been and are being taken to eliminate potential risks to human health and the environment (SAIC 2005).

VII. Women and Children's Health Considerations

Contaminants in the environment may sometimes act on women and children differently from the way those same contaminants affect the general population. Women and children are smaller than the population average, and as a result they may be susceptible to small quantities of contaminants that would have no effect on others. Hormonal variations, pregnancy, and lactation can all change the way a woman's body responds to some substances. Through the placenta or in the mother's milk, past exposures experienced by the mother, as well as exposure during pregnancy and lactation, can similarly expose a fetus or preborn infant to chemicals. Depending on the stage of pregnancy, the nature of the chemical involved, and the dose of that chemical, fetal exposure can result in problems such as miscarriage, stillbirth, and birth defects.

ATSDR recognizes that developing young people—whether fetuses, infants, or children—have unique vulnerabilities. Children are more vulnerable than are adults for many reasons, beginning with the fact that children are not simply small adults. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface area in proportion to their body volume. Behavior and lifestyle also influence exposure. Children crawl on floors, put things in their mouths, play close to the ground, and spend more time outdoors.

In addition to physical and behavioral differences, children's metabolic pathways, especially in the first months after birth, are less developed than are those of adults. In some instances children are better able to deal with environmental toxins. In others, they are less able and more vulnerable; some chemicals that are not toxins to adults are highly toxic to infants.

In the first months and years of life children grow and develop rapidly. If during this period some organ systems—especially the nervous and respiratory systems—are exposed to high concentrations of certain contaminants, permanent damage may occur. Because of their lack of knowledge and their dependence on adults for decisions, young children have less ability to avoid those hazards which may affect them but might not affect adults.

In this PHA, the special susceptibilities of women and children are factored into the health comparison values we use to determine whether environmental concentrations of uranium and HF are likely to cause adverse health effects. Here we use minimal risk levels (MRLs), as

derived by ATSDR, to assess the potential for adverse nonradiological health effects. MRLs are designed to be protective of persons who are particularly susceptible to the toxicologic effects of each chemical (ATSDR 1999a, 2003). Consequently, the estimated exposure calculations and resulting health determinations for nonradiological contaminants are protective for all sensitive persons, including women and children.

For radiological considerations, the dose calculations include age-specific factors to account for the special susceptibilities of children. The ICRP dose coefficients, which underlie the dose calculations in this PHA, apply to several age groups (age at time of intake): 3 months, 1 year, 5 years, 10 years, 15 years, and adults. The ICRP does not specifically evaluate the different sexes. The organ-specific dose coefficients do, however, account for the susceptibilities of the reproductive organs—the testis and uterus. Thus for both men and women, the dose assessment process factors reproductive susceptibility into radiological exposures.

VIII. Conclusions

This public health assessment (PHA) addresses historic off-site (community) exposures to radioactive and nonradioactive hazardous substances released to the atmosphere from the Oak Ridge Gaseous Diffusion Plant (K-25) and from the S-50 liquid thermal diffusion plant. It also assesses potential current and future exposures from the K-25 site, now known as the East Tennessee Technology Park. Historic emissions of UF_6 from the K-25/S-50 facility resulted in potential exposures to uranium and fluorides (primarily as HF) to people living near the site. The process for evaluating public health effects from potential exposures to K-25-released contaminants focused on the closest or most vulnerable communities for both acute (short-term) and chronic (long-term) airborne releases of uranium, associated radionuclides (Np 237 and Tc 99), and fluorides (as HF).

Potential exposures were evaluated for the three residential areas closest to the K-25/S-50 facility: the Union/Lawnville community (about 4 km southwest of K-25), the Sugar Grove community (about 1.4 km north of K-25), and the Happy Valley labor camp (about 1.5 km south of K-25). ATSDR evaluated short-term (1 to 24 hours) and long-term (annual) exposures for these areas using the maximum estimated short- and long-term UF_6 emission rates and air dispersion and dose assessment models.

We estimated contaminant concentrations for all areas. Using these historic chronic off-site exposures, we determined that historic releases of uranium, ionizing radiation, fluoride, and hydrogen fluoride, as well as acute exposure to uranium and ionizing radiation from the K-25 and S-10 sites, constitute *no apparent public health hazard*. This determination means that although people may have been exposed to these contaminants, they were not exposed at levels expected to cause any adverse health effects.

Historic off-site acute exposure to fluoride and HF released as UF_6 during accidents or equipment maintenance at the K-25 site was unlikely, but possible. Nevertheless, because an insufficient amount of environmental air monitoring data are available to determine the actual concentrations of fluoride and HF released during historical accidents or during equipment maintenance, ATSDR classifies this exposure as an *indeterminate public health hazard*. ATSDR

uses the *indeterminate public health hazard* conclusion category when sufficient data are not available to make a professional judgment about the level of health hazard.

ATSDR estimated historic, off-site, acute hydrogen fluoride concentrations using fate and transport mathematical models. Those models incorporated conservative worst-case assumptions and modeled air data. Because, however, the estimated hydrogen fluoride air concentrations are worst-case estimates that are highly unlikely to have actually occurred, and because of the high degree of uncertainty in the modeled results, use of these estimated concentrations as a basis for a health hazard category is not appropriate.

ATSDR has determined as unlikely but possible that following the largest historic short-term or accidental UF_6 releases, acute exposures to hydrogen fluoride and fluoride occurred at the Sugar Grove and Union/Lawnville communities. And because ATSDR does not have specific information to rule out the maximum calculated exposures, we have identified the potential short-term exposures as *an indeterminate public health hazard*. Although ATSDR used worst-case assumptions and modeled air data to evaluate historic short-term exposure to fluoride and hydrogen fluoride released as UF_6 during accidents or equipment maintenance at the K-25 site, an insufficient environmental sampling data history prevents ATSDR from arriving at any conclusions about the true health hazard presented by past accidental or equipment-maintenance releases.

Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the site. ATSDR's evaluation shows that no potential current or future hazards to off-site residents have been identified at this time; site remediation is, however, ongoing.

ATSDR has made these determinations using an evaluation of available historic air and soil monitoring data, contaminant release estimates, physical setting of the site and surrounding area, multiple years of site-specific meteorological data, and air dispersion models developed and approved by the U.S. EPA and the NRC. Although each of the data sources has limitations, the cumulative data set provides an adequate basis for making these public health determinations.

IX. Recommendations

Having evaluated past, current, and future public health activities and available environmental information, ATSDR recommends that DOE continue its precautionary measures to prevent any off-site future releases of contaminants potentially remaining at the K-25 site.

X. Public Health Action Plan

The Public Health Action Plan (PHAP) for K-25/S-50 site releases describes actions to be taken by ATSDR and other government agencies at and in the vicinity of the site after the completion of this public health assessment. The purpose of this PHAP is to ensure that this public health assessment not only identifies public health hazards, but that it also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. If additional information about K-25/S-50 releases becomes available, that information could change any conclusion or conclusions of this public health assessment; if that occurs, then human exposure pathways should be reevaluated and these conclusions and recommendations should be amended, as necessary, to protect public health.

- ORR staff will notify ATSDR if environmental monitoring data indicate that as a result of ongoing remedial activities at the site, a release has occurred. On receipt of such notification, ATSDR will determine appropriate public health actions.
- ATSDR will develop and implement additional environmental health education materials as necessary to help community members understand the findings and implications of this public health assessment.

XI. Preparers of Report

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Appendix A. ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the US Environmental Protection Agency (USEPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-800-CDC-INFO (1-800-232-4636).

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

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

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

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

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

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

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

Antagonistic effect
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

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

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring
Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake
The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

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

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

CAP [see Community Assistance Panel.]

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

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

Carcinogen
A substance that causes cancer.

Case study
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

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

CAS registry number
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

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

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

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

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

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

Completed exposure pathway [see exposure pathway].

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

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

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

Delayed health effect
A disease or an injury that happens as a result of exposures that might have occurred in the past.

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

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

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

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

Disease prevention
Measures used to prevent a disease or reduce its severity.

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

DOD
United States Department of Defense.

DOE
United States Department of Energy.

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

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

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

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

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

Epidemiologic surveillance [see Public health surveillance].

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

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

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

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

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

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

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

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

Geographic information system (GIS)
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

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

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

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

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

Hazardous Substance Release and Health Effects Database (HazDat)
The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

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

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

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

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

Health promotion
The process of enabling people to increase control over, and to improve, their health.

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

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

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

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

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

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

In vitro
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

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

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

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

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/cm^2
Milligram per square centimeter (of a surface).

mg/m^3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

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

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

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

Mutagen
A substance that causes mutations (genetic damage).

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

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

National Toxicology Program (NTP)
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

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

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

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

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)
A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

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

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

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

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

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

Prevalence survey
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

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

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

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

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

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

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

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

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

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

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

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

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

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

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

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

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

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

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

RFA
RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

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

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

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

Sample size
The number of units chosen from a population or an environment.

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

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

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

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

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

Substance
A chemical.

Substance-specific applied research
A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

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

Surveillance [see public health surveillance]

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

Synergistic effect
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen
A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

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

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

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

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

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

U.S. EPA
United States Environmental Protection Agency.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/ocepaterms/)
National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html

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Appendix B. Summary of Other Public Health Activities

Summary of ATSDR Activities

Exposure investigations, health consultations, and other scientific evaluations. ATSDR health scientists have addressed current public health issues and community health concerns related to two areas affected by Oak Ridge Reservation (ORR) operations—the East Fork Poplar Creek (EFPC) area and the Watts Bar Reservoir area. Summaries of some of the ATSDR public health activities at the Watts Bar Reservoir area were presented in Section II.F.1 of this document.

Following are summaries of other ATSDR public health activities related to the Oak Ridge Reservation.

- *ATSDR science panel meeting on the bioavailability of mercury in soil, August 1995.* Using an evaluation of the DOE studies conducted on mercury, ATSDR concluded that outside expertise was needed to assess technical details related to mercury. As a result, a science panel was created that consisted of experts from various government agencies (e.g., U.S. U.S. EPA), private consultants, and others with experience in metal bioavailability research. The panel's goal was to select procedures and strategies that could be used by health assessors to create site-specific and data-supported estimates with regard to the bioavailability of inorganic mercury and other metals (e.g., lead) from soils. ATSDR applied the data from the panel to its assessment of the mercury clean-up level in the EFPC soil. In 1997, the International Journal of Risk Analysis (Volume 17:5) published three technical papers and an ATSDR overview paper that detailed this meeting's results (ATSDR et al. 2000).
- *Health consultation on proposed mercury clean up levels, January 1996.* Following a request from community members and the city of Oak Ridge, ATSDR prepared a health consultation to assess DOE's clean-up levels for mercury in the EFPC floodplain soil. The final health consultation, which was released in January 1996, concluded that DOE's clean-up levels of 180 milligrams per kilogram (mg/kg) and 400 mg/kg of mercury in the soil of the EFPC floodplain would protect public health and did not present a health risk to adults or to children (ATSDR et al. 2000).

- *Community and physician education on PCBs in fish, September 1996*. As a follow-up to the recommendations in the Lower Watts Bar Reservoir Health Consultation, ATSDR created a program to educate the community and various physicians on PCBs in the Watts Bar Reservoir. On September 11, 1996, Daniel Hryhorczuk, MD, MPH, ABMT, from the Great Lakes Center at the University of Illinois at Chicago, presented information on the health risks related to the consumption of PCBs in fish. Dr. Hryhorczuk made his presentation to about 40 area residents at the community health education meeting that was held in Spring City, Tennessee. In addition, on September 12, 1996, an educational meeting for health care providers in the Watts Bar Reservoir area was held at the Methodist Medical Center in Oak Ridge, Tennessee. Furthermore, ATSDR collaborated with local residents, associations, and state officials to create a brochure informing the public about TDEC's fish consumption advisories for the Watts Bar Reservoir (ATSDR et al. 2000).

- *Watts Bar Reservoir exposure investigation, March 1998*. This exposure investigation was conducted as a follow-up to the February 1996 Health Consultation on the Lower Watts Bar Reservoir. Prior to this investigation, studies on the Watts Bar Reservoir and the Clinch River had reviewed several contaminants, but the only contaminant found to be of current public health concern was PCBs in reservoir fish. ATSDR conducted this exposure investigation primarily because of the uncertainties associated with estimating exposure doses and increases in cancer likelihood from ingestion of reservoir fish and turtles. ATSDR believed that before any agency conducted extensive investigations, it should determine if mercury and PCBs were actually elevated in persons who consumed large amounts of fish and turtles from the reservoir.

  Exposure investigations are one of the methods ATSDR uses to develop a better characterization of past, present, or possible future human exposure to hazardous substances in the environment. These investigations, however, only evaluate exposures—they do not assess whether exposure levels resulted in adverse health effects.

The exposure investigation evaluated exposures at one point in time. Because serum PCBs and mercury blood levels are, however, indicators of chronic exposure, the investigation results provide information on both past and present exposure. Participants were recruited through newspaper, radio, and television announcements, as well as through posters and flyers placed at various fishing-related locations. ATSDR interviewed over 550 volunteers;

116 of these had consumed enough fish or turtles to be included in the investigation. ATSDR concluded that the participants' serum PCB levels and blood mercury levels were consistent with those seen in the general population. ATSDR had three major findings (ATSDR et al. 2000; ORHASP 1999):

1. The investigation participants' serum PCB levels and blood mercury levels were very close to levels seen in the general population.

2. Of the 116 persons tested, only 5 (4%) had serum PCB levels above 20 micrograms per liter (μg/L) or parts per billion (ppb), which is the level regarded as elevated for total PCBs. Four of the five participants who exceeded 20 μg/L had levels between 20 and 30 μg/L. The remaining participant had a serum PCB level that measured 103.8 μg/L, which is above the distribution seen in the general population. Follow-up counseling was given to study participants with elevated PCB blood levels.

3. One investigation participant had a total blood mercury level above 10 μg/L, which is regarded as elevated. The other participants had mercury blood levels that varied up to 10 μg/L, which would be likely in the general population. Follow-up counseling was also given to this person.

- *Clinical laboratory analysis*. In June 1992, William Reid, M.D., an Oak Ridge physician, notified the ORHASP and the TDOH that he believed that about 60 of his patients had been exposed to numerous heavy metals through their occupation or through the environment. Dr. Reid felt that these exposures had caused a number of adverse health outcomes, including immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blot clots. Howard Frumkin, M.D., Dr.PH., from the Emory University School of Public Health, requested facilitated clinical laboratory support to evaluate the patients referred by Dr. Reid. As a result of Dr. Frumkin's request, ATSDR and the CDC's NCEH facilitated this laboratory support from 1992 to 1993 through the NCEH Environmental Health Laboratory (ATSDR et al. 2000; ORHASP 1999).

Because of the confidentiality among physicians, as well as the confidentiality between physicians and their patients, the findings of these clinical analyses have not been provided to public health agencies (ATSDR et al. 2000). In an April 26, 1995, letter to the Commissioner of the Tennessee Department of Health, Dr. Frumkin suggested, however, that one should "not evaluate the patients seen at Emory as if they were a cohort for whom group statistics would be meaningful. This was a self-selected group of patients, most with difficult to answer medical questions (hence their trips to Emory), and cannot in any way be taken to typify the population of Oak Ridge. For that reason, I have consistently urged Dr. Reid, each of the patients, and officials of the CDC and the Tennessee Health Department, not to attempt group analyses of these patients."

- *Review of clinical information on persons living in or near Oak Ridge*. Following a request by William Reid, M.D., ATSDR evaluated the medical histories and clinical data associated with 45 of Dr. Reid's patients. The objective of this review was to assess the clinical data for patients who were tested for heavy metals, and to establish whether exposure to metals was related to these patients' various illnesses. ATSDR determined that the case data were not sufficient to support an association between these diseases and low levels of metals. The TDOH, which also evaluated the information, developed the same conclusion as ATSDR. In September 1992, ATSDR provided a copy of its review to Dr. Reid (ATSDR et al. 2000).

- *Health consultation on the assessment of cancer incidence in counties adjacent to the Oak Ridge Reservation, March 2006*. Some area residents expressed concerns about the number of cancer cases in communities around the Oak Ridge Reservation. To address these concerns, the Oak Ridge Reservation Health Effects Subcommittee requested that ATSDR conduct an assessment of cancer incidence to evaluate cancer rates in these communities. For the consultation, ATSDR obtained cancer incidence data—data on newly diagnosed cases of cancer—from the Tennessee Cancer Registry for 42 different cancer types. Data from 1991–2000 were obtained for the eight-county area surrounding the Oak Ridge Reservation, including Anderson, Blount, Knox, Loudon, Meigs, Morgan, Rhea, and Roane Counties. To analyze the data and determine any increases of cancer incidence, ATSDR compared the number of observed cases in each of the eight counties with the expected number of cases in the state of Tennessee. The findings indicated both higher and lower rates of certain cancers

in some of the counties examined when compared with the cancer incidence rates in the state. No consistent pattern of cancer occurrence was, however, identified, and the reasons for the increases and decreases of cancer occurrence are unknown. For more information, the assessment of cancer incidence (released for public comment in 2006) is available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

Health education. Another essential part of the public health assessment process is designing and implementing activities that promote health and provide information about hazardous substances in the environment.

- *Health professional education on cyanide*. In January 1996, an employee from ETTP (formerly the K-25 facility) requested ATSDR's assistance with occupational cyanide exposure. As a result, in August 1996, ATSDR held a physician health education program in Oak Ridge to teach physicians about health effects that could result from potential cyanide intoxication. The purpose of the education program was to help community health care providers respond to concerns from ETTP employees. ATSDR gave the following materials to the concerned employee and to the area physicians: the ATSDR public health statement for cyanide, the NIOSH final health hazard evaluation, and the ATSDR Case Studies in Environmental Medicine publication entitled *Cyanide Toxicity*. ATSDR led the environmental health education workshop for physicians at the Methodist Medical Center in Oak Ridge, Tennessee. The session focused on supplying area physicians and other health care providers with information to assist with the diagnosis of acute and chronic cyanide intoxication, and also to assist with answering patient's questions. In addition, ATSDR established a system that area physicians could use to make patient referrals directly to the Association of Occupational and Environmental Clinics (AOEC) (ATSDR et al. 2000).

- *Workshops on epidemiology*. Following requests from ORRHES members, ATSDR conducted two epidemiology workshops for the subcommittee. The first session took place at the ORRHES meeting on June 2001. During this meeting, Ms. Sherri Berger and Dr. Lucy Peipins of ATSDR's Division of Health Studies presented an overview of the science of epidemiology. Dr. Peipins also presented at the second epidemiology workshop, which was held at the ORRHES meeting on December 2001. The purpose of this second session was to help the ORRHES members build the skills that are required for analyzing scientific reports

(ATSDR et al. 2000). In addition, at the PHAWG meeting on August 28, 2001, Dr. Peipins demonstrated the systematic and scientific approach of epidemiology by guiding the group as they critiqued a report by Joseph Mangano entitled *Cancer Mortality near Oak Ridge, Tennessee* (International Journal of Health Services, Volume 24: 3, 1994, page 521). Using the PHAWG critique, the ORRHES made the following conclusions and recommendations to ATSDR.

1. The Mangano paper is not an adequate, science-based explanation of any alleged anomalies in cancer mortality rates of the off-site public.

2. The Mangano paper fails to establish that radiation exposure from the ORR is the cause of any such alleged anomalies of cancer mortality rates in the general public.

3. The ORRHES recommends to ATSDR that the Mangano paper be excluded from consideration in the ORR public health assessment process (ATSDR et al. 2000).

Coordination with other parties. Since 1992 and continuing to the present, ATSDR has consulted regularly with representatives of other parties involved with the ORR. Specifically, ATSDR has coordinated its efforts with TDOH, TDEC, NCEH, NIOSH, and DOE. These coordinated efforts led to the establishment of the Public Health Working Group in 1999, which then led to the formation of the ORRHES. In addition, ATSDR provided some assistance to TDOH in its study of past public health issues. ATSDR has also obtained and interpreted studies prepared by academic institutions, consulting firms, community groups, and other parties.

Establishment of the ORR Public Health Working Group and the ORRHES. In 1998, under a collaborative effort with the DOE Office of Health Studies, ATSDR and CDC embarked on a process to develop credible, coherent, and coordinated agendas for public health activities and for health studies at each DOE site. In February 1999, ATSDR was given the responsibility to lead the interagency group's efforts to improve communication at the ORR. In cooperation with other agencies, ATSDR established the ORR Public Health Working Group to gather input from local organizations and from persons regarding the creation of a public health forum. After careful consideration of the input collected from community members, ATSDR and CDC determined that the most suitable approach to meet the community's needs was to establish the ORRHES.

Site visits. Since 1992, ATSDR scientists have conducted numerous site visits to the ORR and to the areas surrounding the reservation. These visits have enabled ATSDR to better understand the site-specific exposure conditions that exist with the ORR and with neighboring areas. The site visits have included guided tours of the ORR operation areas, as well as tours of the local communities. As a result of these site visits, ATSDR has been able to identify how community members might come into contact with environmental contamination.

Summary of U.S. Department of Health and Human Services Activities

U.S. Department of Health and Human Services' Evaluation of Data in The Tennessean Article From September 29, 1998. In a November 2,1998 letter, the Honorable William H. Frist, M.D., United States Senator, requested that Donna E. Shalala, Secretary of the Department of Health and Human Services (DHHS), have the CDC, ATSDR, and the National Institutes of Health (NIH) evaluate the data that *The Tennessean* article describes as reporting a pattern of illnesses among residents living near nuclear plants, including the DOE ORR.

In particular, Senator Frist requested the following:

- Assess the quality and usefulness of the data on which the report is based.
- Examine the data for any patterns of illness and assess whether there is sufficient data to establish a relationship to the nuclear plants.
- Summarize the current DHHS studies that are currently underway at the 11 sites.
- Estimate how the key questions raised by the newspaper article could be addressed in a potential study.
- Describe any existing programs at the three agencies that may help address the medical needs of people living near nuclear plants.

In a letter dated February 22, 1999, Donna E. Shalala, Secretary of DHHS, responded to Senator Frist's request. The DHHS evaluated *The Tennessean* article and responded to Senator Frist's five specific issues. DHHS concluded the following:

1. The data in *The Tennessean* article were not compiled from an epidemiologic study and thus have many limitations. It is impossible to calculate rates for the reported illnesses or to determine whether rates of the illnesses were abnormal. It is also difficult to relate excess illnesses to specific nuclear plants because primary exposures differ among the plants.

2. Epidemiologically, tabulation of data collected in an unstandardized manner is unacceptable, as is assessment of illnesses and symptoms based on limited diagnostic information. Thus, if data in this report represent a new or unusual occurrence of symptoms in this population, determination is not possible.

3. DHHS has a significant number of ongoing studies that seek to analyze environmental exposure at each of the 11 sites rather than focusing on general medical evaluations of the populations near the sites. Clinical data from the Fernald Medical Monitoring Program and the Scarboro, Tennessee, survey focus, however, on respiratory illnesses in children and, although quite limited, are most relevant to the issues raised by the report.

4. Sound data using standardized information are essential to establish increased prevalence of a disease and linkage to the nuclear plants.

    - First, the occurrence of a single, definable illness would have to be assessed.
    - Second, studies including structured population surveys would need to be developed for general health and illness data in well-defined population groups near the nuclear sites. The finding would then be compared to results from other well-defined populations living elsewhere.
    - Third, any attempt to determine a causal relationship between disease or illness rates in these populations and exposures to hazards would be difficult, given that historic exposures themselves are difficult to identify and measure.

5. CDC, ATSDR, and NIH are working with DOE to plan appropriate public health follow-up activities to address the concerns of communities and workers regarding the nuclear weapons complexes. Embarking on such a comprehensive program will require considerable resource, planning, and evaluation. Please note that CDC, ATSDR, and NIH do not provide direct primary medical services to communities. Where possible, however,

CDC, ATSDR, and NIH will continue to support community leaders and existing medical care systems to address public health concerns of communities that are near nuclear plants.

Summary of TDOH Activities

Pilot survey. In the fall of 1983, TDOH established an interim soil mercury level to use for making environmental management decisions. CDC evaluated the methodology for this mercury level and advised the TDOH to conduct a pilot survey to determine whether populations with the greatest risk for mercury exposure had elevated mercury body burdens. Between June and July 1984, TDOH and CDC conducted a pilot survey to record the inorganic mercury levels of Oak Ridge residents who had the greatest risk of being exposed to mercury-contaminated fish and soil. In addition, the survey assessed if exposure to mercury through contaminated fish and soil represented an immediate health hazard for the Oak Ridge community. In October 1985, the findings of the pilot study were released. These results indicated that people who lived and worked in Oak Ridge, Tennessee, were unlikely to have a greater risk for significantly high mercury levels. Concentrations of mercury detected in hair and urine samples were lower than levels associated with known health effects (ATSDR et al. 2000).

Health statistics review. As referred to earlier, in June 1992, William Reid, M.D., an Oak Ridge physician, informed the ORHASP and the TDOH that he believed that about 60 of his patients had been exposed to numerous heavy metals through their occupation or through the environment. Dr. Reid felt that these exposures had caused a number of adverse health outcomes including immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blot clots. In 1992, TDOH conducted a health statistics review that evaluated the cancer incidence rates for the counties around the reservation between 1988 and 1990, and compared these rates with the state rates for Tennessee. The health statistics review determined that when compared with state rates, some of the county rates were low and some were high, But the review was unable to distinguish any patterns associated with the site. More detailed findings of the review can be found in a TDOH memorandum dated October 19, 1992, from Mary Layne Van Cleave to Dr. Mary

Yarbrough. In addition, the handouts and minutes from Ms. Van Cleave's presentation at the ORHASP meeting on December 14, 1994, are available through TDOH (ATSDR et al. 2000).

Health statistics review. In 1994, area residents reported several community members had amyotrophic lateral sclerosis (ALS) and multiple sclerosis (MS). TDOH consulted with Peru Thapa, M.D., M.P.H., from the Vanderbilt University School of Medicine, to perform a health statistics review of mortality rates for ALS and MS within certain counties in Tennessee. TDOH also received technical support for the health statistics review from ATSDR (ATSDR et al. 2000).

Because ALS and MS are not reportable diseases, TDOH determined that to calculate reliable incidence rates for these diseases was impossible. Mortality rates for counties surrounding the ORR were analyzed for the time period between 1980 and 1992, and then compared with mortality rates for the state of Tennessee. The review found that the mortality rates did not differ significantly from the rates in the rest of Tennessee (ATSDR et al. 2000). The following results were reported by TDOH at the ORHASP public meeting on August 18, 1994:

- In comparison with the rest of the state, no significant differences in ALS mortality appeared in any of the counties.
- For Anderson County, the rate of age-adjusted deaths from chronic obstructive pulmonary disease (COPD) was significantly higher than were rates in the rest of the state, but rates for total deaths, deaths from stroke, deaths from congenital anomalies, and deaths from heart disease were significantly lower for the period from 1979 to 1988. No significant differences were found in the rates of deaths due to cancer, for all sites, or in comparison with rates in the rest of the state. Although rates of deaths from uterine and ovarian cancer were significantly higher than the rates in the rest of the state, the rate of deaths from liver cancer was significantly lower in comparison with the rest of the state.
- For Roane County, the rates of total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state for the period from 1979 to 1988. Although the total cancer death rate was significantly lower than the rate in the rest of the state, the rate of deaths from lung cancer was significantly higher than the rate in the rest of the state. Rates of

deaths from colon cancer, female breast cancer, and prostate cancer were also significantly lower than the rates in the rest of the state.

- For Knox County, the rates for total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state. No significant difference appeared in the total cancer death rate in comparison to the rest of the state.
- No significant exceedances were found for any cause of mortality studied in Knox, Loudon, Rhea, and Union counties in comparison with the rest of the state.
- Rates of total deaths were significantly higher in Campbell, Claiborne, and Morgan counties in comparison with the rest of the state.
- Cancer mortality was significantly higher in Campbell County in comparison with the rest of the state. The excess in number of deaths from cancer appeared to be attributed to the earlier part of the time period (1980 to 1985); the rate of deaths from cancer was not higher in Campbell County in comparison with the rest of the state for the time periods from 1986 to 1988 and 1989 to 1992.
- Cancer mortality was significantly higher in Meigs County in comparison with the rest of the state from 1980 to 1982. This excess in cancer deaths did not persist from 1983 to 1992.

Knowledge, attitude, and beliefs study. TDOH coordinated a study to evaluate the attitudes, beliefs, and perceptions of residents living in eight counties around Oak Ridge, Tennessee. The purpose of the study was to 1) investigate public perceptions and attitudes about environmental contamination and public health problems related to the ORR, 2) ascertain the public's level of awareness and assessment of the ORHASP, and 3) make recommendations for improving public outreach programs. The report was released in August 1994 (ATSDR et al. 2000; Benson et al. 1994). Following is a summary of the findings (Benson et al. 1994):

- A majority of the respondents regard their local environmental quality as better than the national environmental quality. Most rate the quality of the air and their drinking water as good or excellent. Almost half rate the local groundwater as good or excellent.
- A majority of the respondents think that activities at the ORR created some health problems for people living nearby and most think that activities at the ORR created health

problems for people who work at the site. Most feel that researchers should examine the actual occurrence of disease among Oak Ridge residents. Twenty-five percent know of a specific local environmental condition that they believe has adversely affected public health, but many of these appear to be unrelated to the ORR. Less than 0.1% have personally experienced a health problem that they attribute to the ORR.

- About 25% have heard of the Oak Ridge Health Study and newspapers are the primary source of information about the study. Roughly 33% rate the performance of the study as good or excellent and 40% think the study will improve public health. Also, 25% feel that communication about the study has been good or excellent.

Health assessment. The East Tennessee Region of TDOH conducted a health assessment on the eastern region of Tennessee. The purpose of this health assessment was to review the health status of the population, to evaluate the accessibility and utilization of health services, and to develop priorities for resource allocation. The East Tennessee Region released its first edition of *A Health Assessment of the East Tennessee Region* in December 1991—this edition generally contained data from 1986 to 1990. The second edition, which was released in 1996, generally included data from 1990 to 1995. A copy of the document can be obtained from the East Tennessee Region of TDOH (ATSDR et al. 2000).

Presentation. On February 16, 1995, Dr. Joseph Lyon of the University of Utah gave a TDOH-sponsored presentation at an ORHASP public meeting. The purpose of the presentation was to inform the public and the ORHASP that several studies had been conducted on the fallout from the Nevada Test Site, including the study of thyroid disease and leukemia (ATSDR et al. 2000).

Other Agencies

Assessment reports, environmental studies, health investigations, remedial investigation/feasibility studies, and sampling validation studies. Other agencies have also addressed community health concerns and public health issues through studies and investigations. Two areas that have been investigated by other agencies—Scarboro and Lower East Fork Poplar Creek (LEFPC)—are discussed below.

Following are summaries of investigations related to the Scarboro community:

- *Scarboro Community Assessment Report*. Since 1998, the Joint Center for Political and Economic Studies (with the support of DOE's Oak Ridge Operations) has worked with the Scarboro community to help residents express their economic, environmental, health, and social needs. In 1999, the Joint Center for Political and Economic Studies conducted a survey of the Scarboro community to identify the residents' environmental and health concerns. Although the surveyors' goal was to elicit responses from the entire community, they succeeded in at least achieving an 82% response rate. Because Scarboro is a small community, the community assessment provided new information about the area and its residents that would not be available from sources that evaluate more populated areas, such as the U.S. Census Bureau. In addition, the assessment identified Scarboro's strengths and weaknesses, and illustrated, in comparison with other community concerns, the relative unimportance among residents of environmental and health issues. The assessment showed that environmental and health issues were not a priority among Scarboro residents; the community was more concerned about crime and security, children, and economic development. The Joint Center for Political and Economic Studies recommended an increase in active community involvement in city and community planning (Friday and Turner 2001).

- *Scarboro Community Environmental Study*. In May 1998, soil, sediment, and surface water samples were taken in the Scarboro community to address residents' concerns about previous environmental monitoring in the Scarboro neighborhood (i.e., validity of past measurements). The study was designed to integrate input from the community while also fulfilling the requirements of an U.S. EPA-type evaluation. The Environmental Sciences Institute of Florida Agriculture 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 Protection, as well as DOE subcontractors in the Neutron Activation Analysis Group at the ORNL, conducted the analytical element of this study. These results were compared with findings from an October 1993 report by DOE, entitled *Final Report on the Background Soil Characterization Project (BSCP) at the Oak Ridge Reservation, Oak Ridge, Tennessee*. In general, mercury was detected within the range that was seen in the BSCP, which was between 0.021 mg/kg and 0.30 mg/kg. The

radionuclide findings were within the predicted ranges, including concentrations of total uranium. About 10% of the soil samples indicated, however, an enrichment of uranium 235. In one sample, alpha-chlordane, gamma-chlordane, heptachlor, and heptachlor epoxide exceeded the detection limits. This same sample also had concentrations of lead and zinc that were twice as high as those found in the BSCP. On September 22, 1998, the final Scarboro Community Environmental Study was released (ATSDR et al. 2000).

- *Scarboro Community Health Investigation*. In November 1997, a Nashville newspaper published an article that described various illnesses seen among children who lived in the Scarboro community—a neighborhood located close to the ORR's nuclear weapons facility. The article stated that the Scarboro residents had high rates of respiratory illness, and that 16 children repeatedly experienced "severe ear, nose, throat, stomach, and respiratory illnesses." The reported respiratory illnesses included asthma, sinus infections, hay fever, ear infections, and bronchitis. The article implied that these illnesses were caused by exposure to the ORR, especially because of the proximity of these children's homes to the ORR facilities (ATSDR et al. 2000; Johnson et al. 2000).

In response to this article, on November 20, 1997, the Commissioner of TDOH requested that the CDC assist the TDOH with an investigation of the Scarboro community. TDOH coordinated the *Scarboro Community Health Investigation* to examine the reported excess of pediatric respiratory illness within the Scarboro community. The investigation consisted of a community health survey of parents and guardians, and a follow-up medical examination for children younger than 18 years. Both of these components (survey and exam) were essentially designed to measure the rates of common respiratory illnesses among Scarboro children, compare these rates with national rates for pediatric respiratory illnesses, and determine whether these illnesses had any unusual characteristics. The investigation was not, however, designed to determine the cause of the illnesses (ATSDR et al. 2000; Johnson et al. 2000).

In 1998, CDC and TDOH were assisted by the Scarboro Community Environmental Justice Oversight Committee to develop a study protocol. After the protocol was created, a community health survey was administered to members of households in the Scarboro neighborhood. The purpose of the survey was to assess whether the rates of specific diseases

were higher in Scarboro when compared with the rest of the United States, and to determine whether exposure to different factors increased the Scarboro residents' risk of health problems. In addition, the survey collected information from adults about their occupations, occupational exposures, and general health concerns. The health investigation survey had an 83% response rate, as 220 out of 264 households were interviewed; this included 119 questionnaires about children and 358 questionnaires about adults in these households (ATSDR et al. 2000; Johnson et al. 2000).

In September 1998, CDC released its initial findings from the survey. For children in Scarboro, the asthma rate was 13%; this was compared with nationally estimated rates of 7% for children between the ages of 0 and 18, and 9% for African American children between the ages of 0 and 18. Still, the Scarboro rate fell within the range of rates (6% to 16%) found in comparable studies across the United States. The wheezing rate was 35% for children in Scarboro, as compared with international estimates that fell between 1.6% and 36.8%. With the exception of unvented gas stoves, the study did not find any statistically significant link between exposure to typical environmental asthma triggers (e.g., pests, environmental tobacco smoke) or possible occupational exposures (i.e., living with an adult who works at the ORR) and asthma or wheezing illness (ATSDR et al. 2000; Johnson et al. 2000).

A review of the information obtained in the health investigation survey showed that 36 children were invited to have a physical examination; this number included the children who were discussed in the November 1997 newspaper article. In November and December 1998, these medical examinations were conducted to verify the community survey results, to evaluate whether the children with respiratory illnesses were receiving necessary medical care, and to confirm that the children detailed in the newspaper actually had those reported respiratory medical problems. The children who were invited to have medical examinations had one or more of the following conditions: 1) severe asthma, which was defined as more than three wheezing episodes or going to an emergency room as a result of these symptoms; 2) severe undiagnosed respiratory illness, which was defined as more than three wheezing episodes and going to an emergency room as a result of these symptoms; 3) respiratory illness and no source for regular medical care; or 4) identified in newspaper reports as having respiratory illness. Of the 36 children invited, 23 participated in the physical examination. A

portion of the eligible children had moved away from Scarboro, whereas others were unavailable or opted not to participate (ATSDR et al. 2000; Johnson et al. 2000).

During the physical examinations, nurses asked the participating children and their parents a series of questions about the health of the children; volunteer physicians evaluated the findings from the nurse interviews and examined the children. In addition to these physical examinations, the children were given blood tests and a special breathing test. The examining physician sometimes took an x-ray of the child, but this was determined on a case-by-case basis. All of the tests, examinations, and transportation to and from the examinations were provided without charge (Johnson et al. 2000).

As soon as the examinations were completed, the results were evaluated to determine whether any children required immediate intervention—none of the children needed urgent care. Several laboratory tests revealed levels that were either above or below the normal range, which included blood hemoglobin level, blood calcium level, or breathing test abnormality. After a preliminary review of the findings, laboratory results were conveyed by letter or telephone to the parents of the children and to their doctors. If the parents did not want their child's results sent to a physician, then the parents received the results over the telephone. The parents of children who had any health concern identified from the physical examination were sent a personal letter from Paul Erwin, M.D., of the East Tennessee Regional Office of the TDOH that informed the parents that follow-up was needed with their medical provider. If the children did not have a medical provider, the parents were told to contact Brenda Vowell, R.N.C., a Public Health Nurse with the East Tennessee Regional Office of the TDOH, for help locating a provider and about possibly receiving TennCare or Children's Special Service (ATSDR et al. 2000; Johnson et al. 2000).

On January 5, 1999, a group of physicians from the CDC, TDOH, the Oak Ridge medical community, and the Morehouse School of Medicine, conducted a thorough review of the findings from the community health survey, the physical examinations, the laboratory tests, and the nurse interviews. From the 23 children who were physically examined, 22 of these children had evidence of some type of respiratory illness, which was discovered during the nurse interviews or during the doctor's physical examinations. Overall, the children seemed to be healthy, and no problems requiring immediate assistance were identified. Many of the

children had mild respiratory illnesses at the time of their examination, but only one child was found to have a lung abnormality. In addition, none of the children experienced wheezing at the time of their examination. The examinations did not indicate an unusual illness pattern among children in the Scarboro community. The illnesses that were identified from these examinations were no more severe than would be expected, and they were characteristic of illnesses that could be found in any community. Basically, the results of these examinations validated the results from the community health survey. On January 7, 1999, the results from this team review were presented at a Scarboro community meeting. In July 2000, the final report was released (ATSDR et al. 2000; Johnson et al. 2000).

Three months after the letters had been sent to the parents and to the physicians about the results, efforts were made to telephone the parents of the children who had been examined. Eight of the parents were contacted successfully. Because some of the parents had more than 1 child who participated in the examination, the questions for the 8 parents were applied to 14 children. Despite many attempts on different days, the parents of 9 children could not be contacted by telephone (Johnson et al. 2000).

Out of the 14 children whose parents had been contacted, 7 of the children had been to a doctor since the examinations. For the most part, the health of the children was about the same. Nevertheless, since the examinations one child had been in the hospital because of asthma and another child whose condition worsened had the asthma medication strengthened. In addition, several parents reported that their children had nasal allergies, and many parents noted problems with obtaining medicines because of the expense and the lack of coverage by TennCare for the specific medicines. Subsequently, TDOH nurses have helped these parents obtain the needed medicines (Johnson et al. 2000).

- *Scarboro Community Environmental Sampling Validation Study*. In 2001, U.S. EPA's Science and Ecosystem Division Enforcement Investigation Branch collected soil, sediment, and surface water samples from the Scarboro community to respond to community concerns, identify data gaps, and validate the sampling performed by FAMU in 1998 (FAMU 1998) (see Figure B-1 for sample locations). All samples were subjected to a full analytical scan, including inorganic metals, volatile organic compounds, semi-volatile organic compounds, radiochemicals, organochlorine pesticides, and PCBs. In addition, U.S. EPA collected

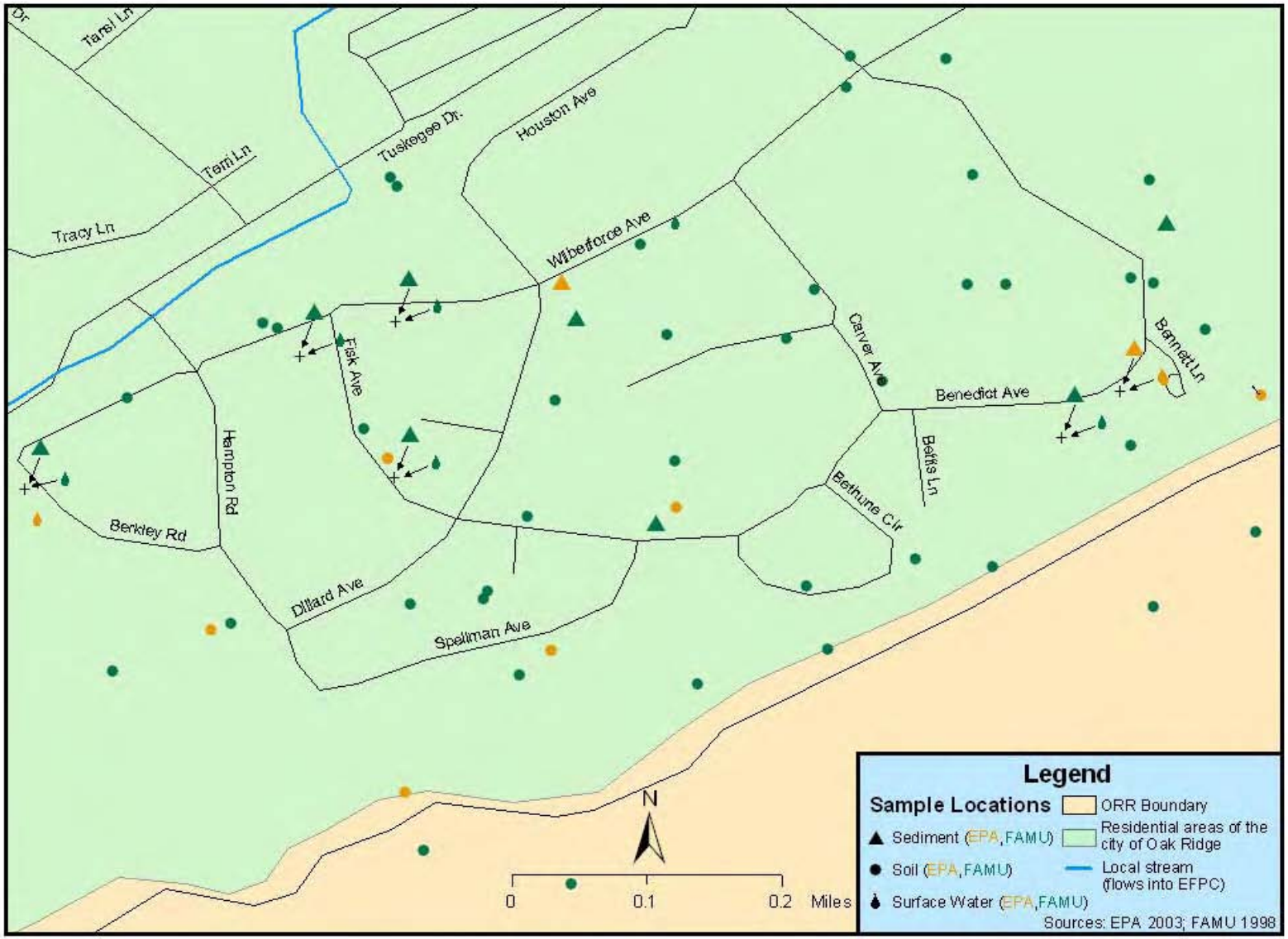
uranium core samples from two locations in Scarboro and conducted a radiation walkover of the areas selected for sampling to determine whether radiation existed above background levels (USEPA 2003).

The level of radiation was below background levels and the radionuclide analytical values did not indicate a level of health concern. Uranium levels in the core soil samples were also below background levels. U.S. EPA concluded that the results support the sampling performed by FAMU in 1998, and chemical, metal, or radionuclides have not elevated above a regulatory health level of concern. The residents of Scarboro are not currently being exposed to harmful levels of substances from the Y-12 plant. The report stated that "based on EPA's results, the Scarboro community is safe. Therefore, additional sampling to determine current exposure is not warranted." A final report was released in April 2003 (USEPA 2003).

Following is a summary of a remedial investigation/feasibility study (RI/FS) for LEFPC:

- *Lower East Fork Poplar Creek Remedial Investigation/Feasibility Study*. Under the Federal Facility Agreement, DOE, U.S. EPA, and TDEC performed an RI/FS at Lower East Fork Poplar Creek (LEFPC) that was completed in 1994. The study was conducted to evaluate the floodplain soil contamination in LEFPC, which has resulted from Y-12 plant discharges since 1950. The goals of the study were to 1) establish the degree of floodplain contamination, 2) prepare a baseline risk analysis according to the level of contaminants, and 3) determine whether remedial action was necessary. The findings of the investigation suggested that sections of the floodplain were contaminated with mercury, and that floodplain soil with mercury concentrations above 400 parts per million (ppm) represented an unacceptable risk to human health and to the environment. As a result of this conclusion, a ROD was approved in September 1995 that requested remedial action at LEFPC. Remedial activities began in June 1996 and were completed in October 1997. The activities consisted of 1) excavating four sections of floodplain soil that had mercury concentrations above 400 ppm, 2) recording the removal by taking confirmatory samples during excavation, 3) disposing of contaminated soil at a Y-12 plant landfill, 4) refilling the excavated areas with soil, and 5) providing a new vegetative cover over the excavated areas (ATSDR et al. 2000).

Figure B-1. FAMU and U.S. EPA Sample Locations in Scarboro



Appendix C. Summary of Remedial and Regulatory Activities

The following remedial activities relate to Zone 1 at the K-25 site (see Figure 5 and Figure 6):

- *East Tennessee Technology Park, Zone 1* comprises about 1,400 acres outside of the main plant (see Figure 5). Areas within Zone 1 include a scrap yard, former cylinder destruction facility, dry quarry, and a sewage treatment facility. The majority of disposal activities at the site occurred within Zone 1, and as a result, this area contains buried waste, debris, and contaminated soils related to former K-25 operations. In August 2001, an interim remedial action plan was issued to address the site contamination, remaining debris, and the quarry. A draft record of decision (ROD) released in November 2001 chose excavation as the remedial alternative to address Zone 1 contamination sources. The plan is to make Zone 1 suitable for industrial uses, which will require the excavation and removal of 84,000 cubic yards of contaminated metal and all other wastes at the site. The ROD was signed in November 2002 and approved by DOE, U.S. EPA, and TDEC in November 2003. This ROD represented one of the initial steps to accelerate the entire K-25 site to a completed clean up by 2008 (Daniels 2002; USDOE 2003d, 2003j; USEPA 2005).

- *K-1070-A Burial Ground,* an approximate 3-acre area in the northwest corner of the K-25 site, was opened in the 1950s and closed in the mid-1970s (see Figure 6). Primarily, the burial ground contained uranium-contaminated waste buried among 62 on-site pits and 26 unlined trenches that was associated with past operations at K-25 and other facilities. Radionuclides and chlorinated solvents were identified as the primary contaminants of concern at the burial ground. Field investigations were finished in 1996. The 1998 remedial investigation (RI) indicated that, although groundwater from the burial ground flows to the K-901-A holding pond (which subsequently discharges to the Clinch River), contamination still remained in the pits and trenches. After discussions at a public meeting, the selected cleanup-up alternative included waste removal and disposal as well as establishing institutional controls (for example, fencing and security patrols). A ROD was approved in January 2000, and in September 2000 a subcontract was initiated to plan activities needed for site remediation. During site restoration activities, which began in

August 2001, about 23,000 cubic yards of debris and soil were excavated. The excavated soil was disposed of at the ORR's Environmental Management Waste Management Facility and the excavated areas were filled with clean soil. Restoration of the site was completed in June 2003 (SAIC 2002, 2005; USDOE 2002a).

- *K-1085 Old Firehouse Burn Area Drum Burial Site* is situated outside of the site perimeter fence, and is bordered by Bear Creek Road, Powerhouse Road, and State Highway 58 (see Figure 6). According to site investigations, the drum burial site measures about 12,000 square feet. While working on a construction project on State Highway 58 in October 2000, the Tennessee Department of Transportation (TDOT) found three buried drums and accidentally punctured two of them. Geophysical surveys suggested that the site contained five drum burial areas. A sixth drum area was added when a highway contractor found black-colored soil containing radiological contamination above background levels. Because the drums contained unknown and possibly hazardous substances, a time-critical removal began on October 11, 2000 to eliminate any potential hazards to human health and the environment. The soil-contaminated area was flagged and an impermeable cover was placed over the contaminated soil. In March 2001, an action memorandum was approved. During excavation at all six sites, about 98 cubic yards of debris and soil were sampled and removed and the excavated areas were restored. Waste characterized as LLW was shipped to the ORR's Environmental Management Waste Management Facility for disposal, whereas mixed waste was sent to the TSCA Incinerator for treatment and disposal. The waste removal and disposal has been completed and a removal action report (RmAR) was approved in February 2003 (SAIC 2002, 2004, 2005; USEPA 2005).

The following remedial activities are associated with Zone 2 at the K-25 site (see Figure 5 and Figure 6):

- *East Tennessee Technology Park, Zone 2* measures about 800 acres and contains the main plant area. In April 2005, a ROD was signed to address contamination in Zone 2, including soil, subsurface structures, buried debris, and slabs. The purpose of the ROD is to remediate Zone 2 to protect future industrial workers and the underlying groundwater

from contamination. Remedial activities are expected to be completed in 2008 as part of the accelerated closure of ETTP (USDOE 2005a; USEPA 2005).

- *K-1417-A and K-1417-B Drum Storage Yards* are situated in the eastern portion of the K-25 site (see Figure 6). After the K-1407-B/C Ponds were closed, between February 1987 and June 1989 raw sludges from these ponds were either treated or put into drums and placed into these storage yards. Because DOE had planned to dispose of the sludges as nonhazardous, low-level radioactive waste, these storage yards were established only to store the sludges temporarily (for about 1 to 2 years). In September 1991, TDEC issued a Commissioner's Order that mandated the execution of the "Plan for the Management of K-1407-B and K-1407-C Pond Waste at the Oak Ridge K-25 Site." The plan required: 1) taking water out of sludges and repacking sludges in appropriate containers, 2) using existent facilities to treat all liquids, and 3) storing all receptacles in present or new indoor facilities (SAIC 2002).

  Also in September 1991, an interim record of decision associated with the treatment and repackaging of waste sludges was issued to prohibit the release of contaminants from deteriorating drums. An additional Commissioner's Order was issued by TDEC in June 1994 because DOE did not repackage the drums by the June 1993 deadline. The required activities specified in TDEC's order were finished in December 1994 and a remedial action report was released in February 1995. Remedial actions included the treatment, repackaging, storage, and removal of the drummed wastes. Following the completion of remedial activities, the drum storage yards were closed under RCRA (SAIC 2002).

- *K-1407-B and K-1407-C Ponds* are settling and holdings ponds located on the eastern portion of the K-25 site (see Figure 6). Mainly, the ponds were used for the secondary treatment of metal hydroxide and additional wastes generated at the K-25 facility. As part of a RCRA closure action, sludges were removed from the ponds from February 1987 to August 1989. In September 1993, a ROD was issued to address possible risks related to wastes and soils remaining in the ponds. The purpose of the remedial action was to "reduce potential threats to human health and the environment posed by residual metal, radiological, and VOC [volatile organic compound] contamination…" Between July

1994 and January 1995, clean-up activities included 1) putting clean soil in excavated areas and covering the surface with rockfill, 2) monitoring groundwater, and 3) maintaining institutional controls (for example, fencing and signage) that limit access and activity in the pond areas. A remedial action report was completed in August 1995 and the ponds were closed under RCRA. Groundwater and surface water have been monitored semiannually since 1996 (except for 1999 and 2000 when a formal submittal request was pending before TDEC to cease monitoring). The 2005 remediation effectiveness report (RER) noted that monitoring of metals, radionuclides, and VOCs in surface water and groundwater in the Mitchell Branch area would continue in fiscal year 2005 (SAIC 2002, 2005).

- *Buildings K-29, K-31, and K-33*, situated inside the security fence on the western section of the K-25 site (see Figure 6), were built to store the low-enrichment part of the gaseous diffusion cascade. The buildings have not operated since 1985 and were deactivated in 1987. As a result of former operations, several sections of the buildings were contaminated with hazardous and radiological substances. Although the contaminants (for example, uranium and PCBs) remain in the buildings, a future release potential remains. An action memorandum was completed in September 1997. The chosen remedial alternative is to remove equipment and decontaminate the buildings. As of fiscal year 2005, over 155,700 tons of material had been removed. Remedial actions to remove equipment and decontaminate the buildings were still in progress as of 2005, but the removal activities were about 96% complete (SAIC 2002, 2005; USDOE 2003e).

- *K-1070-C/D G-Pit and Concrete Pad* are situated in the eastern section of the K-25 site (see Figure 6). Disposal practices took place at the K-1070-C/D area between 1975 and 1989. The G-Pit, which was used as an organic solvent disposal pit, is the main source of organic contaminant discharges to the K-1070-C/D area. Chlorinated hydrocarbons, VOCs, semi-volatile organic compounds (SVOCs), uranium hexafluoride, solvents, and radionuclides are the main contaminants of concern at the G-Pit. The Concrete Pad is located in the southeastern part of the K-1070-C/D area. Because of radiological contaminant levels in soil, the Concrete Pad presents an “unacceptable health risk to workers” for future exposures (SAIC 2002; USDOE 2002a).

As a result of a January, 1998 ROD, in April 1999, 2 feet of soil cover was used to cap the Concrete Pad to protect workers from ionizing radiation exposure. From December 1999 to January 2000, about 230 cubic yards of soil (containing VOCs and low-level PCBs and technetium 99) was excavated from the pit. The soil was thermally treated by June 2001 and a remedial action report was completed in July 2001. All of the treated soil was disposed at the Y-12 Industrial Landfill by April 2002. As of fiscal year 2005, about 60 cubic yards of construction debris was scheduled for incineration at the TSCA Incinerator at the K-25 site. The ROD required the following: 1) periodic radiological surveys, 2) institutional controls (e.g., controls to restrict site access), and 3) maintenance of soil covering the Concrete Pad. Use of institutional controls will continue as long as waste remains buried at the site. Radiological walkover surveys conducted since remedial activities were conducted at the concrete pad have detected no readings above background levels (SAIC 2002, 2005; USDOE 2002b; USEPA 2005).

- *K-25/K-27 Buildings* are located close to the center of the site (see Figure 6). The K-25 building, located on about 40 acres, contains 54 different units. The K-27 building, which is southwest of the K-25 building, occupies nearly 9 acres and includes nine units. Uranium enrichment operations took place at both buildings from 1945 to the early 1960s, when operations ceased entirely. The buildings continue to deteriorate, and as a result hazardous substances and radioactive contamination contained within the buildings could potentially release to the environment. To prevent possible exposures to on-site personnel and the release of hazardous substances, a three-phased demolition was proposed for K-25 and K-27. In 2001, an engineering evaluation/cost analysis (EE/CA) was prepared for building demolition. In February 2002, Phase 1—hazardous materials characterization and removal—began at the site. Phase 1 was about 85 percent completed by the end of fiscal year 2004: over 550,000 cubic feet of waste had been removed and disposed of at the ORR's Environmental Management Waste Management Facility. Phase 2 addresses the process equipment removal and Phase 3 addresses the building demolition. DOE anticipates building demolition to begin in fiscal year 2005. In addition, DOE and other affiliated parties will incorporate public input into a final memorandum of agreement established to preserve these facilities' histories (SAIC 2005; USDOE 2003f; USEPA 2005).

- *Group II Buildings—Main Plant Demolition* refers to 10 main plant buildings at the K-25 site that were torn down as part of the Group II Buildings Phase I project (see Figure 6). In August 2000, an action memorandum was approved to remove the 10 main plant buildings. The remedial alternative for these Group II Buildings is "near-term demolition to slab," which entails removing unneeded equipment, demolishing buildings to the concrete slab, and removing all of the related wastes. The remedial plan was chosen to eliminate hazards to on-site personnel from the deteriorating contaminated structures and to reduce potential exposures to radiation and hazardous materials via uncontrolled releases from equipment, building materials, and dust. Demolition of these main buildings started in the fall of 2000 and was finished by January 2003. A removal action report was approved in September 2004 (SAIC 2002, 2005; USDOE 2003g, 2005a).

- *Group II Buildings—Phase II Demolition Project* refers to 18 facilities located near the K-1064 Peninsula area, which is bordered on three sides by Poplar Creek in the north section of the K-25 site; one facility to the west of the K-1064 Peninsula is also included in this demolition project. The facilities include pump houses, a water treatment facility, old storage facilities, a salvage material yard, various maintenance areas, and other facilities. The Phase II project consists of waste characterization, removal of hazardous materials, physical removal of structures, radiological decontamination of exposed soil surfaces and concrete slabs (or application of additional cover material as needed), packaging debris for disposal, treatment of debris prior to disposal (as necessary), and proper transport of wastes for disposal. An action memorandum to demolish the facilities and remove scrap materials was signed in July 2002. Decontamination and demolition, which began on the 18 facilities in the K-1064 Peninsula area in March 2004, were completed in 2005. A remedial action report is scheduled for submission in September 2006 (SAIC 2005; USDOE 2005a, 2005b; USEPA 2005).

The following remedial activities relate to areas located in both Zone 1 and Zone 2 at the K-25 site (see Figure 5 and Figure 6):

- *ETTP Sitewide Record of Decision* pertains to areas located in Zone 1 and Zone 2. As of 2005, this ROD project was in progress to address contamination in surface water, sediment, and groundwater, and to assess whether further soil remediation was necessary.

To support ongoing investigations and to supplement existing data necessary for the ROD or an action memorandum, more field data were collected in 2004 and 2005. U.S. EPA, TDEC, and DOE have created a detailed schedule of future activities to enable the signing of the ROD in early 2007 (USDOE 2005a, 2005b).

- *Group I Buildings* refers to a collective group of five buildings at the K-25 site: K-724 (Storage Building), K-725 (Beryllium Building), K-1031, (Warehouse), K-1131 (Feed and Tails Facility), and K-1410 (Plating Facility). K-1031, K-1131, and K-1410 are located in the central portion of the site near K-25 and K-27 in Zone 2; K-724 and K-725 are situated southwest of these buildings in Zone 1 (see Figure 5 and Figure 6). The facilities were used for various purposes, such as uranium hexafluoride production, cascade maintenance, and machine shop operations. Contaminants in the buildings included beryllium dust, uranium, PCBs, radionuclides, asbestos, and lead-painted surfaces. In January 1997, an action memorandum required the dismantlement and disposal of the five buildings because the buildings were in poor condition, the buildings were close to surface water and additional structures, or because of the cost of maintenance and surveillance activities. Following building removal, the concrete slabs were cleaned. Because the contamination that remained on slabs from buildings K-1031, K-1131, and K-1410 could not be reduced to acceptable levels, they were covered with a 2-inch layer of soil to decrease future dispersion of radioactive contamination. Demolition was finished in June 1999 and a removal action report was issued in August 1999 (SAIC 2002; USDOE 2001a, 2005a).

The following remedial activities relate to the remaining areas of ETTP or "balance of site" (see Figure 5 and Figure 6):

- *Balance of Site* refers to an estimated 500 aboveground facilities remaining at ETTP that are located outside of Zone 1 and Zone 2. These facilities, consisting of tanks, buildings, sheds, and other structures, either have or potentially have been contaminated with radiological or other hazardous substances resulting from past operations. In August 2003, to prevent future releases of contaminants into the environment, an action memorandum was issued for the demolition and removal of facilities not previously addressed under any environmental decision documents. Remedial activities will include

facility and waste characterization, hazardous material and equipment removal, structure demolition down to concrete slabs, radiological decontamination of any exposed slabs (or application of cover material if decontamination cannot be achieved), preparation of demolition debris for disposal, waste treatment (as necessary), and proper transport and disposal of all wastes generated during these activities. In 2004, demolition began on 169 primarily uncontaminated facilities and on the Balance of Site—Laboratories Group facilities. Demolition and field activities continued in 2005, mainly focusing on the Laboratories Group facilities and K-1008 areas (SAIC 2005; USDOE 2005a, 2005b).

The following remedial activities relate to off-site areas affected by contaminants from the K-25 site (see Figure 3):

- *Clinch River/Poplar Creek* is defined as the operable unit (OU) that consists of biota and sediments in the Melton Hill Reservoir and the Watts Bar Reservoir from Clinch River Mile (CRM) 0.0 (where the Tennessee and Clinch Rivers join) to CRM 43.7, upstream of Melton Hill Dam (see Figure 3). In addition, the OU contains the Poplar Creek embayment from the mouth of Poplar Creek along the Clinch River (at CRM 12.0) to its joining with East Fork Poplar Creek (at Poplar Creek mile [PCM] 5.5). All of the Poplar Creek sections of the OU are within ORR borders of the (SAIC 2002; USDOE 2001b).

  In 1996, a remedial investigation/feasibility study (RI/FS) examined past and present releases to off-site surface water and determined whether remedial action was necessary (ATSDR et al. 2000). The RI/FS concluded that the Clinch River/Poplar Creek OU presented two main risks by exposure to 1) fish tissue that contained chlordane, mercury, PCBs, and arsenic, and 2) deep sediments in the primary river channel that contained arsenic, mercury, cesium 137, and chromium (Jacobs EM Team 1997b; Jacobs Engineering Group Inc. 1996; SAIC 2002; USDOE 2001b). The largest detected radionuclide concentrations are buried between 8 and 32 inches in the deep sediments; radionuclide contamination has *not* been detected in the shoreline sediment (Jacobs EM Team 1997b).

A baseline risk assessment suggested that consumption of certain PCB-contaminated fish posed the greatest risk to public health. In addition, fish contaminated with chlordane, mercury, and arsenic presented a possible chance of causing health effects. The assessment determined that consumption of any type of fish in Poplar Creek posed a health risk, as well as bass from the Clinch River below Melton Hill Dam. Furthermore, the risk assessment determined that contaminants in deep-water sediments would only present a health risk if they were dredged; no exposure pathway currently exists to the deep-water sediments (Jacobs EM Team 1997b).

In September 1997, a ROD determined that the following remedial actions were needed at the OU: 1) yearly monitoring to assess fluctuations in concentration levels and contaminant dispersion, 2) fish consumption advisories, 3) surveys to gauge the usefulness of the fish advisories, and 4) institutional controls to restrict activities that could unsettle the sediment (Jacobs EM Team 1997b; SAIC 2002; USDOE 2001b; USEPA 2005). These institutional controls were developed under an interagency agreement (IAG) established by DOE, U.S. EPA, TVA, TDEC, and the U.S. Army Corps of Engineers (USACE) in February 1991. The IAG allows these agencies to cooperatively work through the Watts Bar Interagency Agreement to review permitting and all other activities that could result in disturbing sediment (for example, building a dock or erecting a pier) (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003c). Please see page 3–12 of the ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf for more details. For additional information on institutional controls to prevent sediment-disturbing activities, please see Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-7, Aquatic Resource Alteration Permit Process; Section 26A of the Tennessee Valley Authority Act of 1933; and Section 10 of the Rivers and Harbors Act of 1910 (USACE) (Jacobs EM Team 1997b).

In February 1991, DOE, EPA, TVA, TDEC, and USACE established an interagency agreement. Under this agreement, these agencies collaboratively work through the Watts Bar Interagency Agreement to review permitting and other activities that could possibly disturb sediment, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; US DOE 2003c). For more details, see the ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf.

In February 1998, an approved remedial action report (RAR) recommended surface water, fish, sediment, and turtle monitoring in the Clinch River/Poplar Creek OU (ATSDR et al. 2000). Beginning in 1998, annual surface water sampling, sediment monitoring, and fish and turtle sampling were conducted at the OU (SAIC 2002; USDOE 2001b). Institutional controls are also used to examine activities that could result in movement of the sediments, and the Tennessee Wildlife Resources Agency (TWRA) prints fish consumption advisories in its *Tennessee Fish Regulations* (SAIC 2002).

- *Lower Watts Bar Reservoir* operable unit stretches from the confluence of the Tennessee River and the Clinch River downstream to the Watts Bar Dam (see Figure 3). All surface water and sediment released from the ORR enter the Lower Watts Bar Reservoir OU (SAIC 2002; USDOE 2001b; USDOE 2003h). In 1995, a RI/FS assessed the level of contamination in the Watts Bar Reservoir, created a baseline risk analysis based on the contaminant levels, and determined whether remedial action was necessary (ATSDR et al. 2000). The RI/FS found that radioactive, inorganic, and organic pollutant discharges from the ORR contributed to biota, water, and sediment contamination in the Lower Watts Bar Reservoir (ATSDR et al. 2000; SAIC 2002; USDOE 2001b, 2003i). The baseline risk analysis indicated that standards for environmental and human health would not be reached if deep channel sediments with cesium 137 were dredged and placed in a residential area, and if people consumed moderate to high quantities of specific fish that contained increased levels of PCBs (ATSDR et al. 2000; Environmental Sciences Division et al. 1995).

In September 1995, a ROD identified the following contaminants of concern (COCs): 1) mercury, arsenic, PCBs, chlordane, and aldrin in fish, 2) mercury, chromium, zinc, and cadmium in dredged sediments and sediments used for growing food products, and 3) manganese through ingestion of surface water (ATSDR et al. 2000; SAIC 2002; USDOE 2001b, 2003i). The largest threat to public health from the Lower Watts Bar Reservoir is related to the consumption of PCB-contaminated fish (SAIC 2002; USDOE 2001b, 2003i). The ROD concluded that if the deep sediments were kept in place, then "…these sediments do not pose a risk to human health because no exposure pathway exists" (USDOE 1995b).

The remedial activities selected for the Lower Watts Bar Reservoir included 1) using preexisting institutional controls to decrease contact with contaminated sediment, 2) fish consumption advisories printed in the *Tennessee Fish Regulations*, and 3) yearly monitoring of biota, sediment, and surface water (ATSDR et al. 2000; SAIC 2002; USDOE 1995b, 2001b, 2003i; USEPA 2005). The institutional controls are developed through the Watts Bar Interagency Agreement under the IAG to restrict sediment-disturbing activities. For example, people are required to obtain a permit before building a pier or constructing a dock (ATSDR 1996; Jacobs EM Team 1997b). According to the IAG, DOE is required to take action if an institutional control is not effective or if a sediment-disturbing activity could cause harm (USDOE 2003c). For more details, please see page 3-5 of the ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf. For additional information on institutional controls to prevent sediment-disturbing activities, please see *Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-7, Aquatic Resource Alteration Permit Process; Section 26A of the Tennessee Valley Authority Act of 1933; and Section 10 of the Rivers and Harbors Act of 1910 (USACE)* (Jacobs EM Team 1997b).

- *Clinch River/Poplar Creek and Lower Watts Bar Reservoir* in September 1999, operable units were combined by DOE for monitoring purposes because these surface water bodies comprise a hydrologically connected system through which ORR contaminants could be transported. Using sampling data collected until 2004, no chemical or radiological contaminants in surface water or near-shore sediments posed an unacceptable risk to humans. As a result of these findings, the previously established long-term monitoring program was modified in fiscal year 2004. The new program, scheduled to commence in fiscal year 2005, requires sediment, surface water, and turtle sampling every 5 years (instead of annually) and fish sampling to continue on an annual basis. As appropriate, DOE will use sediment and surface water sampling data collected by TVA, TDEC, and the Tennessee Wildlife Resources Agency (TWRA) to supplement its data collected under the revised monitoring program (SAIC 2005).

Appendix D. Description and Output from the CAP88-PC Model

The Clean Air Act Assessment Package-1988 (CAP88-PC) is a set of computer programs, databases, and associated utility programs for estimation of dose and risk from radionuclide emissions to air. The U.S. EPA has approved the use of CAP88-PC for "…determining compliance with Clean Air Act National Emission Standards for Hazardous Air Pollutants radionuclide standards at Department of Energy facilities" (USEPA 1999). The following description of the CAP88-PC software is from the 1997 version of the CAP88-PC User's Guide (Parks 1997). The most recent version (2006) of the User's Guide is available at http://www.epa.gov/radiation/docs/cap88/v3userguide2.pdf.

CAP88-PC is a personal computer software system used for calculating both dose and risk from radionuclide emissions to air. CAP88-PC is an approved system for demonstrating compliance with 40 CFR 61 Subpart H, the Clean Air Act standard which applies to U.S. Department of Energy (DOE) facilities that emit radionuclides to air.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six sources. The sources may be either elevated stacks, such as a smokestack, or uniform area sources, such as a pile of uranium mill tailings. Plume rise can be calculated assuming either a momentum or buoyancy-driven plume. Assessments are done for a circular grid of distances and directions with a radius of 80 kilometers (50 miles) around the facility. The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food and intake rates to people from ingestion of food produced in the assessment area. Estimates of the radionuclide concentrations in produce, leafy vegetables, milk, and meat consumed by humans are made by coupling the output of the atmospheric transport models with the U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 terrestrial food chain models. Given that the health effects and dosimetric data are based on low-level radionuclide intakes, dose and risk estimates from CAP88-PC are applicable only to low-level chronic exposures,.

In this public health assessment, ATSDR used CAP88-PC to estimate past chronic (or annual) radiological doses from airborne uranium, technetium 99, and neptunium 237, as well as air

concentrations of uranium and fluoride. Because the health effects and dosimetric data are based on low-level radionuclide intakes, radiological dose estimates from CAP88-PC are applicable only to low-level chronic exposures (Parks 1997). In this assessment, estimated annual airborne radionuclide releases from the K-25/S-50 site (see Table 5) were used to estimate off-site concentrations and doses. CAP88-PC uses site-specific annual weather data in the form of a frequency distribution of wind directions, velocities, and atmospheric stabilities. To evaluate releases from the K-25 and S-50 facilities, ATSDR obtained hourly records of meteorological data from on-site K-25 weather stations (see Appendix F). Because no site-specific meteorological data are available for 1961 or 1963, ATSDR used data from the 1999 weather year as a proxy for historic release conditions. The population estimates used in this evaluation are from the 1980 U.S. Census data provided with the CAP88-PC model.

In this public health assessment, CAP88-PC estimated historic off-site concentrations and annual doses for the year with the highest annual radionuclide emissions. This assessment is based on the assumption that if the year with the highest annual emissions (1961 and 1963) did not represent a public health hazard, then any other year with lower emissions would also not represent a public health hazard. CAP88-PC calculates doses as 50-year effective dose equivalents integrated over a 70-year lifetime, such that ongoing exposures to long-lived radionuclides are included in the dose assessments.

It is important to note that the CAP88-PC system has several significant limitations. Because of these limitations, protective assumptions are used to estimate conservative chronic (or annual) doses to airborne radionuclides—resulting in *overestimates* of the doses that people would have actually received. One limitation of the system is that all emission sources or release points are co-located at the middle of a site. The model can accommodate up to six sources with varying emission parameters (e.g., stack height and emission rates), but all sources will be located at a single location. Site-specific exposures at discrete areas such as Union/Lawnville, Sugar Grove, or Happy Valley must be modeled as specific distances and directions from the plume origin. These locations, with their respective distances and directions, are shown in Figure 14. Specification of these locations assumes that the approximate center of the K-25 building, which is at the approximate center of the K-25 site, is the point of origin for K-25 releases. Similarly, the center of the S-50 footprint (see Figure 14) serves as the point of origin for S-50 releases.

The net result of this co-located source assumption is that it minimizes plume dispersion and maximizes plume concentrations in discrete exposure areas.

Another CAP88-PC limitation is that all sources use the same plume rise mechanism. For this assessment, ATSDR used the stack parameters (within rounding error) from the Task 6 report for air modeling of K-25/S-50 releases: a plume rise (exit velocity) based on a release momentum of 10 meters/second, a stack height of 23 meters, a stack diameter of 2 meters, and an exit temperature of 293 Kelvin.

The dose assessment portion of the CAP88-PC assessment assumes a "rural default" for food consumption. This default conservatively assumes that 70% of vegetables, 40% of milk, and 45% of meat are homegrown (at each exposure location) and the remainder (30% of vegetables, 60% of milk, and 55% of meat) is grown in the local area. The model assumes that no food items are imported from outside the local area.

CAP88-PC assessments are done for a circular grid of distances and directions with a radius of 4,800 meters (3 miles) around the facility; however, the CAP88-PC model does not accommodate for the effect of complex topography on air dispersion. Consequently, dispersion to areas such as Sugar Grove and Union/Lawnville, which are separated from K-25 by significant topographic features (see Figure 7), will be overestimated. The potential overestimation of doses in exposure areas may be particularly important for consideration of UF_6 dispersion because it is a dense gas (heavier than air) that does not rise through the atmosphere like lighter gases. Also, the effect of topography may be moot to the extent that the ridge and valley topography have influenced the site-specific weather data.

The remainder of this appendix contains the input and output data for the CAP88-PC model run for the 1963 annual releases from K-25 using the 1999 meteorological data.

Effective Dose Equivalent (mrem/year)
5.28E+01

At This Location: 1600 Meters Northeast
Dataset Name: K25_1999
Dataset Date: 9/27/2004 12:55:00 PM
Wind File: C:\Program Files\CAP88-PC21\k-25\120899.WND

MAXIMALLY EXPOSED INDIVIDUAL

Location of the Individual: 1600 Meters Northeast
Lifetime Fatal Cancer Risk: 6.68E-04

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Dose Equivalent (mrem/y)
GONADS	5.76E-01
BREAST	3.46E-01
R MAR	6.05E+00
LUNGS	3.93E+02
THYROID	1.28E+00
ENDOST	8.54E+01
RMNDR	7.08E+00

EFFEC 5.28E+01

RADIONUCLIDE EMISSIONS DURING THE YEAR 1963

Nuclide	Class	Size	Source #1 Ci/y	TOTAL Ci/y
U-235	Y	1.00	1.4E-01	1.4E-01
U-238	Y	1.00	5.0E-01	5.0E-01
U-234	Y	1.00	2.5E+00	2.5E+00
NP-237	Y	1.00	5.0E-02	5.0E-02
TC-99	W	1.00	2.5E+00	2.5E+00

SITE INFORMATION

Temperature: 10 degrees C
Precipitation: 100 cm/y
Humidity: 8 g/cu m
Mixing Height: 1000 m

SOURCE INFORMATION

Source Number: 1

Stack Height (m): 23.00
Diameter (m): 2.00

Plume Rise
Momentum (m/s): 10.00

(Exit Velocity)

D O S E A N D R I S K E Q U I V A L E N T S U M M A R I E S

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)
GONADS	5.76E-01
BREAST	3.46E-01
R MAR	6.05E+00
LUNGS	3.93E+02
THYROID	1.28E+00
ENDOST	8.54E+01
RMNDR	7.08E+00
EFFEC	5.28E+01

PATHWAY EFFECTIVE DOSE EQUIVALENT SUMMARY

Pathway	Selected Individual (mrem/y)
INGESTION	4.42E+00
INHALATION	4.84E+01
AIR IMMERSION	1.62E-06
GROUND SURFACE	7.99E-02
INTERNAL	5.28E+01
EXTERNAL	7.99E-02
TOTAL	5.29E+01

NUCLIDE EFFECTIVE DOSE EQUIVALENT SUMMARY

Nuclide	Selected Individual (mrem/y)
U-235	2.22E+00
U-238	7.37E+00
U-234	4.09E+01
NP-237	2.10E+00
TC-99	2.50E-01
TOTAL	5.29E+01

CANCER RISK SUMMARY

Cancer	Selected Individual Total Lifetime Fatal Cancer Risk
LEUKEMIA	6.00E-06
BONE	4.27E-06
THYROID	5.32E-07
BREAST	8.98E-07
LUNG	6.32E-04
STOMACH	7.38E-06
BOWEL	1.03E-06
LIVER	3.84E-06
PANCREAS	3.59E-07
URINARY	1.17E-05
OTHER	4.40E-07
TOTAL	6.68E-04

PATHWAY RISK SUMMARY

Pathway	Selected Individual Total Lifetime Fatal Cancer Risk
INGESTION	3.02E-05
INHALATION	6.36E-04
AIR IMMERSION	3.77E-11
GROUND SURFACE	1.84E-06
INTERNAL	6.66E-04
EXTERNAL	1.84E-06
TOTAL	6.68E-04

NUCLIDE RISK SUMMARY

	Selected Individual

Nuclide	Total Lifetime Fatal Cancer Risk
U-235	2.90E-05
U-238	9.45E-05
U-234	5.19E-04
NP-237	1.63E-05
TC-99	9.13E-06
TOTAL	6.68E-04

INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)				
Direction	1600	2000	2570	3000	4324
N	7.4E+00	5.8E+00	4.4E+00	3.7E+00	2.5E+00
NNW	4.0E+00	3.6E+00	3.0E+00	2.7E+00	2.0E+00
NW	4.0E+00	3.3E+00	2.6E+00	2.3E+00	1.6E+00
WNW	2.3E+00	1.7E+00	1.4E+00	1.3E+00	1.0E+00
W	6.4E+00	5.1E+00	4.0E+00	3.5E+00	2.4E+00
WSW	3.8E+00	3.4E+00	2.9E+00	2.6E+00	1.9E+00
SW	2.9E+00	2.4E+00	2.0E+00	1.9E+00	1.5E+00
SSW	2.8E+00	2.3E+00	1.8E+00	1.5E+00	1.1E+00
S	4.8E+00	4.3E+00	3.7E+00	3.3E+00	2.3E+00
SSE	1.5E+01	1.1E+01	8.2E+00	6.7E+00	4.3E+00
SE	3.6E+01	2.6E+01	1.8E+01	1.5E+01	8.9E+00
ESE	1.9E+01	1.4E+01	9.9E+00	8.0E+00	4.9E+00
E	3.4E+01	2.5E+01	1.7E+01	1.4E+01	8.5E+00
ENE	4.8E+01	3.5E+01	2.4E+01	1.9E+01	1.1E+01
NE	5.3E+01	3.7E+01	2.5E+01	2.0E+01	1.2E+01
NNE	4.0E+01	2.9E+01	2.0E+01	1.6E+01	9.5E+00

AGRICULTURAL DATA

	Vegetable	Milk	Meat
Fraction Home Produced:	0.700	0.400	0.440
Fraction From Assessment Area:	0.300	0.600	0.560
Fraction Imported:	0.000	0.000	0.000

Food Arrays were not generated for this run.
Default Values used.

DISTANCES (M) USED FOR MAXIMUM INDIVIDUAL ASSESSMENT

1600 2000 2570 3000 4324

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

	Distance (m)				
Direction	1600	2000	2570	3000	4324
N	9.2E-05	7.1E-05	5.4E-05	4.5E-05	3.0E-05
NNW	4.8E-05	4.3E-05	3.6E-05	3.2E-05	2.3E-05
NW	4.8E-05	3.9E-05	3.1E-05	2.6E-05	1.8E-05
WNW	2.6E-05	1.9E-05	1.5E-05	1.3E-05	1.1E-05
W	7.8E-05	6.2E-05	4.8E-05	4.1E-05	2.8E-05
WSW	4.5E-05	4.0E-05	3.4E-05	3.0E-05	2.1E-05
SW	3.4E-05	2.8E-05	2.3E-05	2.1E-05	1.6E-05
SSW	3.3E-05	2.7E-05	2.1E-05	1.7E-05	1.2E-05
S	5.8E-05	5.2E-05	4.4E-05	3.9E-05	2.8E-05
SSE	1.9E-04	1.4E-04	1.0E-04	8.3E-05	5.2E-05

SE	4.5E-04	3.3E-04	2.3E-04	1.8E-04	1.1E-04
ESE	2.4E-04	1.8E-04	1.2E-04	9.9E-05	6.0E-05
E	4.3E-04	3.1E-04	2.2E-04	1.7E-04	1.1E-04
ENE	6.1E-04	4.4E-04	3.0E-04	2.4E-04	1.4E-04
NE	6.7E-04	4.7E-04	3.2E-04	2.5E-04	1.4E-04
NNE	5.0E-04	3.6E-04	2.5E-04	2.0E-04	1.2E-04

VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS

Nuclide	Clearance Class	Particle Size (microns)	Scavenging Coefficient (per second)	Dry Deposition Velocity (m/s)
U-235	Y	1.0	1.00E-05	1.80E-03
U-238	Y	1.0	1.00E-05	1.80E-03
U-234	Y	1.0	1.00E-05	1.80E-03
NP-237	Y	1.0	1.00E-05	1.80E-03
TC-99	W	1.0	1.00E-05	1.80E-03

VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS

	DECAY CONSTANT (PER DAY)			TRANSFER COEFFICIENT	
Nuclide	Radio-active (1)	Surface	Water	Milk (2)	Meat (3)
U-235	0.00E+00	5.48E-05	0.00E+00	6.00E-04	2.00E-04
U-238	0.00E+00	5.48E-05	0.00E+00	6.00E-04	2.00E-04
U-234	0.00E+00	5.48E-05	0.00E+00	6.00E-04	2.00E-04
NP-237	0.00E+00	5.48E-05	0.00E+00	5.00E-06	5.50E-05
TC-99	0.00E+00	5.48E-05	0.00E+00	1.00E-02	8.50E-03

FOOTNOTES: (1) Effective radioactive decay constant in plume; set to zero if less than 1.0E-2

(2) Fraction of animal's daily intake of nuclide which appears in each L of milk (days/L)

(3) Fraction of animal's daily intake of nuclide,
which appears in each kg of meat (days/kg)

VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS

Nuclide	CONCENTRATION UPTAKE FACTOR Forage (1)	CONCENTRATION UPTAKE FACTOR Edible (2)	GI UPTAKE FRACTION Inhalation	GI UPTAKE FRACTION Ingestion
U-235	8.50E-03	1.71E-03	2.00E-03	2.00E-01
U-238	8.50E-03	1.71E-03	2.00E-03	2.00E-01
U-234	8.50E-03	1.71E-03	2.00E-03	2.00E-01
NP-237	1.00E-01	4.28E-03	1.00E-03	1.00E-03
TC-99	9.50E+00	6.42E-01	8.00E-01	8.00E-01

FOOTNOTES: (1) Concentration factor for uptake of nuclide from soil for pasture and forage (in pCi/kg dry weight per pCi/kg dry soil)

(2) Concentration factor for uptake of nuclide from soil by edible parts of crops (in pCi/kg wet weight per pCi/kg dry soil)

VALUES FOR RADIONUCLIDE-INDEPENDENT PARAMETERS

HUMAN INHALATION RATE	
Cubic centimeters/hr	9.17E+05
SOIL PARAMETERS	
Effective surface density (kg/sq m, dry weight)	
(Assumes 15 cm plow layer)	2.15E+02

BUILDUP TIMES	
For activity in soil (years)	1.00E+02
For radionuclides deposited on ground/water (days)	3.65E+04
DELAY TIMES	
Ingestion of pasture grass by animals (hr)	0.00E+00
Ingestion of stored feed by animals (hr)	2.16E+03
Ingestion of leafy vegetables by man (hr)	3.36E+02
Ingestion of produce by man (hr)	3.36E+02
Transport time from animal feed-milk-man (day)	2.00E+00
Time from slaughter to consumption (day)	2.00E+01
WEATHERING	
Removal rate constant for physical loss (per hr)	2.90E-03

VALUES FOR RADIONUCLIDE-INDEPENDENT PARAMETERS

CROP EXPOSURE DURATION	
Pasture grass (hr)	7.20E+02
Crops/leafy vegetables (hr)	1.44E+03
AGRICULTURAL PRODUCTIVITY	
Grass-cow-milk-man pathway (kg/sq m)	2.80E-01
Produce/leafy veg for human consumption (kg/sq m)	7.16E-01
FALLOUT INTERCEPTION FRACTIONS	
Vegetables	2.00E-01
Pasture	5.70E-01

GRAZING PARAMETERS	
Fraction of year animals graze on pasture	4.00E-01
Fraction of daily feed that is pasture grass when animal grazes on pasture	4.30E-01
ANIMAL FEED CONSUMPTION FACTORS	
Contaminated feed/forage (kg/day, dry weight)	1.56E+01
DAIRY PRODUCTIVITY	
Milk production of cow (L/day)	1.10E+01
MEAT ANIMAL SLAUGHTER PARAMETERS	
Muscle mass of animal at slaughter (kg)	2.00E+02
Fraction of herd slaughtered (per day)	3.81E-03
DECONTAMINATION	
Fraction of radioactivity retained after washing for leafy vegetables and produce	5.00E-01
FRACTIONS GROWN IN GARDEN OF INTEREST	
Produce ingested	1.00E+00
Leafy vegetables ingested	1.00E+00
INGESTION RATIOS:	
IMMEDIATE SURROUNDING AREA/TOTAL WITHIN AREA	
Vegetables	7.00E-01
Meat	4.40E-01
Milk	4.00E-01

VALUES FOR RADIONUCLIDE-INDEPENDENT PARAMETERS

MINIMUM INGESTION FRACTIONS FROM OUTSIDE AREA
(Minimum fractions of food types from outside area listed below are actual fixed values.)

Vegetables	0.00E+00
Meat	0.00E+00
Milk	0.00E+00

HUMAN FOOD UTILIZATION FACTORS

Produce ingestion (kg/y)	1.76E+02
Milk ingestion (L/y)	1.12E+02
Meat ingestion (kg/y)	8.50E+01
Leafy vegetable ingestion (kg/y)	1.80E+01

SWIMMING PARAMETERS

Fraction of time spent swimming	0.00E+00
Dilution factor for water (cm)	1.00E+00

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
N	1600	U-235	2.7E-04	4.8E-11	4.5E-11	9.3E-11
N	1600	U-238	9.5E-04	1.7E-10	1.6E-10	3.3E-10
N	1600	U-234	4.7E-03	8.5E-10	8.0E-10	1.6E-09

N	1600	NP-237	9.5E-05	1.7E-11	1.6E-11	3.3E-11
N	1600	TC-99	4.8E-03	8.6E-10	8.1E-10	1.7E-09
N	2000	U-235	2.0E-04	3.7E-11	3.6E-11	7.3E-11
N	2000	U-238	7.3E-04	1.3E-10	1.3E-10	2.6E-10
N	2000	U-234	3.6E-03	6.5E-10	6.4E-10	1.3E-09
N	2000	NP-237	7.3E-05	1.3E-11	1.3E-11	2.6E-11
N	2000	TC-99	3.6E-03	6.6E-10	6.4E-10	1.3E-09
N	2570	U-235	1.5E-04	2.7E-11	2.8E-11	5.5E-11
N	2570	U-238	5.4E-04	9.7E-11	9.9E-11	2.0E-10
N	2570	U-234	2.7E-03	4.8E-10	4.9E-10	9.7E-10
N	2570	NP-237	5.4E-05	9.7E-12	9.9E-12	2.0E-11
N	2570	TC-99	2.7E-03	4.9E-10	5.0E-10	9.8E-10
N	3000	U-235	1.2E-04	2.2E-11	2.4E-11	4.6E-11
N	3000	U-238	4.5E-04	8.0E-11	8.5E-11	1.6E-10
N	3000	U-234	2.2E-03	4.0E-10	4.2E-10	8.1E-10
N	3000	NP-237	4.5E-05	8.0E-12	8.5E-12	1.6E-11
N	3000	TC-99	2.2E-03	4.0E-10	4.2E-10	8.2E-10
N	4324	U-235	7.9E-05	1.4E-11	1.6E-11	3.0E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
N	4324	U-238	2.8E-04	5.1E-11	5.7E-11	1.1E-10
N	4324	U-234	1.4E-03	2.5E-10	2.8E-10	5.3E-10
N	4324	NP-237	2.8E-05	5.1E-12	5.7E-12	1.1E-11
N	4324	TC-99	1.4E-03	2.5E-10	2.9E-10	5.4E-10
NNW	1600	U-235	1.3E-04	2.4E-11	3.6E-11	6.0E-11
NNW	1600	U-238	4.7E-04	8.4E-11	1.3E-10	2.1E-10
NNW	1600	U-234	2.3E-03	4.2E-10	6.4E-10	1.1E-09
NNW	1600	NP-237	4.7E-05	8.4E-12	1.3E-11	2.1E-11
NNW	1600	TC-99	2.3E-03	4.2E-10	6.4E-10	1.1E-09
NNW	2000	U-235	1.2E-04	2.1E-11	2.9E-11	5.0E-11

1	NNW	2000	U-238	4.2E-04	7.6E-11	1.0E-10	1.8E-10
2	NNW	2000	U-234	2.1E-03	3.7E-10	5.0E-10	8.8E-10
3	NNW	2000	NP-237	4.2E-05	7.6E-12	1.0E-11	1.8E-11
4	NNW	2000	TC-99	2.1E-03	3.8E-10	5.1E-10	8.9E-10
5	NNW	2570	U-235	9.9E-05	1.8E-11	2.2E-11	4.0E-11
6	NNW	2570	U-238	3.5E-04	6.3E-11	7.8E-11	1.4E-10
7	NNW	2570	U-234	1.7E-03	3.1E-10	3.9E-10	7.0E-10
8	NNW	2570	NP-237	3.5E-05	6.3E-12	7.8E-12	1.4E-11
9	NNW	2570	TC-99	1.8E-03	3.2E-10	3.9E-10	7.1E-10
10	NNW	3000	U-235	8.6E-05	1.5E-11	1.9E-11	3.4E-11
11	NNW	3000	U-238	3.1E-04	5.5E-11	6.6E-11	1.2E-10
12	NNW	3000	U-234	1.5E-03	2.7E-10	3.3E-10	6.0E-10
13	NNW	3000	NP-237	3.1E-05	5.5E-12	6.6E-12	1.2E-11
14	NNW	3000	TC-99	1.5E-03	2.8E-10	3.3E-10	6.1E-10
15	NNW	4324	U-235	5.8E-05	1.0E-11	1.3E-11	2.3E-11
16	NNW	4324	U-238	2.1E-04	3.7E-11	4.5E-11	8.2E-11
17	NNW	4324	U-234	1.0E-03	1.8E-10	2.2E-10	4.0E-10
18	NNW	4324	NP-237	2.1E-05	3.7E-12	4.5E-12	8.2E-12
19	NNW	4324	TC-99	1.0E-03	1.8E-10	2.2E-10	4.1E-10
20	NW	1600	U-235	1.3E-04	2.4E-11	3.9E-11	6.3E-11
21	NW	1600	U-238	4.7E-04	8.5E-11	1.4E-10	2.3E-10
22	NW	1600	U-234	2.3E-03	4.2E-10	6.9E-10	1.1E-09
23	NW	1600	NP-237	4.7E-05	8.5E-12	1.4E-11	2.3E-11
24	NW	1600	TC-99	2.4E-03	4.3E-10	7.0E-10	1.1E-09
25	NW	2000	U-235	1.1E-04	1.9E-11	3.1E-11	5.0E-11
26	NW	2000	U-238	3.8E-04	6.8E-11	1.1E-10	1.8E-10
27	NW	2000	U-234	1.9E-03	3.3E-10	5.5E-10	8.9E-10
28	NW	2000	NP-237	3.8E-05	6.8E-12	1.1E-11	1.8E-11
29	NW	2000	TC-99	1.9E-03	3.4E-10	5.6E-10	9.0E-10
30	NW	2570	U-235	8.1E-05	1.5E-11	2.4E-11	3.9E-11
31	NW	2570	U-238	2.9E-04	5.2E-11	8.6E-11	1.4E-10
32	NW	2570	U-234	1.4E-03	2.6E-10	4.2E-10	6.8E-10
33	NW	2570	NP-237	2.9E-05	5.2E-12	8.6E-12	1.4E-11
34	NW	2570	TC-99	1.4E-03	2.6E-10	4.3E-10	6.9E-10
35	NW	3000	U-235	6.8E-05	1.2E-11	2.0E-11	3.3E-11
36	NW	3000	U-238	2.4E-04	4.4E-11	7.3E-11	1.2E-10
37	NW	3000	U-234	1.2E-03	2.2E-10	3.6E-10	5.8E-10
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ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
NW	3000	NP-237	2.4E-05	4.4E-12	7.3E-12	1.2E-11
NW	3000	TC-99	1.2E-03	2.2E-10	3.6E-10	5.8E-10
NW	4324	U-235	4.3E-05	7.8E-12	1.4E-11	2.2E-11
NW	4324	U-238	1.5E-04	2.8E-11	4.9E-11	7.7E-11
NW	4324	U-234	7.6E-04	1.4E-10	2.4E-10	3.8E-10
NW	4324	NP-237	1.5E-05	2.8E-12	4.9E-12	7.7E-12
NW	4324	TC-99	7.7E-04	1.4E-10	2.5E-10	3.8E-10
WNW	1600	U-235	6.4E-05	1.2E-11	3.8E-11	4.9E-11
WNW	1600	U-238	2.3E-04	4.1E-11	1.3E-10	1.8E-10
WNW	1600	U-234	1.1E-03	2.0E-10	6.6E-10	8.7E-10
WNW	1600	NP-237	2.3E-05	4.1E-12	1.3E-11	1.8E-11
WNW	1600	TC-99	1.1E-03	2.1E-10	6.7E-10	8.8E-10
WNW	2000	U-235	4.4E-05	7.8E-12	3.0E-11	3.8E-11
WNW	2000	U-238	1.6E-04	2.8E-11	1.1E-10	1.3E-10
WNW	2000	U-234	7.7E-04	1.4E-10	5.3E-10	6.7E-10
WNW	2000	NP-237	1.6E-05	2.8E-12	1.1E-11	1.3E-11
WNW	2000	TC-99	7.8E-04	1.4E-10	5.3E-10	6.7E-10
WNW	2570	U-235	3.2E-05	5.7E-12	2.3E-11	2.9E-11
WNW	2570	U-238	1.1E-04	2.0E-11	8.2E-11	1.0E-10
WNW	2570	U-234	5.6E-04	1.0E-10	4.1E-10	5.1E-10
WNW	2570	NP-237	1.1E-05	2.0E-12	8.2E-12	1.0E-11
WNW	2570	TC-99	5.6E-04	1.0E-10	4.1E-10	5.1E-10
WNW	3000	U-235	2.8E-05	5.1E-12	2.0E-11	2.5E-11
WNW	3000	U-238	1.0E-04	1.8E-11	7.0E-11	8.8E-11
WNW	3000	U-234	5.0E-04	8.9E-11	3.5E-10	4.4E-10
WNW	3000	NP-237	1.0E-05	1.8E-12	7.0E-12	8.8E-12
WNW	3000	TC-99	5.0E-04	9.0E-11	3.5E-10	4.4E-10
WNW	4324	U-235	2.0E-05	3.6E-12	1.3E-11	1.7E-11
WNW	4324	U-238	7.2E-05	1.3E-11	4.8E-11	6.1E-11
WNW	4324	U-234	3.6E-04	6.4E-11	2.4E-10	3.0E-10
WNW	4324	NP-237	7.2E-06	1.3E-12	4.8E-12	6.1E-12

WNW	4324	TC-99	3.6E-04	6.5E-11	2.4E-10	3.0E-10
W	1600	U-235	2.2E-04	4.0E-11	5.9E-11	9.9E-11
W	1600	U-238	7.9E-04	1.4E-10	2.1E-10	3.5E-10
W	1600	U-234	3.9E-03	7.0E-10	1.0E-09	1.7E-09
W	1600	NP-237	7.9E-05	1.4E-11	2.1E-11	3.5E-11
W	1600	TC-99	4.0E-03	7.1E-10	1.1E-09	1.8E-09
W	2000	U-235	1.7E-04	3.1E-11	4.7E-11	7.8E-11
W	2000	U-238	6.2E-04	1.1E-10	1.7E-10	2.8E-10
W	2000	U-234	3.1E-03	5.5E-10	8.3E-10	1.4E-09
W	2000	NP-237	6.2E-05	1.1E-11	1.7E-11	2.8E-11
W	2000	TC-99	3.1E-03	5.6E-10	8.4E-10	1.4E-09
W	2570	U-235	1.3E-04	2.4E-11	3.6E-11	6.0E-11
W	2570	U-238	4.7E-04	8.5E-11	1.3E-10	2.1E-10
W	2570	U-234	2.3E-03	4.2E-10	6.4E-10	1.1E-09
W	2570	NP-237	4.7E-05	8.5E-12	1.3E-11	2.1E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
W	2570	TC-99	2.4E-03	4.3E-10	6.5E-10	1.1E-09
W	3000	U-235	1.1E-04	2.0E-11	3.1E-11	5.1E-11
W	3000	U-238	4.0E-04	7.2E-11	1.1E-10	1.8E-10
W	3000	U-234	2.0E-03	3.6E-10	5.4E-10	9.0E-10
W	3000	NP-237	4.0E-05	7.2E-12	1.1E-11	1.8E-11
W	3000	TC-99	2.0E-03	3.6E-10	5.5E-10	9.1E-10
W	4324	U-235	7.2E-05	1.3E-11	2.1E-11	3.4E-11
W	4324	U-238	2.6E-04	4.6E-11	7.5E-11	1.2E-10
W	4324	U-234	1.3E-03	2.3E-10	3.7E-10	6.0E-10
W	4324	NP-237	2.6E-05	4.6E-12	7.5E-12	1.2E-11
W	4324	TC-99	1.3E-03	2.3E-10	3.7E-10	6.1E-10
WSW	1600	U-235	1.2E-04	2.2E-11	3.5E-11	5.7E-11
WSW	1600	U-238	4.4E-04	8.0E-11	1.2E-10	2.0E-10
WSW	1600	U-234	2.2E-03	4.0E-10	6.2E-10	1.0E-09
WSW	1600	NP-237	4.4E-05	8.0E-12	1.2E-11	2.0E-11
WSW	1600	TC-99	2.2E-03	4.0E-10	6.2E-10	1.0E-09
WSW	2000	U-235	1.1E-04	2.0E-11	2.8E-11	4.8E-11
WSW	2000	U-238	3.9E-04	7.1E-11	9.9E-11	1.7E-10
WSW	2000	U-234	1.9E-03	3.5E-10	4.9E-10	8.4E-10
WSW	2000	NP-237	3.9E-05	7.1E-12	9.9E-12	1.7E-11
WSW	2000	TC-99	2.0E-03	3.5E-10	4.9E-10	8.5E-10
WSW	2570	U-235	9.2E-05	1.7E-11	2.1E-11	3.8E-11
WSW	2570	U-238	3.3E-04	5.9E-11	7.6E-11	1.4E-10
WSW	2570	U-234	1.6E-03	2.9E-10	3.8E-10	6.7E-10
WSW	2570	NP-237	3.3E-05	5.9E-12	7.6E-12	1.4E-11
WSW	2570	TC-99	1.6E-03	3.0E-10	3.8E-10	6.8E-10
WSW	3000	U-235	8.0E-05	1.4E-11	1.8E-11	3.3E-11
WSW	3000	U-238	2.9E-04	5.2E-11	6.4E-11	1.2E-10
WSW	3000	U-234	1.4E-03	2.6E-10	3.2E-10	5.7E-10

WSW	3000	NP-237	2.9E-05	5.2E-12	6.4E-12	1.2E-11
WSW	3000	TC-99	1.4E-03	2.6E-10	3.2E-10	5.8E-10
WSW	4324	U-235	5.4E-05	9.7E-12	1.2E-11	2.2E-11
WSW	4324	U-238	1.9E-04	3.5E-11	4.3E-11	7.8E-11
WSW	4324	U-234	9.5E-04	1.7E-10	2.1E-10	3.9E-10
WSW	4324	NP-237	1.9E-05	3.5E-12	4.3E-12	7.8E-12
WSW	4324	TC-99	9.6E-04	1.7E-10	2.2E-10	3.9E-10
SW	1600	U-235	8.8E-05	1.6E-11	4.6E-11	6.1E-11
SW	1600	U-238	3.1E-04	5.7E-11	1.6E-10	2.2E-10
SW	1600	U-234	1.6E-03	2.8E-10	8.0E-10	1.1E-09
SW	1600	NP-237	3.1E-05	5.7E-12	1.6E-11	2.2E-11
SW	1600	TC-99	1.6E-03	2.8E-10	8.1E-10	1.1E-09
SW	2000	U-235	6.9E-05	1.3E-11	3.6E-11	4.9E-11
SW	2000	U-238	2.5E-04	4.5E-11	1.3E-10	1.7E-10
SW	2000	U-234	1.2E-03	2.2E-10	6.4E-10	8.6E-10
SW	2000	NP-237	2.5E-05	4.5E-12	1.3E-11	1.7E-11
SW	2000	TC-99	1.2E-03	2.2E-10	6.5E-10	8.7E-10
SW	2570	U-235	5.6E-05	1.0E-11	2.8E-11	3.8E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
SW	2570	U-238	2.0E-04	3.6E-11	1.0E-10	1.4E-10
SW	2570	U-234	9.9E-04	1.8E-10	4.9E-10	6.7E-10
SW	2570	NP-237	2.0E-05	3.6E-12	1.0E-11	1.4E-11
SW	2570	TC-99	1.0E-03	1.8E-10	5.0E-10	6.8E-10
SW	3000	U-235	5.1E-05	9.2E-12	2.4E-11	3.3E-11
SW	3000	U-238	1.8E-04	3.3E-11	8.5E-11	1.2E-10
SW	3000	U-234	9.0E-04	1.6E-10	4.2E-10	5.8E-10
SW	3000	NP-237	1.8E-05	3.3E-12	8.5E-12	1.2E-11
SW	3000	TC-99	9.1E-04	1.6E-10	4.2E-10	5.9E-10
SW	4324	U-235	3.7E-05	6.6E-12	1.6E-11	2.3E-11

SW	4324	U-238	1.3E-04	2.4E-11	5.7E-11	8.1E-11
SW	4324	U-234	6.5E-04	1.2E-10	2.8E-10	4.0E-10
SW	4324	NP-237	1.3E-05	2.4E-12	5.7E-12	8.1E-12
SW	4324	TC-99	6.6E-04	1.2E-10	2.9E-10	4.1E-10
SSW	1600	U-235	8.7E-05	1.6E-11	2.5E-11	4.1E-11
SSW	1600	U-238	3.1E-04	5.6E-11	9.1E-11	1.5E-10
SSW	1600	U-234	1.5E-03	2.8E-10	4.5E-10	7.2E-10
SSW	1600	NP-237	3.1E-05	5.6E-12	9.1E-12	1.5E-11
SSW	1600	TC-99	1.6E-03	2.8E-10	4.5E-10	7.3E-10
SSW	2000	U-235	6.9E-05	1.2E-11	2.0E-11	3.3E-11
SSW	2000	U-238	2.5E-04	4.5E-11	7.2E-11	1.2E-10
SSW	2000	U-234	1.2E-03	2.2E-10	3.6E-10	5.8E-10
SSW	2000	NP-237	2.5E-05	4.5E-12	7.2E-12	1.2E-11
SSW	2000	TC-99	1.2E-03	2.2E-10	3.6E-10	5.8E-10
SSW	2570	U-235	5.1E-05	9.2E-12	1.5E-11	2.5E-11
SSW	2570	U-238	1.8E-04	3.3E-11	5.5E-11	8.8E-11
SSW	2570	U-234	9.0E-04	1.6E-10	2.7E-10	4.4E-10
SSW	2570	NP-237	1.8E-05	3.3E-12	5.5E-12	8.8E-12
SSW	2570	TC-99	9.1E-04	1.6E-10	2.8E-10	4.4E-10
SSW	3000	U-235	4.1E-05	7.5E-12	1.3E-11	2.1E-11
SSW	3000	U-238	1.5E-04	2.7E-11	4.7E-11	7.4E-11
SSW	3000	U-234	7.3E-04	1.3E-10	2.3E-10	3.6E-10
SSW	3000	NP-237	1.5E-05	2.7E-12	4.7E-12	7.4E-12
SSW	3000	TC-99	7.4E-04	1.3E-10	2.3E-10	3.7E-10
SSW	4324	U-235	2.5E-05	4.4E-12	8.9E-12	1.3E-11
SSW	4324	U-238	8.8E-05	1.6E-11	3.2E-11	4.8E-11
SSW	4324	U-234	4.4E-04	7.8E-11	1.6E-10	2.4E-10
SSW	4324	NP-237	8.8E-06	1.6E-12	3.2E-12	4.8E-12
SSW	4324	TC-99	4.4E-04	7.9E-11	1.6E-10	2.4E-10
S	1600	U-235	1.6E-04	2.9E-11	4.2E-11	7.1E-11
S	1600	U-238	5.8E-04	1.0E-10	1.5E-10	2.5E-10
S	1600	U-234	2.9E-03	5.2E-10	7.4E-10	1.3E-09
S	1600	NP-237	5.8E-05	1.0E-11	1.5E-11	2.5E-11
S	1600	TC-99	2.9E-03	5.2E-10	7.5E-10	1.3E-09
S	2000	U-235	1.5E-04	2.6E-11	3.3E-11	6.0E-11
S	2000	U-238	5.2E-04	9.4E-11	1.2E-10	2.1E-10
S	2000	U-234	2.6E-03	4.6E-10	5.9E-10	1.1E-09

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
S	2000	NP-237	5.2E-05	9.4E-12	1.2E-11	2.1E-11
S	2000	TC-99	2.6E-03	4.7E-10	6.0E-10	1.1E-09
S	2570	U-235	1.2E-04	2.2E-11	2.6E-11	4.8E-11
S	2570	U-238	4.4E-04	7.8E-11	9.1E-11	1.7E-10
S	2570	U-234	2.1E-03	3.9E-10	4.5E-10	8.4E-10
S	2570	NP-237	4.4E-05	7.8E-12	9.1E-12	1.7E-11
S	2570	TC-99	2.2E-03	3.9E-10	4.6E-10	8.5E-10
S	3000	U-235	1.1E-04	1.9E-11	2.2E-11	4.1E-11
S	3000	U-238	3.8E-04	6.9E-11	7.8E-11	1.5E-10
S	3000	U-234	1.9E-03	3.4E-10	3.8E-10	7.2E-10
S	3000	NP-237	3.8E-05	6.9E-12	7.8E-12	1.5E-11
S	3000	TC-99	1.9E-03	3.4E-10	3.9E-10	7.3E-10
S	4324	U-235	7.2E-05	1.3E-11	1.5E-11	2.8E-11
S	4324	U-238	2.6E-04	4.6E-11	5.2E-11	9.9E-11
S	4324	U-234	1.3E-03	2.3E-10	2.6E-10	4.9E-10
S	4324	NP-237	2.6E-05	4.6E-12	5.2E-12	9.9E-12
S	4324	TC-99	1.3E-03	2.3E-10	2.6E-10	4.9E-10
SSE	1600	U-235	5.7E-04	1.0E-10	6.1E-11	1.6E-10
SSE	1600	U-238	2.0E-03	3.6E-10	2.2E-10	5.8E-10
SSE	1600	U-234	1.0E-02	1.8E-09	1.1E-09	2.9E-09
SSE	1600	NP-237	2.0E-04	3.6E-11	2.2E-11	5.8E-11
SSE	1600	TC-99	1.0E-02	1.8E-09	1.1E-09	2.9E-09
SSE	2000	U-235	4.2E-04	7.6E-11	4.8E-11	1.2E-10
SSE	2000	U-238	1.5E-03	2.7E-10	1.7E-10	4.4E-10
SSE	2000	U-234	7.5E-03	1.3E-09	8.5E-10	2.2E-09
SSE	2000	NP-237	1.5E-04	2.7E-11	1.7E-11	4.4E-11
SSE	2000	TC-99	7.5E-03	1.4E-09	8.7E-10	2.2E-09
SSE	2570	U-235	3.0E-04	5.4E-11	3.7E-11	9.2E-11

SSE	2570	U-238	1.1E-03	1.9E-10	1.3E-10	3.3E-10
SSE	2570	U-234	5.3E-03	9.5E-10	6.6E-10	1.6E-09
SSE	2570	NP-237	1.1E-04	1.9E-11	1.3E-11	3.3E-11
SSE	2570	TC-99	5.4E-03	9.7E-10	6.7E-10	1.6E-09
SSE	3000	U-235	2.4E-04	4.4E-11	3.2E-11	7.5E-11
SSE	3000	U-238	8.6E-04	1.6E-10	1.1E-10	2.7E-10
SSE	3000	U-234	4.3E-03	7.7E-10	5.6E-10	1.3E-09
SSE	3000	NP-237	8.6E-05	1.6E-11	1.1E-11	2.7E-11
SSE	3000	TC-99	4.3E-03	7.8E-10	5.7E-10	1.3E-09
SSE	4324	U-235	1.5E-04	2.6E-11	2.2E-11	4.8E-11
SSE	4324	U-238	5.3E-04	9.5E-11	7.8E-11	1.7E-10
SSE	4324	U-234	2.6E-03	4.7E-10	3.8E-10	8.5E-10
SSE	4324	NP-237	5.3E-05	9.5E-12	7.8E-12	1.7E-11
SSE	4324	TC-99	2.6E-03	4.7E-10	3.9E-10	8.6E-10
SE	1600	U-235	1.4E-03	2.4E-10	1.3E-10	3.7E-10
SE	1600	U-238	4.9E-03	8.7E-10	4.5E-10	1.3E-09
SE	1600	U-234	2.4E-02	4.3E-09	2.2E-09	6.5E-09
SE	1600	NP-237	4.9E-04	8.7E-11	4.5E-11	1.3E-10

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
SE	1600	TC-99	2.4E-02	4.4E-09	2.3E-09	6.6E-09
SE	2000	U-235	9.9E-04	1.8E-10	1.0E-10	2.8E-10
SE	2000	U-238	3.5E-03	6.4E-10	3.6E-10	1.0E-09
SE	2000	U-234	1.7E-02	3.1E-09	1.8E-09	4.9E-09
SE	2000	NP-237	3.5E-04	6.4E-11	3.6E-11	1.0E-10
SE	2000	TC-99	1.8E-02	3.2E-09	1.8E-09	5.0E-09
SE	2570	U-235	6.9E-04	1.2E-10	7.8E-11	2.0E-10
SE	2570	U-238	2.5E-03	4.4E-10	2.8E-10	7.2E-10
SE	2570	U-234	1.2E-02	2.2E-09	1.4E-09	3.6E-09
SE	2570	NP-237	2.5E-04	4.4E-11	2.8E-11	7.2E-11

1	SE	2570	TC-99	1.2E-02	2.2E-09	1.4E-09	3.6E-09
2	SE	3000	U-235	5.4E-04	9.8E-11	6.6E-11	1.6E-10
3	SE	3000	U-238	1.9E-03	3.5E-10	2.4E-10	5.9E-10
4	SE	3000	U-234	9.6E-03	1.7E-09	1.2E-09	2.9E-09
5	SE	3000	NP-237	1.9E-04	3.5E-11	2.4E-11	5.9E-11
6	SE	3000	TC-99	9.7E-03	1.8E-09	1.2E-09	2.9E-09
7	SE	4324	U-235	3.3E-04	5.9E-11	4.6E-11	1.0E-10
8	SE	4324	U-238	1.2E-03	2.1E-10	1.6E-10	3.7E-10
9	SE	4324	U-234	5.7E-03	1.0E-09	8.0E-10	1.8E-09
10	SE	4324	NP-237	1.2E-04	2.1E-11	1.6E-11	3.7E-11
11	SE	4324	TC-99	5.8E-03	1.0E-09	8.1E-10	1.9E-09
12	ESE	1600	U-235	7.2E-04	1.3E-10	1.1E-10	2.4E-10
13	ESE	1600	U-238	2.6E-03	4.6E-10	4.0E-10	8.6E-10
14	ESE	1600	U-234	1.3E-02	2.3E-09	2.0E-09	4.3E-09
15	ESE	1600	NP-237	2.6E-04	4.6E-11	4.0E-11	8.6E-11
16	ESE	1600	TC-99	1.3E-02	2.3E-09	2.0E-09	4.3E-09
17	ESE	2000	U-235	5.2E-04	9.3E-11	8.9E-11	1.8E-10
18	ESE	2000	U-238	1.8E-03	3.3E-10	3.2E-10	6.5E-10
19	ESE	2000	U-234	9.1E-03	1.6E-09	1.6E-09	3.2E-09
20	ESE	2000	NP-237	1.8E-04	3.3E-11	3.2E-11	6.5E-11
21	ESE	2000	TC-99	9.2E-03	1.7E-09	1.6E-09	3.3E-09
22	ESE	2570	U-235	3.6E-04	6.4E-11	6.9E-11	1.3E-10
23	ESE	2570	U-238	1.3E-03	2.3E-10	2.5E-10	4.8E-10
24	ESE	2570	U-234	6.3E-03	1.1E-09	1.2E-09	2.4E-09
25	ESE	2570	NP-237	1.3E-04	2.3E-11	2.5E-11	4.8E-11
26	ESE	2570	TC-99	6.4E-03	1.2E-09	1.2E-09	2.4E-09
27	ESE	3000	U-235	2.9E-04	5.1E-11	5.9E-11	1.1E-10
28	ESE	3000	U-238	1.0E-03	1.8E-10	2.1E-10	3.9E-10
29	ESE	3000	U-234	5.0E-03	9.1E-10	1.0E-09	1.9E-09
30	ESE	3000	NP-237	1.0E-04	1.8E-11	2.1E-11	3.9E-11
31	ESE	3000	TC-99	5.1E-03	9.2E-10	1.1E-09	2.0E-09
32	ESE	4324	U-235	1.7E-04	3.0E-11	4.0E-11	7.0E-11
33	ESE	4324	U-238	6.0E-04	1.1E-10	1.4E-10	2.5E-10
34	ESE	4324	U-234	3.0E-03	5.3E-10	7.1E-10	1.2E-09
35	ESE	4324	NP-237	6.0E-05	1.1E-11	1.4E-11	2.5E-11
36	ESE	4324	TC-99	3.0E-03	5.4E-10	7.2E-10	1.3E-09
37							
38							

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
E	1600	U-235	1.3E-03	2.3E-10	1.3E-10	3.6E-10
E	1600	U-238	4.7E-03	8.4E-10	4.6E-10	1.3E-09
E	1600	U-234	2.3E-02	4.1E-09	2.3E-09	6.4E-09
E	1600	NP-237	4.7E-04	8.4E-11	4.6E-11	1.3E-10
E	1600	TC-99	2.3E-02	4.2E-09	2.3E-09	6.5E-09
E	2000	U-235	9.4E-04	1.7E-10	1.0E-10	2.7E-10
E	2000	U-238	3.4E-03	6.1E-10	3.6E-10	9.7E-10
E	2000	U-234	1.7E-02	3.0E-09	1.8E-09	4.8E-09
E	2000	NP-237	3.4E-04	6.1E-11	3.6E-11	9.7E-11
E	2000	TC-99	1.7E-02	3.0E-09	1.8E-09	4.9E-09
E	2570	U-235	6.5E-04	1.2E-10	7.9E-11	2.0E-10
E	2570	U-238	2.3E-03	4.2E-10	2.8E-10	7.0E-10
E	2570	U-234	1.1E-02	2.1E-09	1.4E-09	3.5E-09
E	2570	NP-237	2.3E-04	4.2E-11	2.8E-11	7.0E-11
E	2570	TC-99	1.2E-02	2.1E-09	1.4E-09	3.5E-09
E	3000	U-235	5.2E-04	9.3E-11	6.7E-11	1.6E-10
E	3000	U-238	1.8E-03	3.3E-10	2.4E-10	5.7E-10
E	3000	U-234	9.1E-03	1.6E-09	1.2E-09	2.8E-09
E	3000	NP-237	1.8E-04	3.3E-11	2.4E-11	5.7E-11
E	3000	TC-99	9.2E-03	1.7E-09	1.2E-09	2.9E-09
E	4324	U-235	3.1E-04	5.5E-11	4.6E-11	1.0E-10
E	4324	U-238	1.1E-03	2.0E-10	1.7E-10	3.6E-10
E	4324	U-234	5.4E-03	9.8E-10	8.2E-10	1.8E-09
E	4324	NP-237	1.1E-04	2.0E-11	1.7E-11	3.6E-11
E	4324	TC-99	5.5E-03	9.9E-10	8.3E-10	1.8E-09
ENE	1600	U-235	1.9E-03	3.3E-10	1.8E-10	5.1E-10
ENE	1600	U-238	6.6E-03	1.2E-09	6.3E-10	1.8E-09
ENE	1600	U-234	3.3E-02	5.9E-09	3.1E-09	9.0E-09
ENE	1600	NP-237	6.6E-04	1.2E-10	6.3E-11	1.8E-10

ENE	1600	TC-99	3.3E-02	6.0E-09	3.1E-09	9.1E-09
ENE	2000	U-235	1.3E-03	2.4E-10	1.4E-10	3.8E-10
ENE	2000	U-238	4.8E-03	8.6E-10	5.0E-10	1.4E-09
ENE	2000	U-234	2.4E-02	4.2E-09	2.5E-09	6.7E-09
ENE	2000	NP-237	4.8E-04	8.6E-11	5.0E-11	1.4E-10
ENE	2000	TC-99	2.4E-02	4.3E-09	2.5E-09	6.8E-09
ENE	2570	U-235	9.1E-04	1.6E-10	1.1E-10	2.7E-10
ENE	2570	U-238	3.3E-03	5.9E-10	3.9E-10	9.7E-10
ENE	2570	U-234	1.6E-02	2.9E-09	1.9E-09	4.8E-09
ENE	2570	NP-237	3.3E-04	5.9E-11	3.9E-11	9.7E-11
ENE	2570	TC-99	1.6E-02	2.9E-09	1.9E-09	4.9E-09
ENE	3000	U-235	7.2E-04	1.3E-10	9.2E-11	2.2E-10
ENE	3000	U-238	2.6E-03	4.6E-10	3.3E-10	7.9E-10
ENE	3000	U-234	1.3E-02	2.3E-09	1.6E-09	3.9E-09
ENE	3000	NP-237	2.6E-04	4.6E-11	3.3E-11	7.9E-11
ENE	3000	TC-99	1.3E-02	2.3E-09	1.7E-09	4.0E-09
ENE	4324	U-235	4.2E-04	7.6E-11	6.4E-11	1.4E-10
ENE	4324	U-238	1.5E-03	2.7E-10	2.3E-10	5.0E-10

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
ENE	4324	U-234	7.4E-03	1.3E-09	1.1E-09	2.5E-09
ENE	4324	NP-237	1.5E-04	2.7E-11	2.3E-11	5.0E-11
ENE	4324	TC-99	7.5E-03	1.4E-09	1.1E-09	2.5E-09
NE	1600	U-235	2.0E-03	3.6E-10	2.4E-10	6.0E-10
NE	1600	U-238	7.2E-03	1.3E-09	8.5E-10	2.1E-09
NE	1600	U-234	3.6E-02	6.4E-09	4.2E-09	1.1E-08
NE	1600	NP-237	7.2E-04	1.3E-10	8.5E-11	2.1E-10
NE	1600	TC-99	3.6E-02	6.5E-09	4.3E-09	1.1E-08
NE	2000	U-235	1.4E-03	2.5E-10	1.9E-10	4.4E-10
NE	2000	U-238	5.0E-03	9.1E-10	6.8E-10	1.6E-09

NE	2000	U-234	2.5E-02	4.5E-09	3.4E-09	7.8E-09
NE	2000	NP-237	5.0E-04	9.1E-11	6.8E-11	1.6E-10
NE	2000	TC-99	2.5E-02	4.5E-09	3.4E-09	7.9E-09
NE	2570	U-235	9.4E-04	1.7E-10	1.5E-10	3.2E-10
NE	2570	U-238	3.4E-03	6.0E-10	5.3E-10	1.1E-09
NE	2570	U-234	1.7E-02	3.0E-09	2.6E-09	5.6E-09
NE	2570	NP-237	3.4E-04	6.0E-11	5.3E-11	1.1E-10
NE	2570	TC-99	1.7E-02	3.0E-09	2.6E-09	5.7E-09
NE	3000	U-235	7.3E-04	1.3E-10	1.3E-10	2.6E-10
NE	3000	U-238	2.6E-03	4.7E-10	4.5E-10	9.2E-10
NE	3000	U-234	1.3E-02	2.3E-09	2.2E-09	4.6E-09
NE	3000	NP-237	2.6E-04	4.7E-11	4.5E-11	9.2E-11
NE	3000	TC-99	1.3E-02	2.4E-09	2.3E-09	4.6E-09
NE	4324	U-235	4.2E-04	7.5E-11	8.7E-11	1.6E-10
NE	4324	U-238	1.5E-03	2.7E-10	3.1E-10	5.8E-10
NE	4324	U-234	7.4E-03	1.3E-09	1.5E-09	2.9E-09
NE	4324	NP-237	1.5E-04	2.7E-11	3.1E-11	5.8E-11
NE	4324	TC-99	7.4E-03	1.3E-09	1.6E-09	2.9E-09
NNE	1600	U-235	1.5E-03	2.7E-10	1.5E-10	4.2E-10
NNE	1600	U-238	5.4E-03	9.7E-10	5.4E-10	1.5E-09
NNE	1600	U-234	2.7E-02	4.8E-09	2.6E-09	7.5E-09
NNE	1600	NP-237	5.4E-04	9.7E-11	5.4E-11	1.5E-10
NNE	1600	TC-99	2.7E-02	4.9E-09	2.7E-09	7.5E-09
NNE	2000	U-235	1.1E-03	2.0E-10	1.2E-10	3.1E-10
NNE	2000	U-238	3.9E-03	7.0E-10	4.3E-10	1.1E-09
NNE	2000	U-234	1.9E-02	3.4E-09	2.1E-09	5.6E-09
NNE	2000	NP-237	3.9E-04	7.0E-11	4.3E-11	1.1E-10
NNE	2000	TC-99	1.9E-02	3.5E-09	2.1E-09	5.6E-09
NNE	2570	U-235	7.4E-04	1.3E-10	9.3E-11	2.3E-10
NNE	2570	U-238	2.6E-03	4.8E-10	3.3E-10	8.1E-10
NNE	2570	U-234	1.3E-02	2.4E-09	1.6E-09	4.0E-09
NNE	2570	NP-237	2.6E-04	4.8E-11	3.3E-11	8.1E-11
NNE	2570	TC-99	1.3E-02	2.4E-09	1.7E-09	4.0E-09
NNE	3000	U-235	5.8E-04	1.1E-10	7.9E-11	1.8E-10
NNE	3000	U-238	2.1E-03	3.8E-10	2.8E-10	6.6E-10
NNE	3000	U-234	1.0E-02	1.9E-09	1.4E-09	3.3E-09
NNE	3000	NP-237	2.1E-04	3.8E-11	2.8E-11	6.6E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
NNE	3000	TC-99	1.0E-02	1.9E-09	1.4E-09	3.3E-09
NNE	4324	U-235	3.5E-04	6.2E-11	5.4E-11	1.2E-10
NNE	4324	U-238	1.2E-03	2.2E-10	1.9E-10	4.2E-10
NNE	4324	U-234	6.1E-03	1.1E-09	9.6E-10	2.1E-09
NNE	4324	NP-237	1.2E-04	2.2E-11	1.9E-11	4.2E-11
NNE	4324	TC-99	6.2E-03	1.1E-09	9.7E-10	2.1E-09

WEATHER

HARMONIC AVERAGE WIND SPEEDS (WIND TOWARDS)

	Pasquill Stability Class							
Dir	A	B	C	D	E	F	G	Wind Freq
N	0.773	2.572	2.577	2.873	0.772	0.772	0.772	0.009
NNW	0.775	0.772	2.572	0.773	0.772	0.772	0.772	0.004
NW	0.772	0.772	2.572	0.775	0.772	0.772	0.772	0.004
WNW	0.772	0.772	2.574	2.573	2.572	0.772	0.772	0.004
W	0.773	0.779	9.769	0.780	0.774	0.772	0.772	0.025
WSW	0.776	0.784	2.575	0.773	0.774	0.775	0.772	0.004
SW	0.778	0.773	2.572	0.788	0.776	0.772	0.772	0.005
SSW	2.572	0.773	2.572	0.775	2.572	2.572	0.772	0.003
S	0.772	2.579	2.576	0.775	0.772	0.772	0.772	0.005
SSE	0.772	0.774	2.586	8.134	0.772	2.572	0.772	0.043
SE	0.772	0.774	2.593	8.833	0.772	0.772	0.772	0.117

ESE	0.773	0.772	9.773	5.093	0.772	0.772	0.772	0.079
E	0.774	0.774	9.769	8.706	0.772	0.772	0.772	0.122
ENE	0.774	0.777	9.757	8.818	0.773	2.572	0.772	0.172
NE	0.774	0.792	9.774	8.405	0.781	0.772	0.772	0.260
NNE	0.773	0.774	9.768	8.740	0.775	0.772	0.772	0.143

ARITHMETIC AVERAGE WIND SPEEDS (WIND TOWARDS)

	Pasquill Stability Class						
Dir	A	B	C	D	E	F	G
N	0.774	2.572	2.581	7.913	0.774	0.772	0.772
NNW	0.782	0.774	2.572	0.775	0.773	0.772	0.772
NW	0.772	0.773	2.572	0.783	0.773	0.774	0.772
WNW	0.773	0.773	2.575	2.573	2.572	0.772	0.772
W	0.777	0.795	9.773	0.799	0.778	0.772	0.772
WSW	0.784	0.811	2.576	0.776	0.779	0.784	0.772
SW	0.794	0.778	2.572	0.826	0.787	0.774	0.772
SSW	2.572	0.776	2.572	0.782	2.572	2.572	0.772
S	0.772	2.584	2.579	0.781	0.774	0.773	0.772
SSE	0.772	0.779	2.596	9.618	0.774	2.572	0.772
SE	0.773	0.779	2.608	9.691	0.774	0.773	0.772
ESE	0.775	0.774	9.774	9.061	0.774	0.772	0.772
E	0.780	0.779	9.773	9.679	0.773	0.772	0.772
ENE	0.778	0.788	9.770	9.690	0.777	2.572	0.772
NE	0.780	0.838	9.774	9.648	0.803	0.774	0.772
NNE	0.776	0.778	9.773	9.683	0.783	0.773	0.772

FREQUENCIES OF STABILITY CLASSES (WIND TOWARDS)

	Pasquill Stability Class						
Dir	A	B	C	D	E	F	G
N	0.1454	0.0002	0.0001	0.6180	0.1272	0.0545	0.0545

NNW	0.0419	0.0833	0.0002	0.2918	0.2915	0.0832	0.2081
NW	0.2305	0.3076	0.0001	0.1160	0.1922	0.0769	0.0768
WNW	0.2398	0.2796	0.0003	0.0007	0.0004	0.3195	0.1597
W	0.0417	0.0141	0.7910	0.0282	0.0487	0.0416	0.0347
WSW	0.1737	0.1322	0.0019	0.1729	0.3463	0.0868	0.0862
SW	0.0336	0.2997	0.0006	0.0342	0.1004	0.2991	0.2323
SSW	0.0001	0.2347	0.0005	0.3533	0.0010	0.0005	0.4099
S	0.1782	0.0001	0.0004	0.3223	0.2852	0.1425	0.0712
SSE	0.0240	0.0080	0.0000	0.9279	0.0360	0.0000	0.0040
SE	0.0132	0.0044	0.0000	0.9634	0.0132	0.0029	0.0029
ESE	0.0108	0.0194	0.7369	0.1919	0.0194	0.0108	0.0108
E	0.0028	0.0099	0.1606	0.8056	0.0113	0.0056	0.0042
ENE	0.0080	0.0070	0.1134	0.8567	0.0070	0.0000	0.0080
NE	0.0060	0.0014	0.6014	0.3781	0.0013	0.0059	0.0059
NNE	0.0072	0.0084	0.1367	0.8297	0.0036	0.0096	0.0048
TOTAL	0.0141	0.0124	0.2931	0.6418	0.0158	0.0110	0.0118

ADDITIONAL WEATHER INFORMATION

Average Air Temperature: 9.8 degrees C
283.00 K
Precipitation: 100.0 cm/y
Humidity: 8.0 g/cu m
Lid Height: 1000 meters
Surface Roughness Length: 0.010 meters
Height Of Wind Measurements: 10.0 meters
Average Wind Speed: 9.054 m/s

Vertical Temperature Gradients:
STABILITY E 0.073 k/m
STABILITY F 0.109 k/m
STABILITY G 0.146 k/m

Appendix E. RASCAL3 Model Output for K-25 Releases

The Radiological Assessment System for Consequence AnaLysis (RASCAL) 3.0 is a software package developed by the U.S. Nuclear Regulatory Commission (NRC) for conducting assessments of radiological accidents (NRC 2001). RASCAL3 includes three sets of components for consequence analysis: STDose, FMDose, and DecayCalc. STDose estimates 1) source terms for radiological accidents at nuclear reactors, 2) atmospheric transport, diffusion, and deposition of effluents from accidental releases, and 3) doses from exposure to release effluents. FMDose calculates doses from environmental radiological measurements and DecayCalc calculates future activities of radionuclides due to decay and ingrowth. The STDose, however, is the only component of the model used in this public health assessment.

STDose is composed of five computational modules (STCALC, TADPLUME, TADPUFF, UF6PLUME, and METPROC). The technical basis for these components is presented in the RASCAL3 User Guide (NRC 2001). Of these components, only the UF6PLUME module is used in this PHA. UF_6 is initially a dense gas that reacts with atmospheric water to form hydrogen fluoride (HF) and uranyl fluoride (UO_2F_2). The UF6PLUME module is a version of TADPLUME that has been modified to treat the dense gas dispersion and chemical transformations associated with releases of UF_6 (NRC 2001).

The UF6PLUME module works in two stages. The first stage calculates the spread of UF_6, the conversion of UF_6 to HF and UO_2F_2, and the plume rise of HF and UO_2F_2. In the second stage, a straight-line Gaussian model is used to calculate airborne transport and deposition of the HF and UO_2F_2. The specific calculation procedures are presented in the user guide (NRC 2001).

The RASCAL3 model includes a database of UF_6 processing facilities that can be used for event analysis. The K-25 facility was shut down before the RASCAL3 model was developed, however, so it is not included in the database of UF_6 processing facilities. Though, the model does include information on the U.S. Department of Energy's Paducah Gaseous Diffusion Plant (located just outside Paducah, Kentucky)—a plant which is very similar to that of the former K-25 facility. Consequently, the September 1958 release from the K-1131 building at the K-25 site is modeled as a release from the C-331 building at the Paducah Gaseous Diffusion Plant. Due to the similar

building designs and operations, this substitution is a reasonable approximation of historic conditions at K-25.[9]

Meteorological data used for evaluating a release can be input from site-specific weather conditions or for typical summer or winter weather conditions. Because historic releases from the K-25/S-50 facility could have occurred during any type of weather conditions, ATSDR used worst-case conditions that result in maximum transport and minimum dispersion of the release plume. RASCAL3 is only used to evaluate potential exposures from short-term accidental or episodic releases, thus site-specific meteorological data are not required. Results of this model will be used to evaluate worst-case conditions from the September 1, 1958 accidental UF_6 releases from the K-25 facility. The model will assume that plume dispersion was in the direction of maximum exposure at the time of the release and that worst-case meteorological conditions were present. These worst-case conditions and other release parameters are presented below. As presented in the following case summary, the release of 1,184 kg of UF_6 (0.7% enrichment) is assumed to occur over a 1-hour time period from a 23-meter stack height. Doses are measured over a 6-hour period and meteorological conditions are constant over that period.

Case Summary

Event Type Fuel Cycle / UF_6 / Criticality

Location

Name: K-25

City, county, state: Oak Ridge, Roane, TN

Elevation: 253 m

Latitude, longitude: 35.5 N, 84.4 W

[9] The assumed release height of 23 meters is the same as the CAP88-PC analyses and previous modeling presented

Time zone: Eastern

Source Term

Type: UF_6 Cascade

Building name: K-1131 Cascade / Process

Amount released: 1,184 kg

Time of release: 09/01/1958 00:00

Release fraction: 1.00E+00

Release rate: 1.30E+02 lb/s

UF_6 Enrichment: 0.7 percent

Release Pathway

Type: UF_6 Release

Building flow config: Summer

Release timings

To atmosphere start: 09/01/1958 00:00

To atmosphere stop: 09/01/1958 01:00

in the Task 6 Report (Chemrisk 1999a).

Meteorology

Type: Predefined - Not site specific

Data set name: Summer - Night - Calm

Data set desc: F Stab 4 mph No Precip 55F 80% rh

Summary of data		Dir	Speed	Stability		Temp	RH
at release point:	Type	deg	mph	class	Precip	°F	%
00:00	Obs	270	4.0	F	None	55	80

Calculations

Case description: K-25 Accidental Release summer night calm

End of calculations: 09/01/1958 06:00

Distance of calculation: Close-in only

Close-in distances: 0.5, 1.0, 1.5, 2.0, 2.57, 3.0, 4.32, 5.0 kilometers

Debug Mode Settings

Plume algorithms: RASCAL 3

Puff algorithms: RASCAL 3

Model time step: 5 minutes

Puff cleaning: Off

Maximum Dose Values

Dist from release												
miles	0.311	0.621	0.932	1.243	1.597	1.864	2.687	3.107				
(kilometers)		(0.5)	(1.)	(1.5)	(2.)	(2.57)	(3.)	(4.32)	(5.)			
Avg HF Conc. (ppm)			6.1E+00		1.0E+01		1.5E+00		7.6E-01	4.0E-01	2.6E-01	5.7E-02
	2.9E-02											
1h Eq HF Conc. (ppm)			1.3E+00		2.7E+00		4.6E-01	2.7E-01	1.6E-01	1.1E-01	2.7E-02	1.4E-02
Deposited HF (g/m^2)			9.3E-03	2.4E-02	4.8E-03	3.1E-03	2.0E-03	1.5E-03	4.2E-04	2.4E-04		
U Exposure ($(g-s)/m^3$)			2.9E+01		1.8E+01		2.1E+00		1.5E+00		1.1E+00	
	8.3E-01	3.6E-01	2.4E-01									
U Inhaled (mg)		9.7E+00		5.9E+00		6.9E-01	4.9E-01	3.5E-01	2.8E-01	1.2E-01	8.1E-02	
U Inhaled Dose (rem)			9.4E-01	5.7E-01	6.7E-02	4.8E-02	3.4E-02	2.7E-02	1.2E-02	7.8E-03		
U Deposition (g/m^2)			1.7E-02	4.4E-02	9.4E-03	6.6E-03	4.7E-03	3.8E-03	1.6E-03	1.1E-03		

UF_6 Plume distance: 1,317.4 meters

Notes:

1. NRC action limit for intake of soluble uranium - 10 mg
2. HF limits - 30 ppm, possible death; 20 ppm health effects

Appendix F. K-25 Meteorological Data

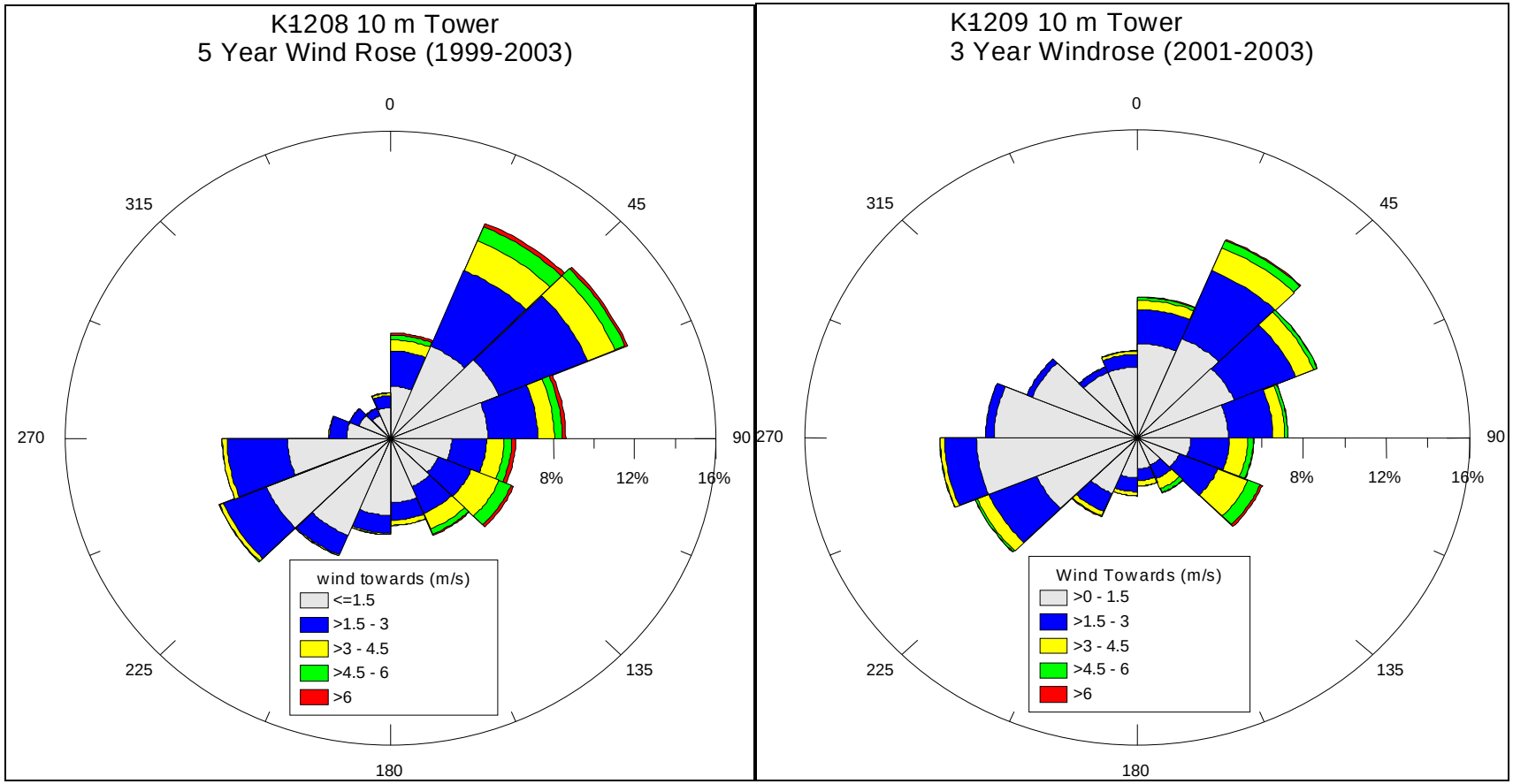
DOE operates two meteorological data towers on the K-25 site (K-1208 and K-1209) (see Figure 14). The K-1208 location includes 10-meter and 60-meter towers, which have been operational since about 1985. The K-1209 location has 10-meter and 30-meter towers that have operated since 1993. To evaluate releases from the K-25 and S-50 facilities, ATSDR obtained hourly and annual meteorological summary data sets from these on-site weather stations. ATSDR used data from the K-1208 10-meter tower in all air dispersion models because it is close to the center of the K-25/S-50 facility and very close to the buildings that are the primary release points for airborne emissions. The K-1209 tower is close to the site of the former S-50 facility.

Multi-year wind roses for each location are shown in Figures F-1 and F-2. These wind roses, based on hourly wind direction and velocity, show the percentage of time that wind of specified velocities and directions (blowing towards) occurred during these years. In general the wind distribution for these years is very similar, with the most frequent and strongest winds blowing towards the northeast and a less frequent trend towards the southwest. This wind distribution pattern is a strong reflection of the orientation of the ridges and valleys. The overall distribution of wind directions is similar for the different towers. The distribution of wind velocities is different with the K-1209 tower, however, which shows a higher percentage of low velocity winds blowing towards the west.

Because the locations (and elevations) of the K-1208 and K-1209 towers approximately correspond with the locations of K-25 and S-50 (respectively), in the CAP88-PC model ATSDR uses meteorological data for each of these locations to evaluate contaminant dispersion and historic exposures from each source. Figure F-2 shows annual wind roses for the K-1208 tower. Overall, the variation in wind patterns between different years is minimal. ATSDR will, however, use additional CAP88-PC evaluations to determine any significant differences in dispersion and dose for different years.

ATSDR obtained 8 and 5 years of hourly data for the K-1208 and K-1209 locations, respectively. Several years of data for each location, however, are in formats unsuitable for use in the CAP88-PC model. In addition, 2002 data for the K-1208 location includes numerous

Figure F-1. Multi-Year Wind Roses From K-1208 and K-1209 Meteorological Towers (10-Meter)



Notes:

Meteorological tower locations are shown in Figure 14.

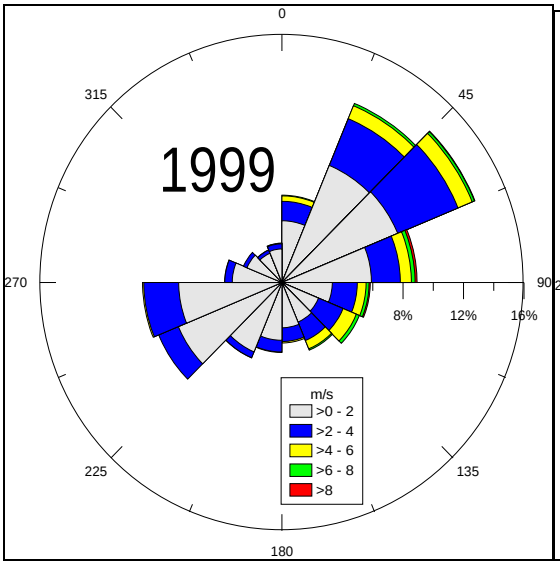
Wind directions are “towards” and speeds are in meter per second (m/s).

Although distribution of directions is similar, there is a difference in velocity distributions.

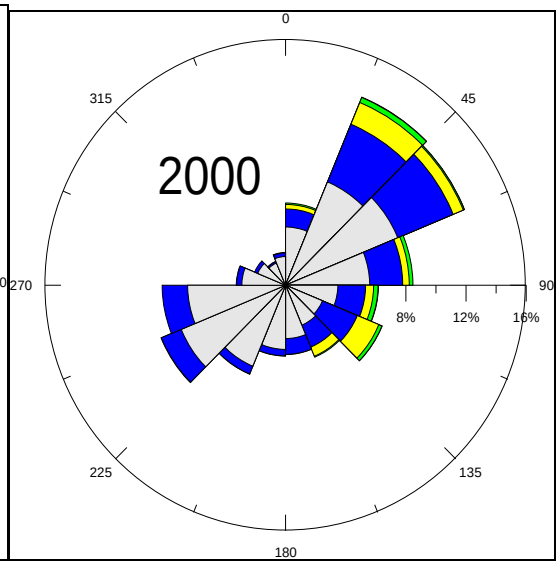
Individual annual wind roses for the towers are very similar.

Figure F-2. Wind Roses for 1999-2003 Meteorological Data

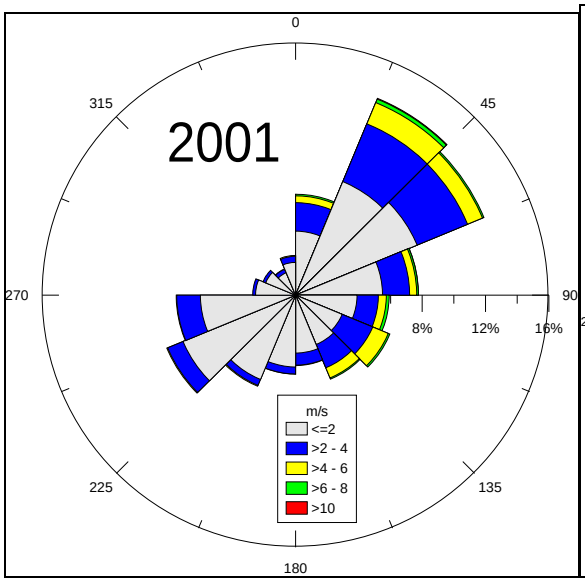
A.



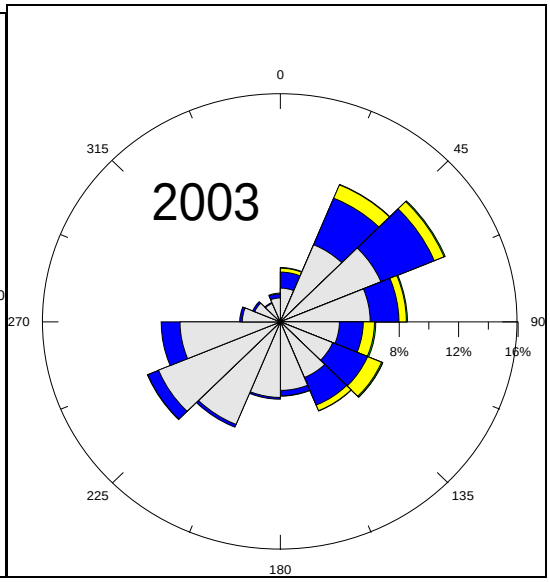
B.



C.



D.



Notes:

Years based on hourly data from the K-1208 10-meter tower.

Wind speeds are in meter/second (m/s) and direction is shown as wind direction "towards."

The highest proportion of all winds, and especially the strongest winds, blows towards the northeast with a less frequent trend toward the southwest.

Although the yearly wind roses are similar, they produced slightly different estimated radionuclide concentrations and doses at the HP-35 and HP-33 locations.

Missing values erroneously interpreted by the CAP88-PC model. Thus, the air dispersion results for the K-25 facility are based on the 1999, 2000, 2001, and 2003 meteorological data years from the K-1208 location. For the S-50 facility, the air dispersion results are based on the 2001, 2002, and 2003 meteorological data years from the K-1209 location.

Appendix G. Measured vs. Predicted Concentrations at Monitoring Locations

G.1. Measured vs. Predicted Gross Alpha Concentrations at Monitoring Locations

Figures G-1 and G-2 show the predicted vs. measured gross alpha concentrations at the HP-35 and HP-33 locations, respectively, for the 1966 to 1983 period. Each figure has three trend lines—the measured annual average gross alpha concentration at that location, the concentrations predicted using CAP88-PC with the DOE report release estimates (plus background), and the predicted concentrations using CAP88-PC with the Task 6 report release estimates (plus background). For the CAP88-PC predictions, the HP-35 location is assumed to be 2,000 meters northeast of the center of the site (point of release) and the HP-33 location is assumed to be 3,000 meters south-southeast of the center of the site. Background concentrations, taken as the annual average of the remote stations (located 12 to 70 miles from the ORR), are added to the CAP88-PC concentrations based on K-25/S-50 emissions.[10] Also, predicted gross alpha concentrations are the sum of the U-234, U-235, U-238, and Np-237 concentrations, and all of the CAP88-PC model concentrations were based on the 1999 meteorological data year.

Even with the simplified assumptions noted above, these figures show substantial agreement between the historic measured gross alpha concentrations and those predicted using the CAP88-PC air dispersion model with K-25/S-50 air release estimates. For most years, the predicted concentrations are slightly higher than measured concentrations with the exception of 1966 and 1967. For those years, the measured concentrations are about 40% greater than the predicted values. There are several potential explanations for the apparent deviation between measured and predicted gross alpha concentrations for those years: a) the emissions were underestimated for those years, b) the 1999 meteorological data are not appropriate, or c) the measured concentrations may be in error. Although all of these potential explanations have some validity, it is interesting to note that background concentrations for 1966 and 1967 (from remote stations 12 to 70 miles from the ORR) were 2 to 3 times higher than subsequent years (from 1966 and 1967 monitoring reports).

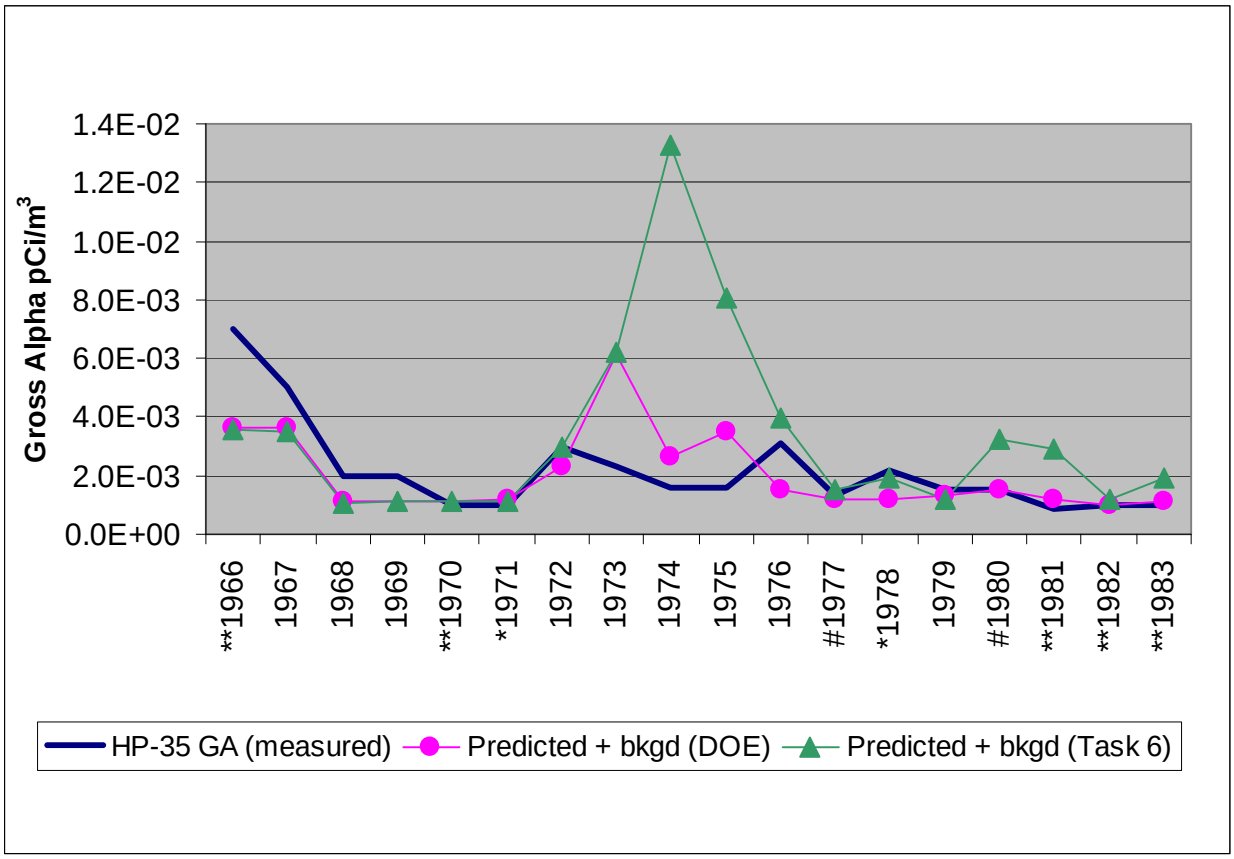
[10] The gross alpha monitoring data measure all ambient gross alpha decays. The CAP88-PC predicted data include only dispersed concentrations from K-25/S-50 sources. Consequently, measured background gross alpha concentrations from remote stations are added to the predicted concentrations to enable comparisons with monitored concentrations.

Although the agreement between measured and predicted gross alpha concentrations is not perfect, the overall trends shown in Figures G-1 and G-2 indicate that CAP88-PC and the estimated emission rates adequately predict the environmental concentrations of radionuclides released from the K-25 facility. This agreement between measured and modeled gross alpha concentrations—during the period when measured gross alpha data are available—provides confidence that the modeling procedure may be used to estimate off-site exposure doses for the earlier maximum release years (1961 and 1963).

It should be noted that both predicted and measured gross alpha for the HP-35 location are about 1.5 to 2 times higher than the HP-33 location. This is expected because HP-35 is in the dominant downwind direction relevant to releases from the K-25 sources. It is also significant to note that the concentrations predicted for HP-35 from DOE-estimated emissions provide a somewhat better agreement with measured gross alpha concentrations than the concentrations predicted with Task 6 report emissions.

The CAP88-PC predicted concentrations shown in Figures G-1 and G-2 all use the 1999 meteorological data (K-1209 tower; Figure 14) with different radionuclide emission estimates (Table 5). Table G-1 shows the predicted annual doses at the HP-35 and HP-33 locations using the 1963 emission estimates and meteorological data for four different years (1999, 2000, 2001, and 2003). The resulting doses from CAP88-PC (whole-body effective dose equivalent rates in millirem/year) show some expected variation, but are reasonably uniform. Subsequent dose estimates at the areas of maximum exposure (Union/Lawnville and Happy Valley) are based on the 1999 meteorological data, which produced the highest dose at the HP-35 location and the second highest dose at the HP-33 location.

Figure G-1. Predicted vs. Measured Gross Alpha Concentrations at HP-35 Location Based on DOE and Task 6 Emission Estimates



Notes:

Bkgd = background

Measured annual average gross alpha concentration (pCi/m^3) from monitoring location HP-35 vs. annual average gross alpha concentrations predicted using CAP88-PC with the DOE and ChemRisk K-25/S-50 emission estimates.

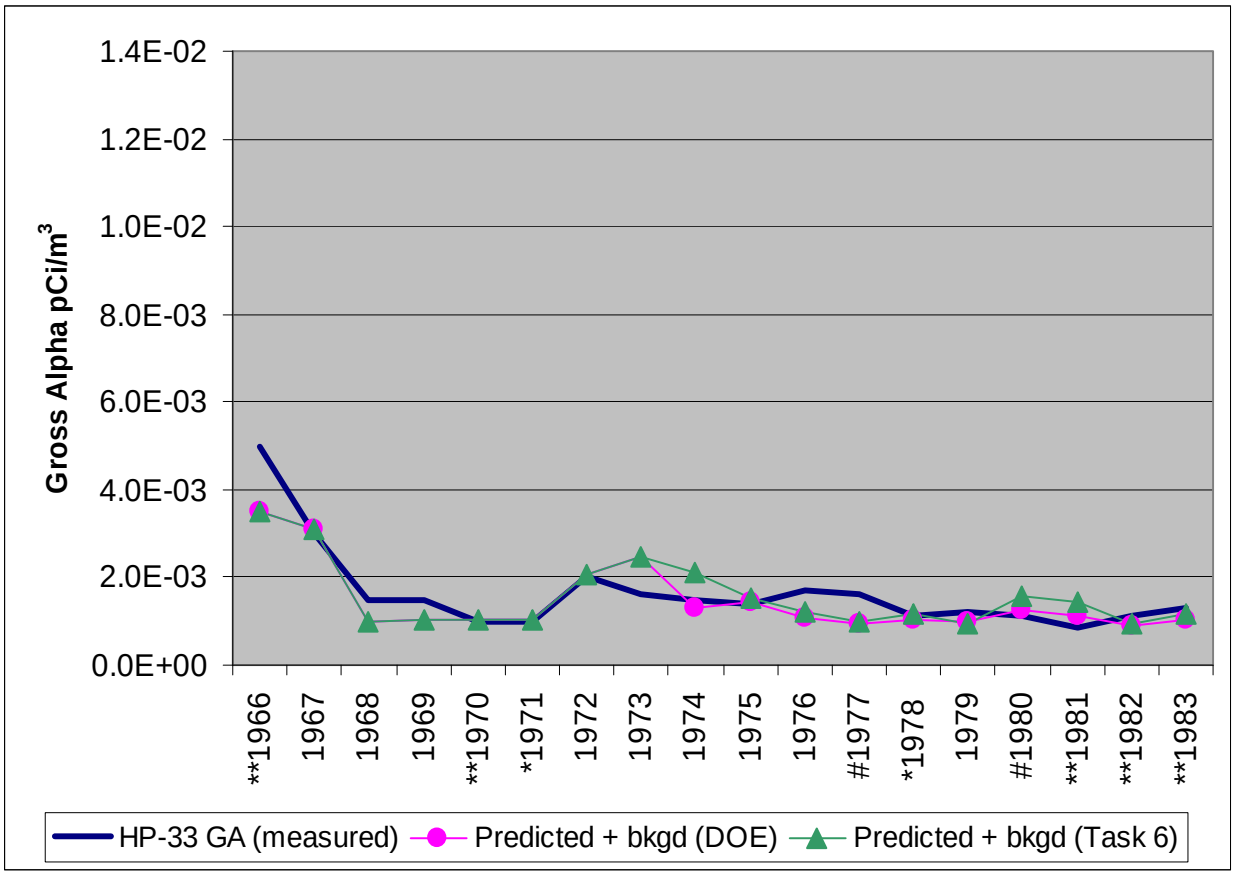
The HP-35 location is taken as 2,000 meters northeast of the plume origin or center of the K-25 facility.

The 1999 meteorological data set was used for all years.

Predicted gross alpha concentrations include measured background gross alpha concentrations from remote stations and are the sum of the U-234, U-235, U-238, and Np-237 concentrations.

*, **, and # symbols represent years with nearly identical emission estimates, such that independent analyses were not conducted.

Figure G-2. Predicted vs. Measured Gross Alpha Concentrations at HP-33 Location Based on DOE and Task 6 Emission Estimates



Notes:

Bkgd = background.

Measured annual average gross alpha concentration (pCi/m^3) from monitoring location HP-33 vs. annual average gross alpha concentrations predicted using CAP88-PC with the DOE and ChemRisk K-25/S-50 emission estimates.

The HP-33 location is taken as 3,000 meters south-southeast of the plume origin or center of the K-25 facility.

The 1999 meteorological data set was used for all years.

Predicted gross alpha concentrations include measured background gross alpha concentrations from remote stations and are the sum of the U-234, U-235, U-238, and Np-237 concentrations.

*, **, and # symbols represent years with nearly identical emission estimates such that independent analyses were not conducted.

Table G-1. Effect of Different Meteorological Data Years on K-25 Releases at the HP-35 and HP-33 Locations

Year	*HP-35 (mrem/yr)*	*HP-33 (mrem/yr)*
1999	37	6.7
2000	30	4.0
2001	29	7.4
2002	--	--
2003	36	2.4
	Avg. 33 Std. 4.1	Avg. 5.1 Std. 2.3

Notes:

Radionuclide emissions are based on 1963 DOE release estimates.

Doses are individual whole-body effective dose equivalent rate (mrem/year) from CAP88-PC.

The 2002 data included numerous missing values, which resulted in inaccurate input for CAP88-PC model for that year.

Avg. equals numeric average.

Std. equals standard deviation.

Appendix H. Summary Briefs

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Dose Reconstruction Feasibility Study Oak Ridge Health Study Phase I Report

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1992
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The Dose Reconstruction Feasibility Study had two purposes: first, to identify past chemical and radionuclide releases from the Oak Ridge Reservation (ORR) that have the highest potential to impact the health of the people living near the ORR; and second, to determine whether sufficient information existed about these releases to estimate the exposure doses received by people living near the ORR.

Background

In July 1991, the Tennessee Department of Health initiated a Health Studies Agreement with the U.S. Department of Energy (DOE). This agreement provides funding for an independent state evaluation of adverse health effects that may have occurred in populations around the ORR. The Oak Ridge Health Agreement Steering Panel (ORHASP) was established to direct and oversee this state evaluation (hereafter called the Oak Ridge Health Studies) and to facilitate interaction and cooperation with the community. ORHASP was an independent panel of local citizens and nationally recognized scientists who provided direction, recommendations, and oversight for the Oak Ridge Health Studies. These health studies focused on the potential effects from off-site exposures to chemicals and radionuclides released at the reservation since 1942. The state conducted the Oak Ridge Health Studies in two phases. Phase 1 is the Dose Reconstruction Feasibility Study described in this summary.

Methods

The Dose Reconstruction Feasibility Study consisted of seven tasks. During Task 1, state investigators identified historical operations at the ORR that used and released chemicals and radionuclides. This involved interviewing both active and retired DOE staff members about past operations, as well as reviewing historical documents (such as purchase orders, laboratory records, and published operational reports). Task 1 documented past activities at each major facility, including routine operations, waste management practices, special projects, and accidents and incidents. Investigators then prioritized these activities for further study based on the likelihood that releases from these activities could have resulted in off-site exposures.

During Task 2, state investigators inventoried the available environmental sampling and research data that could be used to estimate the doses that local populations may have received from chemical and radionuclide releases from the ORR. These data, obtained from DOE and other federal and state agencies (such as the U.S. Environmental Protection Agency, Tennessee Valley

Authority, and the Tennessee Division of Radiological Health), were summarized by environmental media (such as surface water, sediment, air, drinking water, groundwater, and food items). As part of this task, investigators developed abstracts which summarize approximately 100 environmental monitoring and research projects that characterize the historical presence of contaminants in areas outside the ORR.

Based on the results of Tasks 1 and 2, investigators identified a number of historical facility processes and activities at ORR as having a high potential for releasing substantial quantities of contaminants to the off-site environment. These activities were recommended for further evaluation in Tasks 3 and 4.

Tasks 3 and 4 were designed to provide an initial, very rough evaluation of the large quantity of information and data identified in Tasks 1 and 2, and to determine the potential for the contaminant releases to impact the public's health. During Task 3, investigators sought to answer the question: How could contaminants released from the Oak Ridge Reservation have reached local populations? This involved identifying the exposure pathways that could have transported contaminants from the ORR site to residents.

Task 3 began with compiling a list of contaminants investigated during Task 1 and Task 2. These contaminants are listed in Table 1. The contaminants in the list were separated into four general groups: radionuclides, nonradioactive metals, acids/bases, and organic compounds. One of the first steps in Task 3 was to eliminate any chemicals on these lists that were judged unlikely to reach local populations in quantities that would pose a health concern. For example, acids and bases were not selected for further evaluation because these compounds rapidly dissociate in the environment and primarily cause acute health effects, such as irritation. Likewise, although chlorofluorocarbons (Freon) were used in significant quantities at each of the ORR facilities, they were judged unlikely to result in significant exposure because they also rapidly disassociate. Also, some other contaminants (see Table 2) were not selected for further evaluation because they were used in relatively small quantities or in processes that are not believed to be associated with significant releases. Investigators determined that only a portion of contaminants identified in Tasks 1 and 2 could have reached people in the Oak Ridge area and potentially impacted their health. These contaminants, listed in Table 3, were evaluated further in Tasks 3 and 4.

The next step in Task 3 was to determine, for each contaminant listed in Table 3, whether a complete exposure pathway existed. A complete exposure pathway means a plausible route by which the contaminant could have traveled from ORR to off-site populations. Only those contaminants with complete exposure pathways would have the potential to cause adverse health effects. In this feasibility study, an exposure pathway is considered complete if it has the following three elements:

- A source that released the contaminant into the environment;
- A transport medium (such as air, surface water, soil, or biota) or some combination of these media (e.g., air → pasture → livestock milk) that carried the contaminant off the site to a location where exposure could occur; and
- An exposure route (such as inhalation, ingestion, or—in the case of certain radionuclides that emit gamma or beta radiation—immersion) through which a person could come into contact with the contaminant.

In examining whether complete exposure pathways existed, investigators considered the characteristics of each contaminant and the environmental setting at the ORR. Contaminants that lacked a source, transport medium, or exposure route were eliminated from further consideration because they lacked a complete exposure pathway. Through this analysis, investigators identified a number of contaminants with complete exposure pathways.

During Task 4, investigators sought to determine qualitatively which of the contaminants with complete exposure pathways appeared to pose the greatest potential to impact off-site populations. They began by comparing the pathways for each contaminant individually. For each contaminant, they determined which pathway appeared to have the greatest potential for exposing off-site populations, and they compared the exposure potential of the contaminant's other pathways to its most significant pathway. They then divided contaminants into three categories—radionuclides, carcinogens, and noncarcinogens—and compared the contaminants within each category based on their exposure potential and on their potential to cause health effects. This analysis identified facilities, processes, contaminants, media, and exposure routes believed to have the greatest potential to impact off-site populations. The results are provided in Table 4.

The Task 4 analysis was intended to provide a preliminary framework to help focus and prioritize future quantitative studies of the potential health impacts of off-site contamination. These analyses are intended to provide an initial approach to studying an extremely complex site. However, care must be taken in attempting to make broad generalizations or draw conclusions about the potential health hazard posed by the releases from the ORR.

In Task 5, investigators described the historical locations and activities of populations most likely to have been affected by the releases identified in Task 4. During Task 6, investigators compiled a summary of the current toxicologic knowledge and hazardous properties of the key contaminants. Task 7 involved collecting, categorizing, summarizing, and indexing selected documents relevant to the feasibility study.

Study Group

A study group was not selected.

Exposures

Seven completed exposure pathways associated with air, six completed exposure pathways associated with surface water, and ten completed exposure pathways associated with soil/sediment were evaluated for radionuclides and chemical substances (metals, organic compounds, and polycyclic aromatic hydrocarbons) released at the ORR from 1942 to 1992.

Outcome Measures

No outcome measures were studied.

Conclusions

The feasibility study indicated that past releases of the following contaminants have the greatest potential to impact off-site populations.

- **Radioactive iodine**
  The largest identified releases of radioactive iodine were associated with radioactive lanthanum processing from 1944 through 1956 at the X-10 facility.

- **Radioactive cesium**
  The largest identified releases of radioactive cesium were associated with various chemical separation activities that took place from 1943 through the 1960s.

- **Mercury**
  The largest identified releases of mercury were associated with lithium separation and enrichment operations that were conducted at the Y-12 facility from 1955 through 1963.

- **Polychlorinated biphenyls**
  Concentrations of polychlorinated biphenyls (PCBs) found in fish taken from the East Fork Poplar Creek and the Clinch River have been high enough to warrant further study. These releases likely came from electrical transformers and machining operations at the K-25 and Y-12 plants.

State investigators determined that sufficient information was available to reconstruct past releases and potential off-site doses for these contaminants. The steering panel (ORHASP) recommended that dose reconstruction activities proceed for the releases of radioactive iodine, radioactive cesium, mercury, and PCBs. Specifically they recommended that the state should continue the tasks begun during the feasibility study, and should characterize the actual release history of these contaminants from the reservation; identify appropriate fate and transport models to predict historical off-site concentrations; and identify an exposure model to use in calculating doses to the exposed population.

The panel also recommended that a broader-based investigation of operations and contaminants be conducted to study the large number of ORR contaminants released that have lower potentials for off-site health effects, including the five contaminants (chromium VI; plutonium-239, -240, and -241; tritium; arsenic; and neptunium-237) that could not be qualitatively evaluated during Phase 1 due to a lack of available data. Such an investigation would help in modifying or reinforcing the recommendations for future health studies.

Additionally, the panel recommended that researchers explore opportunities to conduct epidemiologic studies investigating potential associations between exposure doses and adverse health effects in exposed populations.

TABLE 1

LIST OF CONTAMINANTS INVESTIGATED DURING TASK 1 AND TASK 2

X-10	K-25	Y-12
Radionuclides		
Americium-241 Argon-41 Barium-140 Berkelium Californium-252 Carbon-14 Cerium-144 Cesium-134,-137 Cobalt-57,-60 Curium-242,-243,-244 Einsteinium Europium-152,-154,-155 Fermium Iodine-129, -131, -133 Krypton-85 Lanthanum-140 Niobium-95 Phosphorus-32 Plutonium-238, -239, -240, -241 Protactinium-233 Ruthenium-103, -106 Selenium-75 Strontium-89, -90 Tritium Uranium-233,-234, -235, -238 Xenon-133 Zirconium-95	Neptunium-237 Plutonium-239 Technetium-99 Uranium-234, -235, -238	Neptunium-237 Plutonium-239, -239, -240, -241 Technetium-99 Thorium-232 Tritium Uranium-234, -235, -238
Nonradioactive Metals		
None initially identified	Beryllium Chromium (trivalent and hexavalent) Nickel	Arsenic Beryllium Chromium (trivalent and hexavalent) Lead Lithium Mercury
Acids/Bases		
Hydrochloric acid Hydrogen peroxide Nitric acid Sodium hydroxide Sulfuric acid	Acetic acid Chlorine trifluoride Fluorine and fluoride compounds Hydrofluoric acid Nitric acid Potassium hydroxide Sulfuric acid	Ammonium hydroxide Fluorine and various fluorides Hydrofluoric acid Nitric acid Phosgene
Organic Compounds		
None initially identified	Benzene Carbon tetrachloride Chloroform Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls 1,1,1-Trichloroethane Trichloroethylene	Carbon tetrachloride Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls Tetrachloroethylene 1,1,1-Trichloroethane Trichloroethylene

TABLE 2

CONTAMINANTS NOT WARRANTING FURTHER EVALUATION IN TASK 3 AND TASK 4

Radionuclides
Americium-241
Californium-252
Carbon-14
Cobalt-57
Cesium-134
Curium-242, -243, -244
Europium-152, -154, -155
Phosphorus-32
Selenium-75
Uranium-233
Berkelium
Einsteinium
Fermium
Nonradioactive Metals
Lithium
Organic Compounds
Benzene
Chlorofluorocarbons (Freons)
Chloroform
Acids/Bases
Acetic acid
Ammonium hydroxide
Chlorine trifluoride
Fluorine and various fluoride compounds
Hydrochloric acid
Hydrogen peroxide
Hydrofluoric acid
Nitric acid
Phosgene
Potassium hydroxide
Sulfuric acid
Sodium hydroxide

TABLE 3

CONTAMINANTS FURTHER EVALUATED IN TASK 3 AND TASK 4

Radionuclides	Nonradioactive Metals	Organic Compounds
Argon-41	Arsenic	Carbon tetrachloride
Barium-140	Beryllium	Methylene chloride
Cerium-144	Chromium (trivalent and hexavalent)	Polychlorinated biphenyls
Cesium-137	Lead	Tetrachloroethylene
Cobalt-60	Mercury	1,1,1-Trichloroethane
Iodine-129, -131, -133	Nickel	Trichloroethylene
Krypton-85		
Lanthanum-140		
Neptunium-237		
Niobium-95		
Plutonium-238, -239, -240, -241		
Protactinium-233		
Ruthenium-103, -106		
Strontium-89, 90		
Technetium-99		
Thorium-232		
Tritium		
Uranium-234 -235, -238		
Xenon-133		
Zirconium-95		

TABLE 4

HIGHEST PRIORITY CONTAMINANTS, SOURCES, TRANSPORT MEDIA, AND EXPOSURE ROUTES

Contaminant	Source	Transport Medium	Exposure Route
Iodine-131, -133	X-10 Radioactive lanthanon (RaLa) processing (1944-1956)	Air to vegetable to dairy cattle milk	Ingestion
Cesium-137	X-10 Various chemical separation processes (1944-1960s)	Surface water to fish Soil/sediment Soil/sediment to vegetables; livestock/game (beef); dairy cattle milk	Ingestion Ingestion Ingestion
Mercury	Y-12 Lithium separation and enrichment operations (1955-1963)	Air Air to vegetables; Livestock/game (beef); dairy cattle milk Surface water to fish Soil/sediment to livestock/game (beef); vegetables	Inhalation Ingestion Ingestion Ingestion
Polychlorinated biphenyls	K-25 and Y-12 Transformers and machining	Surface water to fish	Ingestion

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Screening-Level Evaluation of Additional Potential Materials of Concern, July 1999—Task 7

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1990
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The purpose of this screening-level evaluation was to determine whether additional contaminants that existed at Oak Ridge Reservation (ORR), other than the five already identified in the Oak Ridge Dose Reconstruction Feasibility Study (iodine, mercury, polychlorinated biphenyls [PCBs], radionuclides, and uranium), warrant further evaluation of their potential for causing health effects in off-site populations.

Background

In July 1991, the Tennessee Department of Health in cooperation with the U.S. Department of Energy initiated a Health Studies Agreement to evaluate the potential for exposures to chemical and radiological releases from past operations at ORR. The Oak Ridge Dose Reconstruction Feasibility Study was conducted from 1992 to 1993 to identify those operations and materials that warranted detailed evaluation based on the risks posed to off-site populations. The feasibility study recommended that dose reconstructions be conducted for radioactive iodine releases from X-10 radioactive lanthanum processing (Task 1), mercury releases from Y-12 lithium enrichment (Task 2), PCBs in the environment near Oak Ridge (Task 3), and radionuclides released from White Oak Creek to the Clinch River (Task 4). In addition, the study called for a systematic search of historical records (Task 5), an evaluation of the quality of historical uranium effluent monitoring data (Task 6), and additional screening of materials that could not be evaluated during the feasibility study (Task 7).

The Oak Ridge Health Agreement Steering Panel (ORRHES) was established to direct and oversee the Oak Ridge Health Studies and to facilitate interaction and cooperation with the community. This group is composed of local citizens and nationally recognized scientists.

Methods

During the Task 7 Screening-Level Evaluation, three different methods (qualitative screening, the threshold quantity approach, and quantitative screening) were used to evaluate the importance of materials with respect to their potential for causing off-site health effects. Twenty-five materials or groups of materials were evaluated. Please see Table 1 for a summary of the methods used to evaluate each material/group of materials.

- *Qualitative screening*—All materials used on ORR were qualitatively screened for quantities used, forms used, and/or manners of use. If it was unlikely that off-site releases were sufficient to pose an off-site health hazard, then these materials were not evaluated quantitatively. If off-site exposures were likely to have occurred at harmful levels, then the materials were evaluated quantitatively.

- *Threshold quantity approach*—When information was insufficient to conduct quantitative screening, inventories of materials used at ORR were estimated based on historical records and interviews of workers. These estimated inventories of materials were

determined to be either above or below a conservatively calculated health-based threshold quantity. If the estimates for a material were below the calculated threshold quantity, then it was determined to be highly unlikely to have posed a risk to human health through off-site releases.

- *Quantitative screening*—The quantitative screening used a two-level screening approach to identify those materials that could produce health risks (i.e., doses) to exposed people that are clearly below minimum levels of health concern (Level I Screen) and above minimum levels of health concern (Refined Level I Screen). Health-based decision guides were established by the Oak Ridge Health Agreement Steering Panel and represent minimum levels of health concern.

  — The Level I Screening calculates a screening index for a maximally exposed reference individual who would have received the highest exposure. This conservative (protective) screening index is not expected to underestimate exposure to any real person in the population of interest. If the estimated Level I screening index was below the ORRHES decision guide, then the hazard to essentially all members of the population, including the maximally exposed individual, would be below the minimum level of health concern. In addition, the Level I screening index would be so low that further detailed study of exposures is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies. However, if during the Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was further evaluated using Refined Level I Screening.

  — The Refined Level I Screen calculates a less conservative, more realistic screening index by using more reasonable exposure parameters than the Level I Screen. In addition, depending upon the contaminant, a less conservative environmental concentration was sometimes used. However, the transfer factors and toxicity values remained the same for both screening levels. The Refined Level I Screening maintains considerable conservatism because of these conservative transfer factors and toxicity values.

  If the Refined Level I screening index was below the ORRHES decision guide, then the hazard to most members of the population would be below minimum levels of health concern. In addition, the Refined Level I screening index would be so low that further detail study of exposure is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies and was given a low priority for further study. However, if during the Refined Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was determined to be of high priority for a detail evaluation.

Study Group

The screening evaluation focuses on the potential for health effects to occur in off-site residents. The Level I Screen estimates a dose for the hypothetical maximally exposed individual who would have received the highest exposure and would have been the most at-risk. The Refined Level I Screen estimates a dose for a more typically exposed individual in the targeted population. The study group for exposure from lead were children because they are particularly sensitive to the neurological effects of lead.

Exposures

Quantitative screening used mathematical equations to calculate a screening index (theoretical estimates of risk or hazard) from multiple exposure pathways, including inhalation; ground exposure (for radionuclides); ingestion of soil or sediment; and ingestion of vegetables, meat, milk, and/or fish.

Outcome Measures

No outcome measures were studied.

Results

Screening-level analyses were performed for seven carcinogens. They were evaluated according to source, resulting in 10 separate analyses. Three of the Level I Screen analyses (Np-237 from K-25, Np-237 from Y-12, and tritium from Y-12) yielded results that were below the decision guides. Refined Level I Screens were performed on the other seven carcinogenic assessments. The results of five separate analyses (beryllium from Y-12, chromium VI from ORR, nickel from K-25, technetium-99 from K-25, and technetium-99 from Y-12) were below the decision guides, and two analyses (arsenic from K-25 and arsenic from Y-12) were above the decision guides.

Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.

Screening-level analyses were performed for seven noncarcinogens. These, too, were evaluated according to source, resulting in eight separate analyses. One Level I Screen analysis (beryllium from Y-12) yielded results that were below the decision guide. Refined Level I Screens were performed on the other seven noncarcinogenic assessments. Four analyses (chromium VI from ORR, copper from K-25, lithium from Y-12, and nickel from K-25) were below the decision guides and three analyses (arsenic from K-25, arsenic from Y-12, and lead from Y-12) were above the decision guides.

Three materials (niobium, zirconium, and tetramethylammoniumborohydride [TMAB]) were evaluated using the threshold quantity approach because information was insufficient to perform quantitative screening. None of the three was determined to be present in high enough quantities at the Y-12 Plant to have posed off-site health hazards.

Conclusions

Based on the qualitative and quantitative screening, the materials were separated into three classes in terms of potential off-site health hazards: not candidates for further study, potential candidates for further study, and high priority candidates for further study. (as shown in Table 2).

- *Not candidates*—Five materials at the K-25 and 14 materials used at the Y-12 Plant were determined to not warrant further study. All of these chemicals were eliminated because either (1) quantitatively, they fell below Level I Screening decision guides; (2) not enough material was present to have posed an off-site health hazard according to the threshold quantity approach; or (3) qualitatively, the quantities used, forms used, and/or manners of usage were such that off-site releases would not have been sufficient to cause off-site health hazards.

- *Potential candidates*—Three materials at the K-25 (copper powder, nickel, and technetium-99), three materials used at the Y-12 Plant (beryllium compounds, lithium compounds, and technetium-99), and one material used at ORR (chromium VI) were determined to be potential candidates for further study. These materials were identified as potential candidates because (1) their Level I Screening indices exceeded the decision guides and (2) their Refined Level I Screening indices did not exceed the decision guides.

- *High priority candidates*—One material used at the K-25 (arsenic) and two at the Y-12 Plant (arsenic and lead) were determined to be high priority candidates for further study. They were chosen as high priority materials because their Refined Level I Screening indices exceeded the decision guides.

Two issues remaining from the Dose Reconstruction Feasibility Study were evaluated during Task 7: the possible off-site health risks associated with asbestos and the composition of plutonium formed and released to the environment.

- *Asbestos*—Asbestos could not be fully evaluated during the feasibility study; therefore, it was qualitatively evaluated during this task for the potential for off-site releases and community exposure. Available information on the use and disposal of asbestos, as well as off-site asbestos monitoring, was summarized. None of the investigations performed to date have identified any asbestos-related exposure events or activities associated with community exposure, making it very unlikely that asbestos from ORR has caused any significant off-site health risks.

- *Plutonium*—The records that documented the rate of plutonium release did not specify the isotopic composition of the product formed. As a result, during the feasibility study, the project team made the assumption that the plutonium that was formed and released was plutonium-239. If incorrect, this assumption could have significant ramifications on the screening of past airborne plutonium releases. Therefore, the composition of the plutonium formed and released was evaluated further during this task. Plutonium inventory from X-10 was calculated, and plutonium-239 was found to comprise at least 99.9% of the plutonium present in Clinton Pile fuel slugs. This result confirmed that the assumptions made in the feasibility study did not introduce significant inaccuracy into the screening evaluation that was conducted.

TABLE 1
Summary of Screening Methods Used for Each Material

Qualitative Screening

Material	Source	Notes
Boron carbide, boron nitride, yttrium boride, titanium boride, rubidium nitrate, triplex coating, carbon fibers, glass fibers, and four-ring polyphenyl ether	ORR	Evaluated based on quantities used, forms used, and manners of usage.
Tellurium	Y-12	Evaluated based on quantities used, forms used, and manners of usage.

Threshold Quantity Approach

Material	Source	Media	Threshold Values
Niobium	Y-12 Used in production of two alloys, mulberry and binary	Air Surface water	Evaluated using a reference dose derived from an LD50, an empirically derived dispersion factor for airborne releases from Y-12 to Scarboro, and estimated average East Fork Poplar Creek (EFPC) flow rates.
Tetramethylammoniumboro-hydride (TMAB)	Y-12 Use classified	Air Surface water	Inventory quantities and specific applications remain classified.
Zirconium	Y-12 Used in production of an alloy, mulberry	Air Surface water	Evaluated using a reference dose derived from an ACGIH Threshold Limit Value for occupational exposure, an empirically derived dispersion factor for air released from Y-12 to Scarboro, and estimated average EFPC flow rates.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening			
Material	**Source**	**Media**	**Exposure Values**
Arsenic Level I Screen and Refined Level I Screen	K-25 Y-12 Released as a naturally occurring product in coal, which was used in coal-fired steam plants	Air	Based on coal use and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Used maximum in Poplar Creek (K-25) and the 95% upper confidence limit (UCL) on the mean concentration in McCoy Branch (Y-12).
		Soil/sediment	Used sediment core concentration detected in Poplar Creek to represent the early 1960s (K-25) and the 95% UCL on the mean concentration in McCoy Branch (Y-12).
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Beryllium compounds Level I Screen and Refined Level I Screen	Y-12 Used in production	Air	Used Y-12 stack monitoring data and an empirical dispersion factor for releases to Scarboro.
		Surface water	Used maximum concentration measured in EFPC.
		Soil	Used maximum concentration measured in EFPC.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Copper Level I Screen and Refined Level I Screen	K-25 Use of copper powder is classified	Air	Based on airborne concentrations measured at the most-affected on-site air sampler that were adjusted according to the ratio of dispersion model results at that sampler to those at Union/Lawnville.
		Surface water	Used maximum concentration measured during the Clinch River Remedial Investigation.
		Soil/sediment	Used highest mean concentration in Clinch River.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer factor and an ATSDR bioconcentration factor.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Neptunium-237 Level I Screen	K-25 Y-12 Found in recycled uranium	Air	Based on levels in recycled uranium, an estimated release fraction, and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Based on reported releases to Clinch River (K-25) and EFPC (Y-12), corrected for dilution.
		Soil/sediment	Used maximum concentrations detected in Clinch River (K-25) and EFPC (Y-12).
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Nickel Level I Screen and Refined Level I Screen	K-25 Used in the production of barrier material for the gaseous diffusion process	Air	Based on the 95% UCL for the year of the highest measured concentrations in on-site air samplers and dispersion modeling to Union/Lawnville.
		Surface water	Used 95% UCL for the year of the highest concentrations in Clinch River.
		Soil/sediment	Used highest mean concentration in Clinch River.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Technetium-99 Level I Screen and Refined Level I Screen	K-25 Y-12 Product of fission of uranium atoms and from neutron activation of stable molybdenum-98	Air	Used an average of concentrations modeled to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Used maximum concentration detected in Clinch River (K-25) and EFPC (Y-12).
		Soil/sediment	Used maximum concentration from the K-25 perimeter and EFPC (Y-12).
		Food items	Based on concentrations in air, soil, and water and biotransfer and bioconcentration factors from literature.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Tritium Level I Screen	Y-12 Used in deuterium gas production and lithium deuteride recovery operations	Surface water	Evaluated based on deuterium inventory differences and the peak tritium concentration in the deuterium that was processed at Y-12; the release estimate was used with the International Atomic Energy Agency method for tritium dose assessment, assuming all the tritium that escaped was released to EFPC.

TABLE 2
Categorization of Materials Based on Screening Results

Contaminant Source	Not Candidates for Further Study (Level I result was below the decision guide)	Potential Candidates for Further Study (Refined Level I result was below the decision guide)	High Priority Candidates for Further Study (Refined Level I result was above the decision guide)
K-25	Neptunium-237 (cancer) Evaluated qualitatively (quantities, forms, and manner of use were not sufficient): • Carbon fibers • Four-ring polyphenyl ether • Glass fibers • Triplex coating	• Copper powder (noncancer) • Nickel (cancer) • Nickel (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer)
Y-12 Plant	• Beryllium compounds (noncancer) • Neptunium-237 (cancer) • Tritium (cancer) Evaluated using Threshold Quantity Approach (not enough material was present): • Niobium (noncancer) • TMAB • Zirconium (noncancer) Evaluated qualitatively (quantities, forms, and manner of use were not sufficient): • Boron carbide • Boron nitride • Rubidium nitrate • Rubidium bromide • Tellurium • Titanium boride • Yttrium boride • Zirconium	• Beryllium compounds (cancer) • Lithium compounds (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer) • Lead (noncancer) Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.
ORR (all complexes)		• Chromium VI (cancer) • Chromium VI (noncancer)	

ORRHES Brief
Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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, Report of the Oak Ridge Dose Reconstruction, Vol. 5 The Report of Project Task 6

Site: Oak Ridge Reservation

Conducted by: ChemRisk/ORHASP for the Tennessee Department of Health

Time Period: 1999

Location: Oak Ridge, Tennessee

Purpose

The purpose of the Task 6 study was to further evaluate the quality of historical uranium operations and effluent monitoring records, to confirm or modify previous uranium release estimates for the period from 1944 to 1995 for all three complexes on the Oak Ridge Reservation (ORR), and to determine if uranium releases from the ORR likely resulted in off-site doses that warrant further study. The main results of the study are revised uranium release estimates from the Y-12 plant, K-25 gaseous diffusion plant, and the S-50 liquid thermal diffusion plant and screening-level estimates of potential health effects to people living near the ORR. These results, which are called "screening indices," are conservative estimates of potential exposures and health impacts and are intended to be used with the decision guide established by Oak Ridge Health Agreement Steering Panel (ORHASP) to determine if further work is warranted to estimate the human health risks from past uranium releases.

Background

The 1993 Oak Ridge Health Studies, Phase I Dose Reconstruction Feasibility Study by the Tennessee Department of Health indicated that uranium was not among the list of contaminants that warranted highest priority for detailed dose reconstruction investigation of off-site health effects. After receiving comments from several long-term employees at the ORR uranium facilities, a number of ORHASP members recommended that past uranium emissions and potential resulting exposures receive closer examination. In 1994, the Task 6 uranium screening evaluation was included in the Oak Ridge Dose Reconstruction project.

The Oak Ridge Y-12 plant was built in 1945, as part of the Manhattan project. Located at the eastern end of Bear Creek Valley, the Y-12 complex is within the corporate limits of the city of Oak Ridge and is separated from the main residential areas of the city by Pine Ridge. The Y-12 plant housed many operations involving uranium, including the preparation, forming, machining, and recycling of uranium for Weapon Component Operations.

Construction of the K-25 uranium enrichment facility began in 1943, and the facility was operational by January 1945. The K-25 site is located near the western end of the ORR, along Poplar Creek near where it meets the Clinch River. The primary mission of K-25 was to enrich uranium by the gaseous diffusion process.

Located along the Clinch River near the K-25 site was a liquid thermal diffusion plant (the S-50 site) that operated from October 1944 to September 1945. Because of their close proximity, the K-25 and S-50 complexes were generally discussed together in the Task 6 report.

The X-10 facility, which conducted chemical processing of reactor fuel and other nuclear materials, was not a primary focus of the Task 6 study.

Methods

An extensive information gathering and review effort was undertaken by the project team in searching for information related to historical uranium operations at the Y-12, K-25, and S-50 sites. Thousands of documents were searched and many active and retired workers were interviewed.

The Task 6 investigation followed these basic steps:

- Information that described uranium uses and releases on the ORR was collected.
- Effluent monitoring data were evaluated for quality and consistency with previous U.S. Department of Energy (DOE) historical uranium release reports.
- Updated estimates of airborne uranium releases over time were generated using the more complete data available to the project team.
- Air dispersion models were used to estimate uranium air concentrations at selected reference locations near each ORR facility. The reference locations were:
  - — the Scarboro community (for Y-12),
  - — the Union/Lawnville community (for K-25/S-50), and
  - — Jones Island area along the Clinch River (for X-10).

  Because the terrain surrounding the Y-12 facility has complex topography, air dispersion modeling techniques were not employed. Instead, an empirical relative concentration (chi/Q) relationship was established between measured releases of uranium from Y-12 and measured airborne concentrations of uranium at Scarboro. The chi/Q relationship was then used to extrapolate airborne uranium concentrations for times in which it was not directly measured.
- The screening evaluation of potential offsite exposures to waterborne uranium was based on environmental measurements of uranium at local surface waters. The sampling sites were: White Oak Dam, downstream of New Hope Pond, and the confluence of Poplar Creek and the Clinch River.
- A screening-level evaluation of the potential for health effects was performed by calculating intakes and associated radiation doses. A two-tiered exposure assessment methodology was employed, which provided both upper bound and more typical results. Because of the scarcity of information regarding estimates of uranium concentrations in the environment over the period of interest, some conservatism was maintained in the uranium concentrations used in the Level II screening.
- Annual radiation doses from uranium intake and external exposure were calculated for the adult age group for each screening assessment and then converted to screening indices using a dose-to-risk coefficient of 7.3% Sv^{-1}.
- Estimates of annual-average intakes of uranium by inhalation and ingestion were also used to evaluate the potential for health effects due to the chemical toxicity of uranium compounds, specifically for damage to the kidneys. Uranium was assumed to be in its most soluble form and safety factors were included to minimize the potential for underestimation of the potential for toxic effects.

Study Subjects

The screening evaluation estimated potential off-site exposure and screening indices for hypothetical individuals in three reference locations (Scarboro, Union/Lawnville, and Jones Island). These reference locations represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases. Thus, they are associated with the highest screening indices derived by the screening evaluation.

Exposures

The following potential air exposure pathways were evaluated:

1. Air to humans-direct inhalation of airborne particulates
2. Air to humans (immersion in contaminated air)
3. Air to livestock (via inhalation) to beef to humans
4. Air to dairy cattle (via inhalation) to milk to humans
5. Air to vegetables (deposition) to humans
6. Air to pasture (deposition) to cattle beef to humans
7. Air to pasture (deposition) to dairy cattle to milk to humans

The following potential water exposure pathways were evaluated:

1. Incidental ingestion by humans during recreation
2. Water to livestock (ingestion) to beef to humans
3. Water to dairy cattle (ingestion) to milk to humans
4. Water to fish to humans
5. Water to humans via immersion during recreation

The following potential soil exposure pathways were evaluated:

1. Soil to air (dust resuspension) to humans
2. Soil incidental ingestion
3. Soil to livestock (soil ingestion) to beef to humans
4. Soil to dairy cattle (soil ingestion) to milk to humans
5. Soil to vegetables (root uptake) to humans
6. Soil to pasture (root uptake) to livestock to beef to humans
7. Soil to pasture (root uptake) to dairy cattle to milk to humans
8. Soil to humans via external radiation

Outcome Measures

Health outcomes were not studied.

Results

Airborne uranium releases from the Y-12, K-25, and S-50 sites were found to be greater than previously reported. DOE estimated that the amount of uranium released from the Y-12 plant was 6,535 kilograms. The Task 6 team estimated that 50,000 kilograms of uranium was released to the air by the Y-12 plant. DOE estimated that the amount released from the K-25 and S-50 plants (combined) was 10,713 kilograms. The Task 6 team estimated that 16,000 kilograms were released to the air by the K-25/S-50 complex.

The Scarboro community was associated with the highest total screening index attributable to uranium releases from the Y-12 plant. The screening indices were 1.9×10^{-3} for the Level I assessment and 8.3×10^{-5} for the Level II assessment. While the overall Level I screening index for the Scarboro community is above the ORHASP decision guide of 1.0×10^{-4} (1 in 10,000), the Level II value is below that guide value. This indicates that the Y-12 uranium releases are candidates for further study, but that they are not high priority candidates for further study.

For the K-25/S-50 assessment, the total screening index for Union/Lawnville from the Level I assessment (2.7×10^{-4}) exceeded the ORHASP decision guide. The less conservative Level II screening result (4.0×10^{-5}) did not exceed the

guide. This indicates that the K-25/S-50 uranium releases are also candidates for further study, but that they are not high priority candidates for further study.

The X-10 Level I assessment yielded a screening index for Jones Island (7.6×10^{-5}) below the decision guide. This indicates that releases from the X-10 site warrant lower priority, especially given the pilot-plant nature and relatively short duration of most X-10 uranium operations.

The Scarboro community was selected for the initial chemical toxicity evaluation since its screening index for radiological exposures was the highest. Estimated kidney burdens resulting from simultaneous intake of uranium by ingestion and inhalation under the Scarboro assessment do not exceed an effects threshold criterion (1 microgram per gram of kidney tissue) proposed by some scientists, but they do exceed an effects threshold criterion (0.02 micrograms per gram of kidney tissue) proposed by other scientists. The Task 6 team also evaluated the average-annual intakes using a reference dose/Hazard Index approach and concluded that further study of chemical toxicity from past ORR uranium exposures did not warrant high priority.

Conclusions

The Task 6 team reached the following general conclusions:

- Estimates of uranium releases previously reported by DOE are incomplete and; therefore, were not used in the Task 6 screening evaluation.
- Historical uranium releases from the Y-12 plant are likely significantly higher (over seven times higher) than totals reported by DOE. There are several reasons why previous estimates were so much lower.
- Historical uranium releases from the K-25/S-50 complex are likely higher than totals reported by DOE.
- Operations at the S-50 plant are poorly documented.
- The Scarboro community had the highest total screening index from uranium releases at the ORR, specifically the Y-12 plant. Since the Level II screening index is just below the ORHASP decision criterion, with most of the conservative assumptions regarding source term and exposure parameters removed, potential exposure to uranium releases could have been of significance from a health standpoint and should; therefore, be considered for dose reconstruction.
- The Union/Lawnville community evaluation (releases from the K-25/S-50 complex) had a Level II screening index below the ORHASP criterion. However, without quantification of the uncertainties associated with the release estimates and the exposure assessment, it is not possible to say that these releases do not warrant further characterizations.
- The Level I screening index for the Jones Island area (releases from the X-10 site) are below the ORHASP decision criterion.
- Because Pine Ridge separates the Y-12 plant from Scarboro, an alternate approach (chi/Q) was used to estimate uranium air concentrations in Scarboro.
- The concentrations of uranium in soil are a major factor in the screening analyses. Because limited soil data are available for the reference locations, alternative approaches should be considered for future analyses.
- While the estimated uranium intake from ingestion and inhalation exceed one effects threshold criterion, they do no exceed another. Calculated hazard indices indicate that further study of chemical effects of the kidneys rank as a low priority.

If the evaluation of ORR uranium releases is to proceed beyond a conservative screening stage and on to a nonconservative screening with uncertainty and sensitivity analyses, activities that should be evaluated for possible follow-up work include:

- Additional records research and data evaluation regarding S-50 plant operations and potential releases.
- Additional searching for and review of effluent monitoring data for Y-12 electromagnetic enrichment operations from 1944 to 1947 and data relating to releases from unmonitored depleted uranium operations in the 1950s through the 1990s.
- Uncertainty analysis of the Y-12 uranium release estimates derived in this study.
- Review of additional data regarding unmonitored K-25 uranium releases.
- Refinement of the approach used to evaluate surface water and soil-based exposure concentrations.
- Evaluation of the effects of the ridges and valleys that dominate the local terrain surrounding Y-12 and Scarboro and investigation of alternative approaches to estimate air concentrations at Scarboro with an emphasis on identifying additional monitoring data.
- Performance of a bounding assessment of the amounts of uranium that were handled at the X-10 site.
- Improvement of the exposure assessment to include region-specific consumption habits and lifestyles, identification of likely exposure scenarios instead of hypothetical upper bound and typical assessments, and inclusion of uncertainty analysis to provide statistical bounds for the evaluation of risk.
- Refinement of the chemical toxicity evaluation, possibly to include other approaches and models, as well as an uncertainty analysis.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Health Consultation, U.S. DOE Oak Ridge Reservation, Lower Watts Bar Operable Unit, February 1996

Site: Oak Ridge Reservation
Study authors: Agency for Toxic Substances and Disease Registry
Time period: 1980s and 1990s
Target population: Lower Watts Bar Reservoir Area

Purpose

This health consultation was conducted to evaluate the public health implications of chemical and radiological contaminants in the Watts Bar Reservoir and the effectiveness of the Department of Energy's proposed remedial action plan for protecting public health.

Background

In March 1995, the Department of Energy (DOE) released a proposed plan for addressing contaminants in the Lower Watts Bar Reservoir. The plan presented the potential risk posed by contaminants and DOE's preferred remedial action alternative. DOE's risk assessment indicated that consumption of certain species of fish from the Lower Watts Bar Reservoir and the transfer of sediment from deeper areas of the reservoir to areas on land where crops were grown could result in unacceptable risk to human health.

The September 1995 Record of Decision for the Lower Watts Bar Reservoir presented DOE's remedial action plan for the reservoir. This remedial action included maintaining the fish consumption advisories of the Tennessee Department of Environment and Conservation (TDEC), continuing environmental monitoring, and implementing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediment. The U.S. Environmental Protection Agency (EPA) and TDEC concurred with the remedial action plan.

Concerned about the sufficiency of DOE's plan, local residents asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the health risk related to contaminants in the Lower Watts Bar Reservoir. These residents asked ATSDR to provide an independent opinion on whether DOE's selected remedial actions would adequately protect public health.

Methods

ATSDR agreed to provide a health consultation. A health consultation is conducted in response to a specific request for information about health risks related to a specific site, a specific chemical release, or the presence of other hazardous material. The response from ATSDR may be verbal or written.

To assess the current and recent past health hazards from the Lower Watts Bar Reservoir contamination, ATSDR evaluated environmental sampling data. ATSDR evaluated reservoir studies conducted by DOE and the Tennessee Valley Authority during the 1980s and 1990s. ATSDR also evaluated TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. ATSDR first screened the voluminous environmental data to determine whether any contaminants were present at levels above health–based comparison values. ATSDR next estimated exposure doses for any contaminants exceeding comparison values. It is important to note that the fact that a contaminant exceeds comparison values does

not necessarily mean that the contaminant will cause adverse health effects. Comparison values simply help ATSDR determine which contaminants to evaluate more closely.

ATSDR estimated exposure doses, using both worst case and realistic exposure scenarios, to determine if current chemical and radiological contaminant levels could pose a health risk to area residents. The worst case scenarios assumed that the most sensitive population (young children) would be exposed to the highest concentration of each contaminant in each media by the most probable exposure routes.

Target population

Individuals living along the Watts Bar Reservoir and individuals visiting the area.

Exposures

The exposures investigated were those to metals, radionuclides, volatile organic compounds, polychlorinated biphenyls (PCBs), and pesticides in surface water, sediment, and fish.

Outcome measure

ATSDR did not review health outcome data.

Results

Reservoir Fish and Other Wildlife: Using a realistic exposure scenario for fish consumption that assumed an adult weighing 70 kilogram (kg) consumed one 8-ounce sport fish meal per week, or per month, for 30 years, ATSDR determined that PCB levels in reservoir fish were at levels of health concern. ATSDR estimated ranges of PCB exposure doses from 0.099 to 0.24 micrograms of PCBs per kilogram of human body weight every day (µg/kg/day) for the one fish meal a week scenario and 0.023 to 0.055 µg/kg/day for the one fish per month scenario.

At these exposure doses, ATSDR estimates that approximately one additional cancer case might develop in 1,000 people eating one fish meal a week for 30 years and three additional cancer cases might develop in 10,000 people eating one fish meal a month for 30 years.

At these exposure doses, ATSDR also determined that ingestion of reservoir fish by pregnant women and nursing mothers might cause adverse neurobehavioral effects in infants. Although the evidence that PCBs cause developmental defects in infants is difficult to evaluate and inconclusive, ATSDR's determination was made on the basis of the special vulnerability of developing fetuses and infants.

Using a worst case scenario that assumed adults and children consumed two 8-ounce fish meals a week, containing the maximum concentration of each radioactive contaminant, ATSDR determined that the potential level of radiological exposure, which was less than 6 millirem per year (mrem/yr), was not a public health hazard.

Reservoir Surface Water: Using a worst case exposure scenario that assumed a child would daily ingest a liter of unfiltered reservoir water containing the maximum level of contaminants, ATSDR determined that the levels of chemicals in the reservoir surface water were not a public health hazard.

Levels of radionuclides in surface water were well below the levels of the current and proposed EPA drinking water standards. In addition, the total radiation dose to children from waterborne radioactive contaminants would be less that 1 mrem/yr, which is well below background levels. The radiation dose was estimated using the conservative assumption that a 10-year-old child would drink and shower with unfiltered reservoir water and swim in the reservoir daily.

Reservoir Sediment: ATSDR determined that the maximum chemical and radioactive contaminant concentrations reported in the recent surface sediments data (mercury, Co-60, Sr–89/90, and Cs-137) would not present a public health hazard. The estimated dose from radioactive contaminants was less than 15 mrem/yr, which is below background levels.

ATSDR also evaluated the potential exposure a child might receive if the subsurface sediments were removed from the deep reservoir channels and used as surface soil in residential properties. Using a worst case exposure scenario that included ingestion, inhalation, external, and dermal contact exposure routes, ATSDR determined that the potential radiation dose to individuals living on these properties (less than 20 mrem/yr) would not pose a public health hazard.

Conclusions

ATSDR found that only PCBs in the reservoir fish were of potential public health concern. Other contaminants in the surface water, sediment, and fish were not found to be a public health hazard.

On the basis of current levels of contaminants in the water, sediment, and wildlife, ATSDR concluded the following.

- The levels of PCBs in the Lower Watts Bar Reservoir fish posed a public health concern. Frequent and long-term ingestion of fish from the reservoir posed a moderately increased risk of cancer in adults and increased the possibility of developmental effects in infants whose mothers consumed fish regularly during gestation and while nursing. Turtles in the reservoir might also contain PCBs at levels of public health concern.

- Current levels of contaminants in the reservoir surface water and sediment were not a public health hazard. The reservoir was safe for swimming, skiing, boating, and other recreational purposes. It is safe to drink water from the municipal water systems, which draw surface water from tributary embayments in the Lower Watts Bar Reservoir and the Tennessee River upstream from the Clinch River and Lower Watts Bar Reservoir.

- DOE's selected remedial action was protective of public health.

ATSDR made the following recommendations.

- The Lower Watts Bar Reservoir fish advisory should remain in effect to minimize exposure to PCBs.

- ATSDR should work with the state of Tennessee to implement a community health education program on the Lower Watts Bar fish advisory and the health effects of PCB exposure.

- The health risk from consumption of turtles in the Lower Watts Bar Reservoir should be evaluated. The evaluation should investigate turtle consumption patterns and PCB levels in edible portions of turtles.

- Surface and subsurface sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group.

- Sampling of municipal drinking water at regular intervals should be continued. In addition, at any time a significant release of contaminants from the Oak Ridge Reservation is discharged into the Clinch River, DOE should notify municipal water systems and monitor surface water intakes.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Dose Reconstruction Feasibility Study Oak Ridge Health Study Phase I Report

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1992
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The Dose Reconstruction Feasibility Study had two purposes: first, to identify past chemical and radionuclide releases from the Oak Ridge Reservation (ORR) that have the highest potential to impact the health of the people living near the ORR; and second, to determine whether sufficient information existed about these releases to estimate the exposure doses received by people living near the ORR.

Background

In July 1991, the Tennessee Department of Health initiated a Health Studies Agreement with the U.S. Department of Energy (DOE). This agreement provides funding for an independent state evaluation of adverse health effects that may have occurred in populations around the ORR. The Oak Ridge Health Agreement Steering Panel (ORHASP) was established to direct and oversee this state evaluation (hereafter called the Oak Ridge Health Studies) and to facilitate interaction and cooperation with the community. ORHASP was an independent panel of local citizens and nationally recognized scientists who provided direction, recommendations, and oversight for the Oak Ridge Health Studies. These health studies focused on the potential effects from off-site exposures to chemicals and radionuclides released at the reservation since 1942. The state conducted the Oak Ridge Health Studies in two phases. Phase 1 is the Dose Reconstruction Feasibility Study described in this summary.

Methods

The Dose Reconstruction Feasibility Study consisted of seven tasks. During Task 1, state investigators identified historical operations at the ORR that used and released chemicals and radionuclides. This involved interviewing both active and retired DOE staff members about past operations, as well as reviewing historical documents (such as purchase orders, laboratory records, and published operational reports). Task 1 documented past activities at each major facility, including routine operations, waste management practices, special projects, and accidents and incidents. Investigators then prioritized these activities for further study based on the likelihood that releases from these activities could have resulted in off-site exposures.

During Task 2, state investigators inventoried the available environmental sampling and research data that could be used to estimate the doses that local populations may have received from chemical and radionuclide releases from the ORR. These data, obtained from DOE and other federal and state agencies (such as the U.S. Environmental Protection Agency, Tennessee Valley

Authority, and the Tennessee Division of Radiological Health), were summarized by environmental media (such as surface water, sediment, air, drinking water, groundwater, and food items). As part of this task, investigators developed abstracts which summarize approximately 100 environmental monitoring and research projects that characterize the historical presence of contaminants in areas outside the ORR.

Based on the results of Tasks 1 and 2, investigators identified a number of historical facility processes and activities at ORR as having a high potential for releasing substantial quantities of contaminants to the off-site environment. These activities were recommended for further evaluation in Tasks 3 and 4.

Tasks 3 and 4 were designed to provide an initial, very rough evaluation of the large quantity of information and data identified in Tasks 1 and 2, and to determine the potential for the contaminant releases to impact the public's health. During Task 3, investigators sought to answer the question: How could contaminants released from the Oak Ridge Reservation have reached local populations? This involved identifying the exposure pathways that could have transported contaminants from the ORR site to residents.

Task 3 began with compiling a list of contaminants investigated during Task 1 and Task 2. These contaminants are listed in Table 1. The contaminants in the list were separated into four general groups: radionuclides, nonradioactive metals, acids/bases, and organic compounds. One of the first steps in Task 3 was to eliminate any chemicals on these lists that were judged unlikely to reach local populations in quantities that would pose a health concern. For example, acids and bases were not selected for further evaluation because these compounds rapidly dissociate in the environment and primarily cause acute health effects, such as irritation. Likewise, although chlorofluorocarbons (Freon) were used in significant quantities at each of the ORR facilities, they were judged unlikely to result in significant exposure because they also rapidly disassociate. Also, some other contaminants (see Table 2) were not selected for further evaluation because they were used in relatively small quantities or in processes that are not believed to be associated with significant releases. Investigators determined that only a portion of contaminants identified in Tasks 1 and 2 could have reached people in the Oak Ridge area and potentially impacted their health. These contaminants, listed in Table 3, were evaluated further in Tasks 3 and 4.

The next step in Task 3 was to determine, for each contaminant listed in Table 3, whether a complete exposure pathway existed. A complete exposure pathway means a plausible route by which the contaminant could have traveled from ORR to off-site populations. Only those contaminants with complete exposure pathways would have the potential to cause adverse health effects. In this feasibility study, an exposure pathway is considered complete if it has the following three elements:

- A source that released the contaminant into the environment;
- A transport medium (such as air, surface water, soil, or biota) or some combination of these media (e.g., air → pasture → livestock milk) that carried the contaminant off the site to a location where exposure could occur; and
- An exposure route (such as inhalation, ingestion, or—in the case of certain radionuclides that emit gamma or beta radiation—immersion) through which a person could come into contact with the contaminant.

In examining whether complete exposure pathways existed, investigators considered the characteristics of each contaminant and the environmental setting at the ORR. Contaminants that lacked a source, transport medium, or exposure route were eliminated from further consideration because they lacked a complete exposure pathway. Through this analysis, investigators identified a number of contaminants with complete exposure pathways.

During Task 4, investigators sought to determine qualitatively which of the contaminants with complete exposure pathways appeared to pose the greatest potential to impact off-site populations. They began by comparing the pathways for each contaminant individually. For each contaminant, they determined which pathway appeared to have the greatest potential for exposing off-site populations, and they compared the exposure potential of the contaminant's other pathways to its most significant pathway. They then divided contaminants into three categories—radionuclides, carcinogens, and noncarcinogens—and compared the contaminants within each category based on their exposure potential and on their potential to cause health effects. This analysis identified facilities, processes, contaminants, media, and exposure routes believed to have the greatest potential to impact off-site populations. The results are provided in Table 4.

The Task 4 analysis was intended to provide a preliminary framework to help focus and prioritize future quantitative studies of the potential health impacts of off-site contamination. These analyses are intended to provide an initial approach to studying an extremely complex site. However, care must be taken in attempting to make broad generalizations or draw conclusions about the potential health hazard posed by the releases from the ORR.

In Task 5, investigators described the historical locations and activities of populations most likely to have been affected by the releases identified in Task 4. During Task 6, investigators compiled a summary of the current toxicologic knowledge and hazardous properties of the key contaminants. Task 7 involved collecting, categorizing, summarizing, and indexing selected documents relevant to the feasibility study.

Study Group

A study group was not selected.

Exposures

Seven completed exposure pathways associated with air, six completed exposure pathways associated with surface water, and ten completed exposure pathways associated with soil/sediment were evaluated for radionuclides and chemical substances (metals, organic compounds, and polycyclic aromatic hydrocarbons) released at the ORR from 1942 to 1992.

Outcome Measures

No outcome measures were studied.

Conclusions

The feasibility study indicated that past releases of the following contaminants have the greatest potential to impact off-site populations.

- **Radioactive iodine**
  The largest identified releases of radioactive iodine were associated with radioactive lanthanum processing from 1944 through 1956 at the X-10 facility.

- **Radioactive cesium**
  The largest identified releases of radioactive cesium were associated with various chemical separation activities that took place from 1943 through the 1960s.

- **Mercury**
  The largest identified releases of mercury were associated with lithium separation and enrichment operations that were conducted at the Y-12 facility from 1955 through 1963.

- **Polychlorinated biphenyls**
  Concentrations of polychlorinated biphenyls (PCBs) found in fish taken from the East Fork Poplar Creek and the Clinch River have been high enough to warrant further study. These releases likely came from electrical transformers and machining operations at the K-25 and Y-12 plants.

State investigators determined that sufficient information was available to reconstruct past releases and potential off-site doses for these contaminants. The steering panel (ORHASP) recommended that dose reconstruction activities proceed for the releases of radioactive iodine, radioactive cesium, mercury, and PCBs. Specifically they recommended that the state should continue the tasks begun during the feasibility study, and should characterize the actual release history of these contaminants from the reservation; identify appropriate fate and transport models to predict historical off-site concentrations; and identify an exposure model to use in calculating doses to the exposed population.

The panel also recommended that a broader-based investigation of operations and contaminants be conducted to study the large number of ORR contaminants released that have lower potentials for off-site health effects, including the five contaminants (chromium VI; plutonium-239, -240, and -241; tritium; arsenic; and neptunium-237) that could not be qualitatively evaluated during Phase 1 due to a lack of available data. Such an investigation would help in modifying or reinforcing the recommendations for future health studies.

Additionally, the panel recommended that researchers explore opportunities to conduct epidemiologic studies investigating potential associations between exposure doses and adverse health effects in exposed populations.

TABLE 1

LIST OF CONTAMINANTS INVESTIGATED DURING TASK 1 AND TASK 2

X-10	K-25	Y-12
Radionuclides		
Americium-241 Argon-41 Barium-140 Berkelium Californium-252 Carbon-14 Cerium-144 Cesium-134,-137 Cobalt-57,-60 Curium-242,-243,-244 Einsteinium Europium-152,-154,-155 Fermium Iodine-129, -131, -133 Krypton-85 Lanthanum-140 Niobium-95 Phosphorus-32 Plutonium-238, -239, -240, -241 Protactinium-233 Ruthenium-103, -106 Selenium-75 Strontium-89, -90 Tritium Uranium-233,-234, -235, -238 Xenon-133 Zirconium-95	Neptunium-237 Plutonium-239 Technetium-99 Uranium-234, -235, -238	Neptunium-237 Plutonium-239, -239, -240, -241 Technetium-99 Thorium-232 Tritium Uranium-234, -235, -238
Nonradioactive Metals		
None initially identified	Beryllium Chromium (trivalent and hexavalent) Nickel	Arsenic Beryllium Chromium (trivalent and hexavalent) Lead Lithium Mercury
Acids/Bases		
Hydrochloric acid Hydrogen peroxide Nitric acid Sodium hydroxide Sulfuric acid	Acetic acid Chlorine trifluoride Fluorine and fluoride compounds Hydrofluoric acid Nitric acid Potassium hydroxide Sulfuric acid	Ammonium hydroxide Fluorine and various fluorides Hydrofluoric acid Nitric acid Phosgene
Organic Compounds		
None initially identified	Benzene Carbon tetrachloride Chloroform Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls 1,1,1-Trichloroethane Trichloroethylene	Carbon tetrachloride Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls Tetrachloroethylene 1,1,1-Trichloroethane Trichloroethylene

TABLE 2

CONTAMINANTS NOT WARRANTING FURTHER EVALUATION IN TASK 3 AND TASK 4

Radionuclides
Americium-241
Californium-252
Carbon-14
Cobalt-57
Cesium-134
Curium-242, -243, -244
Europium-152, -154, -155
Phosphorus-32
Selenium-75
Uranium-233
Berkelium
Einsteinium
Fermium
Nonradioactive Metals
Lithium
Organic Compounds
Benzene
Chlorofluorocarbons (Freons)
Chloroform
Acids/Bases
Acetic acid
Ammonium hydroxide
Chlorine trifluoride
Fluorine and various fluoride compounds
Hydrochloric acid
Hydrogen peroxide
Hydrofluoric acid
Nitric acid
Phosgene
Potassium hydroxide
Sulfuric acid
Sodium hydroxide

TABLE 3

CONTAMINANTS FURTHER EVALUATED IN TASK 3 AND TASK 4

Radionuclides	Nonradioactive Metals	Organic Compounds
Argon-41	Arsenic	Carbon tetrachloride
Barium-140	Beryllium	Methylene chloride
Cerium-144	Chromium (trivalent and hexavalent)	Polychlorinated biphenyls
Cesium-137	Lead	Tetrachloroethylene
Cobalt-60	Mercury	1,1,1-Trichloroethane
Iodine-129, -131, -133	Nickel	Trichloroethylene
Krypton-85		
Lanthanum-140		
Neptunium-237		
Niobium-95		
Plutonium-238, -239, -240, -241		
Protactinium-233		
Ruthenium-103, -106		
Strontium-89, 90		
Technetium-99		
Thorium-232		
Tritium		
Uranium-234 -235, -238		
Xenon-133		
Zirconium-95		

TABLE 4

HIGHEST PRIORITY CONTAMINANTS, SOURCES, TRANSPORT MEDIA, AND EXPOSURE ROUTES

Contaminant	Source	Transport Medium	Exposure Route
Iodine-131, -133	X-10 Radioactive lanthanon (RaLa) processing (1944-1956)	Air to vegetable to dairy cattle milk	Ingestion
Cesium-137	X-10 Various chemical separation processes (1944-1960s)	Surface water to fish Soil/sediment Soil/sediment to vegetables; livestock/game (beef); dairy cattle milk	Ingestion Ingestion Ingestion
Mercury	Y-12 Lithium separation and enrichment operations (1955-1963)	Air Air to vegetables; Livestock/game (beef); dairy cattle milk Surface water to fish Soil/sediment to livestock/game (beef); vegetables	Inhalation Ingestion Ingestion Ingestion
Polychlorinated biphenyls	K-25 and Y-12 Transformers and machining	Surface water to fish	Ingestion

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Screening-Level Evaluation of Additional Potential Materials of Concern, July 1999—Task 7

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1990
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The purpose of this screening-level evaluation was to determine whether additional contaminants that existed at Oak Ridge Reservation (ORR), other than the five already identified in the Oak Ridge Dose Reconstruction Feasibility Study (iodine, mercury, polychlorinated biphenyls [PCBs], radionuclides, and uranium), warrant further evaluation of their potential for causing health effects in off-site populations.

Background

In July 1991, the Tennessee Department of Health in cooperation with the U.S. Department of Energy initiated a Health Studies Agreement to evaluate the potential for exposures to chemical and radiological releases from past operations at ORR. The Oak Ridge Dose Reconstruction Feasibility Study was conducted from 1992 to 1993 to identify those operations and materials that warranted detailed evaluation based on the risks posed to off-site populations. The feasibility study recommended that dose reconstructions be conducted for radioactive iodine releases from X-10 radioactive lanthanum processing (Task 1), mercury releases from Y-12 lithium enrichment (Task 2), PCBs in the environment near Oak Ridge (Task 3), and radionuclides released from White Oak Creek to the Clinch River (Task 4). In addition, the study called for a systematic search of historical records (Task 5), an evaluation of the quality of historical uranium effluent monitoring data (Task 6), and additional screening of materials that could not be evaluated during the feasibility study (Task 7).

The Oak Ridge Health Agreement Steering Panel (ORRHES) was established to direct and oversee the Oak Ridge Health Studies and to facilitate interaction and cooperation with the community. This group is composed of local citizens and nationally recognized scientists.

Methods

During the Task 7 Screening-Level Evaluation, three different methods (qualitative screening, the threshold quantity approach, and quantitative screening) were used to evaluate the importance of materials with respect to their potential for causing off-site health effects. Twenty-five materials or groups of materials were evaluated. Please see Table 1 for a summary of the methods used to evaluate each material/group of materials.

- *Qualitative screening*—All materials used on ORR were qualitatively screened for quantities used, forms used, and/or manners of use. If it was unlikely that off-site releases were sufficient to pose an off-site health hazard, then these materials were not evaluated quantitatively. If off-site exposures were likely to have occurred at harmful levels, then the materials were evaluated quantitatively.

- *Threshold quantity approach*—When information was insufficient to conduct quantitative screening, inventories of materials used at ORR were estimated based on historical records and interviews of workers. These estimated inventories of materials were

determined to be either above or below a conservatively calculated health-based threshold quantity. If the estimates for a material were below the calculated threshold quantity, then it was determined to be highly unlikely to have posed a risk to human health through off-site releases.

- *Quantitative screening*—The quantitative screening used a two-level screening approach to identify those materials that could produce health risks (i.e., doses) to exposed people that are clearly below minimum levels of health concern (Level I Screen) and above minimum levels of health concern (Refined Level I Screen). Health-based decision guides were established by the Oak Ridge Health Agreement Steering Panel and represent minimum levels of health concern.

  — The Level I Screening calculates a screening index for a maximally exposed reference individual who would have received the highest exposure. This conservative (protective) screening index is not expected to underestimate exposure to any real person in the population of interest. If the estimated Level I screening index was below the ORRHES decision guide, then the hazard to essentially all members of the population, including the maximally exposed individual, would be below the minimum level of health concern. In addition, the Level I screening index would be so low that further detailed study of exposures is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies. However, if during the Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was further evaluated using Refined Level I Screening.

  — The Refined Level I Screen calculates a less conservative, more realistic screening index by using more reasonable exposure parameters than the Level I Screen. In addition, depending upon the contaminant, a less conservative environmental concentration was sometimes used. However, the transfer factors and toxicity values remained the same for both screening levels. The Refined Level I Screening maintains considerable conservatism because of these conservative transfer factors and toxicity values.

  If the Refined Level I screening index was below the ORRHES decision guide, then the hazard to most members of the population would be below minimum levels of health concern. In addition, the Refined Level I screening index would be so low that further detail study of exposure is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies and was given a low priority for further study. However, if during the Refined Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was determined to be of high priority for a detail evaluation.

Study Group

The screening evaluation focuses on the potential for health effects to occur in off-site residents. The Level I Screen estimates a dose for the hypothetical maximally exposed individual who would have received the highest exposure and would have been the most at-risk. The Refined Level I Screen estimates a dose for a more typically exposed individual in the targeted population. The study group for exposure from lead were children because they are particularly sensitive to the neurological effects of lead.

Exposures

Quantitative screening used mathematical equations to calculate a screening index (theoretical estimates of risk or hazard) from multiple exposure pathways, including inhalation; ground exposure (for radionuclides); ingestion of soil or sediment; and ingestion of vegetables, meat, milk, and/or fish.

Outcome Measures

No outcome measures were studied.

Results

Screening-level analyses were performed for seven carcinogens. They were evaluated according to source, resulting in 10 separate analyses. Three of the Level I Screen analyses (Np-237 from K-25, Np-237 from Y-12, and tritium from Y-12) yielded results that were below the decision guides. Refined Level I Screens were performed on the other seven carcinogenic assessments. The results of five separate analyses (beryllium from Y-12, chromium VI from ORR, nickel from K-25, technetium-99 from K-25, and technetium-99 from Y-12) were below the decision guides, and two analyses (arsenic from K-25 and arsenic from Y-12) were above the decision guides.

Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.

Screening-level analyses were performed for seven noncarcinogens. These, too, were evaluated according to source, resulting in eight separate analyses. One Level I Screen analysis (beryllium from Y-12) yielded results that were below the decision guide. Refined Level I Screens were performed on the other seven noncarcinogenic assessments. Four analyses (chromium VI from ORR, copper from K-25, lithium from Y-12, and nickel from K-25) were below the decision guides and three analyses (arsenic from K-25, arsenic from Y-12, and lead from Y-12) were above the decision guides.

Three materials (niobium, zirconium, and tetramethylammoniumborohydride [TMAB]) were evaluated using the threshold quantity approach because information was insufficient to perform quantitative screening. None of the three was determined to be present in high enough quantities at the Y-12 Plant to have posed off-site health hazards.

Conclusions

Based on the qualitative and quantitative screening, the materials were separated into three classes in terms of potential off-site health hazards: not candidates for further study, potential candidates for further study, and high priority candidates for further study. (as shown in Table 2).

- *Not candidates*—Five materials at the K-25 and 14 materials used at the Y-12 Plant were determined to not warrant further study. All of these chemicals were eliminated because either (1) quantitatively, they fell below Level I Screening decision guides; (2) not enough material was present to have posed an off-site health hazard according to the threshold quantity approach; or (3) qualitatively, the quantities used, forms used, and/or manners of usage were such that off-site releases would not have been sufficient to cause off-site health hazards.

- *Potential candidates*—Three materials at the K-25 (copper powder, nickel, and technetium-99), three materials used at the Y-12 Plant (beryllium compounds, lithium compounds, and technetium-99), and one material used at ORR (chromium VI) were determined to be potential candidates for further study. These materials were identified as potential candidates because (1) their Level I Screening indices exceeded the decision guides and (2) their Refined Level I Screening indices did not exceed the decision guides.

- *High priority candidates*—One material used at the K-25 (arsenic) and two at the Y-12 Plant (arsenic and lead) were determined to be high priority candidates for further study. They were chosen as high priority materials because their Refined Level I Screening indices exceeded the decision guides.

Two issues remaining from the Dose Reconstruction Feasibility Study were evaluated during Task 7: the possible off-site health risks associated with asbestos and the composition of plutonium formed and released to the environment.

- *Asbestos*—Asbestos could not be fully evaluated during the feasibility study; therefore, it was qualitatively evaluated during this task for the potential for off-site releases and community exposure. Available information on the use and disposal of asbestos, as well as off-site asbestos monitoring, was summarized. None of the investigations performed to date have identified any asbestos-related exposure events or activities associated with community exposure, making it very unlikely that asbestos from ORR has caused any significant off-site health risks.

- *Plutonium*—The records that documented the rate of plutonium release did not specify the isotopic composition of the product formed. As a result, during the feasibility study, the project team made the assumption that the plutonium that was formed and released was plutonium-239. If incorrect, this assumption could have significant ramifications on the screening of past airborne plutonium releases. Therefore, the composition of the plutonium formed and released was evaluated further during this task. Plutonium inventory from X-10 was calculated, and plutonium-239 was found to comprise at least 99.9% of the plutonium present in Clinton Pile fuel slugs. This result confirmed that the assumptions made in the feasibility study did not introduce significant inaccuracy into the screening evaluation that was conducted.

TABLE 1
Summary of Screening Methods Used for Each Material

Qualitative Screening

Material	Source	Notes
Boron carbide, boron nitride, yttrium boride, titanium boride, rubidium nitrate, triplex coating, carbon fibers, glass fibers, and four-ring polyphenyl ether	ORR	Evaluated based on quantities used, forms used, and manners of usage.
Tellurium	Y-12	Evaluated based on quantities used, forms used, and manners of usage.

Threshold Quantity Approach

Material	Source	Media	Threshold Values
Niobium	Y-12 Used in production of two alloys, mulberry and binary	Air Surface water	Evaluated using a reference dose derived from an LD50, an empirically derived dispersion factor for airborne releases from Y-12 to Scarboro, and estimated average East Fork Poplar Creek (EFPC) flow rates.
Tetramethylammoniumboro-hydride (TMAB)	Y-12 Use classified	Air Surface water	Inventory quantities and specific applications remain classified.
Zirconium	Y-12 Used in production of an alloy, mulberry	Air Surface water	Evaluated using a reference dose derived from an ACGIH Threshold Limit Value for occupational exposure, an empirically derived dispersion factor for air released from Y-12 to Scarboro, and estimated average EFPC flow rates.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening			
Material	**Source**	**Media**	**Exposure Values**
Arsenic Level I Screen and Refined Level I Screen	K-25 Y-12 Released as a naturally occurring product in coal, which was used in coal-fired steam plants	Air	Based on coal use and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Used maximum in Poplar Creek (K-25) and the 95% upper confidence limit (UCL) on the mean concentration in McCoy Branch (Y-12).
		Soil/sediment	Used sediment core concentration detected in Poplar Creek to represent the early 1960s (K-25) and the 95% UCL on the mean concentration in McCoy Branch (Y-12).
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Beryllium compounds Level I Screen and Refined Level I Screen	Y-12 Used in production	Air	Used Y-12 stack monitoring data and an empirical dispersion factor for releases to Scarboro.
		Surface water	Used maximum concentration measured in EFPC.
		Soil	Used maximum concentration measured in EFPC.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Copper Level I Screen and Refined Level I Screen	K-25 Use of copper powder is classified	Air	Based on airborne concentrations measured at the most-affected on-site air sampler that were adjusted according to the ratio of dispersion model results at that sampler to those at Union/Lawnville.
		Surface water	Used maximum concentration measured during the Clinch River Remedial Investigation.
		Soil/sediment	Used highest mean concentration in Clinch River.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer factor and an ATSDR bioconcentration factor.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Hexavalent chromium (Chromium VI) Level I Screen and Refined Level I Screen	ORR Used in cooling towers to control corrosion	Air	Based on modeling of emission and drift from K-25 cooling towers to Union/Lawnville.
		Surface water	Used maximum concentration measured in Poplar Creek before 1970.
		Soil	Used average concentration of total chromium measured during the EFPC Remedial Investigation; assumed to be 1/6 (16.7%) chromium VI.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Lead EPA's Integrated Exposure Uptake Biokinetic model	Y-12 Used in production of components, in paints, and as radiation shielding	Air	Estimated from background concentrations of lead prior to mid-1970s.
		Surface water	Used maximum concentration measured in EFPC (a higher concentration was detected near Y-12; however it was considered to be anomalous).
		Soil/sediment	Used maximum concentration measured in the EFPC Remedial Investigation, the 95% UCL, and the 95% UCL multiplied by 3.5 for a higher past concentration.
		Food items	Based on concentrations in air, soil, and water and biotransfer and bio-concentration factors from literature.
Lithium Level I Screen and Refined Level I Screen	Y-12 Used in lithium isotope separation, chemical, and component fabrication	Air	Used stack sampling data from two lithium processing buildings and an empirical dispersion factor for releases to Scarboro.
		Surface water	Used highest quarterly average measured in EFPC.
		Soil/sediment	Used maximum concentration measured in the EFPC floodplain.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Neptunium-237 Level I Screen	K-25 Y-12 Found in recycled uranium	Air	Based on levels in recycled uranium, an estimated release fraction, and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Based on reported releases to Clinch River (K-25) and EFPC (Y-12), corrected for dilution.
		Soil/sediment	Used maximum concentrations detected in Clinch River (K-25) and EFPC (Y-12).
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Nickel Level I Screen and Refined Level I Screen	K-25 Used in the production of barrier material for the gaseous diffusion process	Air	Based on the 95% UCL for the year of the highest measured concentrations in on-site air samplers and dispersion modeling to Union/Lawnville.
		Surface water	Used 95% UCL for the year of the highest concentrations in Clinch River.
		Soil/sediment	Used highest mean concentration in Clinch River.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Technetium-99 Level I Screen and Refined Level I Screen	K-25 Y-12 Product of fission of uranium atoms and from neutron activation of stable molybdenum-98	Air	Used an average of concentrations modeled to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Used maximum concentration detected in Clinch River (K-25) and EFPC (Y-12).
		Soil/sediment	Used maximum concentration from the K-25 perimeter and EFPC (Y-12).
		Food items	Based on concentrations in air, soil, and water and biotransfer and bioconcentration factors from literature.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Tritium Level I Screen	Y-12 Used in deuterium gas production and lithium deuteride recovery operations	Surface water	Evaluated based on deuterium inventory differences and the peak tritium concentration in the deuterium that was processed at Y-12; the release estimate was used with the International Atomic Energy Agency method for tritium dose assessment, assuming all the tritium that escaped was released to EFPC.

TABLE 2
Categorization of Materials Based on Screening Results

Contaminant Source	Not Candidates for Further Study (Level I result was below the decision guide)	Potential Candidates for Further Study (Refined Level I result was below the decision guide)	High Priority Candidates for Further Study (Refined Level I result was above the decision guide)
K-25	Neptunium-237 (cancer) Evaluated qualitatively (quantities, forms, and manner of use were not sufficient): • Carbon fibers • Four-ring polyphenyl ether • Glass fibers • Triplex coating	• Copper powder (noncancer) • Nickel (cancer) • Nickel (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer)
Y-12 Plant	• Beryllium compounds (noncancer) • Neptunium-237 (cancer) • Tritium (cancer) Evaluated using Threshold Quantity Approach (not enough material was present): • Niobium (noncancer) • TMAB • Zirconium (noncancer) Evaluated qualitatively (quantities, forms, and manner of use were not sufficient): • Boron carbide • Boron nitride • Rubidium nitrate • Rubidium bromide • Tellurium • Titanium boride • Yttrium boride • Zirconium	• Beryllium compounds (cancer) • Lithium compounds (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer) • Lead (noncancer) Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.
ORR (all complexes)		• Chromium VI (cancer) • Chromium VI (noncancer)	

ORRHES Brief
Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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, Report of the Oak Ridge Dose Reconstruction, Vol. 5 The Report of Project Task 6

Site: Oak Ridge Reservation

Conducted by: ChemRisk/ORHASP for the Tennessee Department of Health

Time Period: 1999

Location: Oak Ridge, Tennessee

Purpose

The purpose of the Task 6 study was to further evaluate the quality of historical uranium operations and effluent monitoring records, to confirm or modify previous uranium release estimates for the period from 1944 to 1995 for all three complexes on the Oak Ridge Reservation (ORR), and to determine if uranium releases from the ORR likely resulted in off-site doses that warrant further study. The main results of the study are revised uranium release estimates from the Y-12 plant, K-25 gaseous diffusion plant, and the S-50 liquid thermal diffusion plant and screening-level estimates of potential health effects to people living near the ORR. These results, which are called "screening indices," are conservative estimates of potential exposures and health impacts and are intended to be used with the decision guide established by Oak Ridge Health Agreement Steering Panel (ORHASP) to determine if further work is warranted to estimate the human health risks from past uranium releases.

Background

The 1993 Oak Ridge Health Studies, Phase I Dose Reconstruction Feasibility Study by the Tennessee Department of Health indicated that uranium was not among the list of contaminants that warranted highest priority for detailed dose reconstruction investigation of off-site health effects. After receiving comments from several long-term employees at the ORR uranium facilities, a number of ORHASP members recommended that past uranium emissions and potential resulting exposures receive closer examination. In 1994, the Task 6 uranium screening evaluation was included in the Oak Ridge Dose Reconstruction project.

The Oak Ridge Y-12 plant was built in 1945, as part of the Manhattan project. Located at the eastern end of Bear Creek Valley, the Y-12 complex is within the corporate limits of the city of Oak Ridge and is separated from the main residential areas of the city by Pine Ridge. The Y-12 plant housed many operations involving uranium, including the preparation, forming, machining, and recycling of uranium for Weapon Component Operations.

Construction of the K-25 uranium enrichment facility began in 1943, and the facility was operational by January 1945. The K-25 site is located near the western end of the ORR, along Poplar Creek near where it meets the Clinch River. The primary mission of K-25 was to enrich uranium by the gaseous diffusion process.

Located along the Clinch River near the K-25 site was a liquid thermal diffusion plant (the S-50 site) that operated from October 1944 to September 1945. Because of their close proximity, the K-25 and S-50 complexes were generally discussed together in the Task 6 report.

The X-10 facility, which conducted chemical processing of reactor fuel and other nuclear materials, was not a primary focus of the Task 6 study.

Methods

An extensive information gathering and review effort was undertaken by the project team in searching for information related to historical uranium operations at the Y-12, K-25, and S-50 sites. Thousands of documents were searched and many active and retired workers were interviewed.

The Task 6 investigation followed these basic steps:

- Information that described uranium uses and releases on the ORR was collected.
- Effluent monitoring data were evaluated for quality and consistency with previous U.S. Department of Energy (DOE) historical uranium release reports.
- Updated estimates of airborne uranium releases over time were generated using the more complete data available to the project team.
- Air dispersion models were used to estimate uranium air concentrations at selected reference locations near each ORR facility. The reference locations were:
  - — the Scarboro community (for Y-12),
  - — the Union/Lawnville community (for K-25/S-50), and
  - — Jones Island area along the Clinch River (for X-10).

  Because the terrain surrounding the Y-12 facility has complex topography, air dispersion modeling techniques were not employed. Instead, an empirical relative concentration (chi/Q) relationship was established between measured releases of uranium from Y-12 and measured airborne concentrations of uranium at Scarboro. The chi/Q relationship was then used to extrapolate airborne uranium concentrations for times in which it was not directly measured.
- The screening evaluation of potential offsite exposures to waterborne uranium was based on environmental measurements of uranium at local surface waters. The sampling sites were: White Oak Dam, downstream of New Hope Pond, and the confluence of Poplar Creek and the Clinch River.
- A screening-level evaluation of the potential for health effects was performed by calculating intakes and associated radiation doses. A two-tiered exposure assessment methodology was employed, which provided both upper bound and more typical results. Because of the scarcity of information regarding estimates of uranium concentrations in the environment over the period of interest, some conservatism was maintained in the uranium concentrations used in the Level II screening.
- Annual radiation doses from uranium intake and external exposure were calculated for the adult age group for each screening assessment and then converted to screening indices using a dose-to-risk coefficient of 7.3% Sv^{-1}.
- Estimates of annual-average intakes of uranium by inhalation and ingestion were also used to evaluate the potential for health effects due to the chemical toxicity of uranium compounds, specifically for damage to the kidneys. Uranium was assumed to be in its most soluble form and safety factors were included to minimize the potential for underestimation of the potential for toxic effects.

Study Subjects

The screening evaluation estimated potential off-site exposure and screening indices for hypothetical individuals in three reference locations (Scarboro, Union/Lawnville, and Jones Island). These reference locations represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases. Thus, they are associated with the highest screening indices derived by the screening evaluation.

Exposures

The following potential air exposure pathways were evaluated:

1. Air to humans-direct inhalation of airborne particulates
2. Air to humans (immersion in contaminated air)
3. Air to livestock (via inhalation) to beef to humans
4. Air to dairy cattle (via inhalation) to milk to humans
5. Air to vegetables (deposition) to humans
6. Air to pasture (deposition) to cattle beef to humans
7. Air to pasture (deposition) to dairy cattle to milk to humans

The following potential water exposure pathways were evaluated:

1. Incidental ingestion by humans during recreation
2. Water to livestock (ingestion) to beef to humans
3. Water to dairy cattle (ingestion) to milk to humans
4. Water to fish to humans
5. Water to humans via immersion during recreation

The following potential soil exposure pathways were evaluated:

1. Soil to air (dust resuspension) to humans
2. Soil incidental ingestion
3. Soil to livestock (soil ingestion) to beef to humans
4. Soil to dairy cattle (soil ingestion) to milk to humans
5. Soil to vegetables (root uptake) to humans
6. Soil to pasture (root uptake) to livestock to beef to humans
7. Soil to pasture (root uptake) to dairy cattle to milk to humans
8. Soil to humans via external radiation

Outcome Measures

Health outcomes were not studied.

Results

Airborne uranium releases from the Y-12, K-25, and S-50 sites were found to be greater than previously reported. DOE estimated that the amount of uranium released from the Y-12 plant was 6,535 kilograms. The Task 6 team estimated that 50,000 kilograms of uranium was released to the air by the Y-12 plant. DOE estimated that the amount released from the K-25 and S-50 plants (combined) was 10,713 kilograms. The Task 6 team estimated that 16,000 kilograms were released to the air by the K-25/S-50 complex.

The Scarboro community was associated with the highest total screening index attributable to uranium releases from the Y-12 plant. The screening indices were 1.9×10^{-3} for the Level I assessment and 8.3×10^{-5} for the Level II assessment. While the overall Level I screening index for the Scarboro community is above the ORHASP decision guide of 1.0×10^{-4} (1 in 10,000), the Level II value is below that guide value. This indicates that the Y-12 uranium releases are candidates for further study, but that they are not high priority candidates for further study.

For the K-25/S-50 assessment, the total screening index for Union/Lawnville from the Level I assessment (2.7×10^{-4}) exceeded the ORHASP decision guide. The less conservative Level II screening result (4.0×10^{-5}) did not exceed the

guide. This indicates that the K-25/S-50 uranium releases are also candidates for further study, but that they are not high priority candidates for further study.

The X-10 Level I assessment yielded a screening index for Jones Island (7.6×10^{-5}) below the decision guide. This indicates that releases from the X-10 site warrant lower priority, especially given the pilot-plant nature and relatively short duration of most X-10 uranium operations.

The Scarboro community was selected for the initial chemical toxicity evaluation since its screening index for radiological exposures was the highest. Estimated kidney burdens resulting from simultaneous intake of uranium by ingestion and inhalation under the Scarboro assessment do not exceed an effects threshold criterion (1 microgram per gram of kidney tissue) proposed by some scientists, but they do exceed an effects threshold criterion (0.02 micrograms per gram of kidney tissue) proposed by other scientists. The Task 6 team also evaluated the average-annual intakes using a reference dose/Hazard Index approach and concluded that further study of chemical toxicity from past ORR uranium exposures did not warrant high priority.

Conclusions

The Task 6 team reached the following general conclusions:

- Estimates of uranium releases previously reported by DOE are incomplete and; therefore, were not used in the Task 6 screening evaluation.
- Historical uranium releases from the Y-12 plant are likely significantly higher (over seven times higher) than totals reported by DOE. There are several reasons why previous estimates were so much lower.
- Historical uranium releases from the K-25/S-50 complex are likely higher than totals reported by DOE.
- Operations at the S-50 plant are poorly documented.
- The Scarboro community had the highest total screening index from uranium releases at the ORR, specifically the Y-12 plant. Since the Level II screening index is just below the ORHASP decision criterion, with most of the conservative assumptions regarding source term and exposure parameters removed, potential exposure to uranium releases could have been of significance from a health standpoint and should; therefore, be considered for dose reconstruction.
- The Union/Lawnville community evaluation (releases from the K-25/S-50 complex) had a Level II screening index below the ORHASP criterion. However, without quantification of the uncertainties associated with the release estimates and the exposure assessment, it is not possible to say that these releases do not warrant further characterizations.
- The Level I screening index for the Jones Island area (releases from the X-10 site) are below the ORHASP decision criterion.
- Because Pine Ridge separates the Y-12 plant from Scarboro, an alternate approach (chi/Q) was used to estimate uranium air concentrations in Scarboro.
- The concentrations of uranium in soil are a major factor in the screening analyses. Because limited soil data are available for the reference locations, alternative approaches should be considered for future analyses.
- While the estimated uranium intake from ingestion and inhalation exceed one effects threshold criterion, they do no exceed another. Calculated hazard indices indicate that further study of chemical effects of the kidneys rank as a low priority.

If the evaluation of ORR uranium releases is to proceed beyond a conservative screening stage and on to a nonconservative screening with uncertainty and sensitivity analyses, activities that should be evaluated for possible follow-up work include:

- Additional records research and data evaluation regarding S-50 plant operations and potential releases.
- Additional searching for and review of effluent monitoring data for Y-12 electromagnetic enrichment operations from 1944 to 1947 and data relating to releases from unmonitored depleted uranium operations in the 1950s through the 1990s.
- Uncertainty analysis of the Y-12 uranium release estimates derived in this study.
- Review of additional data regarding unmonitored K-25 uranium releases.
- Refinement of the approach used to evaluate surface water and soil-based exposure concentrations.
- Evaluation of the effects of the ridges and valleys that dominate the local terrain surrounding Y-12 and Scarboro and investigation of alternative approaches to estimate air concentrations at Scarboro with an emphasis on identifying additional monitoring data.
- Performance of a bounding assessment of the amounts of uranium that were handled at the X-10 site.
- Improvement of the exposure assessment to include region-specific consumption habits and lifestyles, identification of likely exposure scenarios instead of hypothetical upper bound and typical assessments, and inclusion of uncertainty analysis to provide statistical bounds for the evaluation of risk.
- Refinement of the chemical toxicity evaluation, possibly to include other approaches and models, as well as an uncertainty analysis.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Health Consultation, U.S. DOE Oak Ridge Reservation, Lower Watts Bar Operable Unit, February 1996

Site: Oak Ridge Reservation
Study authors: Agency for Toxic Substances and Disease Registry
Time period: 1980s and 1990s
Target population: Lower Watts Bar Reservoir Area

Purpose

This health consultation was conducted to evaluate the public health implications of chemical and radiological contaminants in the Watts Bar Reservoir and the effectiveness of the Department of Energy's proposed remedial action plan for protecting public health.

Background

In March 1995, the Department of Energy (DOE) released a proposed plan for addressing contaminants in the Lower Watts Bar Reservoir. The plan presented the potential risk posed by contaminants and DOE's preferred remedial action alternative. DOE's risk assessment indicated that consumption of certain species of fish from the Lower Watts Bar Reservoir and the transfer of sediment from deeper areas of the reservoir to areas on land where crops were grown could result in unacceptable risk to human health.

The September 1995 Record of Decision for the Lower Watts Bar Reservoir presented DOE's remedial action plan for the reservoir. This remedial action included maintaining the fish consumption advisories of the Tennessee Department of Environment and Conservation (TDEC), continuing environmental monitoring, and implementing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediment. The U.S. Environmental Protection Agency (EPA) and TDEC concurred with the remedial action plan.

Concerned about the sufficiency of DOE's plan, local residents asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the health risk related to contaminants in the Lower Watts Bar Reservoir. These residents asked ATSDR to provide an independent opinion on whether DOE's selected remedial actions would adequately protect public health.

Methods

ATSDR agreed to provide a health consultation. A health consultation is conducted in response to a specific request for information about health risks related to a specific site, a specific chemical release, or the presence of other hazardous material. The response from ATSDR may be verbal or written.

To assess the current and recent past health hazards from the Lower Watts Bar Reservoir contamination, ATSDR evaluated environmental sampling data. ATSDR evaluated reservoir studies conducted by DOE and the Tennessee Valley Authority during the 1980s and 1990s. ATSDR also evaluated TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. ATSDR first screened the voluminous environmental data to determine whether any contaminants were present at levels above health–based comparison values. ATSDR next estimated exposure doses for any contaminants exceeding comparison values. It is important to note that the fact that a contaminant exceeds comparison values does

not necessarily mean that the contaminant will cause adverse health effects. Comparison values simply help ATSDR determine which contaminants to evaluate more closely.

ATSDR estimated exposure doses, using both worst case and realistic exposure scenarios, to determine if current chemical and radiological contaminant levels could pose a health risk to area residents. The worst case scenarios assumed that the most sensitive population (young children) would be exposed to the highest concentration of each contaminant in each media by the most probable exposure routes.

Target population

Individuals living along the Watts Bar Reservoir and individuals visiting the area.

Exposures

The exposures investigated were those to metals, radionuclides, volatile organic compounds, polychlorinated biphenyls (PCBs), and pesticides in surface water, sediment, and fish.

Outcome measure

ATSDR did not review health outcome data.

Results

Reservoir Fish and Other Wildlife: Using a realistic exposure scenario for fish consumption that assumed an adult weighing 70 kilogram (kg) consumed one 8-ounce sport fish meal per week, or per month, for 30 years, ATSDR determined that PCB levels in reservoir fish were at levels of health concern. ATSDR estimated ranges of PCB exposure doses from 0.099 to 0.24 micrograms of PCBs per kilogram of human body weight every day (µg/kg/day) for the one fish meal a week scenario and 0.023 to 0.055 µg/kg/day for the one fish per month scenario.

At these exposure doses, ATSDR estimates that approximately one additional cancer case might develop in 1,000 people eating one fish meal a week for 30 years and three additional cancer cases might develop in 10,000 people eating one fish meal a month for 30 years.

At these exposure doses, ATSDR also determined that ingestion of reservoir fish by pregnant women and nursing mothers might cause adverse neurobehavioral effects in infants. Although the evidence that PCBs cause developmental defects in infants is difficult to evaluate and inconclusive, ATSDR's determination was made on the basis of the special vulnerability of developing fetuses and infants.

Using a worst case scenario that assumed adults and children consumed two 8-ounce fish meals a week, containing the maximum concentration of each radioactive contaminant, ATSDR determined that the potential level of radiological exposure, which was less than 6 millirem per year (mrem/yr), was not a public health hazard.

Reservoir Surface Water: Using a worst case exposure scenario that assumed a child would daily ingest a liter of unfiltered reservoir water containing the maximum level of contaminants, ATSDR determined that the levels of chemicals in the reservoir surface water were not a public health hazard.

Levels of radionuclides in surface water were well below the levels of the current and proposed EPA drinking water standards. In addition, the total radiation dose to children from waterborne radioactive contaminants would be less that 1 mrem/yr, which is well below background levels. The radiation dose was estimated using the conservative assumption that a 10-year-old child would drink and shower with unfiltered reservoir water and swim in the reservoir daily.

Reservoir Sediment: ATSDR determined that the maximum chemical and radioactive contaminant concentrations reported in the recent surface sediments data (mercury, Co-60, Sr–89/90, and Cs-137) would not present a public health hazard. The estimated dose from radioactive contaminants was less than 15 mrem/yr, which is below background levels.

ATSDR also evaluated the potential exposure a child might receive if the subsurface sediments were removed from the deep reservoir channels and used as surface soil in residential properties. Using a worst case exposure scenario that included ingestion, inhalation, external, and dermal contact exposure routes, ATSDR determined that the potential radiation dose to individuals living on these properties (less than 20 mrem/yr) would not pose a public health hazard.

Conclusions

ATSDR found that only PCBs in the reservoir fish were of potential public health concern. Other contaminants in the surface water, sediment, and fish were not found to be a public health hazard.

On the basis of current levels of contaminants in the water, sediment, and wildlife, ATSDR concluded the following.

- The levels of PCBs in the Lower Watts Bar Reservoir fish posed a public health concern. Frequent and long-term ingestion of fish from the reservoir posed a moderately increased risk of cancer in adults and increased the possibility of developmental effects in infants whose mothers consumed fish regularly during gestation and while nursing. Turtles in the reservoir might also contain PCBs at levels of public health concern.

- Current levels of contaminants in the reservoir surface water and sediment were not a public health hazard. The reservoir was safe for swimming, skiing, boating, and other recreational purposes. It is safe to drink water from the municipal water systems, which draw surface water from tributary embayments in the Lower Watts Bar Reservoir and the Tennessee River upstream from the Clinch River and Lower Watts Bar Reservoir.

- DOE's selected remedial action was protective of public health.

ATSDR made the following recommendations.

- The Lower Watts Bar Reservoir fish advisory should remain in effect to minimize exposure to PCBs.

- ATSDR should work with the state of Tennessee to implement a community health education program on the Lower Watts Bar fish advisory and the health effects of PCB exposure.

- The health risk from consumption of turtles in the Lower Watts Bar Reservoir should be evaluated. The evaluation should investigate turtle consumption patterns and PCB levels in edible portions of turtles.

- Surface and subsurface sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group.

- Sampling of municipal drinking water at regular intervals should be continued. In addition, at any time a significant release of contaminants from the Oak Ridge Reservation is discharged into the Clinch River, DOE should notify municipal water systems and monitor surface water intakes.

Appendix I. Toxicological Data

Ionizing Radiation

As previously noted, radiation exposure divides into two broad classes: internal radiation and external radiation. Internal exposures result from radioactive sources taken into the body through the inhalation of radioactive particles or the ingestion of contaminated food. External exposure results from radiation sources originating outside the body, such as radiation emitted from contaminated sediment. These external sources can sometimes penetrate the human skin. Whether an exposure contributed to a person's internal or external exposure depends primarily on the type of radiation—that is, alpha and beta particles or gamma rays—to which that person was exposed.

Beta particles can penetrate human skin and tissues and deliver a dose both internally and externally. **Gamma rays** can travel long distances and easily penetrate body tissues, and are therefore the primary type of radiation that results in external radiation exposures. **Alpha particles** cannot penetrate skin, so they pose a minimal external exposure concern. Alpha particles can inflict biological damage if the body takes them in, for example by breathing or swallowing radioactive material in air or food.

Source: ATSDR 1999b

The following information is from ATSDR's *Toxicological Profile for Ionizing Radiation* (ATSDR 1999b). Radioactive material can be released to the air as particles or gases as a result of natural forces and from human industrial, medical, and scientific activities. Everyone, with no exception, is exposed to ionizing radiation. You are exposed to low levels of ionizing radiation from the sun, rocks, soil, natural sources in your body, fallout from past nuclear weapons tests, some consumer products, and radioactive materials released from hospitals and from nuclear and coal power plants. You are exposed to more if you work as a pilot, flight attendant, astronaut, industrial and nuclear power plant worker, or an x-ray or medical technician. You receive additional exposure with each x-ray exam and nuclear medicine test, and the amount depends on the type and number of tests.

How radiation affects your health depends on how much ionizing radiation you received and over what period of time, and personal factors such as sex, age at the time of exposure, and your health and nutritional status. Increasing the dose results in a more severe effect. Studies so far have not shown that the low dose of ionizing radiation we are exposed to every day causes us

any harm. We do know that exposure to massive amounts of ionizing radiation can cause great harm, so it is wise to not be exposed to any more ionizing radiation than necessary.

Exposure to high doses of ionizing radiation can result in skin burns, hair loss, nausea, birth defects, illness, and death. Increased psychological stress has been shown in large populations exposed to small doses of radiation from nuclear accidents. Mental function has been affected in people exposed before birth to high doses of ionizing radiation. Ionizing radiation is called a carcinogen because it may also increase your chance of getting cancer. Increasing the size of the dose increases your chance of getting cancer. Scientists base radiation safety standards on the assumption that any radiation dose, no matter how small, carries with it a corresponding probability of causing a cancer. This is called a "zero threshold" dose-response relationship. Cancers that are actually caused by radiation are completely indistinguishable from those from other causes, so we can never be certain whether any individual cancer was not caused by radiation.

We have seen health effects from very high doses of ionizing radiation, but not at normal everyday levels. To be cautious, scientists and regulating agencies assume that there could be some harmful effects at any dose, no matter how small. Because ionizing radiation has the potential to cause harmful health effects in overexposed people, regulations and guidelines have been established for ionizing radiation by state, national, and international agencies. The current federal and state regulation limit for the general public is 0.001 Sievert (Sv)/year (0.1 rem/year or 100 mrem/year). To give the public an extra margin of safety, the public dose limit is set at least 10 times lower than the occupational limit.

Uranium

Uranium is a radioactive metal that is naturally present in rocks, soil, groundwater, surface water, air, plants, and animals in small amounts. It contributes to a natural level of radiation in our environment, called background radiation. The amount of uranium in drinking water in the United States is generally less than 1 picoCurie per liter (pCi/L) or approximately 1.5 microgram per liter (µg/L) (ATSDR 1999a).

Natural uranium, enriched uranium, and depleted uranium are mixtures of primarily three uranium isotopes (U 238, U 235, and U 234) that are chemically similar but contain a different number of neutrons. By weight, natural uranium is more than 99% U 238, 0.72% U 235, and 0.005% U 234. Enriched uranium is more than 0.72% U 235 by weight, and depleted uranium is less than 0.72% U 235 by weight. All three isotopes are radioactive but have different specific activities (that is, radioactivity per gram of material). U 238 has the lowest specific activity, and U 234 has the highest.

Uranium can harm people in two ways: as a chemical toxin and as a radioactive substance. (That is, uranium's chemical and radioactive properties can both be harmful so they are considered separately.) Because natural uranium produces very little radioactivity, the chemical effects of uranium are generally more harmful than the radioactive effects. Due to the combined effects of chemical and radioactive properties, however, radioactive mixtures such as enriched uranium can harm the kidney or skeletal system more than natural uranium.

The kidney is the primary target organ for the chemical effects of ingested and inhaled uranium. The extent of toxicity is determined primarily by exposure route, type of uranium compound, and solubility of that compound. Ingested uranium compounds are generally less toxic to the kidneys than are inhaled uranium compounds, partly because uranium is poorly absorbed from the intestinal tract. Highly soluble uranium compounds are generally more toxic to the kidneys than are less-soluble compounds via ingestion; the more soluble compounds are more readily absorbed, thus they pose a greater potential dose to the kidney. Absorption of uranium is low by all (inhalation, ingestion, and dermal) exposure routes—less than 5%).

Studies using laboratory animals provide most of the evidence for kidney toxicity. ATSDR has established intermediate (15 to 364 days) exposure health guidelines for inhalation of both soluble and insoluble uranium compounds. The guideline for insoluble uranium is 8 $\mu g/m^3$. This guideline is based on structural changes (lesions) in kidneys of dogs exposed to uranium dioxide dust for a 5-week period, with exposure occurring over 6 days a week for 6 hours a day (Rothstein 1949). The health guideline for inhalation of soluble uranium of 0.4 $\mu g/m^3$ is based on kidney lesions in dogs exposed to uranium chloride in air over a 1-year period, with exposure occurring over 6 days a weeks for 6 hours a day (Stokinger et al. 1953). Neither study provided

information about the size of the uranium particles used, so ATSDR based its guideline on the conservative assumption that uranium particles were 2 microns or less in diameter.

Fluoride (Fluorine) and Hydrogen Fluoride

The following review is from ATSDR's *Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine* (ATSDR 2003). Fluorides in air may be present in the gas phase (generally as HF) or in a particulate phase. Fluoride ions form stable colorless complexes with certain multivalent ions, such as $(AlF_6)^{3-}$, $(FeF_6)^{3-}$, and $(ZrF_6)^{3-}$. HF is a colorless fuming gas or liquid that is made up of a hydrogen ion and a fluoride ion. HF is used as a catalyst, as a fluorinating agent, in making fluorine and aluminum fluoride, as an additive in rocket fuel, and for the refining of uranium.

HF is an irritant that is soluble in water. It dissolves easily in any water in the air or other media, including the skin, upper respiratory tract, eyes, plants, and soil. When HF is dissolved in water, it is called hydrofluoric acid. Hydrofluoric acid is dangerous to humans because it can burn the skin and eyes. At first, exposure to hydrofluoric acid may not look like a chemical burn. Skin may only appear red and may not be painful at first. Damage to the skin can occur over several hours or days, and deep painful wounds can develop. When not treated properly, serious skin damage and tissue loss can occur. In the worst cases, people who get a large amount of hydrofluoric acid on their skin can die when the fluoride affects the lungs, the heart, or both.

Breathing in a large amount of HF can harm the lungs and heart and cause death. The human health effects for breathing moderate amounts of HF for several months are not well known, but rats that breathed HF for several months suffered kidney damage and nervous system changes, such as learning problems. If you breathe HF or fluoride-containing dust for several years, changes in your bones (called skeletal fluorosis) can occur.

HF is highly corrosive and produces adverse effects at the point of contact, which is usually the respiratory tract (nose, throat, trachea, and bronchi), eyes, and skin. Because HF is absorbed into the bloodstream, it can affect other organs in the body, such as the lungs, liver, kidney, and heart.

Short-term exposure to HF in air at concentrations as low as 20 ppm can be tolerated for 1 minute, although concentrations of 120 ppm irritate the nose, throat, eyes, and skin in humans

(NLM 2000). Vapors can cause ulcers of the respiratory tract at concentrations of 50 to 250 ppm—these concentrations can be dangerous, even for brief exposures. Inhalation of HF at higher concentrations can cause severe throat irritation, cough, lung injury, and pulmonary edema (swelling) resulting in death.

The National Institute of Occupational Safety and Health (NIOSH) recommends that exposure to HF by workers not exceed 3 ppm (or 2.5 mg/m^3), with a 15-minute ceiling of 6 ppm (or 5 mg/m^3). The recommendations, based on studies of workers and laboratory animals, are intended to protect workers from effects on the respiratory tract, eyes, skin, and bones. One study of rabbits and guinea pigs exposed to HF, at concentrations of 24 to 8,000 ppm for 5 to 41 minutes, reported eye and respiratory tract irritation at all exposure concentrations. A significant number of animals died within 5 minutes when they inhaled air containing 1,800 ppm (or 1,500 mg/m^3) of hydrogen fluoride. Weakness and appearance of illness were apparent in all animals at concentrations above 600 ppm (or 500 mg/m^3) for 15 minutes or longer. Rabbits that survived returned to normal within a few weeks, but guinea pigs showed a definite tendency to delayed response and death between the fifth and tenth week following exposure (NIOSH 1997).

HF readily penetrates the skin and can cause deep tissue destruction and burns following dermal exposure. Exposure to the eye can result in irritation to severe ocular damage and visual effects. Studies conducted to determine whether fluoride causes cancer in people who live in areas with fluoridated water or naturally high levels of fluoride in drinking water, or people who may be exposed to fluorides at work, have not found an association between fluoride and cancer.

Uranyl Fluoride

Uranyl fluoride is water soluble. Its toxicity is determined primarily by route of exposure; exposure concentration, duration, and frequency; and particle size. Ingestion generally produces less toxicity than inhaled uranium because uranium is poorly absorbed from the gastrointestinal tract following ingestion. Respiratory and kidney toxicity are the targets for inhaled uranium.