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Risk Screen to Support the Title Transfer of the K-1007 Building at the East Tennessee Technology Park, Oak Ridge, Tennessee

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Risk Screen to Support the Title Transfer of the K-1007 Building at the East Tennessee Technology Park, Oak Ridge, Tennessee

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CONTENTS

FIGURES

TABLES

ACRONYMS

BJC	Bechtel Jacobs Company LLC
cm	centimeter
COPC	contaminant of potential concern
CROET	Community Reuse Organization of East Tennessee
DOE	U. S. Department of Energy
dpm	disintegrations per minute
EBS	Environmental Baseline Survey
EPA	U.S. Environmental Protection Agency
ESU	exterior survey unit
ETTP	East Tennessee Technology Park
EU	exposure unit
g	gram
ISU	interior survey unit
Kg	kilogram
mg	milligram
ORGDP	Oak Ridge Gaseous Diffusion Plant
PAH	polycyclic aromatic hydrocarbons
pCi/g	picocuries per gram
RAGS	*Risk Assessment Guidance for Superfund*
SAIC	Science Applications International Corporation
UCL95	95% upper confidence limit

EXECUTIVE SUMMARY

The goal of this risk evaluation is to determine the potential for adverse health effects associated with Bldg. K-1007 and determine if conditions preclude the use of the facility for its intended purpose, i.e., as an office building for the private sector. The U.S. Department of Energy is proposing to transfer title of this building to the Community Reuse Organization of East Tennessee.

Building K-1007 has two floors and has been used primarily for office space. The K-1007 area was farmland prior to the construction of the Oak Ridge Gaseous Diffusion Plant (ORGDP), later known as the K-25 Site and now designated as the East Tennessee Technology Park (ETTP), in the early 1940s. Numerous warehouses and maintenance buildings occupied the present K-1007 area and were used to support the construction of ORGDP. These buildings were demolished by the late 1950s, and the area was maintained as a grassy field.

For Bldg. K-1007, the representative exposure scenarios considered for the risk evaluation were for the industrial worker and the roving worker. The industrial worker scenario, defined by an individual who spends time doing light industrial activities or office work within the building, is intended to represent exposure to contaminants on interior building surfaces. The roving worker spends break times during the workday outside the building roaming accessible areas of the industrial park. The exposure scenario for this worker is intended to represent exposure to contaminants in soils in the area surrounding the building.

Building K-1007 risks were calculated for the industrial worker scenario assuming exposure by the inhalation, ingestion, and external exposure pathways. The potential risks and doses from exposure to interior survey units (ISUs) in Bldg. K-1007 were calculated. A few areas had risks of ~1×10^{-7}, including ISUs 7 and 17. The highest single unit risk estimate was $1 \times E^{-7}$ for ISU 17. The conservative assumption that 10% of fixed contamination becomes removable resulted in the majority of the risk.

The risk estimate is a value that represents the number of excess cancer incidence that might be expected due to the exposure scenario evaluated. The U. S. Environmental Protection Agency (EPA) has established an acceptable target risk range of 10^{-4} to 10^{-6}. The estimated risk of 1×10^{-7} for the interior of Bldg. K-1007 is an order of magnitude below the EPA target range, indicating a low likelihood of adverse health effects due to the exposure scenarios considered.

The Bldg. K-1007 calculated doses indicated a maximum of ~0.007 mrem/year due to ingestion and inhalation of removable and fixed contamination in ISU 17. The calculated average dose for the interior of Bldg. K-1007 was ~0.004 mrem/year. For comparison the average dose due to ambient sources (medical X-rays, cosmic rays, natural materials, etc.) is approximately 360 mrem/year (National Council on Radiation Protection and Measurement 1987). The dose from the measured background dose rate for ETTP of 0.007 mrem/h is equivalent to ~60 mrem/year assuming 24 h/d and 365 d/year exposure. The calculated doses are significantly below both measures of background dose for Bldg. K-1007.

The risks associated with an industrial worker at Bldg. K-1007 can be summarized as follows:

- the maximum risk associated with an ISU was ~1×10^{-7} for ISU 17, located on the second floor in the northwest corner;
- the maximum calculated dose was ~0.007 mrem/year for ISU 17, located on the second floor in the northwest corner;

- the 95% upper confidence limit of the mean of the dose rate data was calculated to be ~ 0.006 mrem/h, which is below the site background level of 0.007 mrem/h;

- the average risk associated with the interior of Bldg. K-1007 was ~5×10^{-8}, assuming a receptor is equally exposed to all interior survey areas; and

- the average calculated dose associated with the interior of Bldg. K-1007 was ~0.004 mrem/year for the interior of the building as a whole.

An additional scenario, known as the "rover" scenario, was evaluated. It assumes that the industrial worker spends 2 h/d moving around accessible areas of ETTP, both inside and outside of the fence, before the site has been fully remediated. The roving worker risk assessment considered quantitatively 39 surface soil contaminants of potential concern (10 metals, 18 organics, and 11 radionuclides) for the accessible areas of ETTP. The risk to the roving worker was 8×10^{-6}, which is within the EPA acceptable range of 10^{-4} to 10^{-6}. The risk was mainly due to external exposure to ionizing radiation, as well as both ingestion and dermal contact with polycyclic aromatic hydrocarbons. The calculated hazard for the roving worker was 0.2, which is below the EPA acceptable level of 1.0. For additional information, see Appendix A.

The risk evaluation for Bldg. K-1007 indicates that all risks and doses are considered within acceptable levels EPA's target risk range (10^{-4} to 10^{-6}) and below a hazard index of 1.0, which correlates with a low likelihood of adverse health effects to an industrial worker. Therefore, the facility is considered acceptable for transfer for its intended use as an office building by the private sector.

1. INTRODUCTION

The goal of this risk screen is to determine the potential for adverse health effects associated with Bldg. K-1007, located in the southwestern portion of the East Tennessee Technology Park (ETTP). The U. S. Department of Energy (DOE) is proposing to transfer title of this facility to the Community Reuse Organization of East Tennessee (CROET) for its intended use by the private sector (e.g., use as an office building).

Specifically, the objectives of this evaluation are (1) to determine exposure to radiological constituents based on available data, and (2) to use these data to provide a screening-level estimate of the potential for adverse effects to human health. The risk screen approach used in this evaluation is based on the document, *Risk Assessment Guidance for Superfund* (RAGS) [U. S. Environmental Protection Agency (EPA) 1989]. The following sections describe the process used to provide a quantitative analysis of the risks to human health from working in the facility. The risk screen prepared for Bldg. K-1007 also includes a "rover" scenario to address an occupant who might potentially be exposed to contaminated soils as he or she moves around the accessible areas of ETTP prior to completion of site cleanup.

2. DESCRIPTION AND HISTORY

Building K-1007 is located in the southwestern portion of ETTP, near Portal 1, outside the Radiologically Controlled Area fence (Fig. 2.1). It is a two-story brick building that has been used primarily for office space. The K-1007 area was farmland prior to the construction of the Oak Ridge Gaseous Diffusion Plant (ORGDP), later known as the K-25 Site and now designated as ETTP, in the early 1940s. Numerous warehouses and maintenance buildings occupied the present K-1007 area and were used to support the construction of ORGDP. These buildings were demolished by the late 1950s, and the area was maintained as a grassy field until the construction of Bldg. K-1007.

The original K-1007 building was built in 1960 with subsequent additions in 1966, 1972, 1974, 1978, and 1984 to create the present facility. Over the years, Bldg. K-1007 has provided office and workspace for the staff and equipment, User Services and Systems Support, and Technical Applications. Other key operations included micrographics processing, storage of electronic media, and control of production programs. A darkroom on the first floor in the north end of the center wing contained specialized equipment for transferring media to microfilm and an associated silver extraction unit. Two satellite accumulation areas were located in the adjoining room for the accumulation of silver and used fluorescent light bulbs. These areas were closed in July 1998, and portions of the building were leased to CROET in 1998 as part of the Reindustrialization Program. The remainder of the building is used by DOE's prime contractor.

The K-1007 building has two floors and has been primarily used for office space. A canteen trailer in the area, designated K-1007-A, has been used as a lunchroom. The Bldg. K-1007 facility is defined as the K-1007 building (interior, furnishings and exterior surfaces), as well as the K-1007-A canteen trailer. No exterior laydown, parking, or soil areas are associated with the facility.

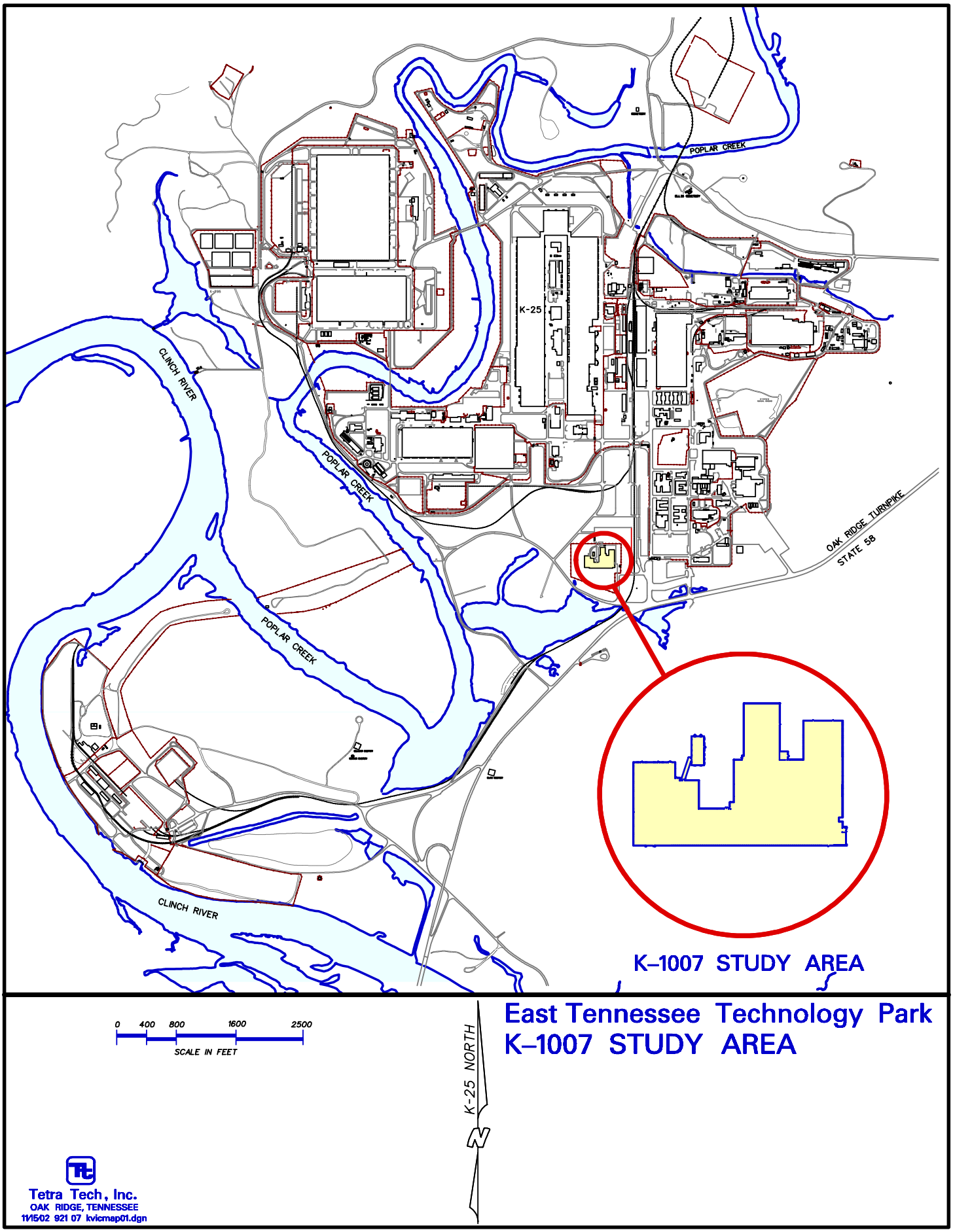

Fig. 2.1. Location of K-1007 within the East Tennessee Technology Park.

3. RADIOLOGICAL SURVEYS AND OTHER DATA

Since 1996, nearly 100 radiological surveys have been completed for the K-1007 building. From 1996 to 2001, a total of 14 area surveys were performed in, or on, the building, including 6 surveys that covered the entire roof area. These surveys indicated that there are no areas with elevated readings/contamination, with the exception of a small, gray handcart with a contaminated wheel that was subsequently removed and taken to a contamination area in another building. Although the surveys prior to 2002 did include the building roof, no measurements were taken from other areas of the building's exterior.

In 2002, 85 surveys were conducted in the K-1007 lease area. Scanned areas included the building interior (walls, floors, ceilings, and work areas), exterior (walls, roof, downspouts, and intakes/vents), and furnishings. Statistical evaluation of the most recent surveys indicates that the interior, exterior, and furnishings were below the DOE surface contamination limits and within the acceptable dose equivalent rate range for building interiors, and therefore, can be released without radiological restrictions [Environmental Baseline Survey (EBS) for K-1007 (BJC 2004)].

There have been no sampling events inside the building to evaluate potential chemical contamination. The EBS (BJC 2004) concluded that asbestos and non-asbestos materials were used in the insulation for the steam and chilled water piping throughout the building. The insulation was judged to be in good condition. Vinyl floor tiles throughout the building were assumed to contain asbestos as well. A number of the tiles were cracked or missing; however, no specific asbestos sampling was conducted. Lead-based paint was not specifically identified in the EBS; however, due to the age of the building, the presence of lead is considered possible. As long as the asbestos-containing materials are maintained in good condition, exposure will not be a concern. Likewise, attention to the possibility of lead-based paint must continue.

Based on discussions with EPA, it has been agreed that the need to collect soil samples to support title transfer activities will be determined on a case-by-case basis. Factors such as a facility's past operational history and geographic location are considered. In addition, the history and knowledge of activities at adjacent properties are evaluated. As discussed in Sect. 6.2 of the EBS, historic and more recent document reviews of the K-1007 property and adjacent areas indicate that there were vehicle maintenance and support operations that took place from 1944 through 1957 within the present footprint and in the vicinity of K-1007.

Information was gathered on these facilities from previously published reports, including site historical investigations and the K-25 Site Access and K-25 Site Decontamination and Decommissioning Facility databases, and compiled into the report entitled *Site Descriptions of Environmental Restoration Units at the Oak Ridge K-25 Site* (Energy Systems 1995). These former facilities included the K-1050 Wash, Grease, and Paint Shop; K-1047 Motor Pool Repair Shop; K-1048 Tire and Battery Shop; K-1049 Repair Shop and Parts Storage; K-1055 Gasoline/Diesel Station; and K-1007 Gas Tank.

The location of only one of the former facilities listed above, the K-1049 Repair Shop and Parts Storage, lies directly within the K-1007 footprint. This facility is not listed in *Site Descriptions of Environmental Restoration Units at the Oak Ridge K-25 Site* (Energy Systems 1995) as an environmental restoration unit in the Environmental Restoration Program, or in Appendix C of the Federal Facility Agreement as an area of concern. After K-1049 was demolished in the late 1950s, the area was graded and maintained as a grassy field until K-1007 was constructed in 1960. For these reasons DOE does not propose any sampling of the underlying fee to support title transfer.

Information on the hydrogeologic environment (including contaminant plume information) was provided in Sect. 4.3 of the EBS to present the potential for vapor intrusion in this area. Subslab soil vapor sampling will be conducted within K-1007 to determine if vapor intrusion is a complete pathway. The results of this sampling will be evaluated and will be made available to the public by posting them on a website, and an announcement will be made regarding their availability. Therefore, the exposure pathway for inhalation of VOCs via groundwater/soil vapor has not been evaluated in this risk assessment.

4. DATA DISCUSSION

The risk calculations for Bldg. K-1007 were based on the most recent radiological survey data as presented in the *Environmental Baseline Survey for the Title Transfer of the K-1007 Building at the East Tennessee Technology Park, Oak Ridge, Tennessee* (BJC 2004). The facility was divided into interior survey units (ISUs), furnishings survey units, and exterior survey units (ESUs). For the risk assessment, it was assumed that the furnishings would remain in place. Therefore, each ISU was assumed to include any current furnishings. Within each survey unit, samples were taken to identify both removable contamination (smear activity data) and fixed contamination (total activity data). The risk assessment was based on data that were aggregated by sampling method (smear or total) and by survey unit. Table 4.1 provides a description of each of the 17 ISUs, and Fig. 4.1 shows the survey units on a building map.

Data for each aggregate were summarized and statistical indicators were computed. The exposure concentration used in the risk calculation was either the computed 95% upper confidence level (UCL95) of the mean or the maximum detection, whichever was smaller. Only detected values were considered in the calculation of the exposure concentration. In the case of ISUs where qualifiers were not available, it was assumed that values of zero, or negative values, were non-detects and all other values were detects.

In addition to the removable and fixed contamination sampling, measurements were made to determine external dose rates for the building interior. The dose rate data were used to estimate the dose to a hypothetical exposed individual.

Table 4.1. Interior survey unit descriptions

ISU Number	Description
ISU 1	1st floor, northeast corner
ISU 2	1st floor, east section
ISU 3	1st floor, southeast corner
ISU 4	1st floor, south rooms
ISU 5	1st floor, north rooms
ISU 6	1st floor, central (Payroll area)
ISU 7	1st floor, west-central
ISU 8	1st floor, southwest corner
ISU 9	1st floor, northwest corner
ISU 10	Covered walkway to K-1007-A canteen trailer
ISU 11	K-1007-A canteen trailer
ISU 12	2nd floor, northeast corner
ISU 13	2nd floor, east-central
ISU 14	2nd floor, west-central
ISU 15	2nd floor, southwest corner
ISU 16	2nd floor, north of west-central
ISU 17	2nd floor, northwest corner

ISU = interior survey area.

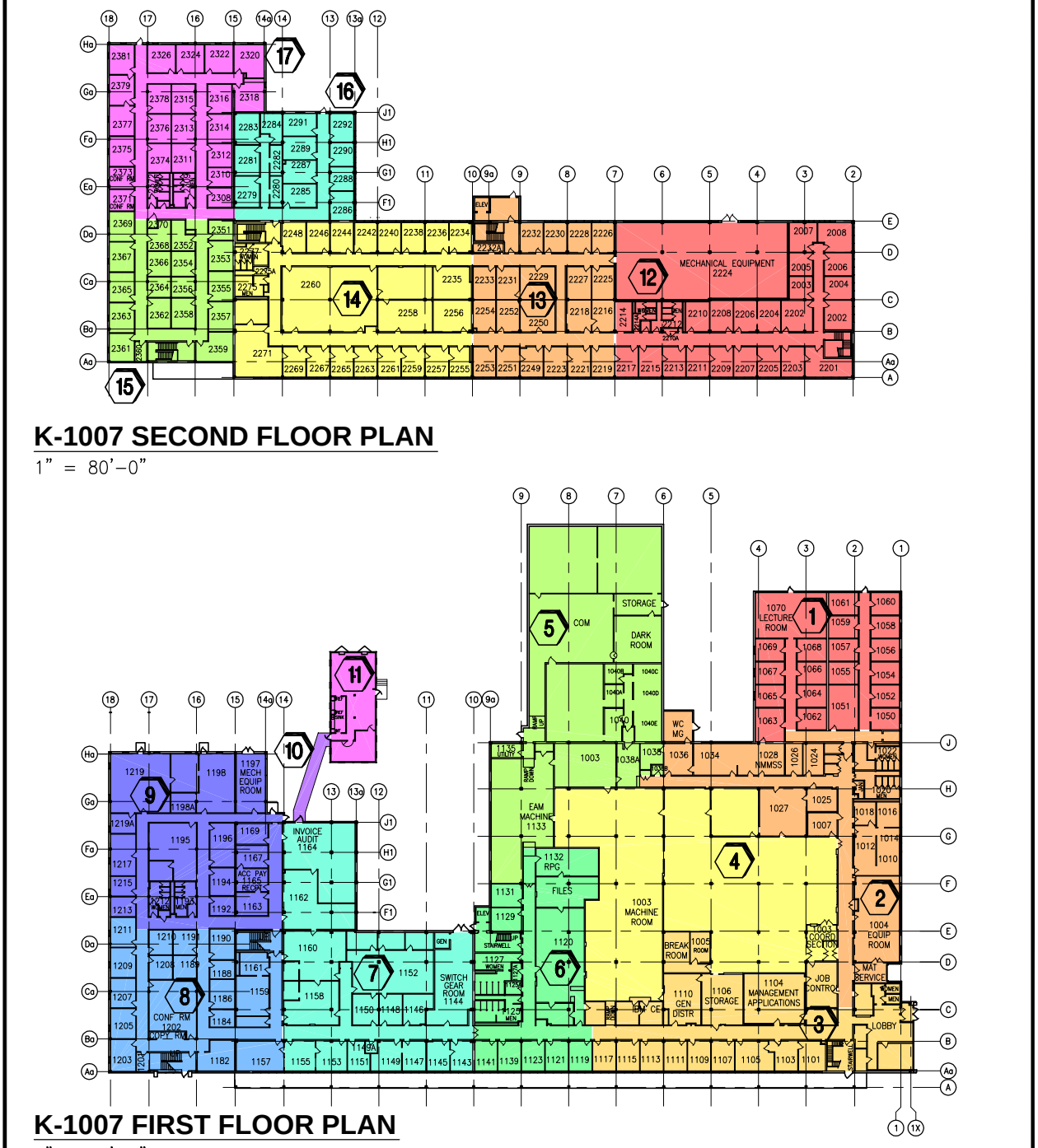

Fig. 4.1. K-1007 interior survey units.

For this risk screen, it was necessary to convert the general survey measurements of beta/gamma activity [in units of disintegrations per minute per 100 square centimeters (dpm/100 cm^2)] into isotopic concentrations [in units of picocuries per gram (pCi/g)]. Conversion of the overall beta/gamma measurements taken from the interior of the building to isotopic concentrations for use in risk assessment requires application of beta/isotope ratios. The most applicable investigation of beta/isotope ratios available is an evaluation of Bldg. K-1401, which included a comparison of isotope-specific measurements with gross beta measurements from the building interior (Rucker, 1998). Ratios of isotopic activity to gross beta activity were established for use in dose and risk assessment for 11 isotopes, including several thorium isotopes of interest to the risk assessment. The Bldg. K-1401 study was conducted specifically to generate beta/isotope ratios and considered a comprehensive list of isotopes. Additionally, the K-1401 building was used for a range of activities and processes that generally represent those activities and processes that took place at ETTP as a whole. Therefore, the risk assessment for Bldg. K-1007 assumes that the large room average results of the K-1401 investigation, presented in Table 4.2, are considered representative of the isotopic activity to beta activity ratios found in the interior of Bldg. K-1007. The resulting isotopic concentrations in dpm/100cm^2 were converted into units of pCi/g assuming a material density of 1.5 grams/cubic centimeter, a material depth of 0.1 cm, and a conversion factor of 2.22 pCi/dpm.

Table 4.2. Isotopic activity ratios

Isotope	Ratio to[a] total beta activity
Am-241	5.70E-04
Np-237+D	2.20E-03
Pu-238	2.10E-04
Pu-239	1.70E-03
Tc-99	6.60E-01
Th-228+D	2.00E-03
Th-230	6.20E-03
Th-232	1.90E-03
U-234	2.70E-01
U-235+D	2.60E-02
U-238+D	1.60E-01

[a]Values reported in Rucker 1998.

Survey results show that all total activities were less than 45.3 dpm/100 cm^2 total alpha and 2498 dpm/100 cm^2 total beta-gamma, with all removable contamination results less than 10.8 dpm/100 cm^2 removable alpha and 53.5 dpm/100 cm^2 removable beta-gamma. These results are below the DOE surface contamination limits.

5. EXPOSURE ASSESSMENT

An exposure assessment combines information about site characteristics and site-related data with exposure assumptions in order to quantify the intake of contaminants by a hypothetically exposed individual. The estimated exposure is based on:

- characterizing the exposure scenario based on site surveys and anticipated future building use,
- identifying complete exposure pathways based on assumed receptor activities and site-specific information, and
- quantifying receptor exposure based on exposure assumptions and chemical-specific data.

The steps in the exposure assessment are discussed in detail in the following sections.

5.1 EXPOSURE SCENARIO EVALUATION

5.1.1 Industrial Worker Scenario

Exposure scenarios are selected based on site surveys and anticipated uses of Bldg. K-1007. The ETTP area is being transferred mainly for industrial uses ranging from light to heavy industrial applications. Because the K-1007 building has mainly been used in the past for office space, it is unlikely that heavy industrial activities would be compatible with the building infrastructure. Therefore, the anticipated building use scenario is for light industrial activity represented by an industrial worker exposure scenario in this evaluation. Exposures to the building worker while spending time outside the building were included in the roving worker exposure scenario (see Sect. 5.1.2).

The exposure scenario for this evaluation of the building interior is based on an industrial worker who may be present performing basic industrial activities during the workday. The industrial worker exposure scenario assumes the following:

- the industrial worker is employed at Bldg. K-1007 for a 25-year period,
- the worker is on-site for 250 d/year, and
- the worker spends an 8-h workday working in the interior of Bldg. K-1007.

An industrial worker is assumed to spend 8 h every workday in a single ISU. Although it is unlikely a worker would be limited to such a small area of the building, this assumption is intended to overestimate potential exposures and provide a conservative estimate of the associated risks.

There is the possibility that an industrial worker would circulate throughout Bldg. K-1007 either in a supervisory or maintenance role. In that case, an average of the exposures for the individual survey units would be more representative of the potential risks or doses for the building as a whole. A risk estimate based on the average exposure throughout the building interior and representing a roaming receptor is presented in the summary tables for comparison to the risk estimate for a non-roaming receptor.

5.1.2 Roving Worker Scenario

In addition to the 8-h working day spent in the interior of the K-1007 building, it is assumed that the worker spends an additional amount of time outdoors at the plant site. To address the potential for exposure outside of a

title transfer area, it was assumed that an industrial worker might spend 2 h each day accessing adjacent areas of ETTP (including locations in both Zones 1 and 2) [see Fig. 5.1]. A roving worker might spend this time by walking throughout areas in the vicinity of ETTP and being exposed to contaminated media. Identification of the specific areas accessed by the "rover" was based on an evaluation of ETTP exposure units (EUs). EUs that could reasonably be accessed were selected based on the location of existing fencing and access controls.

Areas were eliminated if they were within security fencing (to which the rover cannot gain access) or were located at a distance that could not be reasonably accessed on a frequent basis. For example, data from sampling points within a fenced area southeast of Blair Road (in EU Z2-28) were eliminated from the evaluation because the area is inaccessible. The relevance of specific datasets was also a criterion in the selection of EUs for the evaluation. As an example, EU Z2-27, in the Mitchell Branch area, was represented only by sediment sample data and was eliminated since exposure to sediment was considered unlikely. Figure 5.1 presents all of the EUs designated in Zones 1 and 2 at ETTP and highlights the EUs selected for this roving worker evaluation.

The boundaries for Zone 1 EUs were created for the Zone 1 Record of Decision (ROD; DOE 2002a) correspond with EUs delineated for the remedial investigation. It is assumed that the roving worker spends an equal amount of time in each of the areas considered accessible and may be exposed to surface soil during each period of roving. Therefore, the aggregate of soil data with starting depths no deeper than 2 ft from all accessible areas outside the main plant fence was considered a representative dataset for the roving worker exposure scenario evaluation. The boundaries for the Zone 2 EUs were created for the Zone 2 feasibility study (BJC in progress).

The roving building worker scenario applies to a worker who works at ETTP for a 25-year period. The risk calculations for the roving worker assumed that ETTP will be remediated to levels protective of human health by the year 2008 in accordance with the Oak Ridge Performance Management Plan (DOE 2002b). The roving worker would, therefore, be exposed to contaminated soil for a 5-year period (i.e., 2003 to 2008) and to acceptably clean soil (as designated by the Record of Decision) for the remaining 20-year working lifetime. The rover is assumed to spend a 2-h period each day roaming the accessible areas of ETTP, for 250 d each year for 5 years.

5.2 EXPOSURE PATHWAY IDENTIFICATION

Evaluating the exposure pathways requires describing the mechanism by which an individual may become exposed to contaminants associated with Bldg. K-1007. A complete exposure pathway requires the following:

- a source of contamination,
- a pathway of migration from the source of contamination to the exposure point,
- a receptor present at the exposure point, and
- an exposure mechanism at the exposure point.

If any one component of a complete exposure pathway is missing, then the pathway is considered incomplete. Only complete exposure pathways were quantified in the risk screen.

Complete exposure pathways associated with Bldg. K-1007 include ingestion, inhalation, and external exposure to ionizing radiation. The ingestion pathway is complete because contaminated surfaces may be present, a receptor is present in the building, and a receptor may contact and ingest contaminants from the building surfaces. The inhalation pathway is complete because contaminated surfaces may be present, contaminants may become airborne during normal industrial activities, a receptor is present in the building, and a worker may inhale contaminants in the air. External exposure to ionizing radiation is a complete exposure

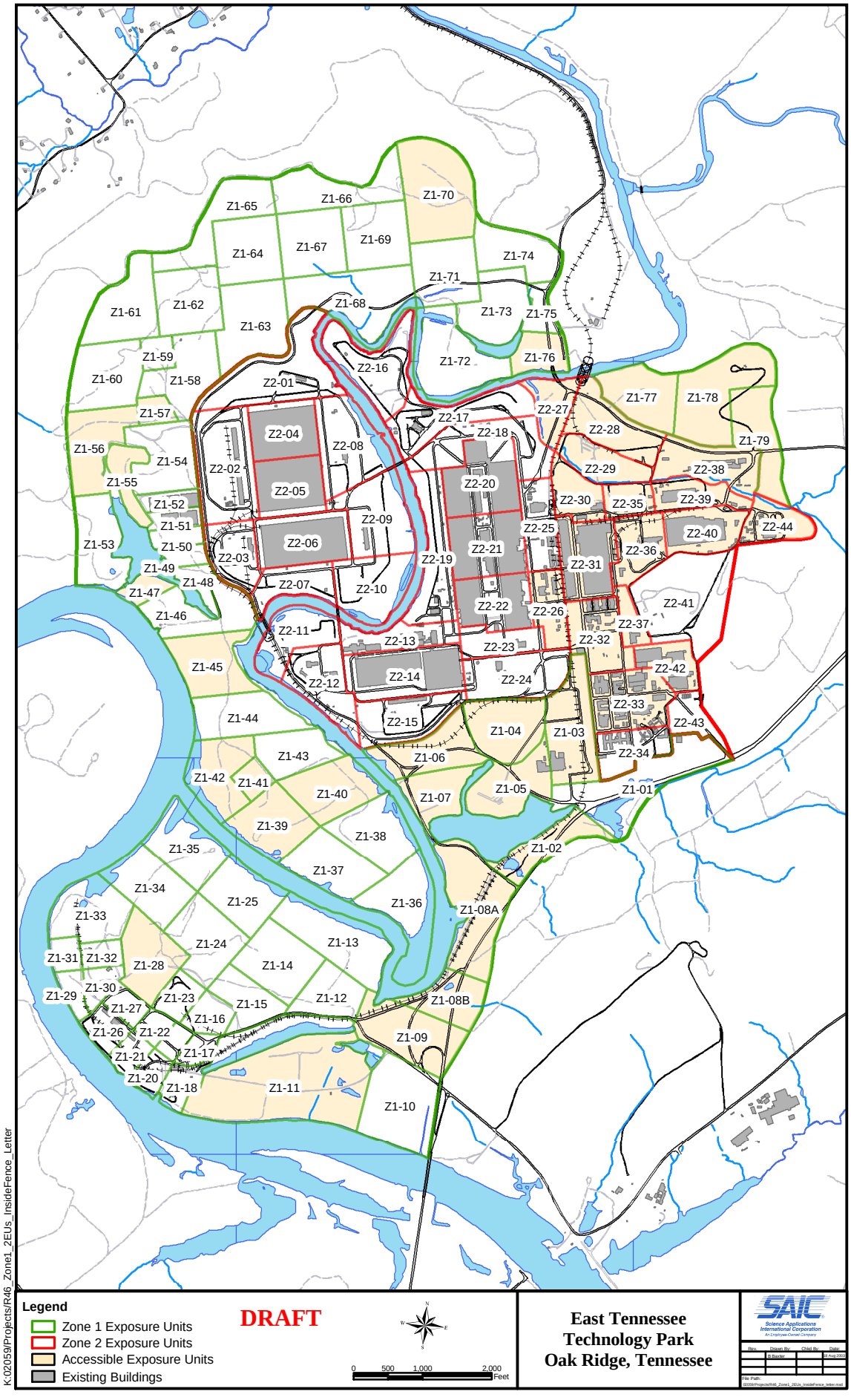

Fig. 5.1. Zone 1 and 2 Exposure Units accessible to the roving worker inside the main plant fence.

pathway because radionuclides may be present on the building surfaces, ionizing radiation may be emitted, and a receptor is present to absorb the radiation. Potential exposure pathways for the roving worker include inhalation of suspended dust and volatile organics, ingestion of soil, dermal contact with soil, and external exposure to ionizing radiation from soil. The following section describes how each of these exposure pathways was quantified in the risk screen.

5.3 QUANTIFICATION OF EXPOSURE

Quantifying the exposure to the receptor requires:

- identification of the exposure concentration at the receptor exposure point,
- estimation of exposure parameters appropriate to the exposed individual, and
- calculation of the receptor exposure.

The purpose of the quantification of exposures is to provide a conservative estimate of exposures related to the exposure scenarios evaluated. At each step in the quantification process, assumptions are made in a conservative manner in an attempt to overestimate the risks/hazards and provide an upper bound estimate of risk that is protective of future workers in the building.

5.3.1 Industrial Worker

The ingestion and inhalation pathways for the building interior were quantified using the sampling data for removable contamination, as well as fixed contamination. For the industrial worker exposure scenario, it was assumed that 100% of the removable contamination is available for ingestion each workday, and 100% of the removable contamination is available for inhalation each workday. In this scenario, there is no depletion of the source material over the working lifetime of the industrial worker. This very conservative assumption that is evaluated because the anticipated industrial worker could contact the interior wall and ceiling surface over the course of normal activities.

The industrial worker scenario does not consider any renovation work; therefore, it is unlikely that any fixed contamination would be disturbed and be removed in any significant quantities. However, to provide greater conservatism in the risk screen for Bldg. K-1007, it was also assumed that some portion of the fixed contamination in each survey unit could be mobilized and become available for ingestion and inhalation.

An estimate of the amount of fixed contamination that could become removable was based on an evaluation of the ISU data. The percent of removable contamination to fixed contamination, based on the calculated exposure concentrations for smear and total data, respectively, ranged from ~ 5% for ISU 17 to ~ 20% for ISU 2 and averaged ~ 10% for all 17 units. Therefore, for conservatism, the risk associated with ingestion and inhalation is assumed to be 10% of the fixed contamination and was also included in the evaluation of survey units that showed detectable levels of removable contamination. The Nuclear Regulatory Commission (NRC) Decontamination and Demolition Code recommends the use of 10% removable unless data specify a higher number. In addition, the use of 10% has been negotiated with the Tennessee Department of Conservation and Environment and EPA. All of the 17 ISUs had detectable removable contamination with the exception of ISU 10. As a result, 16 ISUs were evaluated assuming 100% of removable contamination and 10% of fixed contamination were available for industrial worker exposure.

External dose measurements (mrem/h) were used to quantify potential external exposure. The measurements were generally collected at areas of highest readings in the building interior. The UCL95 of the mean of the dose rate data was calculated to be ~0.006 mrem/h, which is below the background level of 0.007 mrem/h. Therefore, the risks due to external exposure in the interior of the building were not quantified.

Quantifying the exposure requires an estimate of the exposure parameters for the exposed individual. The industrial worker exposure scenario assumes the following:

- the industrial worker is employed at Bldg. K-1007 for a 25-year period (EPA 1989 default),
- the worker is on-site for 250 d/year (EPA 1989 default),
- the worker spends 8 h/d in the interior of Bldg. K-1007 (site-specific assumption),
- the worker ingests 50 mg of contaminated material each day (EPA 1989 default), and
- the worker inhales 20 m^3 of air each day (EPA 1989 default).

Two scenarios were evaluated:

1. The industrial worker is assumed to spend every workday, for the entire workday, in a single ISU. Although it is unlikely a worker would be limited to such a small area of the building, this assumption is intended to overestimate potential exposures and provide a conservative estimate of the associated risks.

2. The industrial worker is assumed to spend every workday spending equal amounts of time in all ISUs, and, thus, the exposure is an average of exposure in all the ISUs

5.3.2 Roving Worker

Quantifying the exposure requires an estimate of the exposure parameters for the exposed individual. The roving worker exposure scenario assumes the following:

- the 2003 roving industrial worker may access contaminated soil for 5 years, until 2008, when remediation will be completed at ETTP;

- the roving worker is on-site for 250 d/year;

- the roving worker spends 2 h each day wandering ETTP among all accessible EUs;

- the roving worker ingests 50 mg of contaminated soil during each 2-h period of wandering; and

- the roving worker inhales 20 m^3 of air during each 2-h period of wandering.

The assumptions of 50 mg of soil ingested and 20 m^3 of air inhaled are generally used when considering exposure for an entire day. However, based on direction from EPA Region 4, these assumptions will not be reduced even though the exposure is only for 2 h each day. Using these parameters for a 2-h period will overestimate the actual risks to a roving worker and provide an upper bound estimate of the associated risks. (For more detail, see Appendix A.)

The quantification of receptor exposure forms the basis of the risk calculation. Prior to quantification, the data are screened, resulting in identification of contaminant of potential concern (COPCs). A list of COPCs is provided in Table A.3. In the risk calculation step, the receptor exposure is compared to benchmark values to determine the probability of adverse health effects. The resulting risk calculations are presented in Chap. 6.

6. RISK RESULTS

6.1 INDUSTRIAL WORKER

Building K-1007 risks were calculated for the industrial worker scenario assuming exposure by the inhalation, ingestion, and external exposure pathways. Table 6.1 presents the risks and doses from exposure to ISUs in Bldg. K-1007. The table shows that a number of areas had risks of ~ 1×10^{-7}, including ISUs 7 and 17. The conservative assumption that 10% of the fixed contamination becomes removable resulted in the majority of the risk, accounting for twice the risk of the removable contamination.

The risk estimate is a value that represents the excess cancer incidence that might be expected due to the exposure scenario evaluated. The EPA has established a target risk range of 10^{-4} to 10^{-6}. The estimated risk of 1×10^{-7} for Bldg. K-1007 is an order of magnitude below the EPA target range, indicating a low likelihood of adverse health effects due to the exposure scenarios considered.

The Bldg. K-1007 calculated doses indicated a maximum of ~ 0.007 mrem/year due to ingestion and inhalation of removable and fixed contamination. The calculated average dose for Bldg. K-1007 was ~ 0.004 mrem/year. For comparison the average dose due to ambient sources (medical X-rays, cosmic rays, natural materials, etc.) is approximately 360 mrem/year (National Council on Radiation Protection and Measurements 1987). The dose from the measured background dose rate for ETTP of 0.007 mrem/h is equivalent to ~ 60 mrem/year assuming 24 h/d and 365 d/year exposure. The calculated doses are significantly below both measures of background dose for Bldg. K-1007.

The risks associated with an industrial worker at Bldg. K-1007 can be summarized as follows:

- the maximum risk associated with an individual survey unit was ~ 1×10^{-7} for ISU 17 (see bolded text in Table 6.1), located on the second floor in the northwest corner;
- the maximum calculated dose was ~ 0.007 mrem/year for ISU 17, located on the second floor in the northwest corner (see bolded text in Table 6.1);
- the UCL95 of the mean of the dose rate data was calculated to be ~ 0.006 mrem/h, which is below the site background level of 0.007 mrem/h;
- the average risk associated with the interior of Bldg. K-1007 was ~ 5×10^{-8}, assuming a receptor is equally exposed to all interior survey areas; and
- the average calculated dose associated with the interior of Bldg. K-1007 was ~ 0.004 mrem/year for the interior of the building as a whole.

6.2 ROVING WORKER

The roving worker risk assessment considered quantitatively 39 surface soil COPCs (10 metals, 18 organics, and 11 radionuclides) for the accessible areas of ETTP. The risk to the roving worker was 8×10^{-6}, which is within the EPA acceptable range of 10^{-4} to 10^{-6}. The risk was mainly due to external exposure to

Table 6.1. Carcinogenic risk and radiological dose estimates for K-1007 interior and furnishings[a]

Carcinogenic risk (risk/lifetime)	Removable activity			10% of total activity			
Interior survey unit	Ingestion risk	Inhalation risk	Total	Ingestion risk	Inhalation risk	Total	Overall total
ISU1	1.91E-08	8.72E-11	1.92E-08	2.41E-08	1.10E-10	2.42E-08	4.34E-08
ISU2	4.08E-08	1.86E-10	4.10E-08	1.99E-08	9.06E-11	2.00E-08	6.09E-08
ISU3	1.92E-08	8.76E-11	1.93E-08	3.51E-08	1.60E-10	3.52E-08	5.45E-08
ISU4	2.63E-08	1.20E-10	2.64E-08	1.40E-08	6.39E-11	1.41E-08	4.05E-08
ISU5	1.62E-08	7.37E-11	1.62E-08	7.94E-09	3.62E-11	7.98E-09	2.42E-08
ISU6	2.72E-08	1.24E-10	2.73E-08	2.43E-08	1.11E-10	2.45E-08	5.18E-08
ISU7	4.14E-08	1.89E-10	4.16E-08	6.09E-08	2.78E-10	6.12E-08	1.03E-07
ISU8	2.53E-08	1.15E-10	2.54E-08	3.12E-08	1.42E-10	3.13E-08	5.68E-08
ISU9	2.98E-08	1.36E-10	2.99E-08	0.00E+00	0.00E+00	0.00E+00	2.99E-08
ISU11	1.96E-08	8.92E-11	1.97E-08	3.30E-08	1.51E-10	3.32E-08	5.29E-08
ISU12	3.52E-08	1.61E-10	3.54E-08	2.77E-08	1.26E-10	2.78E-08	6.32E-08
ISU13	3.40E-08	1.55E-10	3.41E-08	2.03E-08	9.26E-11	2.04E-08	5.45E-08
ISU14	2.40E-08	1.10E-10	2.42E-08	2.38E-08	1.09E-10	2.39E-08	4.81E-08
ISU15	2.72E-08	1.24E-10	2.73E-08	2.11E-08	9.61E-11	2.12E-08	4.85E-08
ISU16	3.32E-08	1.51E-10	3.34E-08	2.52E-08	1.15E-10	2.53E-08	5.87E-08
ISU17	3.54E-08	1.61E-10	3.55E-08	7.15E-08	3.26E-10	7.18E-08	**1.07E-07**
Average[b]	2.84E-08	1.29E-10	2.85E-08	2.75E-08	1.25E-10	2.76E-08	5.61E-08
Radiological dose (mrem/year)	**Removable activity**			**10% of total activity**			
Interior survey unit	**Ingestion dose**	**Inhalation dose**	**Total dose**	**Ingestion dose**	**Inhalation dose**	**Total dose**	Overall total
ISU1	1.32E-03	6.48E-06	1.33E-03	1.66E-03	8.15E-06	1.67E-03	3.00E-03
ISU2	2.82E-03	1.38E-05	2.83E-03	1.37E-03	6.73E-06	1.38E-03	4.21E-03
ISU3	1.33E-03	6.51E-06	1.34E-03	2.42E-03	1.19E-05	2.44E-03	3.77E-03
ISU4	1.82E-03	8.89E-06	1.82E-03	9.70E-04	4.75E-06	9.75E-04	2.80E-03
ISU5	1.12E-03	5.47E-06	1.12E-03	5.49E-04	2.69E-06	5.52E-04	1.67E-03
ISU6	1.88E-03	9.21E-06	1.89E-03	1.68E-03	8.24E-06	1.69E-03	3.58E-03
ISU7	2.86E-03	1.40E-05	2.87E-03	4.21E-03	2.06E-05	4.23E-03	7.11E-03
ISU8	1.75E-03	8.57E-06	1.76E-03	2.16E-03	1.06E-05	2.17E-03	3.93E-03
ISU9	2.06E-03	1.01E-05	2.07E-03	0.00E+00	0.00E+00	0.00E+00	2.07E-03
ISU11	1.35E-03	6.63E-06	1.36E-03	2.28E-03	1.12E-05	2.30E-03	3.66E-03
ISU12	2.44E-03	1.19E-05	2.45E-03	1.92E-03	9.38E-06	1.92E-03	4.37E-03
ISU13	2.35E-03	1.15E-05	2.36E-03	1.40E-03	6.88E-06	1.41E-03	3.77E-03
ISU14	1.66E-03	8.14E-06	1.67E-03	1.65E-03	8.07E-06	1.66E-03	3.33E-03
ISU15	1.88E-03	9.20E-06	1.89E-03	1.46E-03	7.14E-06	1.47E-03	3.35E-03
ISU16	2.30E-03	1.12E-05	2.31E-03	1.74E-03	8.53E-06	1.75E-03	4.06E-03
ISU17	2.45E-03	1.20E-05	2.46E-03	4.94E-03	2.42E-05	4.97E-03	**7.42E-03**
Average[b]	1.96E-03	9.60E-06	1.97E-03	1.90E-03	9.31E-06	1.91E-03	3.88E-03

[a]Uses exposure concentration = lesser of max and 95% upper control level (UCL-95) of the mean (UCL-95 may be larger than max if data are limited).
[b]Assumes receptor is equally exposed to each interior survey unit throughout the workday.
[c]Bold indicates maximum risk/dose

ionizing radiation, as well as both ingestion and dermal contact with PAHs. The calculated hazard for the roving worker was 0.2, which is below the EPA acceptable level of 1.0. For additional information, see Appendix A.

6.3 RISK SUMMARY

The risk evaluation for Bldg. K-1007 indicates that all risks and doses are considered within acceptable levels of EPA's target risk range (See Table 6.2) and below a hazard index of 1.0, which correlate with a low likelihood of adverse health effects to an industrial worker. Therefore, the facility is considered acceptable for transfer for its intended use as an office building by the private sector.

Table 6.2. Summary of risks/hazards for K-1007

Receptor	Hazard	Risk
Industrial worker		
Maximum ISU	N/A	1E-7
Average for all ISUs	N/A	6E-8
Roving worker	0.2	7.9E-6
Total	**0.2**	**8E-6**

ISU = interior survey unit.
N/A = Not applicable.

7. EVALUATION OF UNCERTAINTIES

The estimation of uncertainty, whether quantitative or qualitative, is fundamental to scientific activities that involve measured or assessed quantities. Estimates of risk are conditional based on a number of assumptions concerning exposure. Generation of a point estimate of risk, as has been done in this screening-level assessment, has the potential to yield under- or overestimates of the actual value and can lead to improper decisions. Therefore, it is necessary to specify the assumptions and uncertainties inherent in the screening-level evaluation process to place the risk estimates in perspective and ensure that anyone making risk management decisions is well informed.

Uncertainty about environmental risk estimates is known to be at least an order of magnitude or greater (EPA 1989). The evaluation of uncertainties for the assessment is qualitative since the resource requirements necessary to provide a quantitative statistical uncertainty analysis for this study area would generally outweigh the benefits. The focus of the discussion in this section will be on the important variables and assumptions that contribute most to the overall uncertainty.

7.1 UNCERTAINTY IN THE SOURCE TERM

Several uncertainties are associated with the data set and the data evaluation process. These uncertainties include the selection of COPCs and the determination of the exposure point concentration.

Although the data evaluation process used to select COPCs adheres to established procedures and guidance, it also requires making decisions and developing assumptions on the basis of historical information, process knowledge, and best professional judgment about the data. Uncertainties are associated with all such assumptions. The background concentrations and PRGs used to screen analytes are also subject to uncertainty. The toxicity values used in the derivation of PRGs are subject to change, as additional information (from scientific research) becomes available; these periodic changes in toxicity values may cause the PRG values to change as well, causing increased uncertainty in the data screening process.

Representative concentrations and other statistics are calculated in this risk assessment based on the assumption that the samples collected are truly random samples. Some of the data may not have been taken randomly, but rather may have come from biased sampling, aimed at identifying high contaminant concentration locations. In addition, the soil data used for the rover scenario come from multiple sampling events conducted in multiple years and are not necessarily representative of current conditions. Concentrations of constituents may be lower and, hence, the risks/hazards may be lower than what is reported here.

This evaluation has been performed using only the COPCs with available toxicity data. It should be noted that the qualitative COPCs determined for this study area could potentially increase the risks/hazards to a receptor.

As noted in Chap. 3 of this report, the potential contribution of vapor intrusion has not been evaluated. If vapor intrusion is a complete pathway, and concentrations are high enough, risks/hazards reported here may be underestimated.

7.2 UNCERTAINTY IN THE EXPOSURE ASSESSMENT

For each exposure pathway, assumptions are made concerning the parameters, the routes of exposure, the amount of contaminated media an individual can be exposed to, and intake rates for different routes of

exposure. In the absence of site-specific data, the assumptions used in this assessment are consistent with EPA-approved parameters and default values. When several of these upper-bound values are combined in estimating exposure for any one pathway, the resulting risks can be in excess of the 99th percentile and, therefore, outside the range that may be reasonably expected. It has been assumed that the worker ingests 50 mg of dust inside the building and an additional 50 mg of soil outdoors while roving. The total ingestion of 100 mg is very conservative and may produce an overestimation of the risks/hazards.

The assumptions of 50 mg of soil ingested and 20 m^3 of air inhaled are generally used when considering exposure for an entire day. However, based on direction from EPA Region 4, these assumptions will not be reduced even though the exposure is only for 2 h each day. Using these parameters for a 2-h period will overestimate the actual risks to a roving worker and provide an upper-bound estimate of the associated risks

The guidance values for intake rates and exposure parameters are assumed to be representative of the hypothetical populations evaluated. All contaminant exposures and intakes are assumed to be from the site-related exposure media (i.e., no other sources contribute to the receptor's risk). Even if these assumptions are true, other areas of uncertainty may apply. Selected intake rates and population characteristics (i.e., weight, life span, and activities) are assumed to be representative of the exposed population. The consistent conservatism used in the estimation of these parameters generally leads to overestimation of the potential risk to the postulated receptors.

7.3 UNCERTAINTY IN TOXICITY VALUES AND RISK PREDICTIONS

Uncertainty in the values used to represent the dose-response relationship will highly impact the risk estimates. These uncertainties are contaminant-specific and are embedded in the toxicity value. The factors that are incorporated to represent sources of uncertainty include the source of the data, duration of the study, extrapolations from short- to long-term exposures, intrahuman or interspecies variability, and other special considerations. In addition, toxicity varies with the chemical form.

Uncertainties related to the summation of carcinogenic risk and non-carcinogenic hazard estimates across contaminants and pathways are a primary uncertainty in the risk characterization process. In the absence of information on the toxicity of specific chemical mixtures, additive (cumulative) risks are assumed (EPA 1989).

Limitations of the additive risk approach for exposure to multiple chemicals include:

1. the slope factors may represent the mean but often represent the upper 95th percentile estimate of potency (the central estimate of the mean for radionuclides), so the summation can result in an excessively conservative estimate of lifetime risk;

2. the reference doses do not have equal accuracy or precision and are not based on the same severity of effects; and

3. the effects of a mixture of carcinogens are unknown, and possible interactions could be synergistic or antagonistic.

Despite these limitations and the general unavailability of data on these interactions, summations were performed for the carcinogenic risks and chemical hazards presented in risk assessment. This approach is consistent with RAGS (EPA 1989).

8. REFERENCES

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APPENDIX A

ROVING WORKER SCENARIO FOR TITLE TRANSFER FACILITIES LOCATED OUTSIDE THE MAIN PLANT AREA AT THE EAST TENNESSEE TECHNOLOGY PARK

CONTENTS

FIGURE

TABLES

A.1. INTRODUCTION

In order to address potential risks from areas that are not in the immediate vicinity of the facility, but could reasonably be accessible to the occupant, a roving worker (or "rover"), who may move within East Tennessee Technology Park (ETTP) areas that do not have access restrictions (i.e., portals or gates) for a general worker has been evaluated.

The areas accessible to the "rover" are based on the location of the title transfer area. The overall risk for a building worker will be calculated by adding the risks from the building to the risk calculated for areas accessible to the "rover" where applicable. The roving worker scenario for areas accessible outside the main plant area is described in detail in the following sections. (This scenario is also referred to as the "outside rover.")

A.2. EXPOSURE SCENARIO EVALUATION

It was assumed that a building worker might spend 2 h each day accessing areas of ETTP that are near his/her place of business. A roving worker might spend this time by walking throughout unfenced areas in the vicinity of ETTP and being exposed to contaminated media. Identification of the specific areas accessed by the "rover" was based on an evaluation of ETTP exposure units (EUs), which were previously delineated for risk assessment purposes. EUs that could reasonably be accessed by a general plant worker were selected based on the location of existing security fencing and access controls.

Areas were eliminated if they were within security fencing or were located at a distance that could not be reasonably accessed on a frequent basis. For example, data from sampling points within a security fence southeast of Blair Road (in EU Z2-28) were eliminated from the evaluation because they are inaccessible to a general worker. The relevance of specific datasets was also a criterion in the selection of EUs for the evaluation. As an example, EU Z2-27, in the Mitchell Branch area, was represented only by sediment sample data and was eliminated since exposure to sediment was considered unlikely. Figure A.1 presents all of the EUs designated in Zones 1 and 2 at ETTP and highlights the EUs selected for this roving worker evaluation.

Remediation at ETTP is scheduled to be completed by the year 2008. It was, therefore, assumed that exposure to exterior soils would be of a limited duration of 5 years (2003 through 2008). It was also assumed that a roving worker would be exposed to soils for 2 h on each of the 250 workdays each year. It is unlikely that an individual would spend such an extensive amount of time outdoors in a single area. Therefore, it was assumed that a roving worker might spend equal amounts of time traveling among all of the accessible EUs. This scenario would represent a worker who exercises and/or eats lunch at different locations at the site. Although conservative, this approach is considered more realistic than the alternative of assuming that a "rover" spends all of his time in one location. For these reasons, the rover that is exposed to all EUs is the preferred scenario.

A.3. EXPOSURE PATHWAY IDENTIFICATION

Complete exposure pathways for the roving worker include ingestion, inhalation, dermal contact, and external exposure.

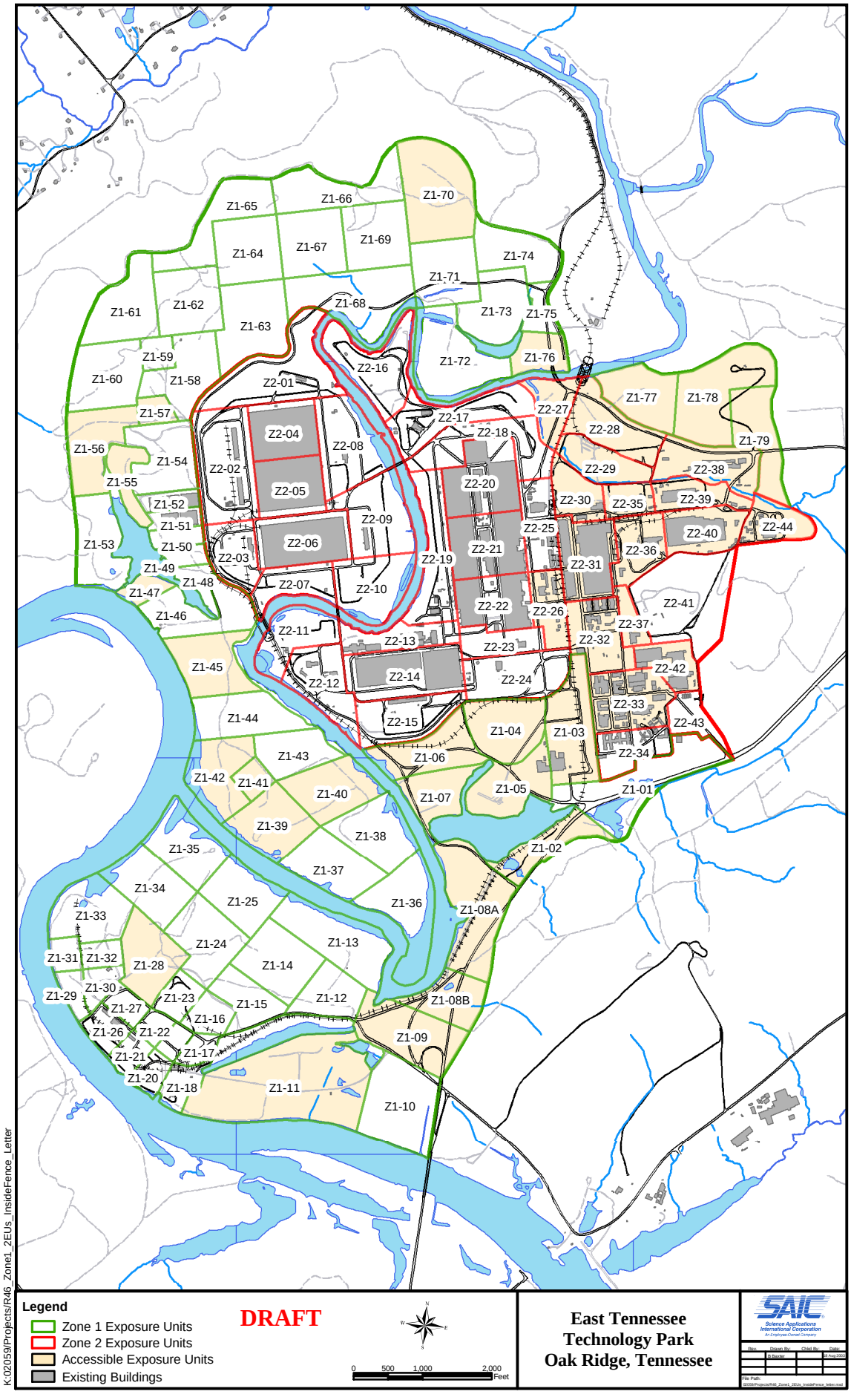

Fig. A.1. Zone 1 and 2 Exposure Units accessible to the roving worker inside the main plant fence.

The ingestion pathway is complete because:

- contaminated media are present in EUs,
- a worker could be present in EUs, and
- a worker could inadvertently ingest media while spending time in EUs.

The inhalation pathway is complete because:

- contaminated media are present in EUs,
- the media may become airborne due to volatilization or dust resuspension,
- a worker could be present in EUs, and
- a worker could inhale some contaminated media while spending time in EUs.

The dermal pathway is complete because:

- contaminated media are present in EUs,
- a worker could be present in EUs, and
- a worker could inadvertently come into contact with contaminated media while spending time in the area.

External exposure to ionizing radiation is a complete exposure pathway because:

- radionuclides may be present in EUs media,
- ionizing radiation could be emitted, and
- a worker could be present in EUs to absorb emitted radiation.

The quantification of each of these exposure pathways is described in the following sections.

A.4. QUANTIFICATION OF EXPOSURE

Quantifying the exposure to the receptor requires:

- statistical evaluation of the representative dataset (Table A.1);
- selection of contaminants of potential concern (COPCs), based on comparison to background concentrations and preliminary remediation goals (PRGs) [Table A.2];
- identification of the COPCs that have available toxicity data and can be quantitatively evaluated (Table A.3);
- estimation of the exposure parameters appropriate to the roving worker (Table A.4);
- selection of toxicity data appropriate for the receptor and exposure pathways (Table A.5); and
- calculation of the intake, risks, and hazards to the roving worker (Tables A.6 and A.7) based on the calculated exposure concentrations.

The ingestion, inhalation, dermal contact, and external exposure pathways were quantified using available soil and radiological survey data for the accessible EU areas.

The list of COPCs was identified, based on comparison to PRGs and background concentrations. [Note: Discussions regarding use of background data are ongoing. Background data will continue to be used until an agreement on a different approach is reached.] A COPC list was also generated for the aggregated data representing all accessible EUs. Exposure concentrations represent the expected concentration the roving worker will encounter in soil and are typically the 95% upper confidence limit of the mean (UCL95) detected concentration or the maximum detected concentration, whichever is smaller. Exposure concentrations, the basis for the quantification of risk, were calculated from the available data for each EU and for the aggregated data for all accessible EUs.

Quantifying the exposure requires an estimate of the exposure parameters for the exposed individual. The roving worker exposure scenario assumes the following:

- the 2003 roving industrial worker may access contaminated soil for 5 years, until 2008 when remediation will be completed at ETTP;
- the roving worker is on-site for 250 d/year;
- the roving worker spends 2 h each day wandering ETTP among all accessible EUs;
- the roving worker ingests 50 mg of contaminated soil during each 2-h period of wandering; and
- the roving worker inhales 20 m^3 of air during each 2-h period of wandering.

The assumptions of 50 mg of soil ingested and 20 m^3 of air inhaled are generally used when considering exposure for an entire day. However, based on direction from EPA Region 4. these assumptions will not be reduced even though the exposure is only for 2 h each day. Using these parameters for a 2-h period will overestimate the actual risks to a roving worker and provide an upper-bound estimate of the associated risks.

A.5. RISK EQUATIONS

The calculation of risks and hazards for ingestion, inhalation, dermal contact, and external exposure to radiation used the equations presented in this section to calculate the intake of contaminants.

Inhalation exposure is evaluated with the following:

$$Intake\ (mg/kg\text{-}d) = C \times IR_a \times (1/VF + 1/PEF) \times EF \times ED \ /(BW \times AT)$$

$$Intake\ (pCi) = C \times IR_a \times (1/VF + 1/PEF) \times ET \times EF \times ED \times Cf_i$$

where

C = Contaminant concentration (mg/kg or pCi/g),
IR_a = Inhalation rate (m^3/d),
PEF = Particulate emission factor (m^3/kg),
VF = Volatilization factor (m^3/kg),

EF = Exposure frequency (d/year),
ED = Exposure duration (years),
AT = Averaging time (d),
BW = Adult body weight (kg),
Cf_i = Conversion factor (g/kg).

Ingestion exposure is evaluated with the following equation:

$$Intake\ (mg/kg\text{-}d) = C \times IR \times EF \times ED / (BW \times AT)$$

$$Intake\ (pCi) = C \times IR \times EF \times ED \times Cf$$

where

C = Contaminant concentration (mg/kg or pCi/g),
IR = Ingestion rate (kg/d),
EF = Exposure frequency (d/year),
ED = Exposure duration (years),
AT = Averaging time (d),
BW = Adult body weight (kg),
Cf = Conversion factor (g/kg).

The dermal contact with soil pathway is evaluated for chemicals with the following equation:

$$Intake\ (mg/kg\text{-}d) = C \times SA \times CF \times AF \times ABS \times EF \times ED / (BW \times AT)$$

where

C = Contaminant concentration (mg/kg or pCi/g),
SA = Surface area (m^2/event),
CF = Conversion factor (kg-cm^2)/(mg-m^2),
AF = Adherence (mg/cm^2),
ABS = Absorption factor (unitless),
EF = Exposure frequency (event/year),
ED = Exposure duration (years),
AT = Averaging time (d),
BW = Adult body weight (kg).

External exposure to ionizing radiation from contaminated soil is evaluated with the following equation:

$$Time\ integrated\ activity\ concentration\ (pCi\text{-}year/g) = CS \times (1\text{-}S_e) \times EF \times ED \times Te$$

where

CS = Contaminant concentration (pCi/g),
S_e = Gamma shielding factor (unitless),
EF = Exposure frequency (d/d),
ED = Exposure duration (years),
Te = Exposure time factor (h/h).

The parameters used in the quantification of exposure are presented in Table A.4. The quantification of receptor exposure forms the basis of the risk calculations.

A.6. CALCULATION OF RISK/HAZARDS

In the risk calculation step, the receptor exposure is compared with benchmark values to determine the probability of adverse health effects.

For carcinogens, risk is calculated as follows:

$$Risk = Intake \times Slope\ Factor$$

where

Risk = carcinogenic risk for receptor (unitless),
Intake = receptor intake for carcinogenic constituents via pathway under consideration (mg/kg-d),

Slope factor = toxicity data specific to the constituent and pathway [risk/(mg/kg-d)].

For non-carcinogens, the hazard is calculated as follows:

$$Hazard = Intake/Reference\ Dose$$

where

Hazard = noncarcinogenic hazard for receptor (unitless),
Intake = receptor intake for non-carcinogenic constituents via pathway under consideration (mg/kg-d),
Reference dose = toxicity data specific to the constituent and pathway (mg/kg-d).

Table A.5 presents the toxicity data used in the calculation of risks/hazards. The risk/hazard results are discussed below.

A.7. RISK RESULTS

Roving worker risks were calculated assuming exposure by ingestion, inhalation, dermal contact, and external exposure to ionizing radiation. Tables A.6 and A.7 present the risks/hazards for a roving worker exposed while moving among all accessible EUs, which are outside the main plant fence at ETTP.

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP outside rover locations

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Metals (mg/kg)												
Aluminum	106/106			2.22E+04	1.66E+04	6.13E+02	5.96E+04	2.49E+04	X	2.49E+04	Yes	
Antimony	31/89	1.15E-01	2.47E+01	3.37E+00	4.08E+00	2.33E-01	1.92E+01	4.09E+00	D	4.09E+00	Yes	
Arsenic	102/106	1.20E+00	2.30E+01	1.34E+01	1.01E+01	9.80E-01	4.72E+01	1.66E+01	L	1.66E+01	Yes	
Barium	106/106			9.17E+01	5.74E+01	1.42E+01	3.03E+02	1.06E+02	L	1.06E+02	Yes	
Beryllium	95/106	2.10E-01	4.87E-01	2.35E+00	1.40E+01	1.42E-01	1.45E+02	4.61E+00	X	4.61E+00	Yes	
Boron	5/5			4.16E+00	4.08E+00	1.50E+00	1.14E+01	1.97E+01	L	1.14E+01	Yes	
Cadmium	56/109	1.25E-02	2.75E-01	1.03E+00	1.78E+00	1.10E-01	1.56E+01	1.31E+00	X	1.31E+00	Yes	
Calcium	106/106			3.34E+04	5.44E+04	2.36E+02	2.63E+05	4.21E+04	X	4.21E+04	Yes*	Essential nutrient
Chromium	106/106			2.63E+01	1.44E+01	4.54E+00	1.03E+02	2.86E+01	X	2.86E+01	Yes	
Chromium, hexavalent	2/15	2.70E-01	3.85E-01	3.46E-01	1.03E-01	5.80E-01	6.00E-01	3.93E-01	D	3.93E-01	Yes	
Cobalt	106/106			1.44E+01	1.20E+01	1.22E+00	9.99E+01	1.64E+01	X	1.64E+01	Yes	
Copper	106/106			2.45E+01	1.59E+01	4.00E+00	1.05E+02	2.74E+01	L	2.74E+01	Yes	
Iron	106/106			2.81E+04	1.37E+04	3.50E+03	7.96E+04	3.03E+04	X	3.03E+04	Yes*	Essential nutrient
Lead	108/109	3.54E+01	3.54E+01	3.60E+01	3.46E+01	4.81E+00	2.80E+02	4.00E+01	L	4.00E+01	Yes	
Lithium	3/3			2.92E+01	1.85E+01	1.25E+01	4.91E+01	2.63E+03	L	4.91E+01	Yes	
Magnesium	106/106			9.26E+03	1.38E+04	1.07E+02	7.38E+04	1.65E+04	L	1.65E+04	Yes*	Essential nutrient
Manganese	106/106			1.03E+03	9.63E+02	3.87E+01	4.91E+03	1.35E+03	L	1.35E+03	Yes	
Mercury	76/109	9.50E-03	6.50E-02	1.15E-01	1.86E-01	2.00E-02	1.30E+00	1.45E-01	X	1.45E-01	Yes	
Molybdenum	4/8	4.95E-01	5.50E-01	4.09E+00	5.03E+00	4.80E-01	1.16E+01	7.46E+00	X	7.46E+00	Yes	
Nickel	109/109			3.20E+01	2.84E+01	3.81E+00	1.69E+02	3.73E+01	L	3.73E+01	Yes	
Potassium	106/106			3.39E+03	3.81E+03	1.31E+02	1.65E+04	4.00E+03	X	4.00E+03	Yes*	Essential nutrient
Selenium	46/109	1.14E-01	1.91E+01	2.26E+00	3.37E+00	4.80E-01	1.32E+01	2.80E+00	D	2.80E+00	Yes	
Silver	8/109	3.00E-02	5.25E+00	6.52E-01	1.30E+00	1.30E-01	1.11E+01	8.59E-01	D	8.59E-01	Yes	
Sodium	74/97	6.10E+00	3.56E+02	1.83E+02	5.33E+02	1.04E+01	5.20E+03	2.73E+02	X	2.73E+02	Yes*	Essential nutrient
Strontium	3/3			7.08E+01	1.01E+02	5.70E+00	1.87E+02	2.10E+16	L	1.87E+02	Yes	
Thallium	26/104	5.50E-02	7.80E+01	4.28E+00	8.06E+00	1.40E-01	1.35E+01	5.59E+00	D	5.59E+00	Yes	
Uranium	20/23	2.88E+00	3.31E+00	4.23E+00	2.68E+00	4.00E-01	1.07E+01	5.19E+00	N	5.19E+00	Yes	
Vanadium	106/106			3.95E+01	1.96E+01	4.30E+00	9.55E+01	4.27E+01	N	4.27E+01	Yes	
Zinc	106/106			7.93E+01	1.36E+02	8.30E+00	1.30E+03	1.01E+02	X	1.01E+02	Yes	
Pesticides/herbicides/polychlorinated biphenyls (mg/kg)												
4,4'-DDD	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects
4,4'-DDE	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects
4,4'-DDT	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects
Aldrin	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
Dieldrin	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP outside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Endosulfan I	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
Endosulfan II	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects
Endosulfan sulfate	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects
Endrin	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects
Endrin ketone	0/5	6.00E-03	4.00E-01	9.56E-02	1.71E-01			2.58E-01	D	2.58E-01	No	No detects
Heptachlor	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
Heptachlor epoxide	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
Lindane	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
Methoxychlor	0/5	3.00E-02	2.00E+00	4.79E-01	8.52E-01			1.29E+00	D	1.29E+00	No	No detects
PCB-1016	1/91	1.80E-03	2.00E-01	2.77E-02	3.95E-02	1.20E-01	1.20E-01	3.45E-02	D	3.45E-02	Yes	
PCB-1221	1/91	1.80E-03	3.85E-01	4.37E-02	6.65E-02	1.20E-01	1.20E-01	5.52E-02	D	5.52E-02	Yes	
PCB-1232	1/91	1.80E-03	2.00E-01	2.77E-02	3.95E-02	1.20E-01	1.20E-01	3.45E-02	D	3.45E-02	Yes	
PCB-1242	1/91	1.80E-03	2.00E-01	2.77E-02	3.95E-02	1.20E-01	1.20E-01	3.45E-02	D	3.45E-02	Yes	
PCB-1248	3/91	1.80E-03	2.00E-01	2.96E-02	4.19E-02	5.30E-02	1.60E-01	3.69E-02	D	3.69E-02	Yes	
PCB-1254	20/91	1.80E-03	1.90E-01	6.61E-02	1.66E-01	2.10E-03	1.20E+00	9.49E-02	D	9.49E-02	Yes	
PCB-1260	22/91	1.80E-03	2.00E-01	5.64E-02	1.48E-01	3.10E-03	1.00E+00	8.21E-02	D	8.21E-02	Yes	
Toxaphene	0/5	6.00E-02	4.00E+00	9.56E-01	1.71E+00			2.58E+00	D	2.58E+00	No	No detects
alpha-BHC	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
alpha-Chlordane	0/5	3.00E-03	2.00E+00	4.19E-01	8.84E-01			1.26E+00	D	1.26E+00	No	No detects
beta-BHC	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
delta-BHC	0/5	3.00E-03	2.00E-01	4.79E-02	8.52E-02			1.29E-01	D	1.29E-01	No	No detects
gamma-Chlordane	0/5	3.00E-03	2.00E+00	4.19E-01	8.84E-01			1.26E+00	D	1.26E+00	No	No detects
Semivolatile organic compounds (mg/kg)												
1,2,4-Trichlorobenzene	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
1,2-Dichlorobenzene	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
1,2-Diphenylhydrazine	0/6	1.87E-01	1.10E+01	4.06E+00	4.35E+00			7.64E+00	D	7.64E+00	No	No detects
1,3-Dichlorobenzene	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
1,4-Dichlorobenzene	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
2,2'-Dichlorodiisopropyl ether	1/40	1.75E-01	1.85E+00	2.43E-01	2.62E-01	3.00E-02	3.00E-02	3.13E-01	D	3.00E-02	Yes	
2,3,4,6-Tetrachlorophenol	0/5	6.00E-01	1.10E+01	4.84E+00	4.38E+00			9.01E+00	D	9.01E+00	No	No detects
2,4,5-Trichlorophenol	0/86	1.75E-01	5.50E+01	1.76E+00	7.35E+00			3.08E+00	D	3.08E+00	No	No detects
2,4,6-Trichlorophenol	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
2,4-Dichlorophenol	1/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00	1.50E-01	1.50E-01	7.62E-01	D	1.50E-01	Yes	
2,4-Dimethylphenol	1/86	1.75E-01	1.10E+01	5.00E-01	1.45E+00	4.10E-02	4.10E-02	7.61E-01	D	4.10E-02	Yes	
2,4-Dinitrophenol	1/86	1.75E-01	5.50E+01	1.77E+00	7.35E+00	3.50E-02	3.50E-02	3.09E+00	D	3.50E-02	Yes	
2,4-Dinitrotoluene	4/86	1.80E-01	1.10E+01	4.97E-01	1.45E+00	2.50E-02	1.10E-01	7.58E-01	D	1.10E-01	Yes	

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP outside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
2,6-Dinitrotoluene	1/86	1.75E-01	1.10E+01	5.00E-01	1.45E+00	4.80E-02	4.80E-02	7.61E-01	D	4.80E-02	Yes	
2-Chloronaphthalene	2/86	1.75E-01	1.10E+01	5.00E-01	1.45E+00	2.50E-02	1.90E-01	7.60E-01	D	1.90E-01	Yes	
2-Chlorophenol	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
2-Methyl-4,6-dinitrophenol	0/86	1.75E-01	5.50E+01	1.77E+00	7.35E+00			3.09E+00	D	3.09E+00	No	No detects
2-Methylnaphthalene	18/86	1.80E-01	1.10E+01	6.28E-01	1.53E+00	2.20E-02	3.30E+00	9.01E-01	D	9.01E-01	Yes	
2-Methylphenol	2/86	1.75E-01	1.10E+01	4.99E-01	1.45E+00	2.20E-02	7.00E-02	7.59E-01	D	7.00E-02	Yes	
2-Nitrobenzenamine	1/86	1.75E-01	5.50E+01	1.77E+00	7.35E+00	5.30E-02	5.30E-02	3.09E+00	D	5.30E-02	Yes	
2-Nitrophenol	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
3,3'-Dichlorobenzidine	2/86	1.75E-01	2.20E+01	7.86E-01	2.95E+00	2.40E-02	5.80E-02	1.32E+00	D	5.80E-02	Yes	
3-Nitrobenzenamine	1/86	1.75E-01	5.50E+01	1.77E+00	7.35E+00	7.00E-02	7.00E-02	3.09E+00	D	7.00E-02	Yes	
4-Bromophenyl phenyl ether	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
4-Chloro-3-methylphenol	2/86	1.75E-01	2.20E+01	7.85E-01	2.95E+00	2.50E-02	2.90E-02	1.32E+00	D	2.90E-02	Yes	
4-Chlorobenzenamine	2/86	1.75E-01	2.20E+01	7.93E-01	2.95E+00	2.90E-01	4.20E-01	1.32E+00	D	4.20E-01	Yes	
4-Chlorophenyl phenyl ether	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
4-Methylphenol	3/86	1.75E-01	1.10E+01	4.96E-01	1.46E+00	2.20E-02	3.50E-02	7.57E-01	D	3.50E-02	Yes	
4-Nitrobenzenamine	1/86	1.75E-01	5.50E+01	1.77E+00	7.35E+00	2.80E-02	2.80E-02	3.09E+00	D	2.80E-02	Yes	
4-Nitrophenol	1/86	1.75E-01	5.50E+01	1.77E+00	7.35E+00	8.50E-02	8.50E-02	3.09E+00	D	8.50E-02	Yes	
Acenaphthene	6/86	1.75E-01	1.10E+01	4.99E-01	1.45E+00	7.80E-02	2.30E-01	7.60E-01	D	2.30E-01	Yes	
Acenaphthylene	13/86	1.80E-01	1.10E+01	5.83E-01	1.50E+00	2.60E-02	3.20E+00	8.52E-01	D	8.52E-01	Yes	
Aniline	0/5	6.00E-01	1.10E+01	4.84E+00	4.38E+00			9.01E+00	D	9.01E+00	No	No detects
Anthracene	17/86	1.80E-01	1.10E+01	5.26E-01	1.47E+00	1.00E-02	2.70E+00	7.90E-01	D	7.90E-01	Yes	
Benz(a)anthracene	29/86	3.60E-02	1.10E+01	9.53E-01	2.70E+00	2.80E-02	1.80E+01	1.44E+00	D	1.44E+00	Yes	
Benzenemethanol	0/5	1.20E+00	2.20E+01	9.78E+00	8.79E+00			1.82E+01	D	1.82E+01	No	No detects
Benzidine	0/2	3.05E+00	5.50E+01	2.90E+01	3.67E+01			1.93E+02	D	1.93E+02	No	No detects
Benzo(*a*)pyrene	27/86	5.50E-02	1.10E+01	1.24E+00	3.43E+00	3.60E-02	2.20E+01	1.86E+00	D	1.86E+00	Yes	
Benzo(*b*)fluoranthene	33/86	4.90E-02	1.10E+01	1.35E+00	3.64E+00	4.40E-02	2.10E+01	2.00E+00	D	2.00E+00	Yes	
Benzo(*g,h,i*)perylene	12/86	1.80E-01	1.10E+01	9.46E-01	2.61E+00	8.80E-02	1.60E+01	1.41E+00	D	1.41E+00	Yes	
Benzo(*k*)fluoranthene	26/86	5.50E-02	1.10E+01	1.19E+00	3.34E+00	3.90E-02	1.90E+01	1.79E+00	D	1.79E+00	Yes	
Benzoic acid	0/5	3.00E+00	5.50E+01	2.42E+01	2.19E+01			4.51E+01	D	4.51E+01	No	No detects
Bis(2-chloroethoxy)methane	1/86	1.75E-01	1.10E+01	5.00E-01	1.45E+00	3.50E-02	3.50E-02	7.61E-01	D	3.50E-02	Yes	
Bis(2-chloroethyl) ether	2/86	1.75E-01	1.10E+01	4.98E-01	1.45E+00	2.00E-02	2.60E-02	7.59E-01	D	2.60E-02	Yes	
Bis(2-chloroisopropyl) ether	0/46	1.80E-01	1.10E+01	7.24E-01	1.96E+00			1.21E+00	D	1.21E+00	No	No detects
Bis(2-ethylhexyl)phthalate	7/86	1.75E-01	1.10E+01	5.30E-01	1.48E+00	7.00E-02	3.10E+00	7.96E-01	D	7.96E-01	Yes	
Butyl benzyl phthalate	5/86	1.75E-01	1.10E+01	4.95E-01	1.46E+00	1.20E-02	1.20E-01	7.56E-01	D	1.20E-01	Yes	
Carbazole	11/84	1.75E-01	6.00E+00	3.84E-01	9.10E-01	1.20E-02	1.00E+00	5.49E-01	D	5.49E-01	Yes	
Chrysene	31/86	5.00E-02	1.10E+01	1.13E+00	3.01E+00	4.20E-02	2.00E+01	1.67E+00	D	1.67E+00	Yes	

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP outside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Di-n-butyl phthalate	6/86	1.75E-01	1.10E+01	5.73E-01	1.49E+00	6.20E-02	2.60E+00	8.40E-01	D	8.40E-01	Yes	
Di-n-octylphthalate	3/86	1.75E-01	1.10E+01	4.98E-01	1.45E+00	2.80E-02	1.20E-01	7.58E-01	D	1.20E-01	Yes	
Dibenz(*a,h*)anthracene	6/86	1.80E-01	1.10E+01	6.00E-01	1.54E+00	1.10E-01	3.90E+00	8.75E-01	D	8.75E-01	Yes	
Dibenzofuran	13/86	1.80E-01	1.10E+01	5.36E-01	1.45E+00	4.10E-02	1.00E+00	7.97E-01	D	7.97E-01	Yes	
Diethyl phthalate	2/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00	3.00E-01	4.80E-01	7.62E-01	D	4.80E-01	Yes	
Dimethyl phthalate	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
Diphenylamine	2/73	1.75E-01	1.85E+00	2.32E-01	2.10E-01	4.60E-02	5.80E-02	2.73E-01	D	5.80E-02	Yes	
Fluoranthene	33/86	1.80E-01	1.10E+01	1.21E+00	3.70E+00	3.40E-02	2.90E+01	1.87E+00	D	1.87E+00	Yes	
Fluorene	7/86	1.75E-01	1.10E+01	4.87E-01	1.45E+00	6.10E-02	6.60E-01	7.46E-01	D	6.60E-01	Yes	
Hexachlorobenzene	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
Hexachlorobutadiene	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
Hexachlorocyclopentadiene	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
Hexachloroethane	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
Indeno(1,2,3-*cd*)pyrene	19/86	1.80E-01	1.10E+01	1.06E+00	2.85E+00	5.90E-02	1.80E+01	1.57E+00	D	1.57E+00	Yes	
Isophorone	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
N-Nitroso-di-n-propylamine	0/86	1.75E-01	1.10E+01	5.02E-01	1.45E+00			7.63E-01	D	7.63E-01	No	No detects
N-Nitrosodimethylamine	0/5	6.00E-01	1.10E+01	4.84E+00	4.38E+00			9.01E+00	D	9.01E+00	No	No detects
N-Nitrosodiphenylamine	0/13	1.95E-01	1.10E+01	1.99E+00	3.44E+00			3.70E+00	D	3.70E+00	No	No detects
Naphthalene	14/86	1.80E-01	1.10E+01	5.98E-01	1.48E+00	9.20E-02	2.30E+00	8.64E-01	D	8.64E-01	Yes	
Nitrobenzene	1/86	1.75E-01	1.10E+01	5.01E-01	1.45E+00	5.70E-02	5.70E-02	7.61E-01	D	5.70E-02	Yes	
Pentachlorophenol	3/86	1.75E-01	5.50E+01	1.77E+00	7.35E+00	3.49E-01	4.02E-01	3.09E+00	D	4.02E-01	Yes	
Phenanthrene	32/86	1.80E-01	1.10E+01	7.68E-01	1.69E+00	2.80E-02	5.70E+00	1.07E+00	D	1.07E+00	Yes	
Phenol	7/86	1.75E-01	1.10E+01	4.92E-01	1.46E+00	2.30E-02	2.30E-01	7.53E-01	D	2.30E-01	Yes	
Pyrene	34/86	1.80E-01	1.10E+01	1.13E+00	3.45E+00	3.70E-02	2.60E+01	1.75E+00	D	1.75E+00	Yes	
Pyridine	0/5	6.00E-01	1.10E+01	4.84E+00	4.38E+00			9.01E+00	D	9.01E+00	No	No detects
				Volatile organic compounds (mg/kg)								
1,1,1-Trichloro-2,2,2-trifluoroethane	0/31	2.70E-03	3.80E-03	3.06E-03	2.16E-04			3.12E-03	D	3.12E-03	No	No detects
1,1,1-Trichloroethane	1/75	2.70E-03	7.25E-03	4.70E-03	1.68E-03	1.08E-02	1.08E-02	5.03E-03	D	5.03E-03	Yes	
1,1,2,2-Tetrachloroethane	1/75	2.70E-03	7.25E-03	4.62E-03	1.57E-03	8.60E-04	8.60E-04	4.92E-03	D	8.60E-04	Yes	
1,1,2-Trichloro-1,2,2-trifluoroethane	0/5	3.15E-03	3.50E-03	3.34E-03	1.39E-04			3.47E-03	D	3.47E-03	No	No detects
1,1,2-Trichloroethane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
1,1-Dichloroethane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
1,1-Dichloroethene	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
1,2-Dichloroethane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
1,2-Dichloroethene	0/36	2.70E-03	3.80E-03	3.10E-03	2.28E-04			3.16E-03	D	3.16E-03	No	No detects
1,2-Dichloropropane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP outside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
1,2-Dimethylbenzene	2/41	2.80E-03	7.25E-03	5.82E-03	9.88E-04	1.70E-03	3.60E-03	6.08E-03	D	3.60E-03	Yes	
2-Butanone	0/53	2.70E-03	7.25E-03	4.13E-03	1.54E-03			4.48E-03	D	4.48E-03	No	No detects
2-Hexanone	0/52	2.70E-03	7.25E-03	4.09E-03	1.53E-03			4.44E-03	D	4.44E-03	No	No detects
4-Methyl-2-pentanone	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Acetone	9/58	2.70E-03	8.75E-03	7.79E-03	1.36E-02	4.20E-03	9.78E-02	1.08E-02	D	1.08E-02	Yes	
Benzene	5/76	2.70E-03	7.25E-03	4.55E-03	1.75E-03	4.50E-04	9.20E-03	4.88E-03	D	4.88E-03	Yes	
Bromochloromethane	0/39	5.25E-03	7.25E-03	6.07E-03	3.88E-04			6.17E-03	D	6.17E-03	No	No detects
Bromodichloromethane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Bromoform	0/74	2.70E-03	7.25E-03	4.62E-03	1.53E-03			4.92E-03	D	4.92E-03	No	No detects
Bromomethane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Carbon disulfide	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Carbon tetrachloride	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Chlorobenzene	0/74	2.70E-03	7.25E-03	4.62E-03	1.53E-03			4.92E-03	D	4.92E-03	No	No detects
Chloroethane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Chloroform	1/75	2.70E-03	7.25E-03	4.60E-03	1.60E-03	2.70E-04	2.70E-04	4.91E-03	D	2.70E-04	Yes	
Chloromethane	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Dibromochloromethane	0/74	2.70E-03	7.25E-03	4.62E-03	1.53E-03			4.92E-03	D	4.92E-03	No	No detects
Dimethylbenzene	4/76	2.70E-03	7.25E-03	4.90E-03	3.06E-03	8.40E-04	2.75E-02	5.49E-03	D	5.49E-03	Yes	
Ethylbenzene	2/75	2.70E-03	7.25E-03	4.61E-03	1.54E-03	1.90E-03	5.30E-03	4.91E-03	D	4.91E-03	Yes	
Methylene chloride	19/75	2.70E-03	8.10E-03	4.57E-03	1.89E-03	1.20E-03	9.80E-03	4.93E-03	D	4.93E-03	Yes	
Styrene	0/73	2.70E-03	7.25E-03	4.65E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Tetrachloroethene	0/74	2.70E-03	7.25E-03	4.62E-03	1.53E-03			4.92E-03	D	4.92E-03	No	No detects
Toluene	12/76	2.75E-03	7.25E-03	4.41E-03	2.22E-03	3.60E-04	1.45E-02	4.83E-03	D	4.83E-03	Yes	
Trichloroethene	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Vinyl chloride	0/75	1.10E-03	7.25E-03	3.88E-03	2.36E-03			4.34E-03	D	4.34E-03	No	No detects
cis-1,2-Dichloroethene	0/39	5.25E-03	7.25E-03	6.07E-03	3.88E-04			6.17E-03	D	6.17E-03	No	No detects
cis-1,3-Dichloropropene	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
trans-1,2-Dichloroethene	0/39	5.25E-03	7.25E-03	6.07E-03	3.88E-04			6.17E-03	D	6.17E-03	No	No detects
trans-1,3-Dichloropropene	0/75	2.70E-03	7.25E-03	4.64E-03	1.53E-03			4.94E-03	D	4.94E-03	No	No detects
Radionuclides (pCi/g)												
Actinium-228	64/66	1.00E-01	1.50E-01	1.27E+00	4.89E-01	4.67E-01	3.10E+00	1.37E+00	X	1.37E+00	No	Daughter
Americium-241	13/69	-8.42E-02	9.93E-02	3.73E-02	3.81E-02	3.71E-02	1.50E-01	4.50E-02	D	4.50E-02	Yes	
Bismuth-214	36/37	-8.50E-02	-8.50E-02	9.49E-01	4.26E-01	3.32E-01	2.04E+00	1.11E+00	L	1.11E+00	No	Daughter
Cesium-134	0/30	-3.10E-02	4.80E-02	5.06E-03	1.91E-02			1.10E-02	D	1.10E-02	No	No detects
Cesium-137	145/211	-3.79E+00	2.18E+00	6.61E-01	3.59E+00	1.00E-02	4.80E+01	1.07E+00	X	1.07E+00	Yes	
Cobalt-57	0/30	-8.40E-02	8.50E-02	3.47E-03	3.33E-02			1.38E-02	D	1.38E-02	No	No detects

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP outside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Cobalt-60	20/199	-1.25E-01	1.90E-01	1.44E-02	4.02E-02	-7.00E-02	1.20E-01	1.91E-02	D	1.91E-02	Yes	
Europium-154	0/11	3.00E-02	7.00E-02	4.55E-02	1.04E-02			5.11E-02	D	5.11E-02	No	No detects
Lead-212	29/30	1.60E-02	1.60E-02	3.68E+00	1.02E+01	2.42E-01	5.58E+01	6.83E+00	X	6.83E+00	No	Daughter
Lead-214	35/37	-8.90E-02	2.29E-01	1.08E+00	5.24E-01	4.21E-01	2.48E+00	1.22E+00	N	1.22E+00	No	Daughter
Neptunium-237	27/125	-2.55E-01	4.00E+00	1.97E-01	6.90E-01	1.20E-02	4.26E+00	2.99E-01	D	2.99E-01	Yes	
Niobium-94	0/11	3.00E-02	7.00E-02	3.91E-02	1.14E-02			4.53E-02	D	4.53E-02	No	No detects
Plutonium-238	10/114	-2.55E-01	1.00E+00	4.57E-02	1.43E-01	8.30E-03	6.64E-01	6.80E-02	D	6.80E-02	Yes	
Plutonium-239	22/125	-2.55E-01	4.20E-01	8.57E-01	4.87E+00	8.90E-03	4.72E+01	1.58E+00	D	1.58E+00	Yes	
Potassium-40	60/62	8.00E-02	6.74E+01	1.32E+01	1.07E+01	2.42E+00	4.78E+01	1.55E+01	X	1.55E+01	Yes	
Protactinium-234m	32/98	-3.54E+01	5.20E+02	8.99E+00	5.37E+01	4.74E-01	8.99E+01	1.80E+01	D	1.80E+01	No	Daughter
Radium-226	50/51	1.15E+00	1.15E+00	1.14E+00	4.73E-01	-8.70E-02	2.26E+00	1.25E+00	N	1.25E+00	Yes	
Radium-228	66/66			1.58E+00	3.24E+00	5.29E-02	2.63E+01	2.25E+00	X	2.25E+00	No	Daughter
Ruthenium-106	0/1	2.30E+01	2.30E+01	2.30E+01					D		No	No detects
Strontium-90	12/66	-3.35E-01	1.00E+00	2.89E-01	5.08E-01	6.40E-01	2.21E+00	3.93E-01	D	3.93E-01	Yes	
Technetium-99	67/207	-3.93E+01	3.66E+01	2.51E+01	1.75E+02	-9.18E+00	2.09E+03	4.52E+01	D	4.52E+01	Yes	
Thallium-208	29/30	2.00E-03	2.00E-03	1.14E+00	3.16E+00	7.10E-02	1.73E+01	2.12E+00	X	2.12E+00	No	Daughter
Thorium-228	183/202	-6.55E-02	1.70E-01	9.60E-01	1.96E+00	9.65E-03	2.63E+01	1.19E+00	X	1.19E+00	No	Daughter
Thorium-230	192/202	2.00E-02	2.35E+00	4.95E+00	2.58E+01	1.06E-02	2.04E+02	7.95E+00	X	7.95E+00	Yes	
Thorium-232	193/202	1.93E-03	1.00E-02	9.18E-01	1.96E+00	6.71E-03	2.63E+01	1.15E+00	X	1.15E+00	Yes	
Thorium-234	110/128	-1.23E+01	5.03E+00	1.39E+01	4.31E+01	2.91E-01	2.35E+02	2.02E+01	X	2.02E+01	No	Daughter
Titanium-44	0/11	3.00E-02	8.00E-02	4.45E-02	1.63E-02			5.35E-02	D	5.35E-02	No	No detects
Uranium-234	205/211	-2.45E-01	1.17E+00	1.42E+01	6.31E+01	2.09E-01	4.90E+02	2.13E+01	X	2.13E+01	Yes	
Uranium-235	112/198	-1.41E+00	3.96E-01	9.38E-01	3.99E+00	-1.00E-02	3.20E+01	1.41E+00	X	1.41E+00	Yes	
Uranium-236	30/73	-7.68E-02	2.14E-01	8.02E-02	5.78E-02	3.79E-02	2.31E-01	9.15E-02	D	9.15E-02	Yes	
Uranium-238	205/211	0.00E+00	3.60E-01	9.03E+00	3.51E+01	1.33E-01	2.28E+02	1.30E+01	X	1.30E+01	Yes	

[a]Distribution flags:
D = Not determined because fewer than 5 detects or < 50% detects; t-statistic used in calculations of 95% upper confidence limit on the mean.
L = Lognormal; H-statistic used in calculations of 95% confidence limit on the mean.
N = Normal; t-statistic used in calculations of 95% confidence limit on the mean.
X = Neither normal nor lognormal; t-statistic used in calculations UCL 95.

[b]Justifications for not proceeding with screening:
No detects = analyte is never detected and is not screened further.
Daughter = short-lived daughter product of isotope that is measured.
Have isotopic data = total activity not considered for further screening due to presence of isotopic data.

*Chemical detected in the soil is an essential nutrient; although unlikely to be site-related, this essential nutrient will be screened against background.

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP outside rover locations

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
				Metals (mg/kg)					
Aluminum	5.96E+04	7.6E+03	Yes		N/A	4.3E+04	Yes	Yes	
Antimony	1.92E+01	3.1E+00	Yes	1.1E+01	Yes	7.6E-01	Yes	Yes	
Arsenic	4.72E+01	3.9E-01	Yes	3.3E+00	Yes	2.0E+01	Yes	Yes	
Barium	3.03E+02	5.4E+02	No	7.4E+03	No	1.5E+02	Yes	No	Max detect < resid. PRG
Beryllium	1.45E+02	1.5E+01	Yes	1.8E-01	Yes	2.0E+00	Yes	Yes	
Boron	1.14E+01	1.6E+03	No	1.7E+04	No	2.8E+01	No	No	Max detect < resid. PRG
Cadmium	1.56E+01	3.7E+00	Yes	3.2E+00	Yes	0.0E+00	Yes	Yes	
Calcium	2.63E+05		N/A		N/A	3.3E+03	Yes	No	Essential nutrient
Chromium	1.03E+02	2.2E+01	Yes	1.5E+02	No	5.4E+01	Yes	Yes	
Chromium, hexavalent	6.00E-01	2.2E+01	No	1.5E+02	No	5.4E+01	No	No	Max detect < resid. PRG
Cobalt	9.99E+01	1.4E+02	No		N/A	3.1E+01	Yes	No	Max detect < resid. PRG
Copper	1.05E+02	3.1E+02	No		N/A	3.6E+01	Yes	No	Max detect < resid. PRG
Iron	7.96E+04	2.3E+03	Yes		N/A	5.8E+04	Yes	No	Essential nutrient
Lead	2.80E+02	4.0E+02	No		N/A	5.8E+01	Yes	No	Max detect < resid. PRG
Lithium	4.91E+01	1.6E+02	No		N/A	3.6E+01	Yes	No	Max detect < resid. PRG
Magnesium	7.38E+04		N/A		N/A	4.4E+03	Yes	No	Essential nutrient
Manganese	4.91E+03	1.8E+02	Yes	3.3E+03	Yes	2.0E+03	Yes	Yes	
Mercury	1.30E+00	2.3E+00	No	3.2E+01	No	3.5E-01	Yes	No	Max detect < resid. PRG
Molybdenum	1.16E+01	3.9E+01	No	8.8E+02	No	5.3E+00	Yes	No	Max detect < resid. PRG
Nickel	1.69E+02	1.6E+02	Yes	3.3E+03	No	3.6E+01	Yes	Yes	
Potassium	1.65E+04		N/A		N/A	5.0E+03	Yes	No	Essential nutrient
Selenium	1.32E+01	3.9E+01	No	8.9E+02	No	1.1E+00	Yes	No	Max detect < resid. PRG
Silver	1.11E+01	3.9E+01	No	7.6E+02	No	0.0E+00	Yes	No	Max detect < resid. PRG
Sodium	5.20E+03		N/A		N/A	4.9E+02	Yes	No	Essential nutrient
Strontium	1.87E+02	4.7E+03	No	9.3E+04	No	2.2E+01	Yes	No	Max detect < resid. PRG
Thallium	1.35E+01	5.2E-01	Yes	7.2E+00	Yes	5.4E-01	Yes	Yes	
Uranium	1.07E+01	1.6E+00	Yes	5.7E+02	No		N/A	Yes	
Vanadium	9.55E+01	5.5E+01	Yes	2.0E+02	No	8.3E+01	Yes	Yes	
Zinc	1.30E+03	2.3E+03	No	4.7E+04	No	1.7E+02	Yes	No	Max detect < resid. PRG
				Polychlorinated biphenyls (mg/kg)					
PCB-1016	1.20E-01	3.9E-01	No	4.8E-01	No		N/A	No	Max detect < resid. PRG
PCB-1221	1.20E-01	2.2E-01	No	5.5E-01	No		N/A	No	Max detect < resid. PRG
PCB-1232	1.20E-01	2.2E-01	No	5.5E-01	No		N/A	No	Max detect < resid. PRG
PCB-1242	1.20E-01	2.2E-01	No	4.6E-01	No		N/A	No	Max detect < resid. PRG

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP outside rover locations (continued)

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
PCB-1248	1.60E-01	2.2E-01	No	5.5E-01	No		N/A	No	Max detect < resid. PRG
PCB-1254	1.20E+00	1.1E-01	Yes	4.9E-01	Yes		N/A	Yes	
PCB-1260	1.00E+00	2.2E-01	Yes	4.8E-01	Yes		N/A	Yes	
				Semivolatile organic compounds (mg/kg)					
2,2'-Dichlorodiisopropyl ether	3.00E-02	2.9E+00	No	3.6E+03	No		N/A	No	Max detect < resid. PRG
2,4-Dichlorophenol	1.50E-01	1.8E+01	No	3.5E+02	No		N/A	No	Max detect < resid. PRG
2,4-Dimethylphenol	4.10E-02	1.2E+02	No	1.8E+03	No		N/A	No	Max detect < resid. PRG
2,4-Dinitrophenol	3.50E-02	1.2E+01	No	2.5E+02	No		N/A	No	Max detect < resid. PRG
2,4-Dinitrotoluene	1.10E-01	7.2E-01	No	4.8E+00	No		N/A	No	Max detect < resid. PRG
2,6-Dinitrotoluene	4.80E-02	7.2E-01	No	4.8E+00	No		N/A	No	Max detect < resid. PRG
2-Chloronaphthalene	1.90E-01	4.9E+02	No	7.2E+03	No		N/A	No	Max detect < resid. PRG
2-Methylnaphthalene	3.30E+00		N/A		N/A		N/A	Yes	
2-Methylphenol	7.00E-02	3.1E+02	No	4.5E+03	No		N/A	No	Max detect < resid. PRG
2-Nitrobenzenamine	5.30E-02	1.7E-01	No	3.8E-01	No		N/A	No	Max detect < resid. PRG
3,3'-Dichlorobenzidine	5.80E-02	1.1E+00	No	5.6E+00	No		N/A	No	Max detect < resid. PRG
3-Nitrobenzenamine	7.00E-02		N/A		N/A		N/A	Yes	
4-Chloro-3-methylphenol	2.90E-02		N/A		N/A		N/A	Yes	
4-Chlorobenzenamine	4.20E-01	2.4E+01	No	3.6E+02	No		N/A	No	Max detect < resid. PRG
4-Methylphenol	3.50E-02	3.1E+01	No	5.2E+02	No		N/A	No	Max detect < resid. PRG
4-Nitrobenzenamine	2.80E-02		N/A		N/A		N/A	Yes	
4-Nitrophenol	8.50E-02		N/A		N/A		N/A	Yes	
Acenaphthene	2.30E-01	3.7E+02	No	4.0E+03	No		N/A	No	Max detect < resid. PRG
Acenaphthylene	3.20E+00		N/A		N/A		N/A	Yes	
Anthracene	2.70E+00	2.2E+03	No	3.3E+04	No		N/A	No	Max detect < resid. PRG
Benz(*a*)anthracene	1.80E+01	6.2E-01	Yes	2.6E+00	Yes		N/A	Yes	
Benzo(*a*)pyrene	2.20E+01	6.2E-02	Yes	2.6E-01	Yes		N/A	Yes	
Benzo(*b*)fluoranthene	2.10E+01	6.2E-01	Yes	2.6E+00	Yes		N/A	Yes	
Benzo(*g,h,i*)perylene	1.60E+01		N/A		N/A		N/A	Yes	
Benzo(*k*)fluoranthene	1.90E+01	6.2E+00	Yes	2.6E+01	No		N/A	Yes	
Bis(2-chloroethoxy)methane	3.50E-02		N/A		N/A		N/A	Yes	
Bis(2-chloroethyl) ether	2.60E-02	2.1E-01	No	3.8E-01	No		N/A	No	Max detect < resid. PRG
Bis(2-ethylhexyl)phthalate	3.10E+00	3.5E+01	No	9.4E+01	No		N/A	No	Max detect < resid. PRG
Butyl benzyl phthalate	1.20E-01	1.2E+03	No	2.0E+04	No		N/A	No	Max detect < resid. PRG
Carbazole	1.00E+00	2.4E+01	No	1.5E+02	No		N/A	No	Max detect < resid. PRG
Chrysene	2.00E+01	6.2E+01	No	2.5E+02	No		N/A	No	Max detect < resid. PRG

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP outside rover locations (continued)

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
Di-n-butyl phthalate	2.60E+00	6.1E+02	No	1.3E+04	No		N/A	No	Max detect < resid. PRG
Di-n-octylphthalate	1.20E-01	2.4E+02	No	2.4E+03	No		N/A	No	Max detect < resid. PRG
Dibenz(*a,h*)anthracene	3.90E+00	6.2E-02	Yes	2.6E-01	Yes		N/A	Yes	
Dibenzofuran	1.00E+00	2.9E+01	No	4.6E+02	No		N/A	No	Max detect < resid. PRG
Diethyl phthalate	4.80E-01	4.9E+03	No	9.6E+04	No		N/A	No	Max detect < resid. PRG
Diphenylamine	5.80E-02	1.5E+02	No	2.3E+03	No		N/A	No	Max detect < resid. PRG
Fluoranthene	2.90E+01	2.3E+02	No	2.7E+03	No		N/A	No	Max detect < resid. PRG
Fluorene	6.60E-01	2.7E+02	No	3.6E+03	No		N/A	No	Max detect < resid. PRG
Indeno(1,2,3-*cd*)pyrene	1.80E+01	6.2E-01	Yes	2.6E+00	Yes		N/A	Yes	
Naphthalene	2.30E+00	5.6E+00	No	2.7E+01	No		N/A	No	Max detect < resid. PRG
Nitrobenzene	5.70E-02	2.0E+00	No	1.2E+01	No		N/A	No	Max detect < resid. PRG
Pentachlorophenol	4.02E-01	3.0E+00	No	2.9E+01	No		N/A	No	Max detect < resid. PRG
Phenanthrene	5.70E+00		N/A		N/A		N/A	Yes	
Phenol	2.30E-01	3.7E+03	No	7.2E+04	No		N/A	No	Max detect < resid. PRG
Pyrene	2.60E+01	2.3E+02	No	2.0E+03	No		N/A	No	Max detect < resid. PRG
Volatile organic compounds (mg/kg)									
1,1,1-Trichloroethane	1.08E-02	2.0E+02	No	7.6E+02	No		N/A	No	Max detect < resid. PRG
1,1,2,2-Tetrachloroethane	8.60E-04	4.1E-01	No	1.0E+00	No		N/A	No	Max detect < resid. PRG
1,2-Dimethylbenzene	3.60E-03		N/A	2.3E+05	No		N/A	Yes	
Acetone	9.78E-02	1.6E+02	No	1.2E+04	No		N/A	No	Max detect < resid. PRG
Benzene	9.20E-03	6.0E-01	No	1.6E+00	No		N/A	No	Max detect < resid. PRG
Chloroform	2.70E-04	3.6E-01	No	5.2E-01	No		N/A	No	Max detect < resid. PRG
Dimethylbenzene	2.75E-02	2.7E+01	No	2.4E+05	No		N/A	No	Max detect < resid. PRG
Ethylbenzene	5.30E-03	8.9E+00	No	2.2E+01	No		N/A	No	Max detect < resid. PRG
Methylene chloride	9.80E-03	9.1E+00	No	2.3E+01	No		N/A	No	Max detect < resid. PRG
Toluene	1.45E-02	6.6E+01	No	2.5E+02	No		N/A	No	Max detect < resid. PRG
Radionuclides (pCi/g)									
Americium-241	1.50E-01	2.2E+00	No	8.0E+00	No	0.0E+00	Yes	No	Max detect < resid. PRG
Cesium-137	4.80E+01	2.1E-02	Yes	1.0E-01	Yes	1.0E+00	Yes	Yes	
Cobalt-60	1.20E-01	4.5E-03	Yes	2.2E-02	Yes	0.0E+00	Yes	Yes	
Neptunium-237	4.26E+00	9.1E-02	Yes	4.5E-01	Yes	1.9E-01	Yes	Yes	
Plutonium-238	6.64E-01	2.7E+00	No	1.1E+01	No	1.7E-01	Yes	No	Max detect < resid. PRG
Plutonium-239	4.72E+01	2.5E+00	Yes	1.0E+01	Yes	5.1E-02	Yes	Yes	
Potassium-40	4.78E+01	7.1E-02	Yes	3.6E-01	Yes	3.4E+01	Yes	Yes	
Radium-226	2.26E+00	2.8E-03	Yes	6.7E-03	Yes	2.6E+00	No	No	Max detect < backgd.

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP outside rover locations (continued)

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
Strontium-90	2.21E+00	1.4E+01	No	5.7E+01	No	1.1E+00	Yes	No	Max detect < resid. PRG
Technetium-99	2.09E+03	5.7E+02	Yes	2.3E+03	No	0.0E+00	Yes	Yes	
Thorium-230	2.04E+02	2.1E+01	Yes	8.1E+01	Yes	1.9E+00	Yes	Yes	
Thorium-232	2.63E+01	2.4E+01	Yes	9.3E+01	No	2.1E+00	Yes	Yes	
Uranium-234	4.90E+02	1.8E+01	Yes	7.0E+01	Yes	2.2E+00	Yes	Yes	
Uranium-235	3.20E+01	1.6E-01	Yes	8.2E-01	Yes	1.6E+00	Yes	Yes	
Uranium-236	2.31E-01	1.9E+01	No	7.4E+01	No	1.7E-01	Yes	No	Max detect < resid. PRG
Uranium-238	2.28E+02	6.3E-01	Yes	3.1E+00	Yes	2.3E+00	Yes	Yes	

Only detected data passing through the first screen (see Table A.1) are shown.

COPC = contaminant of potential concern.

[a]PRG = preliminary remediation goal, at the 10^{-6} risk level or the 0.1 hazard level (whichever is smaller).

[b]Chemical (i.e., nonradiological) residential PRGs are from U. S. Environmental Protection Agency Region IX. Radiological residential PRGs are from Oak Ridge National Laboratory (ORNL).

[c]Chemical and radiological industrial PRGs are from ORNL.

[d]Contaminants never detected in background are assumed to have a background criteria of 0.0 (zero).

[e]Contaminants detected above their respective residential soil PRG and background levels are considered to be COPCs. Detected contaminants without a PRG or background screening value are retained as COPCs.

Table A.3. Type of evaluation of COPCs in surface soil at ETTP outside rover locations

Analyte	Quantitative COPC	Qualitative[a] COPC
	Metals	
Aluminum		✔
Antimony	✔	
Arsenic	✔	
Beryllium	✔	
Cadmium	✔	
Chromium	✔	
Manganese	✔	
Nickel	✔	
Thallium	✔	
Uranium	✔	
Vanadium	✔	
	PCBs	
PCB-1254	✔	
PCB-1260	✔	
	VOCs	
1,2-Dimethylbenzene	✔	
	SVOCs	
2-Methylnaphthalene		✔
3-Nitrobenzenamine		✔
4-Chloro-3-methylphenol		✔
4-Nitrobenzenamine		✔
4-Nitrophenol		✔
Acenaphthylene		✔
Benz(*a*)anthracene	✔	
Benzo(*a*)pyrene	✔	
Benzo(*b*)fluoranthene	✔	
Benzo(*g,h,i*)perylene		✔
Benzo(*k*)fluoranthene	✔	
Bis(2-chloroethoxy)methane		✔
Dibenz(*a,h*)anthracene	✔	
Indeno(1,2,3-*cd*)pyrene	✔	
Phenanthrene		✔
	Radionuclides	
Cesium-137	✔	
Cobalt-60	✔	
Neptunium-237	✔	
Plutonium-239	✔	
Potassium-40	✔	
Technetium-99	✔	
Thorium-230	✔	
Thorium-232	✔	
Uranium-234	✔	
Uranium-235	✔	
Uranium-238	✔	

[a]Based on the lack of available toxicity information, some COPCs were evaluated qualitatively.
COPC = contaminant of potential concern.
ETTP = East Tennessee Technology Park.
PCB = polychlorinated biphenyl.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.

Table A.4. Parameters for evaluation of exposures to soil at ETTP outside rover locations

Pathway	EF (d/year)	ED (year)	BW (kg)	AT_{carc} (d)	AT_{nonc} (d)	CF (various)[a]	IR_{soil} (kg/d)	FI (unitless)	IR_{air} (m^3/d)	SA (m^2/d)	AF (mg/cm^2)	SE (unitless)	TE (h/h)	$EF_{ext.exp.}$ (d/d)
						ETTP rover outside Main Plant fence								
Ingestion	250	5	70	25550	1825	1000.00	0.000050	1.0						
Dermal	250	5	70	25550	1825	0.01				0.316	1.0			
Inhalation	250	5	70	25550	1825	1000.00			20					
External Exposure		5										0.2	2/24	250/365

[a]Conversion factor units:

1000 g/kg for ingestion and inhalation of soil (applies to radionuclides only).

0.01 (kg-cm^2)/(mg-m^2) for dermal exposure to soil [(10^{-6} kg/mg) × (10^4 cm^2/m^2)].

Other factors used:

ABS = dermal absorption factor; value is 0.001 (0.1%) for inorganics and 0.01 (1%) for organics (unitless).

PEF = 5.38E+09 m^3/kg for the inhalation pathway.

VF in m^3/kg is analyte-specific (used for volatile organics only for the inhalation pathway).

Table A.5. Toxicity values[a] for COPCs in surface soil at ETTP outside rover locations

COPC	G. I. absorp. factor[b]	Non-carcinogenic toxicity values: Oral chronic RfD[c]	Non-carcinogenic toxicity values: Dermal chronic RfD[c]	Non-carcinogenic toxicity values: Inhalation chronic RfD[c]	Carcinogenic toxicity values: Oral slope factor[d]	Carcinogenic toxicity values: Dermal slope factor[e]	Carcinogenic toxicity values: Inhalation slope factor[f]	Carcinogenic toxicity values: External exposure slope factor[g]	Other parameters used: Dermal ABS factor[h]	Other parameters used: PEF[i]	Other parameters used: VF[j]
Non-radionuclides											
1,2-Dimethylbenzene	0.8	2.00E+00	1.60E+00						0.01	5.38E+09	6.80E+03
Antimony	0.02	4.00E-04	8.00E-06						0.001	5.38E+09	
Arsenic	0.41	3.00E-04	1.23E-04		1.50E+00	3.66E+00	1.51E+01		0.001	5.38E+09	
Benz(*a*)anthracene	0.31				7.30E-01	2.35E+00	3.10E-01		0.01	5.38E+09	1.05E+07
Benzo(*a*)pyrene	0.31				7.30E+00	2.35E+01	3.10E+00		0.01	5.38E+09	2.72E+07
Benzo(*b*)fluoranthene	0.31				7.30E-01	2.35E+00	3.10E-01		0.01	5.38E+09	5.13E+06
Benzo(*k*)fluoranthene	0.31				7.30E-02	2.35E-01	3.10E-02		0.01	5.38E+09	4.37E+07
Beryllium	0.01	2.00E-03	2.00E-05	5.71E-06			8.40E+00		0.001	5.38E+09	
Cadmium	0.01	1.00E-03	1.00E-05				6.30E+00		0.01	5.38E+09	
Chromium	0.02	3.00E-03	6.00E-05	2.86E-05			4.20E+01		0.001	5.38E+09	
Dibenz(*a,h*)anthracene	0.31				7.30E+00	2.35E+01	3.10E+00		0.01	5.38E+09	1.16E+08
Indeno(1,2,3-*cd*)pyrene	0.31				7.30E-01	2.35E+00	3.10E-01		0.01	5.38E+09	6.33E+07
Manganese	0.04	4.60E-02	1.84E-03	1.43E-05					0.001	5.38E+09	
Nickel	0.27	2.00E-02	5.40E-03						0.001	5.38E+09	
PCB-1254	0.9	2.00E-05	1.80E-05		2.00E+00	2.22E+00	2.00E+00		0.06	5.38E+09	5.89E+05
PCB-1260	0.9				2.00E+00	2.22E+00	2.00E+00		0.06	5.38E+09	4.97E+05
Thallium	0.5	8.00E-05	4.00E-05						0.01	5.38E+09	
Uranium	0.85	6.00E-04	5.10E-04						0.001	5.38E+09	
Vanadium	0.01	7.00E-03	7.00E-05						0.001	5.38E+09	
Radionuclides											
Cesium-137	1				3.17E-11		1.19E-11	2.55E-06		5.38E+09	
Cobalt-60	0.1				7.33E-12		3.58E-11	1.24E-05		5.38E+09	
Neptunium-237	0.0005				4.92E-11		1.77E-08	7.97E-07		5.38E+09	
Plutonium-239	0.0005				1.21E-10		3.33E-08	2.00E-10		5.38E+09	
Potassium-40	1				1.51E-11		1.03E-11	7.97E-07		5.38E+09	
Technetium-99	0.5				1.32E-12		1.41E-11	8.14E-11		5.38E+09	
Thorium-230	0.0005				7.73E-11		2.85E-08	8.19E-10		5.38E+09	
Thorium-232	0.0005				8.47E-11		4.33E-08	3.42E-10		5.38E+09	
Uranium-234	0.02				5.11E-11		1.14E-08	2.52E-10		5.38E+09	
Uranium-235	0.02				5.03E-11		1.01E-08	5.43E-07		5.38E+09	

Table A.5. Toxicity values[a] for COPCs in surface soil at ETTP outside rover locations (continued)

		Non-carcinogenic toxicity values			Carcinogenic toxicity values				Other parameters used		
COPC	G. I. absorp. factor[b]	Oral chronic RfD[c]	Dermal chronic RfD[c]	Inhalation chronic RfD[c]	Oral slope factor[d]	Dermal slope factor[e]	Inhalation slope factor[f]	External exposure slope factor[g]	Dermal ABS factor[h]	PEF[i]	VF[j]
Uranium-238	0.02				5.62E-11		9.35E-09	1.14E-07		5.38E+09	

[a]Toxicity data are from http://risk.lsd.ornl.gov/tox/tox_values.html.
[b]Gastrointestinal absorption factor; unitless.
[c]Units for reference doses (RfDs) are mg/kg-d.
[d]Units for oral slope factors are $(mg/kg\text{-}d)^{-1}$ for chemicals and risk/pCi for radionuclides.
[e]Units for dermal slope factors are $(mg/kg\text{-}d)^{-1}$ (for chemicals only).
[f]Units for inhalation slope factors are $(mg/kg\text{-}d)^{-1}$ for chemicals and risk/pCi for radionuclides.
[g]Units for external exposure slope factors are (risk/year per pCi/g) [for radionuclides only].
[h]Dermal absorption factor; unitless (for chemicals only).
[i]Particulate Emission Factor, in m^3/kg.
[j]Volatilization Factor, in m^3/kg (only used for VOCs).
COPC = contaminants of potential concern.
ETTP = East Tennessee Technology Park.

Table A.6. Cancer risks from exposure to surface soil at ETTP outside rover locations

COPC	EPC[a]	Cancer intakes[b]				Cancer risks					COC?[c]
		Ingestion	Dermal	Inhalation	External exposure	Ingestion	Dermal	Inhalation	External exposure	Total	
ETTP rover outside Main Plant fence											
Arsenic	1.66E+01	5.8E-07	3.7E-08	4.3E-11		8.7E-07	1.3E-07	6.5E-10		1.0E-06	
Beryllium	4.61E+00	1.6E-07	1.0E-08	1.2E-11				1.0E-10		1.0E-10	
Cadmium	1.31E+00	4.6E-08	2.9E-08	3.4E-12				2.1E-11		2.1E-11	
Chromium	2.86E+01	1.0E-06	6.3E-08	7.4E-11				3.1E-09		3.1E-09	
Inorganics pathway total						8.7E-07	1.3E-07	7.7E-10		1.0E-06	
Benz(*a*)anthracene	1.44E+00	5.0E-08	3.2E-08	3.7E-12		3.7E-08	7.5E-08	1.2E-12		1.1E-07	
Benzo(*a*)pyrene	1.86E+00	6.5E-08	4.1E-08	4.8E-12		4.7E-07	9.7E-07	1.5E-11		1.4E-06	
Benzo(*b*)fluoranthene	2.00E+00	7.0E-08	4.4E-08	5.2E-12		5.1E-08	1.0E-07	1.6E-12		1.6E-07	
Benzo(*k*)fluoranthene	1.79E+00	6.3E-08	4.0E-08	4.7E-12		4.6E-09	9.3E-09	1.4E-13		1.4E-08	
Dibenz(*a,h*)anthracene	8.75E-01	3.1E-08	1.9E-08	2.3E-12		2.2E-07	4.6E-07	7.0E-12		6.8E-07	
Indeno(1,2,3-*cd*)pyrene	1.57E+00	5.5E-08	3.5E-08	4.1E-12		4.0E-08	8.2E-08	1.3E-12		1.2E-07	
PCB-1254	9.49E-02	3.3E-09	1.3E-08	2.5E-13		6.6E-09	2.8E-08	4.9E-13		3.5E-08	
PCB-1260	8.21E-02	2.9E-09	1.1E-08	2.1E-13		5.7E-09	2.4E-08	4.3E-13		3.0E-08	
Organics pathway total						8.4E-07	1.7E-06	2.7E-11		2.6E-06	
Chemicals pathway total						1.7E-06	1.9E-06	3.9E-09		3.6E-06	
Cesium-137	1.07E+00	6.7E+01		5.0E-03	2.4E-01	2.1E-09		5.9E-14	6.2E-07	6.2E-07	
Cobalt-60	1.91E-02	1.2E+00		8.9E-05	4.4E-03	8.8E-12		3.2E-15	5.4E-08	5.4E-08	
Neptunium-237	2.99E-01	1.9E+01		1.4E-03	6.8E-02	9.2E-10		2.5E-11	5.4E-08	5.5E-08	
Plutonium-239	1.58E+00	9.9E+01		7.3E-03	3.6E-01	1.2E-08		2.4E-10	7.2E-11	1.2E-08	
Potassium-40	1.55E+01	9.7E+02		7.2E-02	3.5E+00	1.5E-08		7.4E-13	2.8E-06	2.8E-06	
Technetium-99	4.52E+01	2.8E+03		2.1E-01	1.0E+01	3.7E-09		3.0E-12	8.4E-10	4.6E-09	
Thorium-230	7.95E+00	5.0E+02		3.7E-02	1.8E+00	3.8E-08		1.1E-09	1.5E-09	4.1E-08	
Thorium-232	1.15E+00	7.2E+01		5.3E-03	2.6E-01	6.1E-09		2.3E-10	8.9E-11	6.4E-09	
Uranium-234	2.13E+01	1.3E+03		9.9E-02	4.9E+00	6.8E-08		1.1E-09	1.2E-09	7.1E-08	
Uranium-235	1.41E+00	8.8E+01		6.5E-03	3.2E-01	4.4E-09		6.6E-11	1.7E-07	1.8E-07	
Uranium-238	1.30E+01	8.1E+02		6.0E-02	3.0E+00	4.6E-08		5.7E-10	3.4E-07	3.9E-07	

Table A.6. Cancer risks from exposure to surface soil at ETTP outside rover locations (continued)

		Cancer intakes[b]				Cancer risks					
COPC	EPC[a]	Ingestion	Dermal	Inhalation	External exposure	Ingestion	Dermal	Inhalation	External exposure	Total	COC?[c]
Radionuclides pathway total						2.0E-07		3.3E-09	4.1E-06	4.3E-06	

[a]EPC = exposure point concentration, defined as the smaller value between the maximum detected concentration and the UCL95; units are mg/kg for chemicals and pCi/g for radionuclides.

[b]Units for cancer intakes are (mg/kg-d) for chemicals; pCi for radiological ingestion and inhalation; and pCi-year/g for external exposure.

[c]COC = contaminant of concern. When the total risk > 10^{-4}, then any individual contaminant with risk > 10^{-6} is a COA. As seen there are no carcinogenic COCs for either receptor.

COPC = contaminant of potential concern.

ETTP = East Tennessee Technology Park.

Table A.7. Non-carcinogenic hazards from exposure to surface soil at ETTP outside rover locations

COPC	EPC[a]	Non-carcinogenic intakes[b]			Hazard quotients				COC?[c]
		Ingestion	Dermal	Inhalation	Ingestion	Dermal	Inhalation	Total	
				ETTP rover outside Main Plant fence					
Antimony	4.09E+00	2.0E-06	1.3E-07	1.5E-10	5.0E-03	1.6E-02		2.1E-02	
Arsenic	1.66E+01	8.1E-06	5.1E-07	6.0E-10	2.7E-02	4.2E-03		3.1E-02	
Beryllium	4.61E+00	2.3E-06	1.4E-07	1.7E-10	1.1E-03	7.1E-03	2.9E-05	8.3E-03	
Cadmium	1.31E+00	6.4E-07	4.1E-07	4.8E-11	6.4E-04	4.1E-02		4.1E-02	
Chromium	2.86E+01	1.4E-05	8.9E-07	1.0E-09	4.7E-03	1.5E-02	3.6E-05	1.9E-02	
Manganese	1.35E+03	6.6E-04	4.2E-05	4.9E-08	1.4E-02	2.3E-02	3.4E-03	4.0E-02	
Nickel	3.73E+01	1.8E-05	1.2E-06	1.4E-09	9.1E-04	2.1E-04		1.1E-03	
Thallium	5.59E+00	2.7E-06	1.7E-06	2.0E-10	3.4E-02	4.3E-02		7.7E-02	
Uranium	5.19E+00	2.5E-06	1.6E-07	1.9E-10	4.2E-03	3.1E-04		4.5E-03	
Vanadium	4.27E+01	2.1E-05	1.3E-06	1.6E-09	3.0E-03	1.9E-02		2.2E-02	
Inorganics pathway total					9.5E-02	1.7E-01	3.5E-03	2.7E-01	
1,2-Dimethylbenzene	3.60E-03	1.8E-09	1.1E-09	1.0E-07	8.8E-10	7.0E-10		1.6E-09	
PCB-1254	9.49E-02	4.6E-08	1.8E-07	3.5E-12	2.3E-03	9.8E-03		1.2E-02	
Organics pathway total					2.3E-03	9.8E-03		1.2E-02	
Chemicals pathway total					9.7E-02	1.8E-01	3.5E-03	2.8E-01	

[a]EPC = exposure point concentration, defined as the smaller value between the maximum detected concentration and the 95% upper confidence limit (UCL95); units are in mg/kg.

[b]Units for non-carcinogenic intakes are mg/kg-d.

[c]COC = Contaminant of Concern. When the total hazard ≥ 1.0, then any individual contaminant with a hazard ≥ 0.1 is a COA. As seen there are no non-carcinogenic COCs for either receptor.

COPC = contaminant of potential concern.

ETTP = East Tennessee Technology Park.

PCB = polychlorinated biphenyl.

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