III. EVALUATION OF ENVIRONMENTAL CONTAMINATION AND POTENTIAL EXPOSURE PATHWAYS

III.A. Introduction

In 2001, ATSDR scientists conducted a review and analysis of the Phase I and Phase II screening evaluation of TDOH's Oak Ridge Health Studies to identify contaminants that require further public health evaluation. In the Phase I and Phase II screening evaluation, the TDOH conducted extensive reviews of available information and conducted qualitative and quantitative analyses of past (1944–1990) releases and off-site exposures to hazardous substances from the entire ORR. On the basis of ATSDR's review and analysis of Phase I and Phase II screening evaluations, ATSDR scientists determined that past releases of uranium, mercury, iodine 131, fluorides, radionuclides from White Oak Creek, and PCBs require further public health evaluations. The public health assessment is the primary public health process ATSDR is using to further evaluate these contaminants. The public health assessment process will

1. Identify populations off the site who may have been exposed to hazardous substances at levels of health concern.
2. Determine the public health implications of the exposure.
3. Address the health concerns of people in the community.
4. Recommend follow-up public health actions or studies to address the exposure.

ATSDR scientists are conducting public health assessments on the following releases: Y-12 releases of uranium, Y-12 releases of mercury, X-10 release of iodine 131, X-10 release of radionuclides from White Oak Creek, K-25 releases of uranium and fluoride, and PCBs released from all three facilities. Public health assessments will also be conducted on other issues of concern, such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater. ATSDR is also screening current (1990 to 2003) environmental data to determine whether additional chemicals will require further evaluation.

This public health assessment on the Y-12 uranium releases evaluates and analyzes the information, data, and findings of previous studies and investigations of releases of uranium from the Y-12 plant and assesses the health implications of past and current uranium exposures to residents living near the ORR, specifically the residents of the reference community (that is, Scarboro).

III.A.1. Exposure Evaluation

What is meant by exposure?

ATSDR's public health assessments are driven by exposure or contact. Contaminants (chemicals or radioactive materials) released into the environment have the potential to cause harmful health effects. Nevertheless, a release does not always result in exposure. People can only be exposed to a chemical contaminant if they come into contact with that contaminant. If no one comes into contact with a contaminant, then no exposure occurs, and thus no health effects could occur. Often the general public does not have access to the source area of contamination or areas where contaminants are moving through the environment. This lack of access to these areas becomes important in determining whether people could come into contact with the contaminants. However, in the case of radiological contamination, exposure can occur without direct contact because of the emission of radiation, which is a form of energy.

An exposure pathway has five elements: (1) a source of contamination, (2) an environmental media, (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population. The source is the place where the chemical or radioactive material was released. The environmental media (such as, groundwater, soil, surface water, or air) transport the contaminants. The point of exposure is the place where persons come into contact with the contaminated media. The route of exposure (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body. The people actually exposed are the receptor population.

The route of a contaminant's movement is the pathway. ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a contaminant. An exposure pathway could involve air, surface water, groundwater, soil, dust, or even plants and animals. Exposure can occur by breathing, eating, drinking, or by skin contact with a substance containing the chemical contaminant. Exposure to radiation can occur by being near the radioactive material.

How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate site-specific conditions to determine whether people are being exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) is occurring through ingestion, dermal (skin) contact, or inhalation.

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

A comparison value is used by ATSDR to screen chemicals that require additional evaluation.

Comparison values are not thresholds for harmful health effects. ATSDR comparison values represent contaminant concentrations that are many times lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. If contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (such as site-specific exposure, duration, and frequency) for health effects, including the toxicology of the contaminant, other epidemiology studies, and the weight of evidence. Figure 6 illustrates ATSDR's chemical screening process.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/HAGM/ or by contacting ATSDR at 1-888-42-ATSDR.

Figure 6. ATSDR Chemical Screening Process

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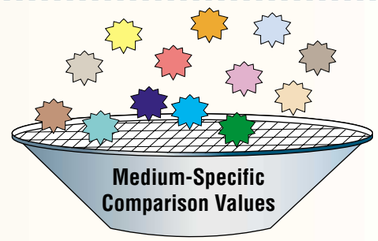
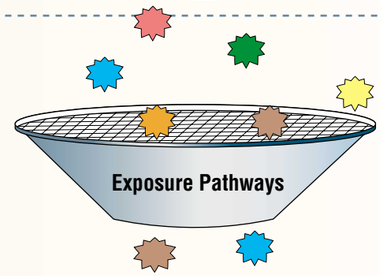
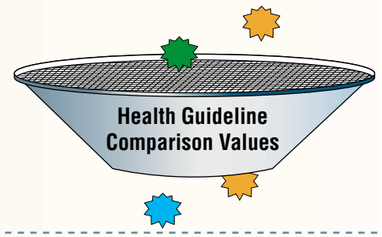
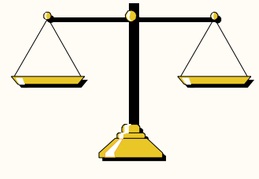
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

	Decision Diagram	Illustration	Criteria
Preliminary Screening	Chemicals detected in environmental media YES Are the chemical concentrations higher than medium-specific comparison values? NO → Not a contaminant of concern	 	• Based on the results of environmental investigations • Based on maximum exposure conditions – maximum concentration detected – maximum exposure duration – maximum exposure frequency – maximum exposure bioavailability
Pathway Evaluation	YES Are there completed and/or potential exposure pathways where chemicals have been detected? NO → Not a contaminant of concern		• Can or are exposures occurring • Identify potential or completed exposure pathways
Exposure Dose Comparison	YES Are estimated exposure doses higher than health guideline values? NO → Not a contaminant of concern		• Estimate doses based on site-specific exposure conditions • Use more realistic exposure assumptions – realistic concentrations – realistic exposure duration – realistic exposure frequency – realistic exposure bioavailability – site-specific receptor population
Contaminants of Concern	YES Contaminants of concern		• Evaluate the public health implications of contaminants of concern in greater detail
Public Health Implications	YES Evaluate public health implications	 Public Health Implications Evaluation—Weight of Evidence	• Review toxicologic, medical, epidemiologic, and other scientific data on the contaminants of concern • Evaluate whether contaminants of concern can affect public health in the vicinity of the site

If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects that occur in an individual as the result of contact with a contaminant depend on the exposure concentration (how much), the frequency (how often) and duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (combination of contaminants). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how that individual absorbs, distributes, metabolizes, and excretes the contaminant. Taken together, these factors and characteristics determine the health effects that can occur as a result of exposure to a contaminant in the environment.

III.A.2. Evaluating Exposure

To evaluate exposures to the reference population, Scarboro, ATSDR evaluated available past and current data to determine whether uranium concentrations were above natural background levels and/or ATSDR's comparison values. In the case of radiation doses, ATSDR calculated the doses based on site-specific data obtained from various environmental investigations and exposure factor sources. ATSDR also reviewed relevant toxicologic and epidemiologic data to obtain information about the toxicity of uranium (discussed in Appendix C). Both the chemical and radioactive properties of uranium can be harmful, and therefore they are evaluated separately.

It is important to remember that exposure to a certain contaminant does not always result in harmful health effects. The type and severity of health effects expected to occur depend on the exposure concentration, the toxicity of the contaminant, the frequency and duration of exposure, and the multiplicity of exposures.

Comparing Environmental Data to ATSDR's Comparison Values

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

Comparison values are derived using conservative exposure assumptions and health-based doses. Comparison values reflect concentrations that are much lower than those that have been observed to cause adverse health effects. Thus, comparison values are protective of public health in essentially all exposure situations. As a result, **concentrations detected at or below ATSDR's comparison values are not considered to warrant health concern**. While concentrations at or below the relevant comparison value can reasonably be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would be expected to produce adverse health effects. **It cannot be emphasized strongly enough that comparison values are not thresholds of toxicity.** The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual lifestyle, and genetic factors that affect the route, magnitude, and duration of actual exposure; an environmental concentration alone will not cause an adverse health outcome.

When evaluating chemical effects of uranium exposure, ATSDR scientists used comparison values that are specific to each environmental media. The comparison values used are shown in Table 2.

Table 2. Comparison Values for Uranium

Media	Comparison Value	Source
Air	0.3 µg/m^3	Chronic EMEG for highly soluble uranium salts
Surface water	20 µg/L	Intermediate child EMEG for highly soluble uranium salts
Soil	100 mg/kg	Intermediate child EMEG for highly soluble uranium salts
Fish	4.1 mg/kg	RBC for soluble uranium salts

µg/m^3: microgram per cubic meter
µg/L: microgram per liter
mg/kg: milligram per kilogram

ATSDR's environmental media evaluation guides (EMEGs) are nonenforceable, health-based comparison values developed for screening environmental contamination for further evaluation. EPA's risk-based concentration (RBC) is a health-based comparison value developed to screen

sites not yet on the NPL, respond rapidly to citizens' inquiries, and spot-check formal baseline risk assessments.

Comparing Estimated Doses to ATSDR's Minimal Risk Level and Other Comparison Values

Deriving exposure doses

Exposure doses are expressed in milligrams per kilogram per day (mg/kg/day). When estimating exposure doses, health assessors evaluate chemical concentrations to which people could have been exposed, together with the length of time and the frequency of exposure. Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. Where possible, ATSDR used site-specific information regarding the frequency and duration of exposures. When site-specific information was not available, ATSDR employed several conservative exposure assumptions to estimate exposures.

A toxicologic dose is the amount of chemical a person is exposed to over time. The radiation dose is the amount of energy from radiation that is actually absorbed by the body.

The following equation was used to estimate uranium chemical doses via ingestion from the surface water and soil pathways: Dose = Intake / Body Weight, where intake is defined as the concentration times the intake rate (Conc × IR); an adult male was assumed to weigh 78 kilograms (kg), an adult female was assumed to weigh 71 kg, a 12-year-old child was assumed to weigh 45 kg, and a 6-year-old child was assumed to weigh 23 kg. The adult body weights are representative of the average African American man and woman age 18–74 (National Center for Health Statistics 1987 as cited in EPA 1997). The child body weights are representative of an average 12-year-old and 6-year-old child (all races, both genders) (National Center for Health Statistics 1987 as cited in EPA 1997).

Minimal Risk Level

When evaluating chemical effects, ATSDR also derived toxicologic doses that residents living near the site may have received and compared these estimated site-specific doses against

ATSDR's minimal risk levels (MRLs). MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. MRLs are derived when reliable and sufficient data exist to identify the target organs of effect or the most sensitive health effects for a specific duration for a given route of exposure. Proposed MRLs undergo a rigorous review process: Health Effects/MRL workgroup reviews within ATSDR's Division of Toxicology; expert panel of external peer reviews; and agency-wide MRL workgroup reviews, with participation from other federal agencies, including EPA; and are then submitted for public comment.

An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse *noncancer* health effects over a specified duration of exposure. These substance-specific estimates, which are intended to serve as screening levels, are used by ATSDR health assessors to identify contaminants and potential health effects that are not expected to cause adverse health effects. It is important to note that MRLs are not intended to define clean-up or action levels. MRLs are intended only to serve as a screening tool to help public health professionals decide where to look more closely.

MRLs are derived for hazardous substances using the no-observed-adverse-effect level (NOAEL)/uncertainty factor approach. They are below levels that might cause adverse health effects in the people most sensitive to such effects. Most MRLs contain a degree of uncertainty because of the lack of precise toxicologic information on the people who might be most sensitive (for example, infants, the elderly, or persons who are nutritionally or immunologically compromised) to the effects of hazardous substances. Consistent with the public health principle of prevention, ATSDR uses a conservative (that is, protective) approach to address this uncertainty.

MRLs are generally based on the most sensitive end point considered to be of relevance to humans. Serious health effects (such as birth defects or irreparable damage to the liver or kidneys) are not used as a basis for establishing MRLs. Exposure to levels above the MRL does not mean that adverse health effects will occur. Estimated doses that are less than these values are not considered to be of health concern. To maximize human health protection, MRLs have built-in uncertainty or safety factors, making these values considerably lower than levels at

which health effects have been observed. The result is that even if a dose is higher than the MRL, it does not necessarily follow that harmful health effects will occur.

Table 3 shows the MRLs developed for uranium. Figure 7 shows ATSDR's process of determining radiological doses. More detailed information is available in two ATSDR publications, the Toxicological Profile for Uranium (ATSDR 1999a) and the Toxicological Profile for Ionizing Radiation (ATSDR 1999b). Additional information about the toxicologic implications of uranium exposure is provided in Appendix C.

Other Comparison Values

When evaluating the carcinogenic effects of radiation from uranium exposure, ATSDR scientists use the dose of 5,000 millirem (mrem) over 70 years as the radiogenic cancer comparison value. This value is a committed effective dose equivalent (CEDE) calculated from the intake of uranium, with the assumption that the entire dose (a 70-year dose, in this case)[3] is received in the first year following the intake. ATSDR believes the radiogenic cancer comparison value of 5,000 mrem over 70 years is protective of human health. ATSDR derived this value after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (see Appendix D for more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years).

The committed effective dose equivalent (CEDE) is the radiation dose accumulated over a 70-year exposure and assuming the entire 70-year dose is received in the first year following intake of a radioactive substance. By definition, the CEDE is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to the organs or tissues. The CEDE is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues.

[3] In this case, the entire dose is the dose a person would receive over 70 years of exposure. ATSDR chose a 70-year period of exposure to be protective of public health.

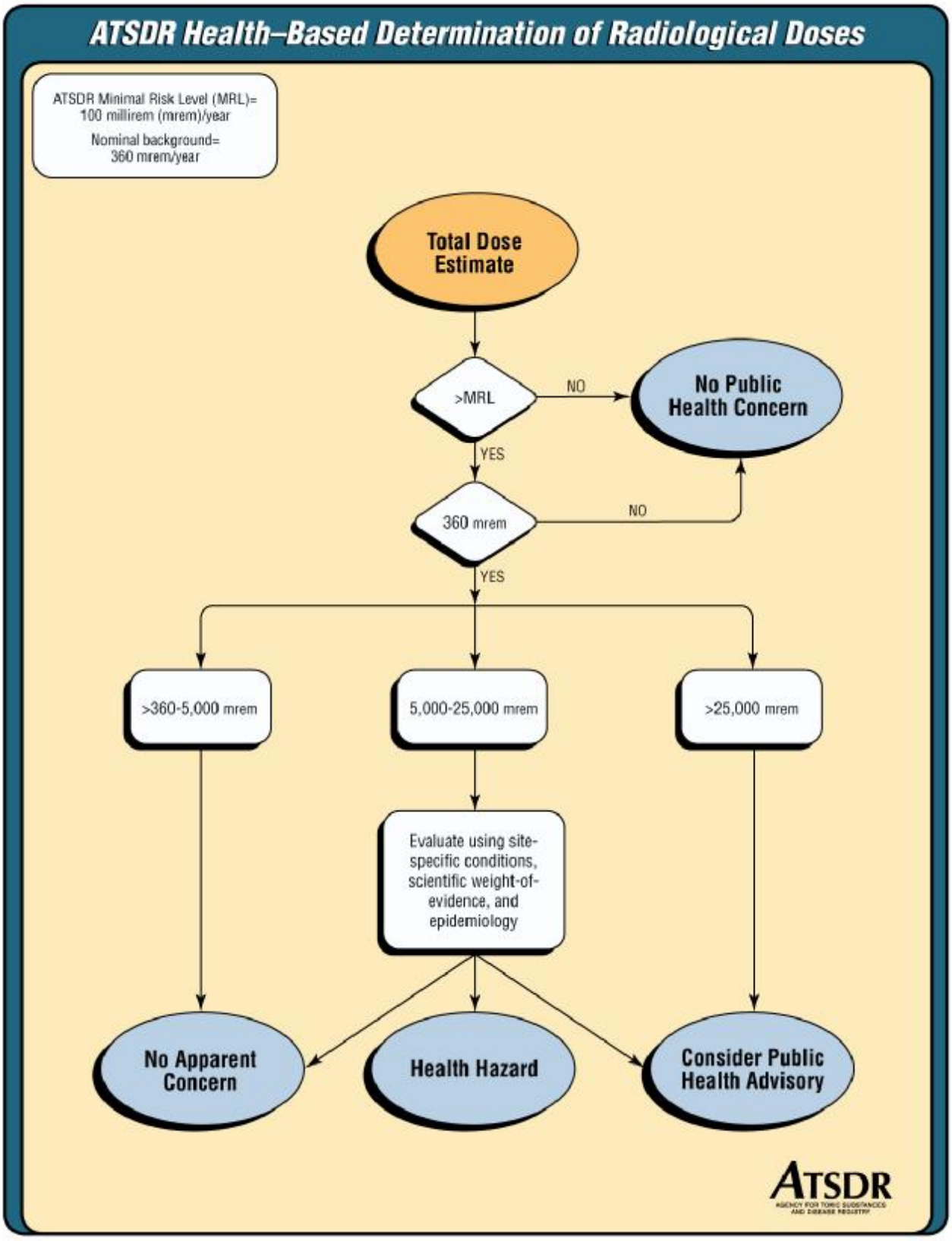
Table 3. ATSDR's Minimal Risk Levels (MRLs) for Uranium

Route	Duration	Form	MRL Value	Dose Endpoint	Source
Inhalation	Intermediate	Soluble	0.0004 mg/m^3	LOAEL; Minimal microscopic lesions in the renal tubules in half the dogs examined were observed at doses of 0.15 mg/m^3.	Rothstein 1949a
Inhalation	Intermediate	Insoluble	0.008 mg/m^3	NOAEL; No adverse health effects were observed in dogs exposed to doses of 1.1 mg/m^3.	Rothstein 1949b
Inhalation	Chronic	Soluble	0.0003 mg/m^3	NOAEL; No adverse health effects were observed in dogs exposed to doses of 0.05 mg/m^3.	Stokinger et al. 1953
Oral	Intermediate		0.002 mg/kg/day	LOAEL; Renal toxicity was observed in rabbits exposed to doses of 0.05 mg/kg/day.	Gilman et al. 1998b
External Radiation	Acute	Ionizing Radiation	400 mrem	NOAEL; The difference of 0.3 IQ point in intelligence test scores between separated and unseparated identical twins is considered the NOAEL.	Burt 1966
External Radiation	Chronic	Ionizing Radiation	100 mrem/year	NOAEL; The annual dose of 360 mrem/year has not been associated with adverse health effects in humans or animals.	BEIR V 1990

Source: ATSDR 1999a, 1999b

Acute duration is defined as less than or equal to 14 days.
Intermediate duration is defined as 15 to 364 days.
Chronic duration is defined as exposures exceeding 365 days.
The no-observed-adverse-effect level (NOAEL) is the highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.
The lowest-observed-adverse-effect level (LOAEL) is the lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.
The MRL level for intermediate-duration oral exposure is also protective for chronic-duration oral exposure. This is because the renal effects of uranium exposure are more dependent on the dose than on the duration of the exposure.
The rabbit is the mammalian species most sensitive to uranium toxicity and is likely to be even more sensitive than humans.
mg/m^3: milligram per cubic meter
mg/kg/day: milligram per kilogram per day
mrem: millirem
mrem/year: millirem per year

Figure 7. ATSDR Health-Based Determination of Radiological Doses



III.B. Public Health Evaluation

ATSDR evaluated past and current exposure to uranium contamination released from the Y-12 plant and found that the levels that people were exposed to were too low to be of health concern for both radiation and chemical health effects.

III.B.1. Past Exposure (1944–1995)

ATSDR used the screening results from the Task 6 report to evaluate past uranium releases to the environment from the Y-12 plant and past uranium exposures to residents living near the Y-12 plant. The Scarboro community located within the city of Oak Ridge was selected as a reference location to estimate concentrations of uranium in the air, surface water, and soil in an off-site area where residents resided during years of past Y-12 plant uranium releases. The Task 6 team identified Scarboro as the reference location using air dispersion modeling, specifically EPA's Industrial Source Complex Short Term (ISCST3) dispersion model, Version 96113 (USEPA 1995 as cited in ChemRisk 1999). Ground-level uranium air concentrations were estimated for a 40 by 47 kilometer grid to quantitatively relate past Y-12 plant uranium release rates to resulting average airborne uranium concentrations at locations surrounding the reservation. Using this method, the Task 6 team was able to identify off-site locations with the highest estimated uranium air concentrations. The Task 6 report stated that "while other potentially exposed communities were considered in the selection process, the reference locations [Scarboro] represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases…Scarboro is the most suitable for screening both a maximally and typically exposed individual" (ChemRisk 1999). Scarboro represents an established community surrounding the Y-12 plant with the highest estimated uranium air concentrations.

ATSDR evaluated both the radiation and chemical aspects of past uranium exposure. Neither the total radiation dose[4], nor the chemical ingestion and inhalation doses from exposure to

[4] The total radiation dose for past exposures is the sum of both internal and external exposures to the air, surface water, and soil pathways.

uranium released from the Y-12 plant in the past would cause harmful health effects for people living near ORR, including those in the Scarboro community.

III.B.1.a. Past Radiation Effects

ATSDR evaluated whether exposure to past levels of uranium released from the Y-12 plant would cause harmful radiation effects in communities near the Y-12 plant, especially the reference location (the Scarboro community), which is considered the area that would have received the highest exposures. The total past uranium dose received by the reference population (155 mrem, discussed in the next paragraph) is well below levels of health concern and is not expected to have caused any adverse health effects in the past.

During the development of the Task 6 report, uranium radiation doses from the air, surface water, and soil pathways were estimated for the reference location, Scarboro, using a 52-year exposure scenario (Figure 8 shows the exposure pathways evaluated). To evaluate potential radiation health effects to the population in Scarboro, ATSDR adjusted the Task 6 committed effective dose equivalents (CEDEs) to be equivalent to a 70-year exposure (see Table 4).[5] The total past uranium radiation dose received by the reference population, the Scarboro community, from multiple routes of internal and external exposure pathways is a CEDE of 155 millirem (mrem) over 70 years. This total past radiation dose (CEDE of 155 mrem over 70 years) is well below (32 times less than) the ATSDR radiogenic cancer comparison value of a CEDE of 5,000 mrem over 70 years (see Figure 9). ATSDR derived this radiogenic cancer comparison value after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (Appendix D provides more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years). This radiogenic cancer comparison value assumes that from the intake of uranium, the entire radiation dose (a 70-year dose, in this case) is received in the first year following the intake. ATSDR believes this radiogenic cancer comparison value to be protective of human health and, therefore, does not

[5] The Task 6 level II committed effective dose equivalents (CEDEs) were converted from Sievert (Sv) to mrem by multiplying by 10^5. These CEDE values were then multiplied by 1.35 (70 years/52 years) for comparison with the ATSDR radiogenic cancer comparison value, which is based on a 70-year exposure.

expect carcinogenic health effects to have occurred from past radiation doses received from past Y-12 uranium releases.

To evaluate noncancer health effect from the total past uranium radiation dose (CEDE of 155 mrem over 70 years) received by the Scarboro community, an approximation can be made to compare the CEDE of 155 mrem, which is based on 70 years of exposure, to the ATSDR chronic exposure MRL for ionizing radiation (100 mrem/year) which is based on one year of exposure. The CEDE of 155 mrem over 70 years could be divided by 70 years to approximate a value of 2.2 mrem as the radiation dose in the first year which is well below (45 times less than) the 100 mrem/year ATSDR chronic exposure MRL for ionizing radiation (see Figure 9). The ATSDR MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. The ATSDR MRL of 100 mrem/year for chronic ionizing radiation exposure is derived by dividing the average annual effective dose to the U.S. population (360 mrem/year) by a safety factor of 3 to account for human variability (ATSDR 199b). The average U.S. annual effective dose of 360 mrem/year is obtained mainly from naturally occurring radioactive material, medical uses of radiation, and radiation from consumer products (see Figure 9) (BEIR V 1990 as cited in ATSDR 1999b). This average annual background effective dose of 360 mrem/year has not been associated with adverse health effects in humans or animals (ATSDR 1999b). ATSDR believes the chronic ionizing radiation MRL of 100 mrem/year is below levels that might cause adverse health effects in persons most sensitive to such effects; therefore, ATSDR does not expect noncancer health effects to have occurred from radiation doses received from past Y-12 uranium releases.

Table 4. Total Past Uranium Radiation Dose to the Scarboro Community

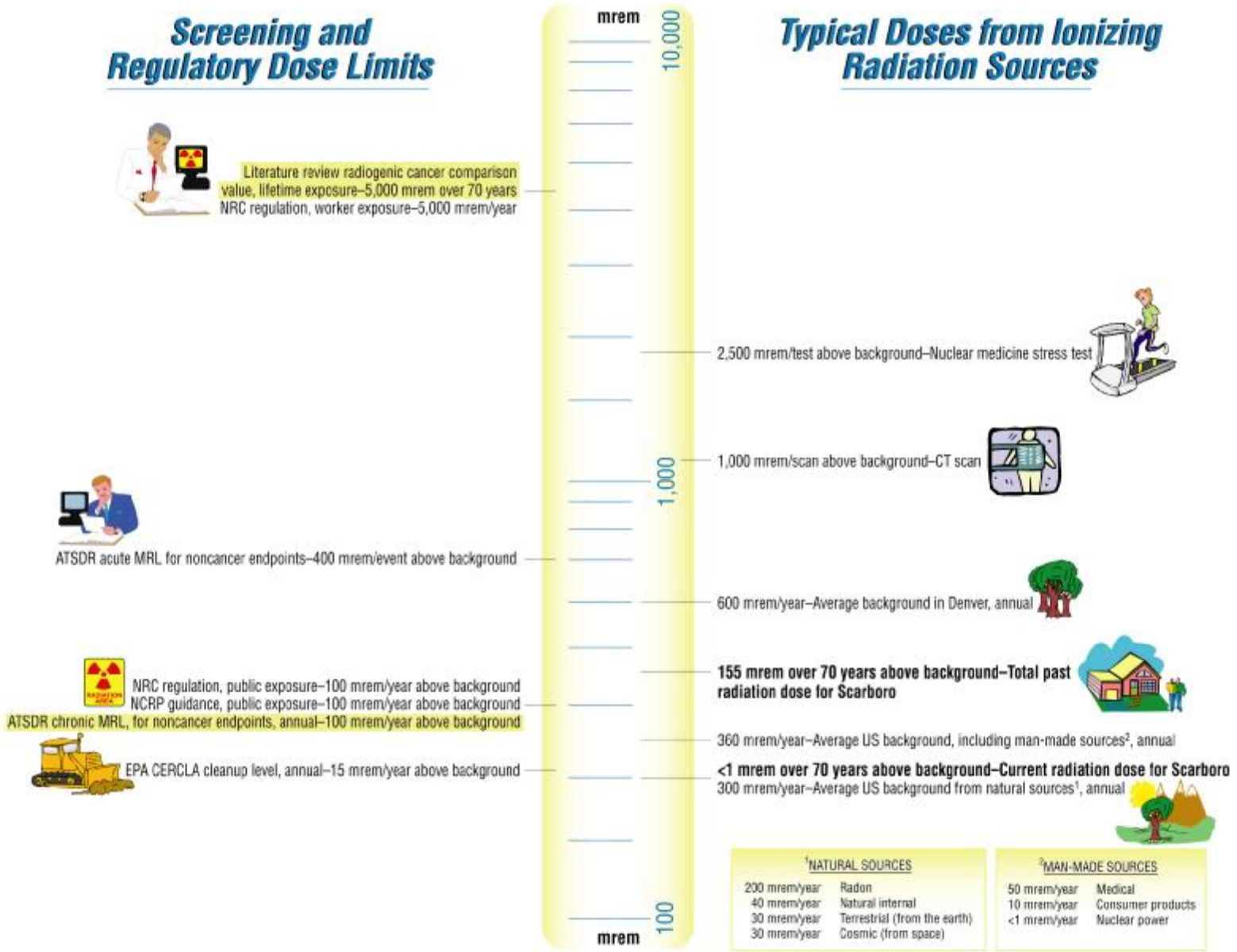
Exposure Pathway	Isotope	Committed Effective Dose Equivalents (CEDE) in mrem	Total CEDE for Each Exposure Pathway (mrem)
Sum of doses from the air pathway	U 234/235	34	40
	U 238	6	
Sum of doses from the surface water (EFPC) pathway	U 234/235	27	49
	U 238	22	
Sum of doses from the soil pathway	U 234/235	38	66
	U 238	28	
Total across all media	U 234/235	99	**155**
	U 238	56	

Source: ChemRisk 1999

The Task 6 level II CEDEs were converted from Sievert (Sv) to mrem by multiplying by 10^5. In addition, the values were multiplied by 1.35 (i.e., 70 years/52 years) for comparison with the ATSDR radiogenic cancer comparison value, which is based on a 70-year exposure.

Figure 8. Exposure Pathways Evaluated

Figure 9. Comparison of Radiation Doses



Additionally, it should be noted that several levels of conservatism were built into the Task 6 evaluation of past exposures. The Task 6 values that ATSDR relied on to evaluate past exposures came from a screening evaluation that routinely and appropriately used conservative and overly protective assumptions and approaches, which led to an overestimation of concentrations and doses. Even using these overestimated concentrations and doses, persons in the reference community, Scarboro, were exposed to levels of uranium that are below levels of health concern. Following is a list of conservative aspects in this evaluation.

1. The majority of the total uranium radiation dose (54% of the total U 234/235 dose and 78% of the total U 238 dose) is attributed to frequently eating fish from the EFPC and eating vegetables grown in contaminated soil over several years. If a person did not regularly eat fish from the creek or homegrown vegetables over a prolonged period of time (which is very probable), then that person's uranium dose would likely have been substantially lower than the estimated doses reported in this public health assessment.

2. The Task 6 report noted that late in the project it was ascertained that the Y-12 uranium releases for some of the years used to develop the empirical χ/Q (χ is chi) value may have been understated due to omission of some unmonitored release estimates. This would cause the empirical χ/Q values to be overestimated and in turn would cause the air concentrations to be overestimated.

3. According to ATSDR's regression analysis, the method that the Task 6 team used to estimate historical uranium air concentrations overestimated uranium 234/235 concentrations by as much as a factor of 5. Consequently, airborne uranium 234/235 doses based on this method were most likely overestimated.

4. Using the International Commission on Radiological Protection's dose coefficients tends to overestimate the actual radiation doses due to the built-in conservative assumptions (i.e., selecting variables that typically overestimate the true, but uncertain physical and

biological interactions associated with radiation exposure) (for examples, see Harrison et al. 2001; Leggett 2001).

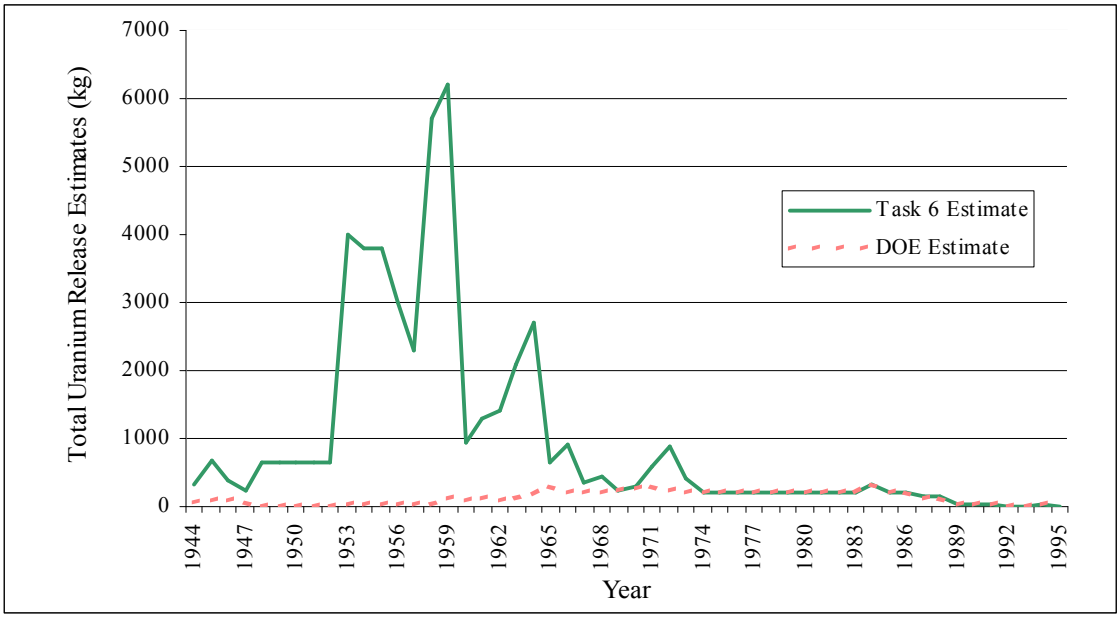
5. In evaluating the soil exposure pathway, the Task 6 team used EFPC floodplain soil data to calculate doses. Actual measured uranium concentrations in Scarboro soil are much lower than the uranium concentrations in the floodplain soil. Consequently, the uranium doses that were estimated for the residents were overestimated because of the use of the higher EFPC floodplain uranium concentrations. The estimated doses would be much lower if they were based on actual measured concentrations in Scarboro.

This conservatism and overestimation, used in the Task 6 evaluation, resulted in overestimation of radiation doses from uranium that the residents of Scarboro were exposed to in the past; however, even those overestimated doses were below levels of health concern. Therefore, Scarboro residents would not be expected to have any adverse health effects from past exposure to uranium. Each past exposure pathway is evaluated separately in the following sections.

Past Air Exposure Pathway

The Task 6 team independently evaluated past Y-12 airborne uranium releases and generated release estimates much higher than those previously reported by DOE (see Figure 10 and Table 5). They attributed the difference to DOE's use of incomplete sets of effluent monitoring data and release documents, along with their use of release estimates based on effluent monitoring data not adequately corrected to account for sampling biases (ChemRisk 1999). It is ATSDR's understanding that DOE and the community have not disputed the release estimates generated by the Task 6 team. Please see Section 2.0 in the Task 6 report for more details about how the airborne uranium release estimates were determined.

Figure 10. Annual Airborne Uranium Release Estimates for the Y-12 Plant



Source: ChemRisk 1999

Table 5. Annual Airborne Uranium Release Estimates for Y-12 Plant (1944–1995)

Year	Task 6 Estimate (kg)	DOE Estimate (kg)	Year	Task 6 Estimate (kg)	DOE Estimate (kg)
1944	310	55	1970	300	259
1945	670	102	1971	580	290
1946	390	102	1972	870	222
1947	250	55	1973	410	206
1948	650	0	1974	210	207
1949	650	0	1975	210	209
1950	650	0	1976	210	207
1951	650	0	1977	210	206
1952	650	0	1978	210	205
1953	4,000	30	1979	210	206
1954	3,800	32	1980	220	218
1955	3,800	32	1981	210	207
1956	3,000	43	1982	210	207
1957	2,300	41	1983	210	208
1958	5,700	41	1984	330	329
1959	6,200	120	1985	210	210
1960	930	99	1986	210	211
1961	1,300	109	1987	150	116
1962	1,400	100	1988	150	116
1963	2,100	103	1989	44*	44
1964	2,700	170	1990	21*	21
1965	640	281	1991	21*	21
1966	920	212	1992	7*	7
1967	340	212	1993	3*	3
1968	440	211	1994	24*	24
1969	250	223	1995	2*	2
			Total	**50,000**	**6,535**

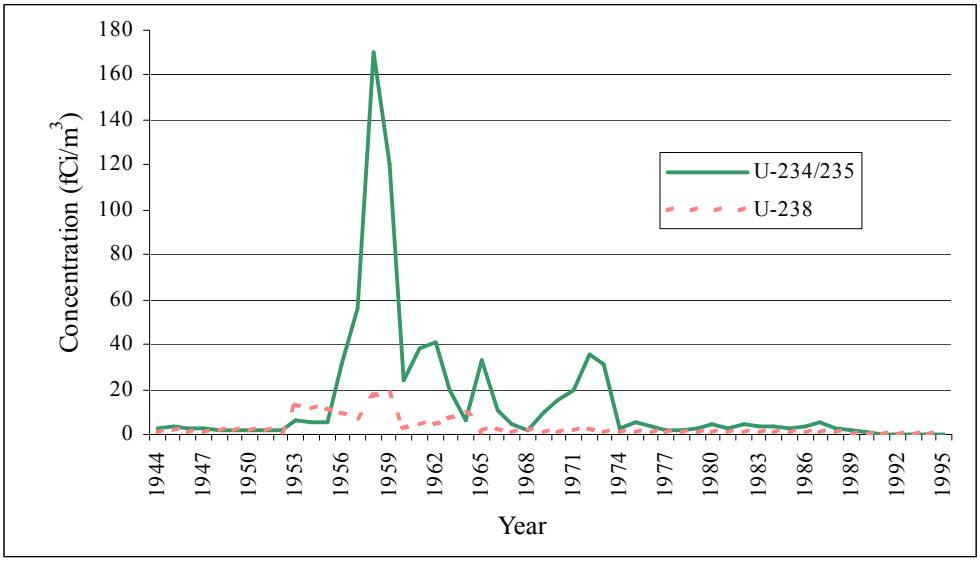
Source: ChemRisk 1999

* Values for 1989 to 1995 were based on releases reported by DOE. Release estimates for these years were not independently reconstructed during the dose reconstruction.

Using Task 6's newly generated annual airborne uranium release estimates for the Y-12 plant from 1944 to 1995 and the measured air radioactivity concentrations from DOE air monitoring station 46, located in the reference location of Scarboro, from 1986–1995 (DOE began monitoring station 46 in 1986), the Task 6 team used an empirical χ/Q (χ is chi) approach to estimate average annual air radioactivity concentrations in Scarboro from the 1944 to 1995 Y-12 plant uranium releases (see Figure 11 and Table 6). The empirical χ/Q is the ratio of measured air radioactivity concentration (air monitoring station 46 data) to release rate (Task 6 annual airborne uranium release estimates). Please see Section 3.0 in the Task 6 report for more details about how the uranium air concentrations were estimated.

The Task 6 team used these average annual U 234/235 and U 238 air radioactivity concentrations based on the empirical χ/Q method to calculated past uranium CEDEs to the Scarboro community via the air exposure pathways. These past uranium CEDEs for each air exposure pathway in Scarboro were summed to calculate the past U 234/235 CEDE of 34 mrem and the past U 238 CEDE of 6 mrem from the air pathway (see Table 4). The total uranium CEDE from the air exposure pathway in Scarboro, after being adjusted to reflect a 70-year exposure, is 40 mrem.

Figure 11. Task 6 Estimated Average Annual Air Radioactivity Concentrations in Scarboro from Y-12 Uranium Releases



Source: ChemRisk 1999

Table 6. Task 6 Estimated Average Annual Air Radioactivity Concentrations in Scarboro from Y-12 Uranium Releases (1944–1995)

Year	U 234/235 (fCi/m^3)	U 238 (fCi/m^3)	Year	U 234/235 (fCi/m^3)	U 238 (fCi/m^3)
1944	2.4	1.1	1970	15	0.91
1945	4.0	2.2	1971	20	1.8
1946	3.0	1.3	1972	36	2.7
1947	2.5	0.81	1973	31	1.2
1948	1.6	2.1	1974	2.7	0.67
1949	1.6	2.1	1975	5.0	0.67
1950	1.6	2.1	1976	3.2	0.67
1951	1.6	2.1	1977	1.6	0.67
1952	1.6	2.1	1978	1.7	0.67
1953	6.5	13	1979	2.3	0.67
1954	5.6	12	1980	4.6	0.71
1955	5.7	12	1981	2.8	0.67
1956	31	10	1982	4.7	0.66
1957	56	7.8	1983	4.0	0.67
1958	170	17	1984	3.4	1.1
1959	120	19	1985	2.7	0.68
1960	24	3.0	1986	3.4	0.69
1961	38	4.2	1987	5.7	0.48
1962	41	4.5	1988	2.9	0.47
1963	20	6.8	1989	1.4	0.024
1964	6.5	8.8	1990	0.77	0.014
1965	33	2.0	1991	0.38	0.063
1966	11	3.0	1992	0.36	0.022
1967	1.9	1.1	1993	0.29	0.0093
1968	2.2	1.4	1994	0.31	0.078
1969	9.4	0.77	1995	0.17	0.0055

Source: ChemRisk 1999

fCi/m^3 is femtocuries per cubic meter. 1 femtocurie equals 1×10^{-15} curies.
Concentrations were estimated using the empirical χ/Q approach.
All values are rounded to two significant figures.

The Task 6 report noted that late in the project it was ascertained that the Y-12 uranium releases for some of the years used to develop the empirical χ/Q value may have been understated (ChemRisk 1999). This would cause the empirical χ/Q values to also be overestimated and in turn would cause the estimated average air radioactivity concentrations in Scarboro to be overestimated (ChemRisk 1999).

ATSDR evaluated the Task 6 methodology for estimating annual average air radioactivity concentrations in Scarboro from Y-12 uranium releases relative to measured uranium air radioactivity concentrations at the DOE air monitoring station 46 in Scarboro from 1986 to 1995.

According to ATSDR's evaluation, the Task 6 empirical χ/Q estimation of the average U 234/235 air radioactivity concentrations for Scarboro from 1986 to 1995 consistently overestimated the measured U 234/235 air radioactivity concentrations in Scarboro from 1986 to 1995 (see Figure 12). In addition, estimated average U 238 air radioactivity concentrations using the Task 6 empirical χ/Q method overestimated or slightly underestimated measured U 238 air radioactivity concentrations (see Figure 13). A detailed discussion of the linear regression evaluation by ATSDR is in Appendix E.

Consequently, the estimated average U 234/235 and U 238 air radioactivity concentrations at Scarboro from 1945 to 1995 Y-12 uranium releases (see Table 6) are most likely overestimated because these concentrations are based on the Task 6 empirical χ/Q value. In addition, the Task 6 team used these likely overestimated average U 234/235 and U 238 air radioactivity concentrations based on the empirical χ/Q method to calculated past uranium CEDEs to the Scarboro community via the air exposure pathways (see Table 7 for a list of air exposure pathways considered by the Task 6 team). As shown in Table 7, the majority of the estimated total radiation dose via the air pathway in Scarboro from Y-12 uranium releases is attributed to inhalation of airborne particles.

Figure 12. Comparison of Average U234/235 Air Radioactivity Concentrations in Scarboro Measured vs. Estimated

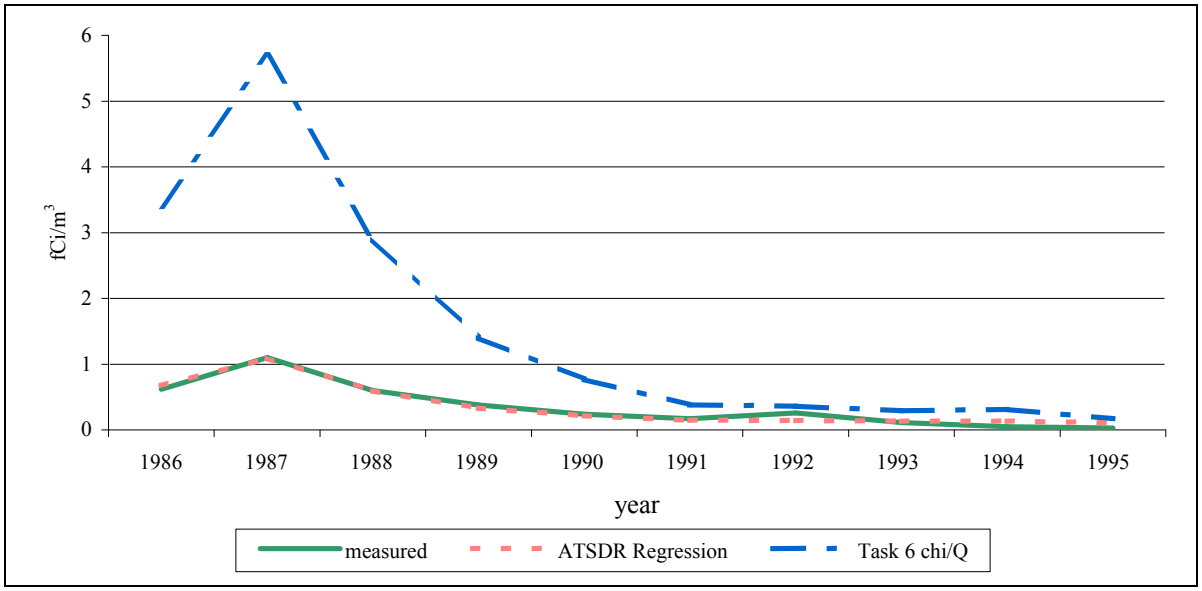


Figure 13. Comparison of Average U 238 Air Radioactivity Concentrations In Scarboro Measured vs. Estimated

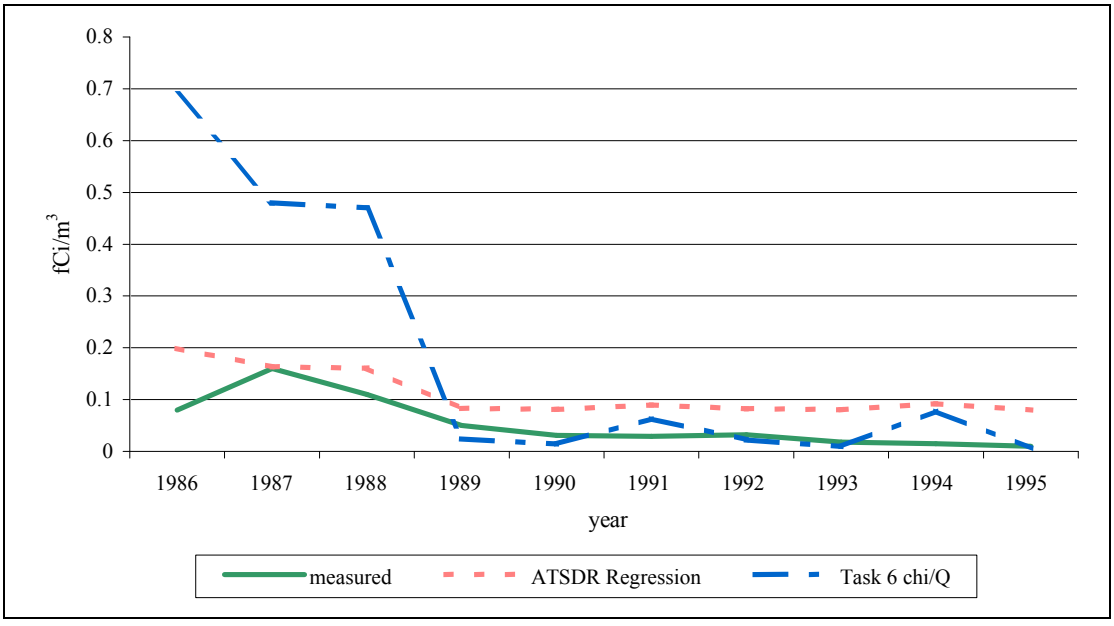


Table 7. Air Pathways Considered by the Task 6 Team

Exposure Pathway to Humans	% Pathway Contributes to Total Radiation Dose	
	U 234/235	U 238
Inhalation of airborne particles	30%	10%
Direct contact with air containing uranium particulates	<1%	<1%
Ingestion of meat from livestock that inhaled airborne particles	<1%	<1%
Ingestion of milk from dairy cows that inhaled airborne particles	<1%	<1%
Consumption of vegetables contaminated with deposited particles	4%	<1%
Consumption of meat from livestock that ate pasture contaminated with deposited particles	<1%	<1%
Consumption of milk from dairy cows that ate pasture contaminated with deposited particles	<1%	<1%

Source: ChemRisk 1999

To calculate an estimated uranium radiation dose, the Task 6 team used the latest dose coefficients recommended by the International Commission on Radiological Protection (ICRP) (ChemRisk 1999). Dose coefficients are a combination of factors containing much uncertainty. To compensate for these uncertainties, the ICRP added conservative assumptions to the dose conversion factor values, which resulted in potentially overestimated radiation doses. Please see Appendix F for additional information about the conservatism built into ICRP's dose coefficients (for examples, see Harrison et al. 2001; Leggett 2001).

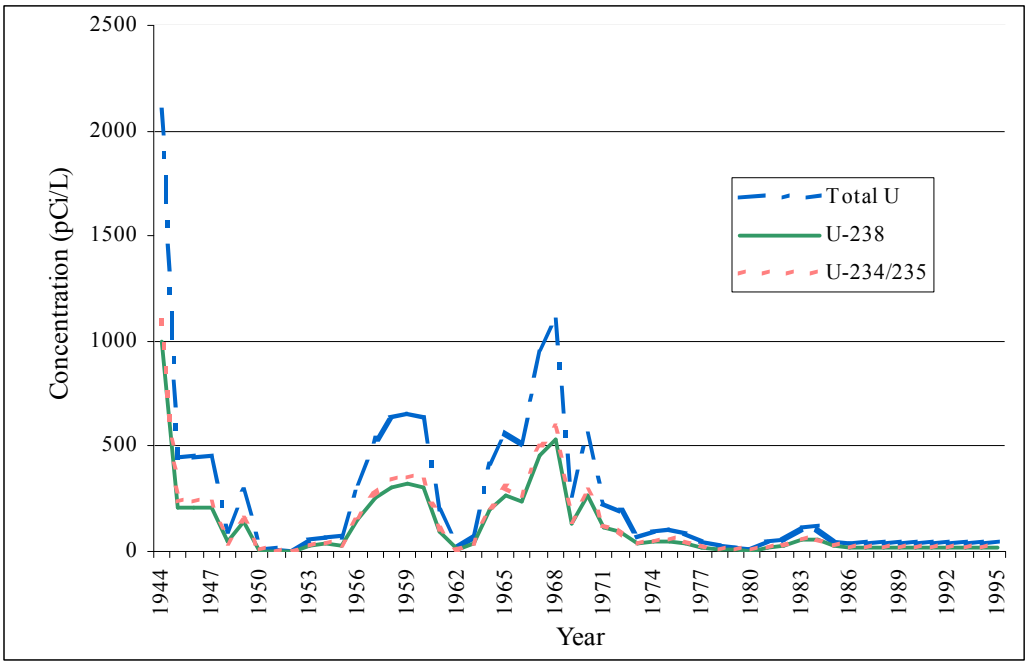
Past Surface Water Exposure Pathway

The closest surface water body to the reference location, Scarboro, is EFPC, which originates from within the Y-12 plant boundary, flows through the city of Oak Ridge, and confluences with Poplar Creek (ChemRisk 1999). EFPC passes about 0.4 miles to the northeast of the populated area of Scarboro at its closest point (ChemRisk 1999). EFPC represents the most credible source of surface water exposure for Scarboro residents (ChemRisk 1999). Public access to the creek exists after it leaves the reservation. However, the creek appears to be too shallow for swimming, although some areas, are suitable for wading and fishing.

To calculate annual average uranium radioactivity concentrations in EFPC from 1944 to 1995, the Task 6 team divided the annual waterborne uranium release estimates from the Y-12 plant by

the EFPC annual flow rate (see Figure 14 and Table 8). Please see Section 3.3 in the Task 6 report for more details about how the uranium surface water concentrations were determined.

Figure 14. Average Annual Uranium Concentrations in EFPC Surface Water



Source: ChemRisk 1999

The Task 6 team then calculated estimated CEDEs via the EFPC surface water exposure pathways. The total past uranium CEDE from EFPC surface water exposure pathways, after being adjusted to reflect a 70-year exposure[6], is 49 mrem (see Table 4). As shown in Table 9, the majority of the exposure to uranium is attributed to frequently eating fish from EFPC (24% of the total U 234/235 dose and 35% of the total U 238 dose). It is ATSDR's understanding that EFPC is not a very productive fishing location and very few people actually eat fish from the creek. If a person did not frequently eat EFPC fish over a prolonged period of time, the person's uranium radioactivity dose from the surface water pathway would be expected to be substantially lower than the estimated radioactivity doses reported in this public health assessment.

[6] The total past uranium CEDEs for the EFPC surface water pathway from the Task 6 report were multiplied by 1.35 (70 years/52 years) for comparison with ATSDR's comparison values.

Table 8. Average Annual Uranium Concentrations in East Fork Poplar Creek Surface Water (1944–1995)

Year	Total Uranium (pCi/L)	U 238 (pCi/L)	U 234/235 (pCi/L)	Uranium (mg/L)	Year	Total Uranium (pCi/L)	U 238 (pCi/L)	U 234/235 (pCi/L)	Uranium (mg/L)
1944	2,100	1,000	1,100	3.0	1970	560	270	290	0.79
1945	450	210	240	0.63	1971	230	110	120	0.32
1946	450	210	240	0.63	1972	190	92	100	0.27
1947	450	210	240	0.63	1973	71	34	37	0.099
1948	99	47	52	0.14	1974	99	47	52	0.14
1949	290	140	150	0.41	1975	104	50	55	0.15
1950	9.1	4.3	4.8	0.013	1976	87	42	46	0.12
1951	6.2	2.9	3.3	0.0088	1977	48	23	25	0.067
1952	0.0070	0.0033	0.0037	0.000010	1978	26	12	14	0.036
1953	61	29	32	0.085	1979	23	11	12	0.033
1954	71	34	37	0.099	1980	9.9	4.7	5.2	0.014
1955	68	32	36	0.095	1981	44	21	23	0.062
1956	320	150	170	0.45	1982	54	25	28	0.075
1957	540	260	280	0.76	1983	110	54	60	0.16
1958	640	300	340	0.89	1984	110	54	60	0.16
1959	660	320	350	0.93	1985	50	24	26	0.070
1960	640	300	340	0.90	1986	42	20	22	0.058
1961	200	93	100	0.27	1987	42	20	22	0.058
1962	14.8	7.0	7.8	0.021	1988	42	20	22	0.058
1963	80	38	42	0.11	1989	42	20	22	0.058
1964	420	200	220	0.59	1990	42	20	22	0.058
1965	570	270	300	0.79	1991	42	20	22	0.058
1966	510	240	270	0.71	1992	42*	20*	22*	0.058*
1967	970	460	510	1.4	1993	42*	20*	22*	0.058*
1968	1,100	530	590	1.6	1994	42*	20*	22*	0.058*
1969	270	130	140	0.38	1995	42*	20*	22*	0.058*
EFPC Average Concentrations (1944–1995)							**121**	**134**	**0.36**

Source: ChemRisk 1999

*Assumed same concentration as 1991.
All values are rounded to two significant figures.

Table 9. Surface Water Pathways Considered by the Task 6 Team

Exposure Pathway to Humans	% Pathway Contributes to Total Radiation Dose	
	U 234/235	U 238
Incidental ingestion of EFPC water	<1%	<1%
Ingestion of meat from livestock that drank water from EFPC	<1%	<1%
Ingestion of milk from dairy cows that drank water from EFPC	2%	3%
Consumption of fish from EFPC	24%	35%
Immersion in EFPC water	<1%	<1%

Source: ChemRisk 1999

As with the air pathway, to calculate an estimated uranium radiation dose for the surface water pathway, the Task 6 team used the conservative dose coefficients recommended by the ICRP (ChemRisk 1999). Consequently, the radiation doses are most likely overestimated. Please see Appendix F for additional information about the conservatism built into ICRP's dose coefficients (for examples, see Harrison et al. 2001; Leggett 2001).

Past Soil Exposure Pathway

At the beginning of the Task 6 dose reconstruction, uranium soil data from the reference location, Scarboro, were not available. In its place, uranium soil data from the EFPC floodplain were used as a surrogate for past uranium radioactivity concentrations in Scarboro soil (ChemRisk 1999). The Task 6 team used the average soil concentrations of U 234/235 and U 238 collected from EFPC floodplain between the Y-12 boundary and EFPC MILE 8.8 to estimate past uranium radioactivity doses via the soil pathways in Scarboro. Please see Section 3.4 in the Task 6 report for more details about how uranium concentrations in soil were determined.

The Task 6 report noted that the use of uranium concentrations in EFPC floodplain soil to represent uranium concentrations in Scarboro soil, which is outside of the floodplain, probably introduced conservatism (ChemRisk 1999). The Task 6 report also noted that the uranium concentrations in EFPC floodplain soil, which were available at that time, were not sufficient to support a defensible analysis of average or typical exposure to members of the Scarboro community during the years from the community's inception to the present (ChemRisk 1999).

The Task 6 team estimated past uranium radiation doses by using uranium radioactivity concentrations in EFPC floodplain soil to calculate estimated CEDEs via the soil exposure pathways to residents of Scarboro. The total past uranium CEDE from the soil pathway, after being adjusted to reflect a 70-year exposure[7], is 66 mrem (see Table 4). As shown in Table 10, the majority of the past uranium radiation dose (30% of the total U 234/235 dose and 43% of the total U 238 dose) for the soil pathways is attributed to frequently eating vegetables grown in contaminated floodplain soil over a prolonged period of time. If a person did not frequently eat homegrown vegetables over a prolonged period of time, the person's uranium dose from the soil pathway would have been substantially lower than the estimated doses reported in this public health assessment.

Table 10. Soil Pathways Considered by the Task 6 Team

Exposure Pathway to Humans	% Pathway Contributes to Total Radiation Dose	
	U 234/235	U 238
Inhalation of resuspended dust	2%	3%
Ingestion of soil	<1%	1%
Consumption of meat from livestock that ingested soil	<1%	<1%
Consumption of milk from dairy cows that ingested soil	<1%	1%
Consumption of vegetables grown in contaminated soil	30%	43%
Consumption of meat from livestock that ate pasture grown in contaminated soil	<1%	<1%
Consumption of milk from dairy cows that ate pasture grown in contaminated soil	<1%	1%
External exposure to contaminated soil	3%	<1%

Source: ChemRisk 1999

Toward the end of the Task 6 project (in May 1998), 40 soil samples from the Scarboro community were collected by the Environmental Sciences Institute at FAMU (FAMU 1998). In 2001, EPA collected six soil samples from the Scarboro community to validate the 1998 FAMU results (EPA 2002b). An independent review by Auxier & Associates (Prichard 1998) of the Task 6 report and the report generated by FAMU noted that aerial deposition of uranium was the

[7] The total past uranium CEDEs for the EFPC floodplain soil pathway from the Task 6 report were multiplied by 1.35 (70 years/52 years) for comparison with ATSDR's comparison values.

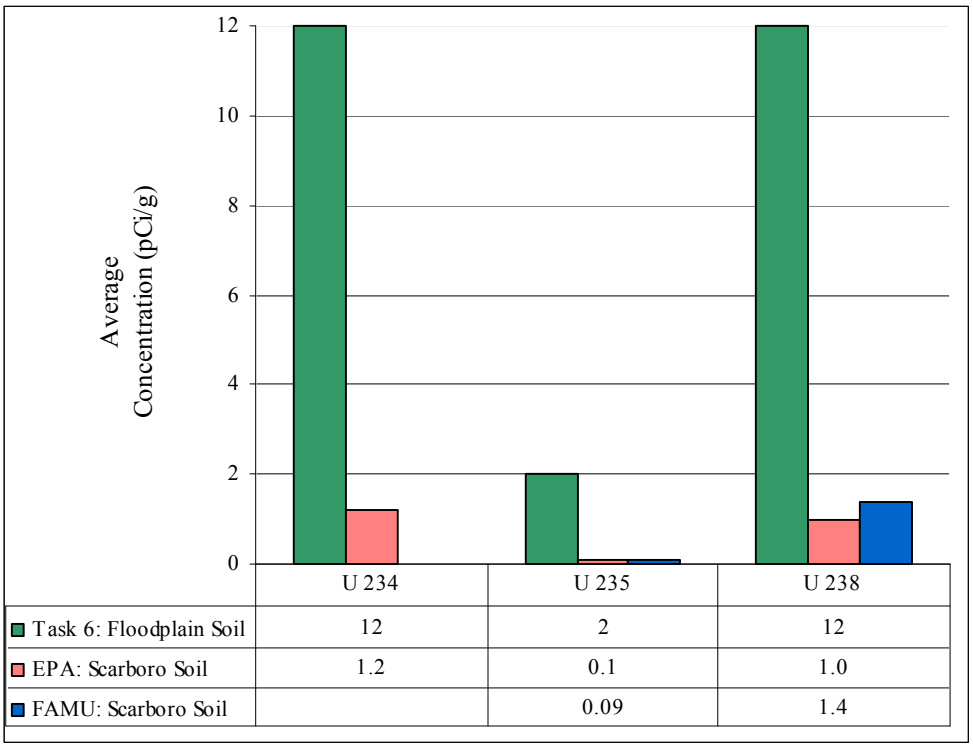
primary source of uranium contamination in Scarboro soil, rather than the transportation of EFPC floodplain soils for use as fill. It was concluded that the radioactivity concentrations of uranium within the Task 6 report (based on EFPC floodplain soil samples) are inconsistent with the radioactivity concentrations of uranium observed in Scarboro soils and that the Task 6 assumptions are unlikely to accurately represent past uranium radioactivity concentrations in Scarboro soil (Prichard 1998). Additionally, technical reviews of the Auxier report, the Task 6 report, and the report generated by FAMU noted that the use of actual Scarboro soil data is preferable to the reliance on floodplain soil data. However, the reviewers cautioned using the FAMU data to estimate past exposure without additional research into the environmental distribution of uranium in the area[8]. Appendix G contains a summary of the technical reviewers' comments.

Based on the FAMU and EPA uranium soil data, the actual uranium radioactivity concentrations in Scarboro soil were much lower than the uranium radioactivity concentrations from the EFPC floodplain soil that the Task 6 team used as a surrogate. As shown in Figure 15 and Table 11, the actual uranium radioactivity concentrations in Scarboro soil are approximately 8 to 22 times less than the EFPC floodplain soil concentrations. Consequently, if the uranium radioactivity concentrations from Scarboro soil were used to estimate the past uranium radioactivity doses instead of the EFPC floodplain soil, the total past uranium CEDE of 66 mrem for the soil exposure pathway in Table 4 would have been significantly lower.

As with the air and surface water pathways, to calculate an estimated uranium radiation dose for the soil exposure pathway, the Task 6 team used the conservative dose coefficients recommended by the ICRP, causing the radiation doses to be overestimated (ChemRisk 1999). Please see Appendix F for additional information about the conservatism built into ICRP's dose coefficients.

[8] The mobility of uranium in soil and its vertical transport (leaching) to groundwater depend on the form of uranium and the properties of the soil, as well as the amount of water available (ATSDR 1999a). The sorption of uranium in most soils is such that it may not leach readily from soil to groundwater; the migration is typically quite local (ATSDR 1999a). In addition, the predominant chemical form of uranium released into the air from the Y-12 plant was highly insoluble uranium oxide (ChemRisk 1999). Leaching is not expected to be a major loss mechanism for insoluble materials, which bind tightly to soil particles (Prichard 1998).

Figure 15. Comparison of the Average Uranium Radioactivity Concentrations EFPC Floodplain Soil vs. Scarboro Soil



Sources: ChemRisk 1999, EPA 2002b, FAMU 1998

FAMU did not analyze for U 234.

Table 11. Comparison of Average Uranium Radioactivity Concentrations EFPC Floodplain Soil vs. Scarboro Soil

		Average U 234 Concentration (pCi/g)	Average U 235 Concentration (pCi/g)	Average U 238 Concentration (pCi/g)
Task 6: Floodplain Soil		12	2	12
EPA: Scarboro Soil		1.2	0.1	1.0
FAMU: Scarboro Soil		not available	0.09	1.4
How much lower are the soil radioactivity concentrations in Scarboro than the EFPC floodplain?	Task 6 vs EPA	10 times	20 times	12 times
	Task 6 vs FAMU	not available	22 times	8.6 times

Sources: ChemRisk 1999, EPA 2002b, FAMU 1998

III.B.1.b. Past Chemical Effects

ATSDR evaluated whether exposure to past levels of uranium released from the Y-12 plant would cause harmful chemical effects in communities near the Y-12 plant, especially the reference location (the Scarboro community), which is considered the area that would have received the highest exposures. Based upon the chemical toxicity of uranium, residents living near the ORR were not exposed through inhalation of air or ingestion of surface water and soil to harmful levels of uranium in the past.

Past Exposure via Inhalation

Using the average air concentrations generated by the Task 6 team (converted from radioactivity values to mass units[9]), ATSDR calculated the average air concentrations of total uranium in Scarboro for each year from 1944 to 1995 and compared them to the ATSDR MRL for inhalation of insoluble uranium (see Table 12). All the average air concentrations of uranium in Scarboro are less than 1% of the ATSDR MRL. As shown in Figure 16, the average annual air concentrations of total uranium are well below the inhalation MRL of 0.008 mg/m^3 for every year. Values below the MRL are not of health concern, so they do not warrant any further evaluation. Additionally, as noted previously in the past radiation effects section, the uranium air concentrations are most likely overestimated. Therefore, ATSDR concludes that residents living near Oak Ridge were not exposed to airborne uranium at levels that would cause harmful chemical effects.

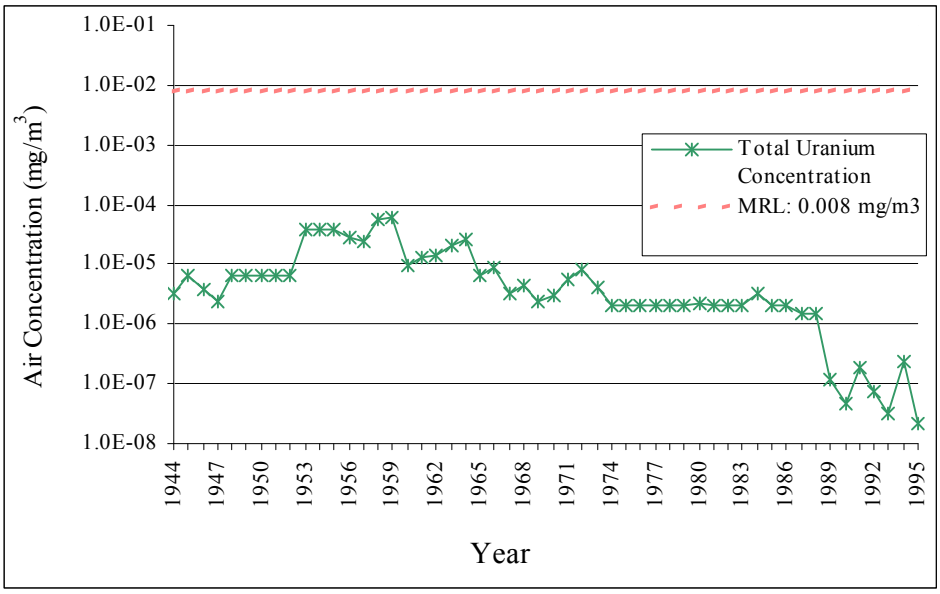
[9] Each individual isotope (U 234, U 235, and U 238) has a separate and distinct half life and mass. Therefore, one can convert the activity of each individual isotope using its specific activity expressed as curies of radioactivity per gram of pure radionuclide (0.331 pCi/µg for U 238, 0.34 pCi/µg for U 234, 0.0154 pCi/µg for U 235). To convert the radioactive measurement of the isotope to grams, one divides the radioactive measurement by its specific activity while ensuring the units of measurement are consistent.

Table 12. Estimated Average Annual Air Concentrations of Uranium in Scarboro

Year	Total Uranium Concentration (mg/m^3)	Is the concentration above the MRL?	Percent of MRL	Year	Total Uranium Concentration (mg/m^3)	Is the concentration above the MRL?	Percent of MRL
1944	3.2×10^{-6}	no	0.04%	1970	2.9×10^{-6}	no	0.04%
1945	6.6×10^{-6}	no	0.08%	1971	5.7×10^{-6}	no	0.07%
1946	3.8×10^{-6}	no	0.05%	1972	8.2×10^{-6}	no	0.10%
1947	2.5×10^{-6}	no	0.03%	1973	4.0×10^{-6}	no	0.05%
1948	6.4×10^{-6}	no	0.08%	1974	2.1×10^{-6}	no	0.03%
1949	6.4×10^{-6}	no	0.08%	1975	2.1×10^{-6}	no	0.03%
1950	6.4×10^{-6}	no	0.08%	1976	2.1×10^{-6}	no	0.03%
1951	6.4×10^{-6}	no	0.08%	1977	2.0×10^{-6}	no	0.03%
1952	6.4×10^{-6}	no	0.08%	1978	2.1×10^{-6}	no	0.03%
1953	4.0×10^{-5}	no	0.50%	1979	2.1×10^{-6}	no	0.03%
1954	3.7×10^{-5}	no	0.47%	1980	2.2×10^{-6}	no	0.03%
1955	3.7×10^{-5}	no	0.47%	1981	2.0×10^{-6}	no	0.03%
1956	2.9×10^{-5}	no	0.36%	1982	2.0×10^{-6}	no	0.03%
1957	2.4×10^{-5}	no	0.30%	1983	2.1×10^{-6}	no	0.03%
1958	5.4×10^{-5}	no	0.68%	1984	3.3×10^{-6}	no	0.04%
1959	6.0×10^{-5}	no	0.75%	1985	2.1×10^{-6}	no	0.03%
1960	9.3×10^{-6}	no	0.12%	1986	2.1×10^{-6}	no	0.03%
1961	1.3×10^{-5}	no	0.16%	1987	1.5×10^{-6}	no	0.02%
1962	1.4×10^{-5}	no	0.17%	1988	1.4×10^{-6}	no	0.02%
1963	2.1×10^{-5}	no	0.26%	1989	1.2×10^{-7}	no	<0.01%
1964	2.6×10^{-5}	no	0.33%	1990	4.7×10^{-8}	no	<0.01%
1965	6.3×10^{-6}	no	0.08%	1991	1.9×10^{-7}	no	<0.01%
1966	9.1×10^{-6}	no	0.11%	1992	7.1×10^{-8}	no	<0.01%
1967	3.3×10^{-6}	no	0.04%	1993	3.2×10^{-8}	no	<0.01%
1968	4.4×10^{-6}	no	0.05%	1994	2.4×10^{-7}	no	<0.01%
1969	2.5×10^{-6}	no	0.03%	1995	2.1×10^{-8}	no	<0.01%

None of the concentrations exceeded the ATSDR inhalation MRL of 0.008 mg/m^3 (i.e., 8.0×10^{-3}) for insoluble uranium.

Figure 16. Estimated Average Annual Air Concentrations of Total Uranium in Scarboro



The air concentration values can be written different ways, for example 1.0E-01 mg/m^3 is the same as 1.0×10^{-1} mg/m^3 and 0.1 mg/m^3.

Past Exposure via Ingestion

The Task 6 team calculated an annual average intake of uranium from 1944 to 1995 through both surface water and soil exposure pathways to residents of Scarboro. They considered (1) incidental ingestion of EFPC water, (2) ingestion of meat from livestock that drank water from EFPC, (3) ingestion of milk from dairy cows that drank water from EFPC, (4) consumption of fish from EFPC, (5) ingestion of soil, (6) consumption of meat from livestock that ingested soil, (7) consumption of milk from dairy cows that ingested soil, (8) consumption of vegetables grown in contaminated soil, (9) consumption of meat from livestock that ate pasture grown in contaminated soil, and (10) consumption of milk from dairy cows that ate pasture grown in contaminated soil (Figure 8 shows the exposure pathways evaluated).

ATSDR used the Task 6 annual average intakes of uranium to calculate past uranium doses for an adult male, adult female, 12-year-old child, and 6-year-old child for each year from 1944 to 1995 (see Table 13). Please see Section *III.A.2. Evaluating Exposures* for an explanation of how ATSDR calculated doses. As shown in Figure 17, the doses for several of the individual years exceeded ATSDR's intermediate-duration oral MRL for chemical toxicity of uranium

(0.002 milligrams per kilogram per day; mg/kg/day). Remember that the MRL is a screening level; values below the MRL are not of health concern and values above are used to determine whether additional evaluation is needed. Therefore, ATSDR further investigated the toxicologic literature to find doses associated with known health effects. The lowest oral (ingestion) dose of uranium that has caused the most sensitive harmful health effect considered to be of relevance to humans was 0.05 mg/kg/day which caused renal (kidney) toxicity in rabbits (ATSDR 1999a). The rabbit is the mammalian species most sensitive to uranium kidney toxicity and is likely to be even more sensitive than humans (ATSDR 1999a). Therefore, ATSDR is comfortable with extrapolating the results from this animal toxicity study to humans. This oral uranium dose of 0.05 mg/kg/day is the minimum lowest-observed-adverse-effect level (LOAEL) that is used by ATSDR to derive the MRL for intermediate-duration oral exposure to uranium. This intermediate-duration oral MRL is also protective for chronic-duration oral exposure because the renal effects of uranium exposure are more dependent on the dose than on the duration of exposure. All the estimated past uranium doses from ingestion of uranium via the soil and surface water pathways in Table 13 and Figure 17 are well below the LOAEL of 0.05 mg/kg/day at which health effects have been observed (renal toxicity observed in rabbits at doses of 0.05 mg/kg/day; ATSDR 1999a). Therefore, ATSDR concludes that residents living near Oak Ridge were not exposed to uranium at levels that would cause harmful chemical effects.

Table 13. Estimated Average Annual Doses from Ingestion of Uranium via the Soil and Surface Water Pathways (1944–1995)*

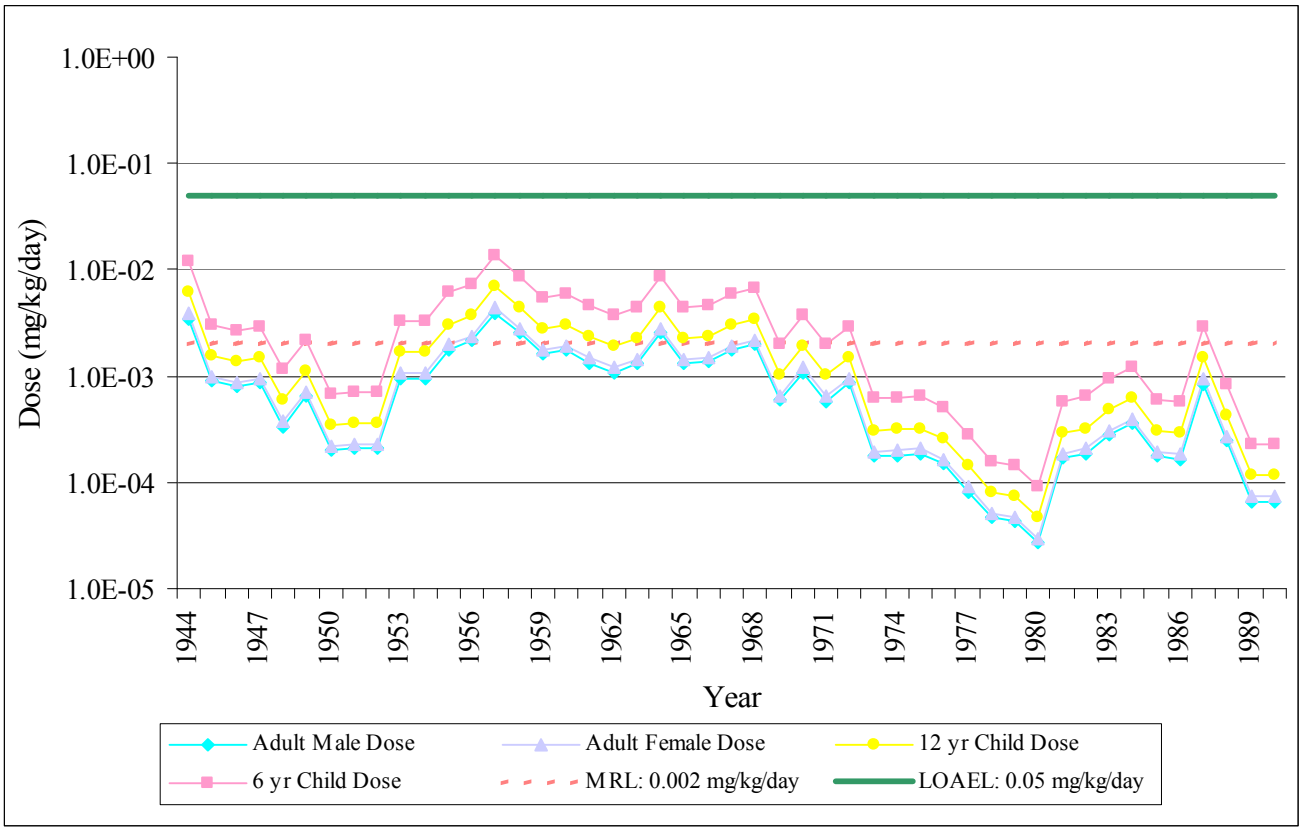
Year	Annual Average Intake (mg/d)	Dose (mg/kg/day)				Is the dose above the MRL?			
		Adult Male	Adult Female	12-yr Child	6-yr Child	Adult Male	Adult Female	12-yr Child	6-yr Child
1944	0.273	3.5×10^{-3}	3.9×10^{-3}	6.1×10^{-3}	1.2×10^{-2}	yes	yes	yes	yes
1945	0.069	8.9×10^{-4}	9.7×10^{-4}	1.5×10^{-3}	3.0×10^{-3}	no	no	no	yes
1946	0.061	7.8×10^{-4}	8.6×10^{-4}	1.4×10^{-3}	2.7×10^{-3}	no	no	no	yes
1947	0.066	8.5×10^{-4}	9.4×10^{-4}	1.5×10^{-3}	2.9×10^{-3}	no	no	no	yes
1948	0.026	3.4×10^{-4}	3.7×10^{-4}	5.9×10^{-4}	1.1×10^{-3}	no	no	no	no
1949	0.050	6.5×10^{-4}	7.1×10^{-4}	1.1×10^{-3}	2.2×10^{-3}	no	no	no	yes
1950	0.015	2.0×10^{-4}	2.2×10^{-4}	3.4×10^{-4}	6.7×10^{-4}	no	no	no	no
1951	0.016	2.1×10^{-4}	2.3×10^{-4}	3.6×10^{-4}	7.1×10^{-4}	no	no	no	no
1952	0.016	2.1×10^{-4}	2.3×10^{-4}	3.6×10^{-4}	7.1×10^{-4}	no	no	no	no
1953	0.075	9.6×10^{-4}	1.1×10^{-3}	1.7×10^{-3}	3.3×10^{-3}	no	no	no	yes
1954	0.075	9.6×10^{-4}	1.1×10^{-3}	1.7×10^{-3}	3.3×10^{-3}	no	no	no	yes
1955	0.139	1.8×10^{-3}	2.0×10^{-3}	3.1×10^{-3}	6.1×10^{-3}	no	no	yes	yes
1956	0.170	2.2×10^{-3}	2.4×10^{-3}	3.8×10^{-3}	7.4×10^{-3}	yes	yes	yes	yes
1957	0.308	4.0×10^{-3}	4.3×10^{-3}	6.8×10^{-3}	1.3×10^{-2}	yes	yes	yes	yes
1958	0.198	2.5×10^{-3}	2.8×10^{-3}	4.4×10^{-3}	8.6×10^{-3}	yes	yes	yes	yes
1959	0.125	1.6×10^{-3}	1.8×10^{-3}	2.8×10^{-3}	5.4×10^{-3}	no	no	yes	yes
1960	0.138	1.8×10^{-3}	1.9×10^{-3}	3.1×10^{-3}	6.0×10^{-3}	no	no	yes	yes
1961	0.104	1.3×10^{-3}	1.5×10^{-3}	2.3×10^{-3}	4.5×10^{-3}	no	no	yes	yes
1962	0.084	1.1×10^{-3}	1.2×10^{-3}	1.9×10^{-3}	3.7×10^{-3}	no	no	no	yes
1963	0.103	1.3×10^{-3}	1.4×10^{-3}	2.3×10^{-3}	4.5×10^{-3}	no	no	yes	yes
1964	0.201	2.6×10^{-3}	2.8×10^{-3}	4.5×10^{-3}	8.7×10^{-3}	yes	yes	yes	yes
1965	0.104	1.3×10^{-3}	1.5×10^{-3}	2.3×10^{-3}	4.5×10^{-3}	no	no	yes	yes
1966	0.108	1.4×10^{-3}	1.5×10^{-3}	2.4×10^{-3}	4.7×10^{-3}	no	no	yes	yes
1967	0.138	1.8×10^{-3}	1.9×10^{-3}	3.1×10^{-3}	6.0×10^{-3}	no	no	yes	yes
1968	0.154	2.0×10^{-3}	2.2×10^{-3}	3.4×10^{-3}	6.7×10^{-3}	no	yes	yes	yes
1969	0.046	5.9×10^{-4}	6.5×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	no	no	no	no
1970	0.085	1.1×10^{-3}	1.2×10^{-3}	1.9×10^{-3}	3.7×10^{-3}	no	no	no	yes
1971	0.045	5.8×10^{-4}	6.4×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	no	no	no	no
1972	0.068	8.7×10^{-4}	9.5×10^{-4}	1.5×10^{-3}	2.9×10^{-3}	no	no	no	yes
1973	0.014	1.8×10^{-4}	2.0×10^{-4}	3.1×10^{-4}	6.1×10^{-4}	no	no	no	no
1974	0.014	1.8×10^{-4}	2.0×10^{-4}	3.1×10^{-4}	6.1×10^{-4}	no	no	no	no
1975	0.015	1.9×10^{-4}	2.1×10^{-4}	3.3×10^{-4}	6.4×10^{-4}	no	no	no	no
1976	0.012	1.5×10^{-4}	1.6×10^{-4}	2.6×10^{-4}	5.1×10^{-4}	no	no	no	no
1977	0.006	8.2×10^{-5}	9.0×10^{-5}	1.4×10^{-4}	2.8×10^{-4}	no	no	no	no
1978	0.004	4.6×10^{-5}	5.1×10^{-5}	8.0×10^{-5}	1.6×10^{-4}	no	no	no	no
1979	0.003	4.3×10^{-5}	4.8×10^{-5}	7.5×10^{-5}	1.5×10^{-4}	no	no	no	no
1980	0.002	2.7×10^{-5}	3.0×10^{-5}	4.7×10^{-5}	9.1×10^{-5}	no	no	no	no
1981	0.013	1.7×10^{-4}	1.8×10^{-4}	2.9×10^{-4}	5.7×10^{-4}	no	no	no	no
1982	0.015	1.9×10^{-4}	2.1×10^{-4}	3.2×10^{-4}	6.4×10^{-4}	no	no	no	no
1983	0.022	2.8×10^{-4}	3.1×10^{-4}	4.9×10^{-4}	9.6×10^{-4}	no	no	no	no

* This table is continued on the following page.

Year	Annual Average Intake (mg/d)	Dose (mg/kg/day)				Is the dose above the MRL?			
		Adult Male	Adult Female	12-yr Child	6-yr Child	Adult Male	Adult Female	12-yr Child	6-yr Child
1984	0.028	3.6×10^{-4}	4.0×10^{-4}	6.2×10^{-4}	1.2×10^{-3}	no	no	no	no
1985	0.014	1.8×10^{-4}	2.0×10^{-4}	3.1×10^{-4}	6.1×10^{-4}	no	no	no	no
1986	0.013	1.7×10^{-4}	1.8×10^{-4}	2.9×10^{-4}	5.7×10^{-4}	no	no	no	no
1987	0.066	8.5×10^{-4}	9.3×10^{-4}	1.5×10^{-3}	2.9×10^{-3}	no	no	no	yes
1988	0.019	2.5×10^{-4}	2.7×10^{-4}	4.3×10^{-4}	8.4×10^{-4}	no	no	no	no
1989	0.005	6.7×10^{-5}	7.3×10^{-5}	1.2×10^{-4}	2.3×10^{-4}	no	no	no	no
1990	0.005	6.7×10^{-5}	7.3×10^{-5}	1.2×10^{-4}	2.3×10^{-4}	no	no	no	no
Number of years the dose is above the MRL (0.002 mg/kg/day)						**5**	**6**	**14**	**24**
Number of years the dose is above the LOAEL (0.05 mg/kg/day)						**0**	**0**	**0**	**0**

Doses were calculated using the following formula: Dose = Intake / Body Weight assuming an adult male weighed 78 kg; an adult female, 71 kg; a 12-year-old child, 45 kg; and a 6-year-old child, 23 kg.
The LOAEL is the lowest-observed-adverse-effect level.
The dose of 0.05 mg/kg/day is the minimal LOAEL from a study in which an increased incidence of renal toxicity (specifically, anisokaryosis and nuclear vesiculation) was observed in New Zealand rabbits. The rabbit is the mammalian species most sensitive to uranium toxicity and is likely to be even more sensitive than humans.

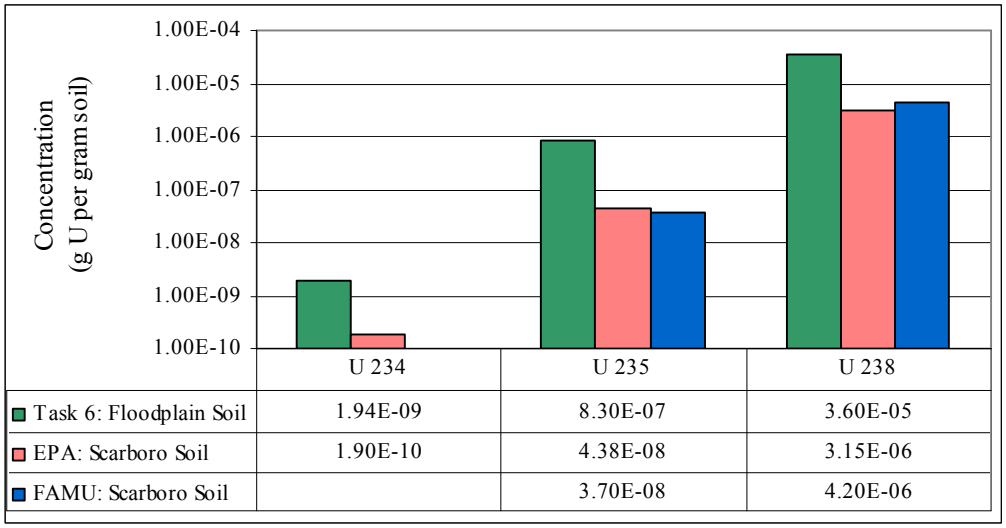
Figure 17. Estimated Average Annual Doses of Uranium via the Soil and Surface Water Pathways



The dose values can be written different ways, for example 1.0E-01 mg/kg/day is the same as 1.0×10^{-1} mg/kg/day and 0.1 mg/kg/day.

For some of the same reasons described previously in the past radiation effects section, the past ingestion doses of uranium (as shown in Table 13 and Figure 17) are overestimated. The annual intakes were calculated using the same overestimated EFPC floodplain soil concentrations in place of actual Scarboro soil concentrations (converted from radioactivity values to mass units[10]). The uranium concentrations in the Scarboro soil are at least 8.6 times less than the EFPC floodplain soil (see Figure 18). Also, the calculated ingestion doses are based on potential exposures from recreating in EFPC, eating fish from EFPC, eating livestock raised in the EFPC floodplain, drinking milk from dairy cows raised in the EFPC floodplain, and eating homegrown vegetables grown in the EFPC floodplain. Livestock is (and was) not allowed within the city limits, and EFPC is not a very productive fishing location. Very few people frequently ate livestock raised in the floodplain, fish from the creek, or vegetables grown in the floodplain over a prolonged period of time. A person's exposure is actually much lower if the person did not frequently engage in these activities over a prolonged period of time.

Figure 18. Comparison of Uranium Concentrations EFPC Floodplain Soil vs. Scarboro Soil



	U 234	U 235	U 238
Task 6: Floodplain Soil	1.94E-09	8.30E-07	3.60E-05
EPA: Scarboro Soil	1.90E-10	4.38E-08	3.15E-06
FAMU: Scarboro Soil		3.70E-08	4.20E-06

FAMU did not analyze for U 234.
The concentration values can be written different ways, for example 1.00E-04 g U per gram soil is the same as 1.00×10^{-4} g U per gram soil and 0.0001 g U per gram soil.

[10] Each individual isotope (U 234, U 235, and U 238) has a separate and distinct half life and mass. Therefore, one can convert the activity of each individual isotope using its specific activity (0.331 pCi/µg for U 238, 0.34 pCi/µg for U 234, 0.0154 pCi/µg for U 235). To convert the radioactive measurement of the isotope to grams, one divides the radioactive measurement by its specific activity while ensuring the units of measurement are consistent.

Given that the past average annual doses of uranium (shown in Table 13) are overestimated and that they are below levels at which health effects have been observed in the mammalian species most sensitive to uranium toxicity, ATSDR does not expect that people living in communities near the Y-12 plant, including in the reference community (i.e., the residents of Scarboro), have ingested levels of uranium via the soil and surface water exposure pathways that would have resulted in harmful chemical effects.

III.B.2. Current Exposure (1995 to 2002)

This section discusses the current uranium exposures from 1995 to 2002 to residents living near ORR. The Scarboro community was selected as the reference population after air dispersion modeling indicated that its residents were expected to have received the highest exposures (ChemRisk 1999). The Task 6 report stated that "while other potentially exposed communities were considered in the selection process, the reference locations [Scarboro] represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases…Scarboro is the most suitable for screening both a maximally and typically exposed individual" (ChemRisk 1999). ATSDR determined that current exposures to uranium can include the following pathways: (1) ingestion of soils, (2) ingestion of foods, (3) ingestion of water from nearby creeks, (4) inhalation of air, and (5) external exposure from uranium in soils.

Based on our review of data collected in and around the reference location (Scarboro), ATSDR has determined that the presence of uranium is not a public health concern to people living near the ORR.

III.B.2.a. Current Radiation Effects

ATSDR evaluated whether exposure to the levels of uranium currently being released from the Y-12 plant would cause harmful radiation effects in the reference population, the Scarboro community. The current uranium radiation dose received by the Scarboro community from the air and soil exposure pathways (0.216 mrem) is well below levels of health concern and is not expected to cause adverse health effects.

The current radiation CEDE[11] received by the reference population, the Scarboro community, from exposure to uranium through ingestion of soil and vegetables and inhalation of air is 0.216 mrem over 70 years (see Table 14). This current radiation dose (0.216 mrem) to the residents of Scarboro is well below (23,000 times less than) the radiogenic cancer comparison value of 5,000 mrem over 70 years (see Figure 9). ATSDR derived this CEDE after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (Appendix D contains more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years). The CEDE assumes that from the intake of uranium, the entire radiation dose (a 70-year dose, in this case) is received in the first year following the intake. ATSDR believes this comparison value to be protective of human health and, therefore, does not expect carcinogenic health effects to have occurred from radiation doses received from current uranium exposures in Scarboro.

To evaluate noncancer health effects from the current uranium radiation dose (CEDE of 0.216 mrem over 70 years) estimated to be received by the Scarboro community, an approximation can be made to compare the CEDE of 0.216 mrem, which is based on 70 years of exposure, to the ATSDR chronic exposure MRL for ionizing radiation (100 mrem/year), which is based on one year of exposure. The CEDE of 0.216 mrem over 70 years could be divided by 70 years to approximate a value of 0.003 mrem as the radiation dose for the first year, which is well below (33,000 times less than) the 100 mrem/year ATSDR chronic exposure MRL for ionizing radiation (see Figure 9). ATSDR MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. The ATSDR MRL for chronic ionizing radiation exposure is derived by dividing the average annual effective dose to the U.S. population (360 mrem/year) by a safety factor of 3 to account for human variability (ATSDR 199b). The average U.S. annual effective dose of 360 mrem/year is obtained mainly from naturally occurring radioactive material, medical uses of radiation, and radiation from consumer products (see Figure 9) (BEIR V 1990 as cited in ATSDR 1999b). This annual effective dose of 360 mrem/year has not been associated with adverse health effects in humans or animals (ATSDR 1999b). ATSDR believes the chronic ionizing radiation MRL of 100 mrem/year is below levels that might cause adverse health effects in people most sensitive to such effects; therefore, ATSDR does not expect

[11] For current exposure, ATSDR evaluated the radiation dose resulting from internally deposited radionuclides only.

noncancer health effects to have occurred from radiation doses received from current uranium exposure communities near the Y-12 plant.

Table 14. Current Uranium Radiation Dose to the Scarboro Community

Exposure Pathway	Committed Effective Dose Equivalents (mrem)
Inhalation of air in Scarboro	3.95×10^{-2}
Soil ingestion by a 1-year old Scarboro resident	3.97×10^{-2}
Ingestion of vegetables from a private garden	1.37×10^{-1}
Summed Radiation Dose	**2.16×10^{-1}**

The radiation doses calculated by ATSDR as resulting from the internal deposition of uranium include the background contribution of uranium typically in the body from other natural sources.

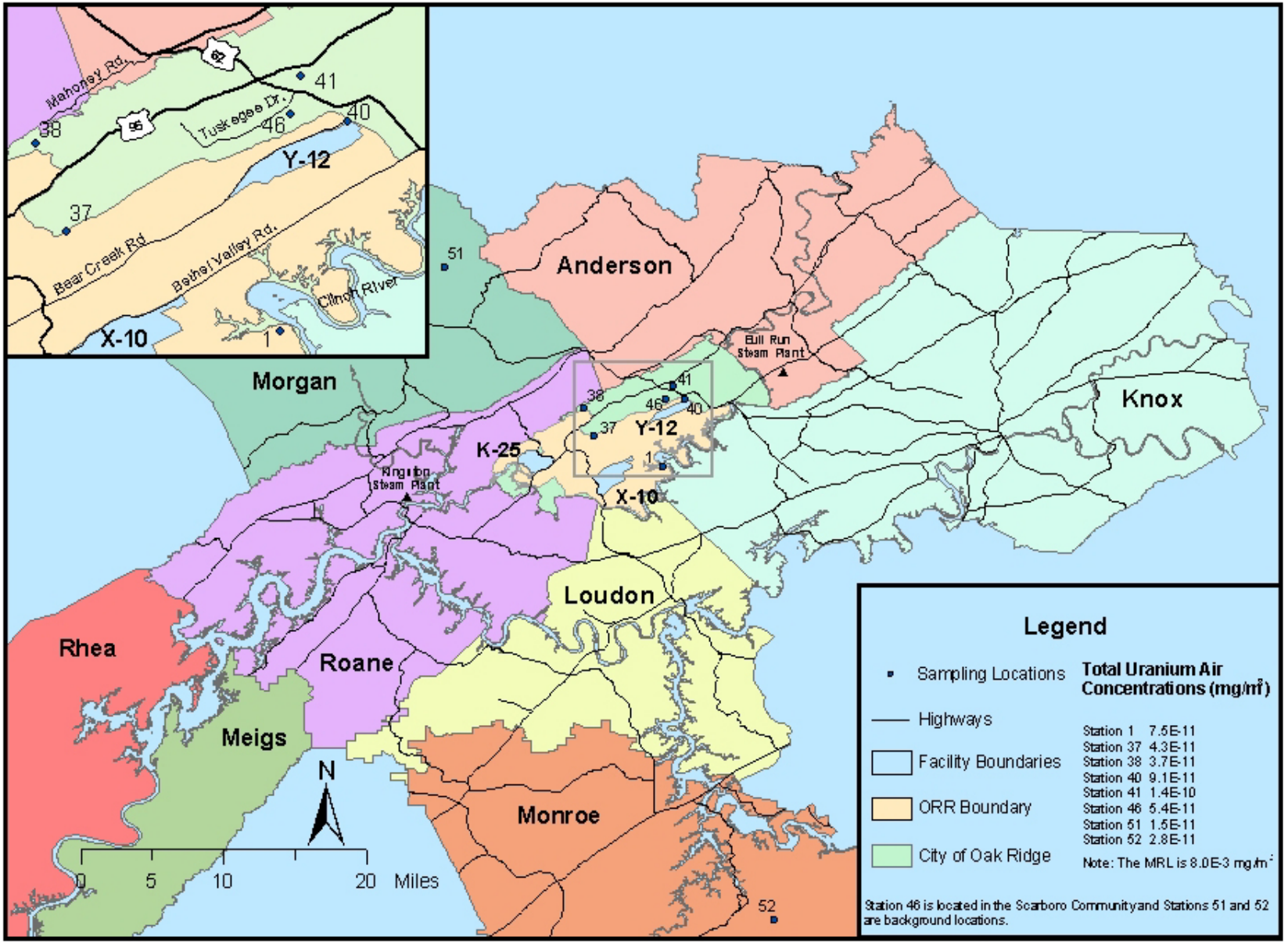
Current Air Exposure Pathway

Operations at the Y-12 plant continue to release materials to the atmosphere. In addition to monitoring the release of uranium from exhaust ventilation systems at the source, DOE has established a series of perimeter air monitoring stations around the reservation, including air monitoring station 46 located in Scarboro west of the Scarboro Community Center. ATSDR reviewed air data accumulated since 1995[12] from four on-site perimeter air monitoring stations, two off-site remote air monitoring stations, and two off-site perimeter air monitoring stations located in Scarboro and the city of Oak Ridge. ATSDR used these values to assess the current radiation impact of inhaling air containing uranium[13] (see Figure 19 for the locations of the air monitoring stations).

[12] ATSDR evaluated data from 1986 to 1991 for Station 41.

[13] Fossil fuel plants, such as coal burning plants, release naturally occurring radioactive materials through their stacks. Because the Bull Run and Kingston Steam Plants are in the vicinity of Oak Ridge, these facilities could be impacting the uranium analyses performed in Oak Ridge. ATSDR could not locate specific information about these plants from the Tennessee Valley Authority. The agency did, however, locate information from a peer-reviewed publication that reported the typical concentrations of uranium in coal ash and fly ash. These values were 4 picocuries per gram (pCi/g) and 5.4 pCi/g, respectively (Stranden 1985).

Figure 19. Locations of Air Monitoring Stations



To estimate the radiation dose, the isotopic activity was evaluated using the appropriate ICRP dose coefficient and a protective inhalation rate. The EPA Exposure Factors Handbook recommends an inhalation rate of 8.7 cubic meters per day (m^3/day) for a child 1 to 12 years of age and an average inhalation rate of 13.25 m^3/day for adults (EPA 1997). For the assessment, ATSDR used a slightly more conservative inhalation rate of 15.25 m^3/day (i.e., 5.5 million liters/year) for adults. Radiation doses resulting from the inhalation pathway are presented in Table 15. As shown in Table 15, people living in the reference location, Scarboro, are expected to inhale sufficient uranium to impart a CEDE of 3.95×10^{-2} mrem.

Furthermore, as the uranium inhaled is considered insoluble, the organ receiving the greatest radiation dose would be the lung. Therefore, ATSDR also calculated radiation doses to the lung. These doses to the lung are not at levels known to cause any adverse health outcomes.

Table 15. Estimated Current Total Radiation Doses from Inhalation of Uranium

Station	Whole Body Dose (mrem)	Lung Dose (mrem)
1 (on-site perimeter monitor)	4.18×10^{-2}	3.47×10^{-1}
37 (on-site perimeter monitor)	2.40×10^{-2}	1.99×10^{-1}
38 (on-site perimeter monitor)	2.13×10^{-2}	1.77×10^{-1}
40 (on-site perimeter monitor)	7.94×10^{-2}	6.59×10^{-1}
41 (city of Oak Ridge)	4.79×10^{-2}	3.98×10^{-1}
46 (Scarboro)	3.95×10^{-2}	3.28×10^{-1}
51 (Norris Dam)	9.31×10^{-3}	7.73×10^{-2}
52 (Fort Loudoun Dam)	1.68×10^{-2}	1.40×10^{-1}

Values are expressed as committed effective dose equivalents (CEDE).
Total uranium doses were calculated using the average concentrations for the data available since 1995, except the doses for Station 41 were calculated using the average concentration for data from 1986 to 1991.

Current Surface Water Exposure Pathway

To evaluate current exposures to uranium through the surface water pathway, ATSDR analyzed available surface water data taken from 1995 to 2002 at off-site locations (Scarboro drainage ditches and Lower EFPC) and for comparison, three on-site locations (Upper EFPC, Bear Creek, and the on-site portion of Lower EFPC after it joins with Bear Creek) (see Figure 20). As shown on Figure 20, the Upper EFPC, located entirely on the reservation, originates and flows through the Y-12 plant to the eastern site boundary and into Lower EFPC. Lower EFPC flows north from

the Y-12 plant off site through the business and residential sections of city of Oak Ridge, but does not flow through Scarboro. After flowing through Oak Ridge for about 12 miles, Lower EFPC enters the ORR site again on the western end of the city and joins Poplar Creek, which flows to the Clinch River near the K-25 site. Bear Creek, also located entirely on the site, originates on the western end of the Y-12 plant and flows southwest to join Lower EFPC near the K-25 site. While access to the three on-site locations is restricted, the public has access to the portion of Lower EFPC that flows through the city. However, the creek appears to be too shallow for swimming, and the state has issued a fishing advisory for EFPC that warns the public to avoid eating fish from the creek and to avoid contact with the water. The Scarboro surface water samples were collected in 1998 and 2001 from drainage ditches in Scarboro and analyzed by FAMU and EPA. Also, Scarboro is located at a higher elevation along Pine Ridge than the EFPC floodplain, thus, surface water in Scarboro flows into EFPC.

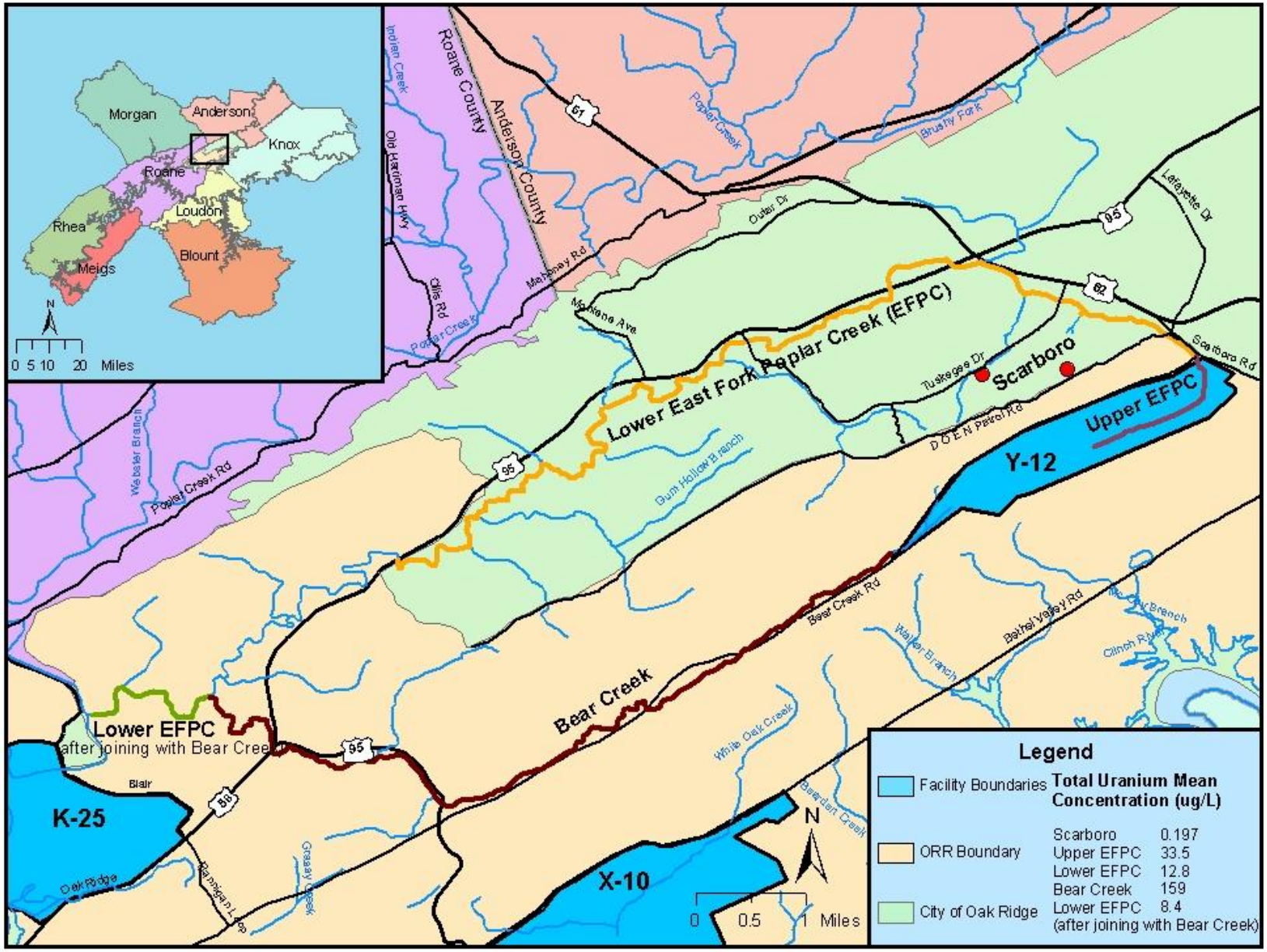
Table 16 shows the mean total uranium concentrations for surface water samples collected from 1995 to 2002 at the two off-site locations and the three on-site locations. The mean uranium concentrations (0.197 μg/L) in surface water from Scarboro ditches are well below (100 times less than) the ATSDR EMEG of 20 μg/L for highly soluble uranium salts (see Table 2). The ATSDR EMEG is a nonenforceable, health-based comparison value developed for screening environmental contaminants for further evaluation. Exposure to concentrations at or below ATSDR's comparison values are not considered to warrant health concern. Even though the mean uranium concentrations are above ATSDR's EMEG of 20 μg/L in Upper EFPC and Bear Creek (on-site locations with access restricted), the mean uranium concentrations decrease to below the EMEG in the off-site portions of Lower EFPC. The total uranium mean concentration in Bear Creek decreases dramatically after joining with Lower EFPC. The total uranium mean concentrations in Scarboro and in the off-site areas of Lower EFPC are below ATSDR's EMEG; therefore, the concentrations of uranium that people might be exposed to are not of health concern.

Table 16. Total Uranium Concentrations in EFPC and Bear Creek

Location	Mean Concentration (μg/L)	Is the mean above the EMEG of 20 μg/L?
Scarboro drainage ditches (off site)	0.197	no
Upper EFPC (on site)	33.5	yes
Lower EFPC (off site)	12.8	no
Bear Creek (on site)	159	yes
Lower EFPC (on site after joining with Bear Creek)	8.4	no

In addition, the mean total uranium concentrations in Scarboro and Lower EFPC are below EPA's maximum contaminant level (MCL) for uranium (30 μg/L). The MCL is the level of a contaminant that is allowed in drinking water. EFPC, however, is not used as a drinking water source. The city of Oak Ridge, including the community of Scarboro, is served by municipal water obtained from the Clinch River (Melton Hill Lake), upstream from the reservation.

Figure 20. Locations of Surface Water Samples



Current Soil Exposure Pathway

In 1997, residents of Scarboro and the local chapter of the National Association for the Advancement of Colored People (NAACP) raised concerns that activities at the Y-12 plant could have produced enriched uranium in Scarboro soils. Enriched uranium contains higher than normal amounts of U 235 as compared to natural uranium and is more radioactive than naturally occurring uranium. The detection and identification of enriched uranium, however, can be difficult in environmental samples, especially because the typical levels of U 235 are low in natural soils. Therefore, enrichment is typically based on the percent by weight of U 235 in the uranium samples, not necessarily by the radioactivity of the sample. In response to the concerns expressed by the residents and the NAACP, FAMU collected soil and water samples for the analysis of uranium and other radionuclides (FAMU 1998).

The results of the FAMU study were released in 1998. In 1999, EPA proposed a study to validate the FAMU results and released a draft of their findings in 2002 (EPA 2002b). Each of these studies only collected samples in the Scarboro community, thus no comparison to other areas of Oak Ridge were made[14]. To address exposure to the soil pathway, ATSDR evaluated soil data recently collected in the reference location, Scarboro. ATSDR compared these Scarboro soil data to national background values, as well as to soil samples collected by DOE for the Background Soil Characterization Project in the Oak Ridge area (DOE 1993). During this background characterization project, DOE collected soil samples from uncontaminated areas on ORR, as well as from areas off site.

[14] ATSDR attempted to locate other background soil sampling data within other areas of the city of Oak Ridge, but as of this writing was unsuccessful. Areas that ATSDR attempted to obtain data from included backgrounds collected for the Atomic City Auto Parts (ACAP) remediation. ACAP is a privately owned company contaminated with materials derived and purchased from Oak Ridge operations. Under consent orders from the state of Tennessee, DOE assumed responsibility for the cleanup of the contaminated areas. In the case of ACAP, environmental media were sampled for U 234, U 235, and U 238. ATSDR was informed by DOE that only one monitoring well and soil boring were collected around ACAP. Therefore, ATSDR does not consider any data derived from this site as representative soil background samples. ATSDR is also trying to locate information related to the CSX Railroad remediation and sampling data collected in the Woodland area of Oak Ridge.

Prior to the nuclear age, background concentration and natural background were identical. After the advent of nuclear weapons, the natural background concentration has been impacted by atmospheric testing. This change of background and natural concentrations now means that there are two separate values, a naturally occurring concentration that is indicated as a pre-nuclear age concentration and a background concentration, which has been impacted by atmospheric testing. To evaluate the presence or absence of enriched uranium, the data are best evaluated on a percent basis. For the purposes of evaluating the radiation dose, however, activity in the form of picocuries (pCi) is necessary.

To evaluate the results of EPA's and FAMU's sampling for public health implications, ATSDR compared the isotopic composition of the uranium in Scarboro soil to the isotopic composition found in naturally occurring uranium. ATSDR also compared the isotope ratio to see if these could indicate elevated uranium, even if the concentrations appeared typical. The EPA isotopic analyses of Scarboro soil indicated that the average radioactivity concentrations were 1.2 picocuries per gram (pCi/g) for U 234, 0.1 pCi/g for U 235, and 1.0 pCi/g for U 238. The isotopic ratio of U 235/U 238 suggested that the radioactivity concentration of U 235 in Scarboro soil was elevated greater than typical concentrations found in nature (see Table 17). Based on an initial observation, the U 235 detected in Scarboro soil appears to be representative of enriched uranium as the isotopic ratio of U 235/U 238 is larger (0.096) than the expected isotopic ratio (0.047) in nature. However, the ratio of the activities can be misleading because the activity of U 235 detected was close to the detection limit and the associated uncertainty of the measurement was large, in some cases 75% of the measured value.

Table 17. Comparison of Uranium Isotopic Ratios Scarboro Soil to Naturally Occurring Uranium

	U 234	U 235	U 238
Scarboro soil concentration	1.2 pCi/g	0.1 pCi/g	1.0 pCi/g
Isotopic ratio in Scarboro soil	1.16 (U 234/U 238)	0.096 (U 235/U 238)	
Isotopic ratio in nature	0.972 (U 234/U 238)	0.047 (U 235/U 238)	

Source: EPA 2002b

Not shown in the table is the considerable uncertainty in the U 235 measurement. This uncertainty is a function of the amount of U 235 found in nature and the method of analysis.

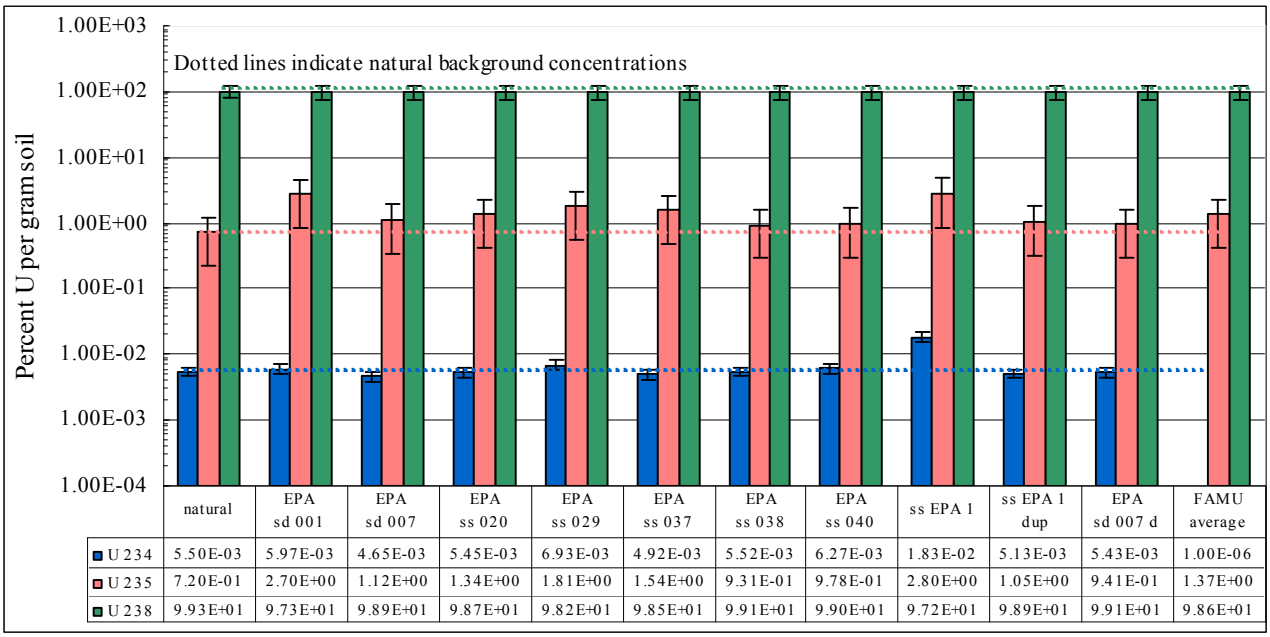
Therefore, the next step was to determine if the U 235, as a percentage of total uranium, was significantly elevated, which would indicate the presence of enriched uranium. ATSDR converted the measured uranium activity levels obtained from the FAMU and EPA studies to

mass units[15]. ATSDR then compared the results of both EPA's sampling efforts (EPA 2002b) and FAMU's (FAMU 1998) sampling efforts to measured soil background concentrations reported by DOE (DOE 1993). ATSDR also compared the results to the established isotopic abundance of the three uranium isotopes. The results of this evaluation are shown in Figure 21. This figure shows the isotopic concentrations of uranium, expressed as a percent of uranium isotopes in soil, in naturally occurring uranium, 10 Scarboro soil and sediment samples from the EPA study, and the average uranium concentrations in Scarboro soil samples from the FAMU study. The dotted lines at 0.005% (U 234), 0.72% (U 235), and 99.2% (U 238) are the concentrations of uranium isotopes found in nature. The error bars represent the uncertainties associated with the analyses of the uranium measurements. The data show that two of the EPA samples (sd 007, ss EPA 1) including the uncertainty, appear to be above the U 235 concentrations found in nature. However, closer evaluation of EPA samples SS EPA 1 and SS EPA 1 dup (a duplicate sample) shows that the uncertainty of these samples is within the range of naturally occurring U 235. Therefore, ATSDR considers only one EPA sample (sd 001) slightly in excess of the naturally occurring concentrations of U 235. Figure 22 compares the uranium isotopic concentrations in naturally occurring uranium to the average uranium isotopic concentrations in soil samples from Scarboro (EPA and FAMU studies) and in background soil samples from uncontaminated areas on and off the ORR (DOE study).

The overall results indicate that the concentrations of uranium detected in the Scarboro community by EPA and FAMU are indistinguishable from the background concentrations of uranium in the area around Oak Ridge. Furthermore, the percentages of uranium in the Scarboro community are essentially identical to the amount of uranium found in nature. However, the Oak Ridge area appears to contain more U 235 than typically found in nature.

[15] To convert the radioactive measurement of the isotope to grams, one divides the radioactive measurement by its specific activity.

Figure 21. Comparison of Uranium Isotopic Concentrations in Natural Uranium, 10 EPA Scarboro Soil Samples, and Average FAMU Scarboro Soil Samples

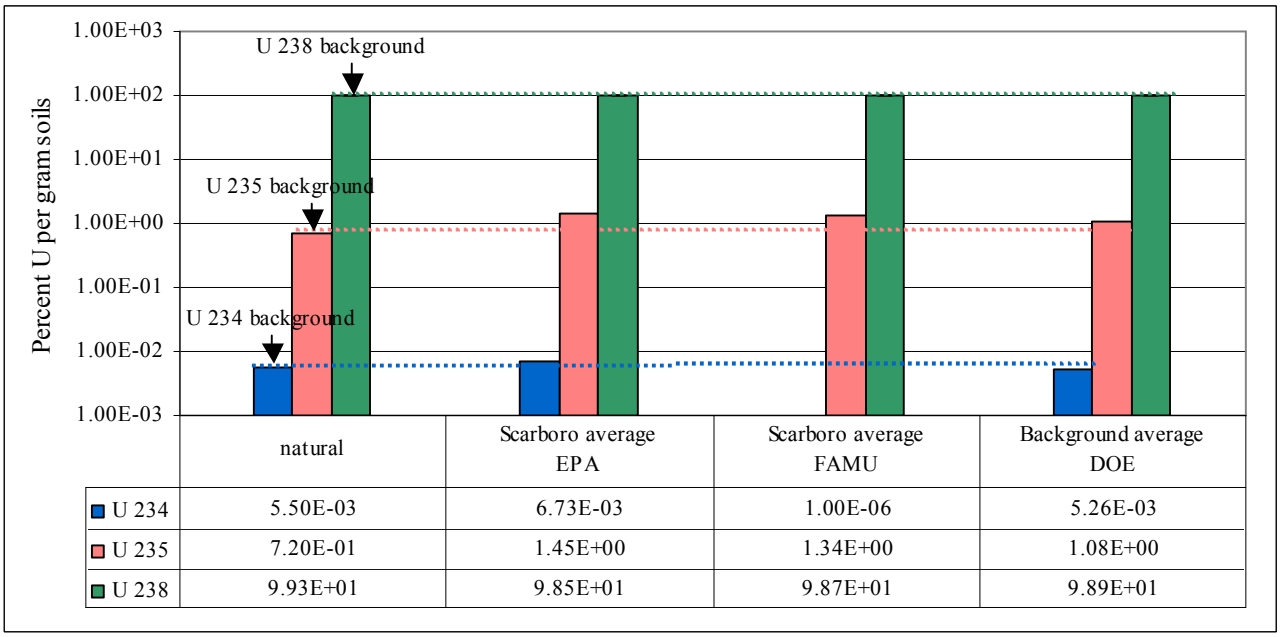


	natural	EPA sd 001	EPA sd 007	EPA ss 020	EPA ss 029	EPA ss 037	EPA ss 038	EPA ss 040	ss EPA 1	ss EPA 1 dup	EPA sd 007 d	FAMU average
U 234	5.50E-03	5.97E-03	4.65E-03	5.45E-03	6.93E-03	4.92E-03	5.52E-03	6.27E-03	1.83E-02	5.13E-03	5.43E-03	1.00E-06
U 235	7.20E-01	2.70E+00	1.12E+00	1.34E+00	1.81E+00	1.54E+00	9.31E-01	9.78E-01	2.80E+00	1.05E+00	9.41E-01	1.37E+00
U 238	9.93E+01	9.73E+01	9.89E+01	9.87E+01	9.82E+01	9.85E+01	9.91E+01	9.90E+01	9.72E+01	9.89E+01	9.91E+01	9.86E+01

Sources: EPA 2002b; FAMU 1998

The isotopic concentration values can be written different ways, for example 1.00E+03 percent U per gram soil is the same as 1.00×10^3 percent U per gram soil and 1,000 percent U per gram soil.

Figure 22. Comparison of the Average Uranium Isotopic Concentrations in Natural Uranium, EPA and FAMU Scarboro Soil Samples, and Background Soil Samples



	natural	Scarboro average EPA	Scarboro average FAMU	Background average DOE
U 234	5.50E-03	6.73E-03	1.00E-06	5.26E-03
U 235	7.20E-01	1.45E+00	1.34E+00	1.08E+00
U 238	9.93E+01	9.85E+01	9.87E+01	9.89E+01

Sources: DOE 1993; EPA 2002b; FAMU 1998

The background average is from the DOE Background Soil Characterization Project, for which soil samples were taken from uncontaminated areas on and off the ORR.
The isotopic concentration values can be written different ways, for example 1.00E+03 percent U per gram soil is the same as 1.00×10^3 percent U per gram soil and 1,000 percent U per gram soil.

Concern has also been expressed that the Scarboro community has been impacted by uranium releases to EFPC. To evaluate this concern, ATSDR evaluated the location and surface elevation of Scarboro and EFPC. Lower EFPC flows north from the Y-12 plant off site through the business and residential sections of city of Oak Ridge, but does not flow through Scarboro. At its closest point, the EFPC passes about 0.4 miles to the northeast of the populated areas of Scarboro (ChemRisk 1999b). Also, Scarboro is located at a higher elevation along Pine Ridge than the EFPC floodplain, and Scarboro does not receive surface water from the EFPC. In addition, ATSDR compared the average uranium isotopic ratios (U 234/U 238; U 235/U 238) of Scarboro soil and EFPC floodplain soil from off-site areas to that of natural occurring uranium. The isotopic ratios are shown in Table 18.

Table 18. Comparison of the Average Uranium Isotopic Ratios in Scarboro Soil, EFPC Floodplain Soil, and Natural Uranium

Location	U 234/U 238	U 235/U 238
Scarboro	4.79×10^{-5}	0.01
EFPC	2.84×10^{-5}	0.004
Natural	5.54×10^{-5}	0.0072

The ratios are based on the percentages of the specific isotopes found in nature, not their radioactivity.

These data suggest that the ratio of U 234/U 238 in Scarboro soil is elevated over the ratio found in EFPC floodplain soils; however, the ratios for both locations are less than the ratio typically found in nature. The ratio of U 235/U 238 in Scarboro soil is not elevated over those found in the EFPC floodplain or in nature. The uranium content in soils within the Scarboro community is representative of uranium found in areas not impacted by Y-12 operations; that is, the soils in Scarboro are not contaminated by atmospheric releases related to ORR operations. Additionally, in 1993, ATSDR scientists released a public health consultation that evaluated the environmental sampling data from EFPC to determine the public health implications of past and current Y-12 plant releases into the creek. ATSDR concluded that the concentrations of uranium and other radionuclides detected in soil, sediment, surface water, and fish from EFPC were not present at levels of public health concern (ATSDR 1993b).

Soil Ingestion Pathway

Typically, the proportion of a population exposed to contaminated soils is identified by estimating the area of contaminant dispersion and then determining the population within the contaminated area. Furthermore, the population can be characterized by identifying individuals who are more likely to ingest soil (i.e., children). However, the entire population in the contaminated area may ingest some soil. People incidentally (accidentally) ingest soil when they use their hands to handle food that they eat, smoke cigarettes, or put their fingers in their mouths because soil or dust particles can adhere to food, cigarettes, and hands. Children are particularly sensitive because they are likely to ingest more soil than adults. Displaying hand-to-mouth behavior is a normal phase of childhood and therefore they have more opportunities to ingest soil than adults do.

For the purposes of this assessment, ATSDR evaluated soil ingestion for Scarboro children (assuming they incidentally ingest 100 mg/day) and their resulting uranium CEDEs over a period of 70 years. For this scenario, ATSDR chose dose coefficients for an infant as these would result in the highest dose to a child who might ingest soils at various ingestion rates. Furthermore, as the uranium ingested is considered insoluble, the organ receiving the greatest radiation dose would be the bone (see Table 19). Therefore, ATSDR also calculated uranium CEDEs to the bone and whole body. These radiation doses to the bone and whole body are well below the ATSDR radiogenic cancer comparison value of 5,000 mrem over 70 years and are not at levels known to cause any adverse health outcomes.

Table 19. Uranium Radiation Doses Following Soil Ingestion by a 1-year old Scarboro Resident at Each Sample Location

Sample Location	Bone (mrem)	Whole body (mrem)
S. Benedict 1	4.37×10^{-1}	3.05×10^{-2}
S. Dillard	6.02×10^{-1}	4.17×10^{-2}
S. Fisk	5.96×10^{-1}	4.15×10^{-2}
Parcel	6.27×10^{-1}	4.38×10^{-2}
S. Benedict 2	6.12×10^{-1}	4.25×10^{-2}
Spellman	7.34×10^{-1}	5.11×10^{-2}
Hampton	5.56×10^{-1}	3.88×10^{-2}
Bennett Lane	3.85×10^{-1}	2.73×10^{-2}
Average	$\mathbf{5.69 \times 10^{-1}}$	$\mathbf{3.97 \times 10^{-2}}$

The dose is the CEDEs expected to be received over a period of 70 years following an intake. It is based on the ingestion of 100 milligrams of soil daily for the course of one year.

Ingestion of vegetables grown near the Y-12 plant

When uptake into plants is possible, the identification of populations that are exposed or potentially exposed through consumption of contaminated plants is evaluated. Because of the chemical nature and solubility in water, uranium oxides, the form of uranium released from the Y-12 plant, are not taken up by plants readily (Dreesen et al. 1982; Moffett and Tellier 1977 as cited in ATSDR 1999a). The uptake, called the concentration ratio (CR), is expressed as a ratio of uranium in soil to the amount of uranium in plants. The concentration ratio is dependent on the soil and type of plant, with recommended values ranging from 0.002 to 0.017 (LANL 2000; NCRP 1999). For example, if a kilogram of soil contains a microgram of uranium, a kilogram of plant material may contain 0.002 to 0.017 micrograms of uranium.

From 1998 to 2000, DOE collected homegrown vegetables from a Scarboro resident and analyzed these foods for radionuclides, including the uranium isotopes. ATSDR analyzed the private garden vegetable data to evaluate the uranium radiation dose a person might receive from the ingestion of these vegetables. The rate of consumption of contaminated plants may differ considerably from the national average for certain populations living near hazardous waste sites. EPA has published a handbook, the Exposure Factors Handbook (EPA 1997), in which regional rates for foods are listed. ATSDR used the food intake parameters specific to the South (see Table 20).

Table 20. Food Ingestion Rates for the Southern United States

Food	Per Capita Intake (g/kg/day)	Standard Error
Total fruit	3.017	0.105
Total vegetable	4.268	0.047
Total meat	2.249	0.025
Homegrown fruits	2.97	0.3
Homegrown vegetables	2.27	0.122
Home-produced meat	2.24	0.194

Source: EPA 1997

g/kg/day: grams per kilogram per day

ATSDR estimates that a person who frequently eats vegetables from a private garden in Scarboro is expected to receive about 0.137 mrem of uranium per year. The summary of this analysis from the ingestion of foods collected from a private garden in Scarboro is provided in Table 21.

Table 21. Radiation Doses from Uranium Following Ingestion of Private Garden Vegetables Grown in Scarboro

Vegetable type	Total Radiation Dose (mrem per gram food)
Leafy	1.87×10^{-3}
Tomatoes	4.34×10^{-5}
Turnips	1.54×10^{-4}
Total per gram food	2.06×10^{-6}
Total following ingestion	1.37×10^{-1} mrem per year

Ingestion is based on an 80-kilogram adult eating 2.27 grams of produce per kilogram of body weight per day for 365 days a year (EPA 1997).

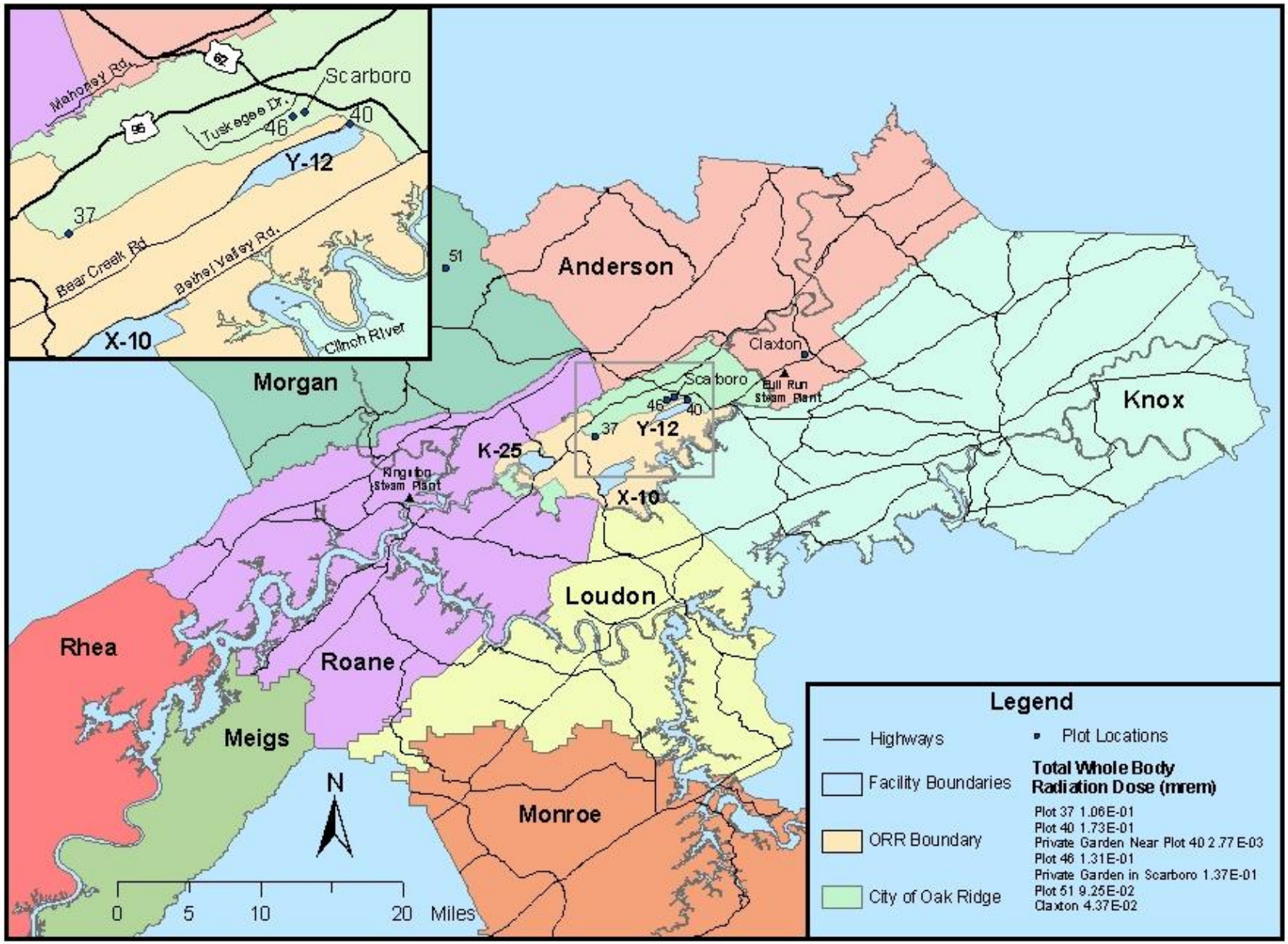
In addition, DOE collects and analyzes vegetables grown in plots near on-site and off-site air monitoring stations and in private gardens (Figure 23 gives sample locations). The vegetables included lettuce, turnips, turnip greens, and tomatoes. These vegetables are analyzed for radionuclides, including the uranium isotopes. ATSDR estimated the annual dose a resident might receive from ingesting equal amounts of these vegetables using the same default values estimated for a Scarboro resident. That is, the typical resident would ingest 2.27 grams of produce per day for each kilogram of their body weight. For these calculations, we used a body weight of 80 kilograms (approximately 176 pounds) and 365 days per year. The estimated average radiation doses from uranium are summarized in Table 22. These results indicate that the

produce grown and consumed in the Scarboro community contains essentially the same amount of uranium as produce grown in the outlying areas.

Table 22. Radiation Doses from Uranium Following Ingestion of Garden Vegetables Grown On and Off the Oak Ridge Reservation

Plot Identification Number	Location	Total Whole Body Radiation Dose (mrem)
Plot 37	Monitoring station 37 On site west of Y-12 in the ORR	1.06×10^{-1}
Plot 40	Monitoring station 40 On site near Bear Creek Road and Scarboro Road Intersection	1.73×10^{-1}
Private Garden	Off site near station 40	2.77×10^{-3}
Plot 46	Monitoring station 46 Off site in Scarboro	1.31×10^{-1}
Private Garden	Off site in Scarboro	1.37×10^{-1}
Plot 51	Monitoring Station 51 Off site in Morgan County	9.25×10^{-2}
Claxton	Off site in Claxton	4.37×10^{-2}
	Average ± SD	$9.8 \times 10^{-2} \pm 5.8 \times 10^{-2}$
	Average excluding Plot 46 and Scarboro private garden	8.36×10^{-2}

Figure 23. Locations Where Vegetable Samples Were Grown On and Off the Oak Ridge Reservation



External exposure from uranium in soils

Uranium is a very weak emitter of radiation and is considered a health problem if internalized within the body. A comparison of dose factors using federal guidance documents (EPA 1988, 1993) indicates that uranium in the soil pathway can be removed from any additional evaluation.

III.B.2.b. Current Chemical Effects

ATSDR evaluated whether exposure to the levels of uranium currently being released from the Y-12 plant would cause harmful chemical effects in people living near the Y-12 plant, including the reference population (the Scarboro community). On the basis of the chemical toxicity of uranium, it can be stated that residents living near the ORR are not currently being exposed to harmful levels of uranium through inhalation of air or ingestion of soils, homegrown vegetables, and surface water.

Current Inhalation Exposure Pathway

ATSDR reviewed the air monitoring data accumulated since 1995 in the Scarboro community (Station 46) and air monitoring data accumulated from 1986 to 1991 in the city of Oak Ridge (Station 41). ATSDR used these data to assess the chemical impact of inhaling air containing uranium[16]. These data were compared to data from perimeter air monitoring stations (Stations 1, 37, 38, and 40) on the reservation as well as to background data at remote air monitoring stations (Stations 51 and 52) (Figure 19 shows the locations of the air monitoring stations). For the comparisons, ATSDR converted the isotopic uranium values to mass[17], expressing the activity in

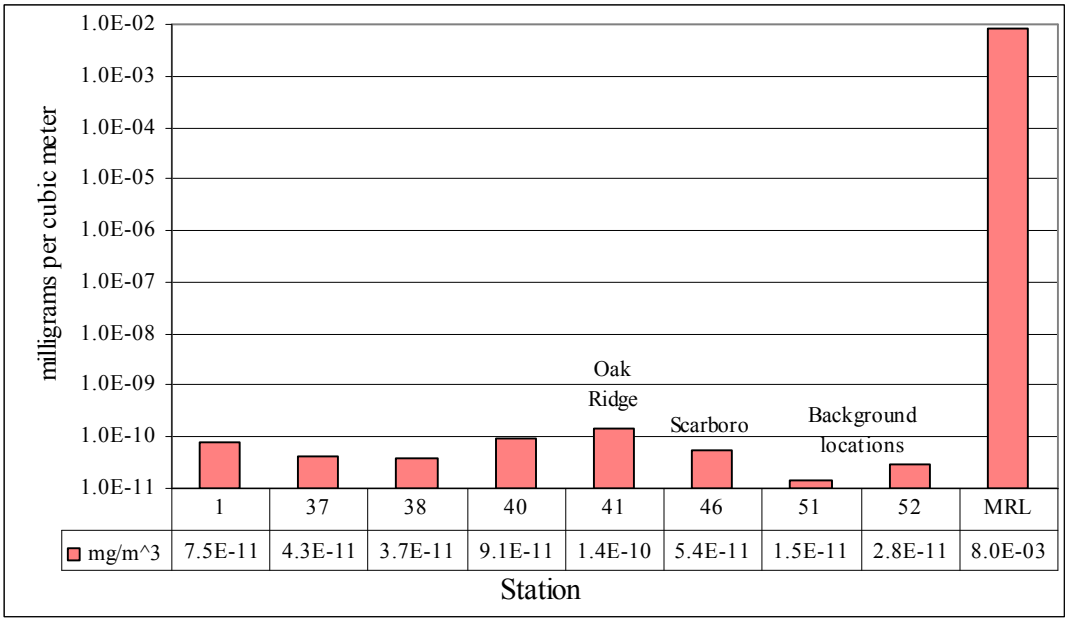
[16] Fossil fuel plants, such as coal burning plants, release naturally occurring radioactive materials through their stacks. Because the Bull Run and Kingston Steam Plants are in the vicinity of Oak Ridge, these facilities could be impacting the uranium analyses performed in Oak Ridge. ATSDR could not locate specific information about these plants from the Tennessee Valley Authority. The agency did, however, locate information from a peer-reviewed publication that reported the typical concentrations of uranium in coal ash and fly ash. These values were 4 picocuries per gram (pCi/g) and 5.4 pCi/g, respectively (Stranden 1985).

[17] Each individual isotope (U 234, U 235, and U 238) has a separate and distinct half life and mass. Therefore, one can convert the activity of each individual isotope using its specific activity expressed as curies of radioactivity per gram of pure radionuclide (0.333 pCi/µg for U 238, 6,187 pCi/µg for U 234, 2.14 pCi/µg for U 235). To convert the radioactive measurement of the isotope to milligrams, one divides the radioactive measurement by its specific activity while ensuring the units of measurement are consistent.

units of milligrams of uranium per cubic meter of air (mg/m^3). The air concentrations of uranium in Scarboro averaged 5.4×10^{-11} mg/m^3 and in the city of Oak Ridge averaged 1.4×10^{-10} mg/m^3 (see Figure 24). The average uranium air concentrations from perimeter monitoring stations on the reservation to the west of Scarboro are about 20% lower than the average concentrations measured in the Scarboro location. The average background uranium air concentrations from the remote air monitoring stations are about 60% lower than that of Scarboro; however, the average concentration from Station 1, located on site near X-10, is about 40% higher than Scarboro. Station 41, located in Oak Ridge near the intersection of South Illinois Avenue and the Oak Ridge Turnpike, has an average concentration about 60% higher than Scarboro. Therefore, ATSDR believes this indicates that a portion of the uranium detected in the air around Scarboro is from the Y-12 plant.

The current air concentrations were compared to ATSDR's intermediate-duration inhalation MRL of 8×10^{-3} mg/m^3 for insoluble uranium. As shown in Figure 24, air concentrations from all stations, including Scarboro, are more than a million times less than the MRL and therefore well below levels that would be expected to cause harmful chemical effects.

Figure 24. Average Uranium Air Concentrations Compared to the MRL



The air concentration values can be written different ways, for example 1.0E-02 milligrams per cubic meter is the same as 1.0×10^{-2} milligrams per cubic meter and 0.01 milligrams per cubic meter.
Values are averages of monitoring station data available from 1995 to present; except the value for Station 41 is an average of data from 1986 to 1991.
Station 46 is in the Scarboro community, and Stations 51 and 52 (located at the Norris and Fort Loudoun Dams, respectively) are monitoring locations that have not been impacted by releases from the ORR. The remaining stations are on the reservation.
ATSDR's MRL is also shown.

Current Ingestion Exposure Pathway

Ingestion of soils

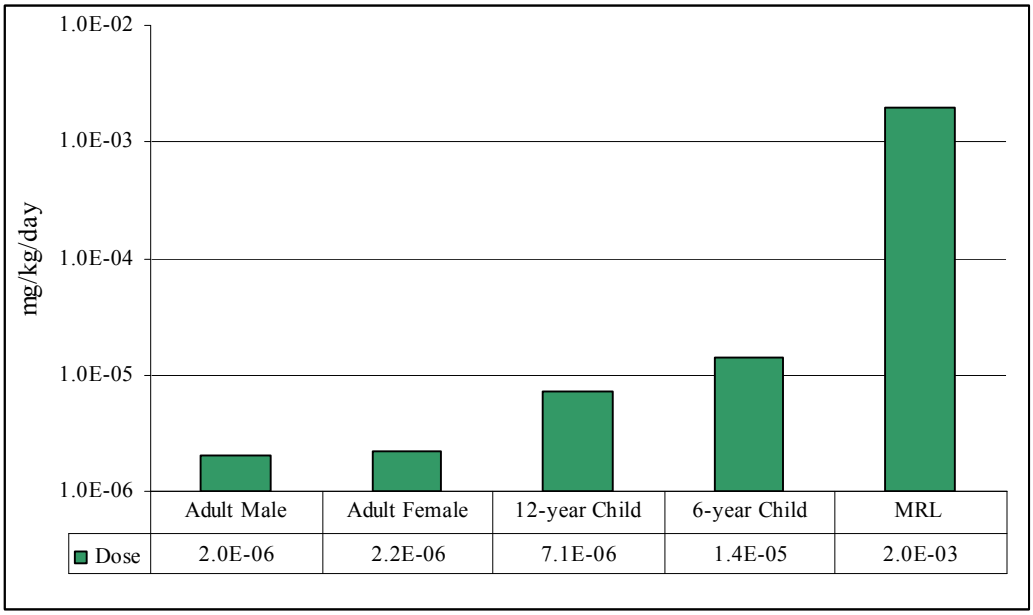
As with the evaluation of radiation effects, ATSDR considered that the entire population of Scarboro incidentally ingests soil. Adults were assumed to incidentally ingest 50 mg of soil/day, whereas children were assumed to incidentally ingest 100 mg/day. For the purposes of the assessment, ATSDR evaluated current doses for an adult male, an adult female, a 12-year-old child, and a 6-year-old child. The results are summarized in Table 23 and Figure 25. Section *III.A.2. Evaluating Exposures* explains ATSDR's method of calculating doses.

Table 23. Uranium Doses from Ingestion of Scarboro Soil

Population	Body Weight (kg)	Intake Rate (mg/day)	Dose (mg/kg/day)
Adult Male	78	50	2.0×10^{-6}
Adult Female	71	50	2.2×10^{-6}
12-year Child	45	100	7.1×10^{-6}
6-year Child	23	100	1.4×10^{-5}
		Ingestion MRL	2.0×10^{-3}

The average soil uranium concentration of 3.19 mg U/kg soil (EPA 2002b) was used in the formula Dose = (Conc. × IR) / BW to calculate the uranium dose from incidental ingestion of soil.

Figure 25. Uranium Dose Following Ingestion of Soil



The dose values can be written different ways, for example 1.0E-02 mg/kg/day is the same as 1.0×10^{-2} mg/kg/day and 0.01 mg/kg/day.

The estimated uranium doses from ingestion of Scarboro soil by all receptor populations are well below the ATSDR MRL for intermediate-duration oral exposure to uranium (0.002 mg/kg/day) (shown in Table 23). The maximum uranium dose to the receptor population (6-year-old child) is approximately 140 times less that the ATSDR MRL. Remember that the MRL is a screening level for which values below are not of health concern. This intermediate-duration oral MRL is also protective for chronic-duration oral exposure because the renal effects of uranium exposure are more dependent on the dose than on the duration of exposure. Therefore, residents of

Scarboro are not currently being exposed to harmful levels of uranium through incidentally ingesting soil.

Ingestion of vegetables grown near the Y-12 plant

Because of its chemical nature and solubility in water, uranium oxide is transported poorly from soils to plants (Dreesen et al. 1982; Moffett and Tellier 1977 as cited in ATSDR 1999a). The uptake varies widely (i.e., concentration ratios range from 0.002 to 0.017; LANL 2000; NCRP 1999) and is dependent on the nature of the soil, the pH, and the concentration of uranium in the soil.

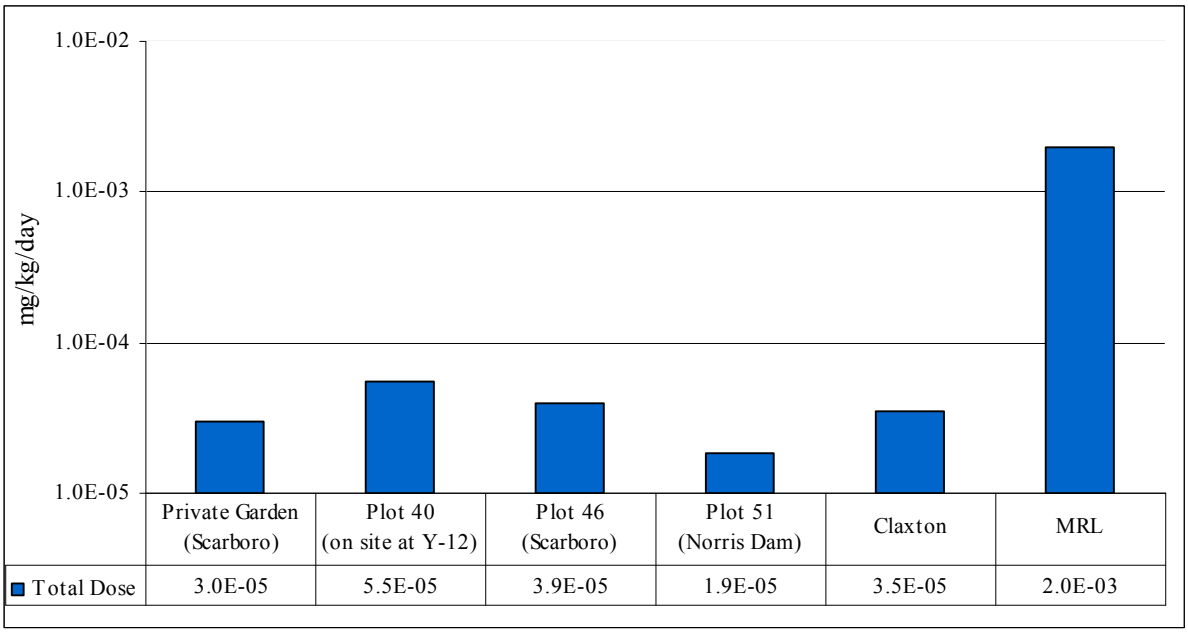
As noted previously in the radiation effects section, DOE collected homegrown vegetables from plots near on-site and off-site air monitoring stations and in private gardens in Scarboro and Claxton and analyzed these foods for the uranium isotopes. ATSDR used food ingestion rates (listed in Table 20) to evaluate the mass intake one might receive from the ingestion of these vegetables. The estimated doses of uranium from ingestion of vegetables from several locations on and around the ORR, including a private garden in Scarboro and a garden grown at air monitoring station 46 (also located in Scarboro), are given in Table 24 and Figure 26.

Table 24. Total Uranium Dose Following Ingestion of Vegetables Grown On and Off the Oak Ridge Reservation

Location	Total Intake (mg/g)	Total Dose (mg/kg/day)
Private Garden (Scarboro)	1.3×10^{-5}	3.0×10^{-5}
Plot 40 (on site at Y-12)	2.4×10^{-5}	5.5×10^{-5}
Plot 46 (Scarboro)	1.7×10^{-5}	3.9×10^{-5}
Plot 51 (Norris Dam)	8.2×10^{-6}	1.9×10^{-5}
Claxton	1.5×10^{-5}	3.5×10^{-5}
MRL		2.0×10^{-3}

The total uranium doses were calculated by multiplying the total intakes by 2.27 g/kg/day, which is the mean intake of homegrown vegetables for people who live in the South and garden (EPA 1997).

Figure 26. Total Uranium Dose Following Ingestion of Vegetables Grown On and Off the Oak Ridge Reservation



The dose values can be written different ways, for example 1.0E-02 mg/kg/day is the same as 1.0×10^{-2} mg/kg/day and 0.01 mg/kg/day.

ATSDR has established an MRL of 0.002 mg/kg/day for the ingestion of uranium. As shown in Table 24, the total uranium doses from ingestion of vegetables grown in all on-site and off-site locations, including the Scarboro community, are well below the ATSDR MRL for intermediate-duration oral exposure to uranium (0.002 mg/kg/day). The estimated total uranium doses from ingestion of vegetables grown in private gardens in Scarboro are more than 50 times less than the MRL, and therefore ingestion of these vegetables is not of health concern.

Ingestion of water from nearby creeks

EFPC is not used as a drinking water source. The city of Oak Ridge, including Scarboro, is served by municipal water, which must meet specific drinking water quality standards set by EPA. Under the authorization of the Safe Drinking Water Act, EPA has set national health-based standards to protect drinking water and its sources. More information concerning the Safe Drinking Water Act can be found on EPA's website at http://www.epa.gov/safewater or by calling EPA's Safe Drinking Water Hotline at 1-800-426-4791. The total uranium mean concentrations in surface water from Scarboro ditches and Lower EFPC are below EPA's MCL

for uranium (30 μg/L). In addition, Table 16 shows that the mean total uranium concentrations for surface water samples collected from Scarboro ditches and Lower EFPC are below ATSDR's EMEG of 20 μg/L. Therefore, the concentrations of uranium that people might be exposed to are not of health concern.

The MCL is the level of a contaminant that is allowed in drinking water.